The Representation of Objects, Non-solid Substances, and Collections in Infancy and Early Childhood

by

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ABSTRACT

We take it for granted that the physical world comes in two flavors: "things" and "stuff." This distinction is not a property of the world in and of itself, but a property of mind. Given any configuration of matter we may invoke either construal. For example, depending on the circumstances, what you have in your hands is either "a thesis" or "some paper." Our understanding of "stuff" can go through a similar alternation. We may see water on the ground either as "some water" or as "a puddle."

Despite the option to invoke either construal we have systematic biases; we tend to see configurations of solid matter as objects and configurations of non-solid substances as mere "stuff."

There happens to be a relationship between these two modes of construal, our knowledge of language, and our numerical ability. Concepts under one mode can be lexicalized as count nouns; and under the other mode as mass nouns. In addition, under one mode we quantify discretely (i.e., we count) and under the other we quantify continuously (as in some stuff vs. more stuff). Under the latter mode number is irrelevant.

This thesis consists of arguments and empirical evidence that bear on the nature and the development of these construals. It includes an introduction and three self-contained sections. Chapter 1 is the introduction to the thesis. In Chapter 2 the infant's understanding of the physical properties of non-solid substances is discussed. It is argued that infants can distinguish objects from a non-solid substance (sand) on the basis of cohesional properties. In Chapter 3, how that understanding affects infants' quantificational judgments (judgments about "how many") is assessed. It is found that while infants will enumerate objects, their understanding of sand as a non-solid substance is such that number is irrelevant. Finally in Chapter 4, preschoolers' lexical development is explored in terms of the following question: Given that children have evidence from adult language that a discrete mode of construal is being invoked, how do they decide what counts as "one" when learning a word? It is found that preschoolers often take count nouns referring to collections ("army", "family", "forest") as referring to kinds of individual objects.

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"I am only an egg"
Robert Heinlen, *Stranger in a Strange Land*

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PROLOGUE

This thesis consists of an introductory chapter followed by three self-contained works. Each addresses a different problem in Cognitive Science and is independently motivated from the perspective of that problem. Chapter 2 is concerned with the development of physical reasoning. That is, our principled but naive understanding of matter, both solid and non-solid. Chapter 3 addresses a problem in language development. It is assumed that concepts are in place before words are found to express them. I examine whether pre-linguistic infants have the capacity to represent the count/mass distinction. Chapter 4 is concerned with the inductive problem of language learning. Given a novel word, children might come up with any number of possible meanings. This section examines what limits preschoolers place on those possible meanings.

As different as these areas seem to be, I propose in Chapter 1 that they share a common theme having to do with the meanings we assign to count nouns.

Chapter 1:
Introduction

The Representation of Objects, Non-solid Substances, and Collections in Infancy and Early Childhood

We take it for granted that the physical world comes in two flavors: "things" and "stuff." This distinction is not a property of the world in and of itself, but a property of mind. Given any configuration of matter we may invoke either construal. For example, depending on the circumstances, what you have in your hands is either "a thesis" or "some paper." Our understanding of "stuff" can go through a similar alternation. We may see water on the ground either as "some water" or as "a puddle." Despite the option to invoke either construal we have systematic biases; we tend to see configurations of solid matter as objects and configurations of non-solid substances as mere "stuff."

There happens to be a relationship between these two modes of construal, our knowledge of language, and our numerical ability. Concepts under one mode can be lexicalized as count nouns; and under the other mode as mass nouns. In addition, under one mode we quantify discretely (that is, we count) and under the other we quantify continuously (as in some stuff versus more stuff); under the latter mode number is irrelevant.

The problem of understanding these two modes of construal and their relationship to judgments of number and count/mass syntax can be boiled down to two questions (see Prasada, 1995, for a similar analysis):

1) *Question of representational structure*. What are the properties of our representations such that: Under one mode we access mechanisms that count, and trigger the lexical reflexes which generate count nouns (i.e., interpretable strings when in combination with words like "a", "another", "many", "fewer", "several"); whereas under the other we contemplate entities to which number is irrelevant and generate mass nouns (i.e., interpretable strings when in combination with words like "much" and "less")?

2) *Question of cognitive bias.* What pieces of physical evidence influence the bias to construe of some configurations of matter one way rather than the other?

Answers to the first question can be found in the literature on the psychology and philosophy of language (Frege, 1884/1953; Jackendoff, 1991; Macnamara, 1994; Quine, 1960). I will touch on such attempts briefly in this introduction. However the bulk of this thesis consists of arguments and evidence that bear on the second question. In it is discussed the infant's understanding of the physical properties of non-solid substances and how that understanding affects quantificational judgments (judgments about "how many"). In addition, preschoolers' lexical development is explored in terms of the following question: Given that children have evidence from adult language that a discrete mode of construal is being invoked, how do they decide what counts as "one" when learning a novel word?

Question of Representational Structure.

Let us examine two proposals which are candidate solutions to Question (1). First, we owe to Frege the insight that certain concepts are central to our judgments of number ...

> The concept "letters in the word 'three'" isolates the 't' from the 'h', the 'h' from 'r', and so on. The concept "syllables in the word 'three'" picks out the word as a whole, and as indivisible in the sense that no part of it falls any longer under that same concept. Not all concepts possess this quality. We can, for example, divide up something falling under the concept "red" into parts in a variety of ways, without the parts thereby ceasing to fall under the same concept "red." To a concept of this kind no finite number will belong. The proposition asserting that units are isolated and indivisible can, accordingly, be formulated as follows:

> Only a concept which isolates what falls under it in a definite manner, and which does not permit any arbitrary division of it into parts, can be a unit relative to a finite Number.
>
> Frege (1884/1953, p. 66)

Second, we owe to Quine (1960) the analysis of the count/mass distinction in terms of quantificational logic. The following quotation exemplifies Quine's view.

> To learn "apple" it is not sufficient to learn how much of what goes on counts as apple; we must learn how much counts as *an* apple, and how much as another. Such terms possess built in modes ... of dividing their reference.... So-called *mass* terms like 'water", "footwear", and "red" have the semantical property of referring cumulatively: any sum of the parts which are water is water
>
> (Quine, 1960, p. 91)

Frege introduced what are called "sortal" concepts. That is, ideas that specify constraints on individuation (what to count as one) and numerical identity (sameness in the sense of "same one"). For example, the count noun "dog" picks out a sortal concept and knowing what the word "dog" means is to know what counts as one dog and what counts as two dogs. It also means knowing what would count as evidence that the dog you see now is the dog you saw last night. In addition, understanding what the word "dog" means is to know that not every part of a dog is a dog. Mass nouns label a different type of concept: understanding the word "sand" does not entail knowing what counts as "one sand" and what counts as "two sands." In fact it clearly does not make sense to talk about "one sand." Furthermore in contrast to "dog", knowing what "sand" means is to know that every portion of sand is "sand."

Frege argued that sortal concepts are essential for judgments of number. To see his point consider the following question: "How many are in this room?". This question is syntactically well formed but not interpretable or answerable. We must supply a sortal concept to get an answer, for example "How many *people* are in this room?" or even "How many *legs* are there in this room." Since understanding "sand" does not tell you what to count as one, we cannot answer questions like "How many sand are in this room?" (See Hirsch, 1982 and Macnamara and Reyes, 1994 for detailed discussions of the logic of sortals).

In the quotation above, Frege appears to suggest above that sortal concepts may be lexicalized as count nouns and are to be contrasted with adjectives. Quine is not concerned with number per se but makes a similar distinction. His semantic analysis of the logic of count nouns is that of sortals. It should be noted however that it is not clear that the concept "which isolates what falls under it in a definite matter" always gets lexicalized as a count noun, as in "*an* apple" (Pelletier, 1979). Among the problems are that traditionally count nouns like "object", "thing", and "entity" are not considered sortals while non-count nouns like the complex (partitive) phrase: "pile of sand" seem to provide criteria for individuation and numerical identity. This is a matter of considerable debate. Recently empirical evidence has been provided that for both adults and infants, the notion OBJECT functions as a sortal. It is argued that there are spatio-temporal criteria for individuation and identity (Xu, 1995).[1]

If Xu's (1995) arguments about the sortal-hood of spatio-temporally defined objects are right then the analysis of count nouns as sortals may be correct. Given that partitives like "pile of sand" seem to function as sortals we may conclude that some sortals are lexicalized as count nouns and that the human language faculty confers the ability to express sortal concepts in a number of different ways. Researchers in the psychology of language have

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[1] Note that the notion OBJECT in this case is a technical one referring to bounded entities which cohere under movement (Spelke, Breinlinger, Macomber, & Johnson, 1992). Thereby excluding continued on next page

attempted to provide a unified treatment of count nouns and phrases like "pile of sand" within the framework of "conceptual semantics" (Bloom, 1990; Jackendoff, 1990). These approaches involve the invocation of semantic features and they depend on the combinatorial expressive power of a "grammar of sentential concepts." Shifts in construal are captured by means of "correspondence rules" by which representations of uncountable entities are transformed into representations of countable entities, as in WATER -> CUP OF WATER.

It is often taken for granted that the relationship between non-linguistic cognition and the construal of countable and non-countable entities is "transparent" in the material domain (i.e., Bloom, 1990). That is non-solid substances are immediately recognized as uncountable stuff and objects are just as readily understood to be countable "things." Indeed this may be so, for basic level terms there is relatively little cross-linguistic variation (Markman, 1985). Nevertheless, given that we have the rather general capacity to alternate construals, it is legitimate to ask along the lines of Question (2) above: *In virtue of what is this so?* In this next section we shall consider the clues that are used in the judgment that some configuration of matter is "a thing" or just "stuff."

Question of Cognitive Bias.

It is known that adults are sensitive to many different factors in their division of the world into kinds of stuff and kinds of things. Of course adults are sensitive to the syntax which *encodes* these alternate construals. That is, when some configuration of matter is described using count noun syntax it will be understood quantified discretely whereas when it is described using mass noun syntax it is understood as quantified continuously. However, of

Footnote continued from previous page

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connected entities like noses, arms, and handles which are referred to as "objects" colloquially speaking.

particular interest are the non-linguistic factors which influence the construal one way or the other.

At least three non-linguistic factors have been studied. The first is "perceptual homogeneity" (Bloom, 1990). Bloom argued that when one looks at the distribution of count/mass syntax across superordinate categories one finds that the more the members of a category look alike the more likely it is that the category is labeled by a mass noun. Thus words like "linen" are more likely to be mass nouns across different languages than words like "animal." The second is "arbitrariness of internal structure or shape" (Prasada, 1995). Cues that affect the perception of arbitrariness include whether the structure of some configuration of matter was intentionally generated. Prasada reported two pilot studies in which adults were shown to be sensitive to manipulation of perceived "arbitrariness" of structure/shape. The more arbitrary a structure/shape appeared to be the more likely adult subjects were to invoke a continuously quantified construal. The third factor is whether some configuration of matter coheres or not. For example non-solid substances are understood to be continuously quantified. To my knowledge there are no studies which examine the influence of cohesional properties on adults' construals. Since the development of such a construal concerns a major portion of the thesis, let us now consider the relationship between cohesional properties and quantification in more detail.

As adults we understand that non-solid substances do not cohere and thus we do not treat such substances as intrinsically countable. For example one portion of a non-solid substance can easily come apart into two or more portions of the same material and multiple portions can be coalesced into a single portion of same material. Thus despite the means to refer to portions of non-solid substances as discretely quantified "puddles" or "piles" or "pieces", we label non-solid substances using mass nouns. In contrast a single object will cohere when moved and when two objects come into contact they maintain their boundaries. Thus despite the fact that objects are composed of non-countable stuff like "wood", or "rubber", or "plastic", coherent objects are seen as countable and we label objects using count nouns.

A question may be raised about continuity of development: Do children have the same biases as adults to construe objects as countable things and non-solid substances as uncountable stuff? And do they have the logical resources to distinguish between terms that divide their reference -- like "dog" -- and terms, like "water" and "red", that do not?

The philosopher Quine argued that they do not (Quine, 1960). He proposed that the development of the distinction between countable things and uncountable stuff depends on language development. His suggestion is that children somehow pick up on the syntactic differences between count nouns and mass nouns and then learn the deeper quantificational distinction by which the assignment of determiners is constrained.

The earliest empirical work which bears on this issue was conducted by Roger Brown (Brown, 1957). He showed 3 and 4 year old children an ambiguous event: hands moving in a bowl of confetti. He found that when children were asked about the event using count noun syntax, they pointed to the bowl; when they were asked using mass noun syntax, they pointed to the confetti in the bowl. So at 3 and 4 years of age children are sensitive to the relationship between the quantificational distinction between count nouns and mass nouns and they will use that information to identify potential referents based on their cohesional properties.

Unfortunately these children were old enough to have already mastered count/mass syntax. So with respect to Quine's hypothesis it is not clear whether they learned the quantificational distinction before or after learning count/mass syntax. More recently Nancy Soja and colleagues tested younger children. They found that young 2-year-olds ignored number of portions when projecting meanings of words learned of a non-solid substance and paid attention to the number of portions when projecting the meanings of words learned of an object (Soja, Carey, & Spelke, 1991). Contrary to the suggestion by Quine, these children had not yet begun to use count/mass syntax. Indeed, it was found that 2-year-olds resisted the non-canonical construal of non-solid substances in terms of portions (e.g., "puddle"), until they had begun to use count/mass syntax (Soja, 1992). This suggests, that at least by 2 years of age children have similar biases to adults to construe non-solid substances as uncountable "stuff" and objects as countable "things."

Although Soja and colleagues tried to rule out the possibility children had learned count/mass syntax by looking at children's production of such syntax, it is not certain whether children of that age do not *comprehend* such syntax. In this thesis, I address Quine's proposal by testing infants too young to use language and before the age at which babies first show that they comprehend words. However at 8 months these subjects were just old enough to begin to show signs of understanding non-solid substances as material entities.

Before we can determine whether infants distinguish between objects and non-solid substances quantificationally, we must see whether they know anything at all about such substances. Until now there has been no work on the infant's understanding of the physical properties of non-solid substances. In Chapter 2 of this thesis I examine whether 8-month-old infants understand the non-solid substances using sand as the non-solid substance stimulus. I explore whether babies understand non-solid substances to be 1) like objects in that they are material entities subject to physical laws but 2) different from objects with respect to cohesion. I argue that infants know that the movement of both objects and non-solid substances is constrained by barriers. In addition, I find that infants can distinguish a non-solid substance from an object on the basis of cohesional properties. However, while babies know that non-solid substances are not objects it is also found that babies do not understand that sand as a non-solid substance must not cohere.

If infants are sensitive to these properties, more or less along the same lines as adults, then cohesion or lack thereof should be relevant for quantificational judgments. In Chapter 3, I investigate how the understanding of non-solid substances affects infants' quantificational judgments. In this

Chapter, I pose the question: Do babies construe non-solid substances as "stuff" while understanding objects as "things?" I find that while infants will enumerate objects, their understanding of sand as a non-solid substance is such that number is irrelevant. Thus I confirm that infants have the same biases as adults with respect to countable objects and non-countable non-solid substances.

In summary, while infants are sensitive to the quantificational distinction at issue, they appear to be different from adults with respect the easy alternation between an understanding of non-solid substances in terms of uncountable stuff and countable portions (piles).

In Chapter 4 there is a shift in perspective. I examine preschoolers understanding of non-object discretely quantified entities. Of course adults know many different kinds of discretely quantified entities which are not spatio-temporally defined objects. For example, we use our intuition about the functional organization of the human body to individuate noses and fingernails. Collection words label discretely quantified entities which range over groups of objects (e.g., "forest", "army", "family"). Understanding the meaning of a collection word sometimes involves sensitivity to spatio-temporal cues ("forest", "flock") and social cues ("family", "army") among others. When faced with a novel collective count noun preschoolers have to override the salience of discretely quantified objects in order to pick out a group as a potential candidate referent. Such a task sometimes requires that the young word learner be sensitive to the relevant non-spatiotemporal cues. Of course in the case of words like "army" this is unlikely. Indeed a testament to the salience of spatio-temporally defined objects is that at the late age of 4-years-old children often take count nouns referring to collections ("army", "family", "forest") as referring to kinds of individual objects (a soldier, a baby, a tree).

In summary, this thesis is the first to examine the capacity of infants to construe the world, as adults do, in terms of the fundamental distinction between countable things and uncountable stuff. I have shown that, for young infants, this distinction has the right quantificational consequences. That is, objects are understood to be discretely quantified whereas non-solid substances are not. It remains to be seen when babies begin to have positive expectations about the cohesional properties of sand. Furthermore future work will examine whether the continuous quantification system (which supports judgments of some plus some is more) is in place in infants. Finally, the experiments with preschoolers show that the salience of objects as discretely quantified entities persists into early childhood. In general this work suggests that in the material domain, spatio-temporally defined objects are the canonical discretely quantified entity.

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Chapter 2:

Physical Reasoning in Infancy: The distinction between Objects and Non-solid Substances

SUMMARY OF CHAPTER 2

Young infants represent objects in terms of interrelated principles: cohesion, continuity, and contact. These principles not only enable babies to identify the objects in the world but also constrain reasoning about them. However the physical world also contains non-objects; there is little work on infants' understanding of non-solid substances. Adults know that non-solid substances (e.g., sand) satisfy the continuity and contact principles but not cohesion. Evidence concerning how babies reason about non-solid substances has a bearing on the question of how tightly specified the domain of physical reasoning is. If interrelated principles determine precisely the entities (objects) that fall into the domain, then we might expect one of two outcomes when we present infants with arrays involving non-solid substances:

1. The baby observes that non-solid substances have some of the properties of objects (e.g. they are tangible, visible, rest on surfaces, ...) and thus mistakenly concludes that they have all the properties of objects (the "miscategorization as objects" possibility).
2. The baby notes that non solid substances do not fall in the domain of objects (because they do not maintain their boundaries over time) and thus has no expectations about the behavior of non-solid substances (the "all bets are off" possibility).

Alternatively the infant might appropriately split the domain of physical entities early on.

3. The baby distinguishes objects from non-solid substances, and recognizes some principles non-solid substances satisfy and some they do not (the "two types of physical entities" possibility).

Four studies address whether infants' expectations about non-solid substances are derived from their properties as material entities (e.g., continuity) and whether infants distinguish non-solid substances from objects on the basis of cohesion. It is argued, against the "all bets are off" possibility, that 8-month-olds recognize non-solid substances as material and thus subject to the continuity principle. In addition, contrary to the "miscategorization-as-object" possibility, it is found that infants distinguish objects from non-solid substances with respect to cohesion. It is concluded that by 8 months, infants have split the domain of physical entities into at least two types: objects and non-objects. However it remains to be seen whether non-solid substances are understood as such since 8-month-olds do not yet have positive expectations about the cohesional properties of sand.

INTRODUCTION

Very young infants' understanding of the physical world is articulated in terms of representations of objects -- bounded, coherent individuals which move on spatio-temporally continuous paths (Baillargeon, 1993, in press; Spelke, 1990; Spelke, Breinlinger, Macomber & Jacobson, 1992). The principles which enable babies to identify the objects in the world also constrain their reasoning about them (Carey & Spelke, 1994). One such principle is the *principle of continuity:* an object moves on exactly one connected path through space and time. The infant knows that objects do not capriciously go in and out of existence and cannot get from one place to another without passing through the intervening space. Evidence that infants' representations are governed by the principle of continuity includes the fact that babies as young as 4 months of age expect object permanence (e.g., Baillargeon, 1987) and the fact that 5-month-olds interpret observed discontinuous paths of motion as evidence that two numerically distinct objects are involved in an event (Spelke, Kestenbaum, Simons, & Wein, 1995; Xu & Carey, in press a).

The *principle of cohesion* is a second principle by which infants identify and reason about objects: objects are connected and bounded entities that maintain their connectedness and their boundaries as they move about freely. Evidence that infants' reasoning is constrained by the principle of cohesion includes the fact that babies as young as 5 months of age interpret displays in which surfaces are separated in space or which move independently as displays of more than one object (Hofsten & Spelke, 1985; Kellman & Spelke, 1983). Additionally, in an experiment on which one of the present studies is based, Spelke, Breinlinger, Jacobson and Phillips (1993) showed that 3-month-olds who were habituated to a stationary object generalized habituation when that object was lifted and moved as a whole, but recovered from habituation when that "object" came apart when lifted from above.

The principles of cohesion and continuity play an important role in determining the objects in an array, whereas other principles come into play in constraining reasoning about objects once identified. Examples of the latter include the *principle of contact:* objects interact causally only if they touch (Leslie, 1982, 1988; Spelke, Phillips & Woodward, in press; Van de Walle, Woodward, & Phillips, 1994) and the *principle of solidity:* one object cannot pass through the space occupied by another (Baillargeon, 1986, 1987; Spelke et al. 1992). The principles of physical reasoning are not logically independent; for example, the principle of solidity is derivable from the principles of cohesion and continuity. Indeed, these interrelations among principles is what makes physical reasoning a coherent domain (Carey & Spelke, 1994; Wellman & Gelman, 1992).

Such interrelated principles serve the baby well in identifying objects in the world, and in interpreting and learning more about objects' behaviors. However the physical world also contains entities that are not objects. Our naive physical knowledge must include representations not only of objects like cups and tables but also of non-solid substances like water and sand. The behavior of non-solid substances can be interpreted in terms of some of the principles which apply to objects -- non solid substances cannot pass through the space occupied by objects, and non-solid substances interact causally with other physical entities only when they come into contact. Non-solid substances also satisfy the principle of continuity; they move on spatio-temporally continuous paths. However, non-solid substances are not subject to the principle of cohesion. They do not maintain their boundaries over time because they can be easily separated and recoalesced.

Evidence concerning how babies reason about non-solid substances has a bearing on the question of how tightly specified is the domain of physical reasoning. If interrelated principles determine precisely the entities (objects) that fall into the domain, then we might expect one of two outcomes when we present infants with arrays involving non-solid substances:

1. The baby observes that non-solid substances have some of the properties of objects (e.g. they are tangible, visible, rest on surfaces, ...) and thus mistakenly concludes that they have all the

properties of objects (the "miscategorization as objects" possibility).

2. The baby notes that non solid substances do not fall in the domain of objects (because they do not maintain their boundaries over time) and thus has no expectations about the behavior of non-solid substances (the "all bets are off" possibility).

Alternatively the infant might appropriately split the domain of physical entities early on.

3. The baby distinguishes objects from non-solid substances, and recognizes some principles non-solid substances satisfy and some they do not (the "two types of physical entities" possibility).

There is very little information about what young children know about non-solid substances. Yet, from early infancy children have much experience with such entities, since most of their food is in this form. Some studies on containment have used non-solid substances (sand, salt) in their stimuli; these studies suggest that children as young as 5.5 months of age know that salt and sand satisfy the solidity principle; they know that salt/sand will not pass through the bottom of a container, but will pass through a bottomless tube (Baillargeon, in press -- 5.5-8.5 months; MacLean & Schuler, 1989 -- 14 months). Besides entailing that infants' reasoning about sand/salt is subject to the solidity constraint, these studies also require that infants recognize that sand/salt are subject to the continuity principle; babies realize that sand/salt do not just disappear when hidden from view.

These infant experiments draw on babies' knowledge about commonalties between non-solid substances and objects. They provide preliminary evidence that infants recognize that non-solid substances are like objects in at least some respects, contrary to the "all bet's are off" possibility outlined above. The question remains whether infants *distinguish* non-solid substances from objects. Maybe infants think that non-solid substances are like objects in all respects including cohesion. Toddlers have the distinction in place; by age 2, children take boundaries into account in their extension of names for unfamiliar objects, whereas they ignore boundaries in their extension of names for unfamiliar non-solid substances (Soja, Carey & Spelke, 1990). We know of no studies with younger children or infants concerning whether they represent the difference between these two kinds of physical entities.

The studies in this paper explore whether 8-month-old infants distinguish objects from non-solid substances. This age was chosen for two reasons. First, current evidence suggests that it is at 9 to 10 months of age that babies first begin to comprehend words for kinds of objects and also first begin to represent concepts with the logical force of basic-level count nouns (Xu & Carey, in press a, in press b). For the present studies we wanted babies as yet uninfluenced by linguistic cues to the individuation of objects. Second, 8-month-olds are within the age range of Baillargeon's (in press) studies of containment, which suggest that by this age infants include at least some non-solid substances in their domain of physical reasoning.

To ensure that only the contrast between objects and non-solid substances underlies any difference in babies' reactions to them, we devised stimuli so that in the outcome displays of the following experiments the non-solid substance (i.e., sand) were physically identical to the object displays (i.e., a pile shaped, sand covered object that was identical in shape, size and texture to the pile of sand; see Figure 1). Before we turned to the studies on infants' capacity to *distinguish* sand from objects, we sought to confirm that 8-month-olds treat both the object and the sand as entities subject to at least one principle of physical reasoning -- the solidity constraint. To this end, we replicated Spelke et al.'s (1992) finding that young infants are surprised if an object dropped onto a shelf behind a screen ends up *below* the shelf, and sought to extend this result to sand.

EXPERIMENT 1

Method

Subjects

Forty-eight full-term 8-month-olds (25 boys and 23 girls) were tested (M_{age}: 8 months, 7 days; SD = 13 days). Thirteen additional infants were excluded because of fussiness, experimenter error or equipment failure. The infants' names were retrieved from the birth records in the Greater Boston area and their parents were contacted by letter and phone. Parents were compensated with token gifts (T-shirts, bibs and plastic cups).

Materials

Two types of stimuli were used in this experiment: a small portion of sand and a sand-pile shaped object. The object stimulus was roughly the shape of a flattened cone. It measured 15 cm in diameter at the base and 4.5 cm high at the center. The surface of the object was completely coated with glued on sand. To an adult, at a distance the object looked like a pile of sand. A piece of string was attached to the top center of the object allowing it to be raised and lowered without being held directly. The sand used as the non-solid substance stimulus was poured into a pile approximately the same size and shape as the object (see Figure 1).

In each of the experiments reported here the experimenter ensured that the events involving the sand stimulus were similar to the events involving the object stimulus. For example, whenever the object was brought into view it was partially lowered towards a surface and then stopped and shaken in mid-descent before being placed onto that surface. This shaking was always performed at exactly the point where, in the sand trials, a transparent container of sand was held to be poured. The timing of these events was matched so that lowering the object onto a surface from a given distance took exactly as long as pouring a comparable amount of sand onto that surface.

In addition to the sand and the object, the stimuli included a removable shelf which fit into place 11 cm above the stage floor. The stage floor was light blue; the shelf was bright red.

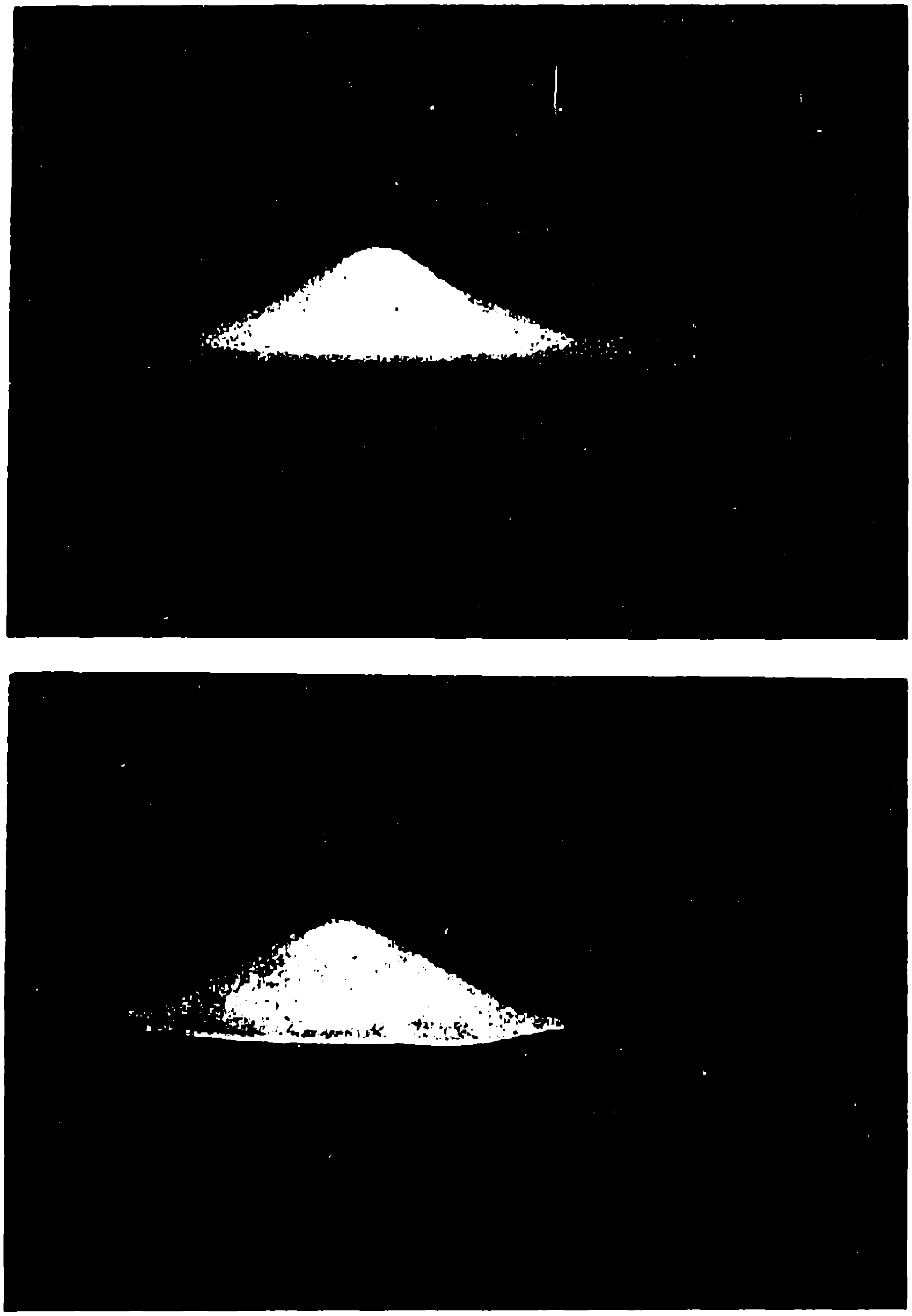

Figure 1. Photograph of stimuli: sand pile (top) and object (bottom)

Setup

The experimental events took place on a stage measuring 38 cm x 88 cm x 34 cm and raised 100 cm from ground level. There was a black felt backdrop for the stage which hid the movements of the experimenter. Attached to the front of the stage was a screen which could be raised by the experimenter to partially obscure the stage. The stage area itself was surrounded by black curtains from floor to ceiling. These curtains hid two observers who recorded looking time data. During the experiment, the lab was darkened and the stage was lit directly from above. The infant was lit indirectly by lamps in front of and on either side of the stage.

The infant sat facing the stage with its head about 70 cm away and it's eyes slightly above the floor level of the stage. The child's parent/guardian sat on the infant's left facing away from the stage. Parents were instructed to interact with the baby as little as possible and to resist the urge to turn and look at the display. The observers could see the infant through an invisible hole in the curtain. They could not see the stage however, and thus were blind to the details of the experimental manipulation.

Each pair of observers included at least one highly trained and experienced "primary observer." Each observer measured looking time by pressing a button connected to a computer. The computer signaled the end of each trial based on the recording of the primary observer. Trials ended when the infant looked away for 2 continuous seconds having looked for at least 0.5 s before that. A white noise generator masked any sound from the movements of the observers and the experimenter.

Procedure

The 48 subjects were randomly assigned to one of three conditions: object, sand or baseline. The two experimental conditions (object, sand) each had three sections: an introduction to the stimuli, familiarization trials, and test trials. During the introductory section infants were allowed to physically handle the stimuli. Next they were familiarized to the stage and to the pouring of sand or the lowering of objects onto the stage. Finally during the test trials, the shelf was introduced and the infants were shown partially hidden events in which the sand was poured or the object was lowered behind the screen. In this experiment the test trials probed whether infants found the outcome to be unexpected when either the object or the sand apparently had passed through the shelf ("impossible" for adults). This should result in elevated looking times relative to those in which the outcome was the expected one of the sand or the object sitting on top of the shelf ("possible" for adults). In the baseline trials subjects simply saw alternating outcomes of the test conditions without any pouring of sand or lowering of the pile shaped object beforehand. We will begin by describing the procedure for the object condition in detail and then we will describe the sand condition and the baseline condition. Condition (object, sand, baseline) was a between subjects variable.

Object Condition, introductory exposure. Each infant in the object condition was given a chance to manipulate the object. The experimenter held the object by it's string for the infant to see. Then she walked towards the infant's high chair drawing the baby's attention[2] to the object before lowering it onto the high chair tray. Babies often grasped the object spontaneously. The parent prompted the infant to manipulate the object if the infant was initially reluctant to touch it. Each baby handled the stimulus for 60 s.

Object Condition, familiarization trials. After the introductory exposure babies were provided with four familiarization trials. Subjects saw the object dangled and jiggled for 5 s about 40 cm above the stage floor before it was lowered. In the first familiarization trial the object was lowered in full view of the baby. In the remaining three familiarization trials infants were first shown an empty stage; then the screen was raised to hide the stage floor. The object was then lowered behind the screen which was thereafter removed to reveal the object resting on the stage floor. Infants looking time at the object was measured. Once the trial had ended the object was removed from the display, leaving an empty stage.[3]

Object Condition, test trials. Six test trials followed the four familiarization trials. The experimenter brought out the shelf, showed it to the baby, and tapped it to show that it was solid. The experimenter then placed the shelf into the display 11 cm above the stage floor. The screen was then raised into position hiding both the shelf and the stage floor. Next, the object was lowered behind the screen as in the familiarization trials. The screen was then removed to reveal the object resting on top of the shelf (possible outcome) or below the shelf (impossible outcome). Looking times at these outcomes were measured. Outcomes (on top of shelf, below the shelf) were alternated and the order of these alternations was counterbalanced across infants.

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[2] In general experimenters drew the baby's attention by calling out his or her name, speaking to the baby in "motherese" and making unusual vocalizations.

[3] The stage floor of the apparatus actually consists of two identically colored boards; one on top of the other. Stimuli were removed by pulling the top board, and the stimuli it supported, through a flap in the backdrop of the stage. The top board was then emptied and placed back
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Sand Condition, introductory exposure. Each infant in the sand condition was given a chance to handle a portion of sand. The experimenter stood in front of from the infant holding a plastic transparent measuring cup of sand in one hand and an empty measuring cup in the other. She drew the infant's attention to the measuring cups before pouring the sand back and forth between them. The experimenter then walked towards the infant's high chair and poured the sand onto a plate on the high chair tray. If infants were reluctant to touch the pile of sand, their parents prompted them to do so. Each stage of the introductory exposure in the sand condition was timed to match the stages of introductory exposure in the object condition. Each baby handled the stimulus for 60 s.

Sand Condition, familiarization trials. As in the object condition, one trial took place in full view and the other three involved a screen. Babies were familiarized to the sand being poured onto the stage floor in the first trial. In the remaining trials first a screen was raised hiding the stage floor; next the sand was poured. The experimenter made sure that the measuring cup was visible as the sand was poured and that the pouring sand could be seen leaving the cup. After 5 s of pouring, the cup was withdrawn and the screen was removed to reveal a pile of sand sitting on the stage floor.

Sand Condition, test trials. Immediately following the familiarization trials were six test trials. The shelf was introduced, tapped, placed into the display, and hidden by a screen as in the object condition. The sand was poured behind the screen. Finally the screen was removed to reveal a pile of sand either on top of the shelf (possible outcome) or below the shelf (impossible outcome). At this point the baby's looking time was measured. Order of outcome was counterbalanced across infants.

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onto the stage floor for the next trial. The removal of the board took place in full view of the infants and this procedure was followed for all of the experiments in this paper.

Baseline Condition

Infants in the baseline condition were not introduced to the stimuli beforehand; neither did they see pouring or lowering. They were given six baseline trials. They were first shown the screen already raised and hiding the stage with the shelf in place. Then the screen was lowered revealing the object/pile[4] on top of the shelf or resting below the shelf. As in the test trials these two outcomes were alternated, and the orders were counterbalanced across subjects. Looking times were measured as in the test trials of the Experimental conditions.

Results

Looking by 30 of the 48 infants was measured by two observers. Mean inter-observer reliability for those 30 infants was 90%.

In this experiment and those which follow alpha has been set at .05. Preliminary ANOVAs found no effects of order of outcome or sex of subject; subsequent analyses collapsed across these variables. Figure 2 shows the mean looking times for the two outcomes (on top of the shelf/below the shelf) in each of the 3 conditions. A 3 x 2 ANOVA examined the effects of condition (baseline, sand, object) and outcome (on top of, below) on looking times. There was no main effect of condition. There was a main effect of outcome; subjects looked longer overall at the outcome in which the object/pile was below the shelf, $F(1,45) = 8.01, p<.01$. There was an Outcome x Condition interaction, $F(2,45) = 6.02, p<.005$. Separate oneway ANOVAs revealed that this interaction reflected the fact that the infants in the baseline condition did not differentiate these 2 outcomes, $F(1,15) = 2.21$, *ns*; whereas those in each of the experimental conditions did (Object: $F(1,15) = 5.1, p<.04$; Sand: $F(1,15) = 13.25, p<.003$).

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[4] Because of ease of manipulation, the stimulus in the baseline trials was actually the object. But since the baby had no experience with either the object or sand, and since the object and the sand
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pile looked identical from the distance at which the baby viewed them, these looking times serve equally well as a baseline for the sand condition.

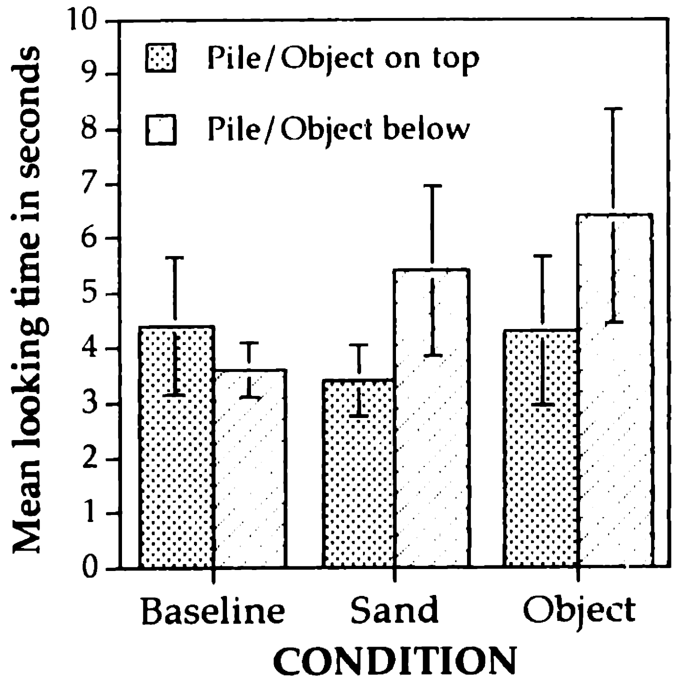


Figure 2. Looking time data for Experiment 1

In sum, babies in both the object and the sand conditions succeeded at this task, looking longer at the impossible outcome of the object/pile below the shelf. There was no baseline preference for this outcome.

Two focused ANOVAs compared the sand and object conditions separately to the baseline condition. The interaction between the baseline condition and the experimental condition was significant in each case (object condition, $F(1,30) = 7.67, p<.02$; sand condition, $F(1,30) = 13.24, p<.002$). In addition, subjects succeeded equally well in the object and the sand conditions. An ANOVA examining the effects of condition (object/sand) and outcome on looking times revealed only the main effect of outcome, $F(1,30) = 16.01, p<.001$. There was no main effect of condition nor any interaction between condition and outcome.

Non-parametric analyses revealed the same pattern. Only 6 of the 16 babies in the baseline condition had a preference for the outcome where the object/pile was below the shelf, Wilcoxon $Z = 1.34$, *ns*. In the object condition, 13 of the 16 babies preferred the impossible (below the shelf) outcome, Wilcoxon $Z = 2.15$, $p<.04$. Similarly in the sand condition 14 out of 16 babies preferred the impossible outcome, Wilcoxon $Z = 3.08$, $p<.005$.

Discussion

Young infants' adherence to the solidity constraint on object motion appears to be robust. Experiment 1 provides a replication of Spelke et al.'s (1992) results albeit with older babies but with a very different object as stimulus, and under conditions of brief familiarization rather than full habituation. The important result of Experiment 1 is the extension of this finding to sand, confirming the finding that 5.5 to 8.5-month-old infants do not expect a non-solid substance (in that case, salt) to fall through the bottom of a container (Baillargeon, in press).

That babies expected the sand, like the object, would not pass through the shelf argues against the "all bets are off" possibility. Babies were provided evidence that sand violates one of the fundamental principles that determines objects in the world: cohesion; yet they still treated sand as a physical entity, subject to the solidity principle. Before we can be certain of this argument, however, we must be sure that babies encoded the non-cohesiveness of sand. Perhaps they interpreted the behavior of sand as reflecting non-rigidity (i.e., like a flexible piece of rope) rather than non-cohesiveness, and thus distorted the evidence for non-cohesiveness as consistent with the sand being an object (consistent with the "miscategorization as object" possibility). Before we accept that babies have differentiated two types of physical entities by 8-months of age, we must provide positive evidence for this putative differentiation. Experiments 2 - 4 explore this issue.

The principle of cohesion underlies the status of objects as countable entities. Infant number studies provide ample evidence that babies' representations of the world are articulated in terms of individuated objects (Wynn, 1992; see also Spelke et al., 1991; Uller, Carey, Huntley-Fenner, & Klatt, 1994; and Xu & Carey, in press a). Because objects maintain their boundaries, we may establish representations of individual objects which we track through time. Objects do not leave portions of themselves behind as they move through space, whereas non-solid substances often do. Experiments 2 - 4 explore whether 8-month-olds distinguish sand and objects on these grounds. In Experiment 2 we compare infants' expectations concerning the result of two acts of pouring sand behind a screen versus the result of two successive jigglings of the pile shaped object at the top edge of the screen before it is finally released. Given the voluminous evidence that infant individuate objects and trace their identity through time (e.g. Spelke et al., 1991, Xu & Carey, in press a), they should expect only one object on the stage floor when the screen is removed, and should be surprised if two objects are revealed upon the screen's removal. If babies do not differentiate sand from objects with respect to cohesion they should have the same expectancy in the case of sand; that is, they should expect one pile of sand rather than two.

EXPERIMENT 2

Method

Subjects

Subjects were 32 full-term infants (17 boys, 15 girls) at 8 months of age (M_{age}: 8 months, 5 days; SD = 17 days). Three additional infants were excluded because of fussiness. Babies were contacted and compensated as in Experiment 1.

Materials and Set-up

The sand and the pile shaped object of Experiment 1 were the stimuli in Experiment 2 as well. The stage set-up was also identical to that of Experiment 1 except that in Experiment 2 the shelf was not used.

Procedure

Babies were randomly assigned into the sand condition (n= 16) or the object condition (n = 16). Each condition consisted of three sections: an initial introductory exposure to sand or to the object, as in Experiment 1; baseline/ familiarization trials; and test trials. The introductory period served to acquaint the babies with the novel object (object condition) or with the sand (sand condition). The baseline/familiarization trials introduced infants to the apparatus and to the stage set-up and established whether they had an intrinsic preference for outcomes of one or two objects/piles of sand. In the test trials subjects were required to represent the trajectory of the partially hidden object/sand and to make a judgment about how many objects/piles there should be based on that representation.

Stimulus (object, sand) was a between subjects variable but condition (baseline, test) varied within subjects. As before, we will begin by describing the procedure for the object condition and then we will describe the sand condition.

Object Condition, introductory exposure. Each infant in the object condition was given a chance to manipulate the pile shaped object exactly as in Experiment 1. Each baby was exposed to the stimulus for 60 s.

Object Condition, baseline/familiarization trials. There were three pairs of baseline trials. In the first pair there was no screen and in the other pairs a screen obscured the stage floor. Each pair of trials consisted of a "single object" trial and a "double object" trial.

In single object trials of the first pair the object was attached to a string which was held by the experimenter. It was then lowered towards the stage floor. The object was stopped halfway down and the experimenter drew the infant's attention to the object by shaking it for 5 s. Finally the object was placed on the stage floor; where to get the infant's attention, the experimenter tapped the object five times before letting the string go. Once the experimenter's hand was retracted from the display the observers were signaled by the experimenter to begin measuring looking time. In double object trials of the first pair two objects were lowered simultaneously; they paused halfway down, were jiggled for 5 s, and then simultaneously tapped on the floor of the stage before being released. Looking time was measured to the display of two objects on the stage floor.

The second pair and third pair of trials were the same except that the single object or the double objects were lowered behind the screen. Subjects were first shown that the stage floor was empty. Next a screen was introduced which obscured the lower half of the display. In the single object trial, the infant's attention was drawn to a single object which was lowered towards the screen. This object paused halfway down so that its bottom was partially obscured by the screen while its top was visible. The infant's attention was drawn to the object which was jiggled for 5 s before it was lowered behind the screen towards the stage floor. The object was then tapped on the stage floor and released. Finally the screen was removed and the infant's looking time at the display was measured. In the double object trial the empty stage was shown and then partially hidden by a screen. Then two objects were lowered simultaneously towards the stage floor; they paused on the way down; were jiggled for 5 s while partially hidden; then lowered, tapped, and released. The screen was then removed and looking time at the two objects was measured. The baseline/familiarization trials involving a screen served to inform the babies that an object (or objects) lowered in a hidden trajectory lands where it (or they) should. The baseline/familiarization trials overall provided a measure of the a priori preference for looking at one or two objects. None of the baseline/familiarization trials provided information about what to expect on test trials.

There were a total of six baseline/familiarization trials -- two without screens and four with screens. These trials alternated between one and two object outcomes in two possible orders (1-2-2-1-2-1 or 2-1-1-2-1-2). Order and the side of the stage floor to which the single object was lowered were counterbalanced across subjects.

Object Condition, test trials. Six test trials immediately followed the baseline trials. First, the subject's attention was drawn to the empty stage; then the screen was raised to hide the floor of the stage. The object was brought into view on one side of the stage and lowered until it was partially hidden by the screen. The infant's attention was drawn by the experimenter to the object which was jiggled for 5 s. The experimenter then raised the object above the screen and moved it to the other end of the stage and then lowered it again so that it was again partially hidden. The infant's attention was drawn to the object which was jiggled for 5 s. Finally the object was lowered onto the stage floor. The screen was then removed to reveal either one ("possible outcome" for adults) or two ("impossible outcome" for adults) objects on the stage floor; test trials alternated between these two outcomes. Side of presentation (left, right) and the order of the outcomes (one object first, two objects first) were counterbalanced across subjects.

Sand Condition, introductory exposure. Each infant in the sand condition was given a chance to handle a portion of sand just as in Experiment 1. Each baby was exposed to the stimulus for approximately 60 s.

Sand Condition, baseline/familiarization trials. As in the object condition, in the sand condition there were three pairs of trials; one pair without a screen and two pairs with a screen. We will begin by describing the first pair of trials. In single pile trials a hand holding a transparent measuring cup of sand was introduced into the display. The experimenter encouraged the infant to look and poured some of the sand onto the stage floor.[5] During the pouring, both the cup and the sand leaving the cup were fully visible. After about 5 s, the sand formed a pile approximately the same size, shape, and color as the object in the object condition. The measuring cup containing the remaining sand was then withdrawn from the display. Once the measuring

[5] Some of the sand was left in the measuring cup after each pouring event. This was done to provide infants with additional evidence that sand does not cohere and to help rule out the possibility that what was being seen was some kind of flexible object.

cup was no longer visible the observers were signaled to begin measuring looking time. The double pile trials involved two measuring cups containing sand. These measuring cups were introduced simultaneously and poured simultaneously onto the stage floor. Once each pile was the same size as the pile shaped object the measuring cups were withdrawn and looking time to the two piles of sand was measured.

The second pair and third pairs of baseline trials were similar to the first pair except that sand was poured behind a screen. In the single pile baseline trials subjects were first shown an empty stage and then the screen was introduced. Next, a measuring cup containing sand was lowered and shown to the infant. The experimenter poured the sand behind the screen onto the stage floor. Finally the measuring cup was withdrawn and the screen was removed. Looking time at the display of the single pile of sand was measured. In the double pile trials the infant was shown the empty stage and then the screen was raised. Next, two measuring cups of sand were introduced and sand was simultaneously poured from them behind the screen onto the stage floor. The measuring cups were withdrawn and the screen was removed. The looking time to the display of two piles of sand was measured.

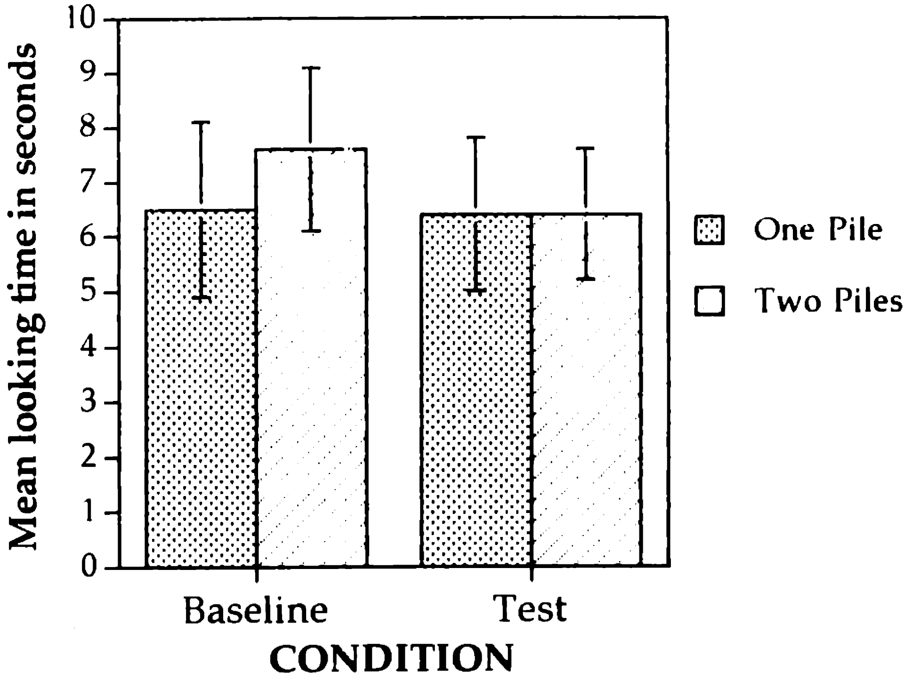
There were a total of six baseline trials in the sand condition -- two without screens and four with screens. These trials alternated between one and two piles of sand in two possible orders (1-2-2-1-2-1 or 2-1-1-2-1-2). Order and the side of the stage floor on which the single pile was poured were counterbalanced across subjects.

Sand Condition, test trials. The baseline trials were followed immediately by six test trials. Infants were shown the empty stage; then the screen was raised to hide the stage floor. Next, a measuring cup of sand was introduced and shown to the infant. The experimenter poured sand behind one end of the screen from the measuring cup. Both the cup and the sand leaving the cup were fully visible. The cup was then moved to the other end of the stage. The experimenter again drew the infant's attention to the measuring cup. Sand was poured behind the other end of the screen. The measuring cup was then withdrawn and the screen was removed. Subjects saw either one pile of sand (impossible outcome) or two piles (possible outcome). As in the Object condition, order of outcome (one pile first, two piles first) and side of presentation (left, right) were counterbalanced across subjects.

If subjects misidentify sand as an object, they should expect one pile of sand when the screen is removed, and should look longer at two pile outcomes. Adult expectancies, of course, are exactly the opposite; adults expect two piles of sand in these circumstances.

Results

Looking time data for all 32 subjects were coded by two observers; inter-observer reliability in Experiment 2 was 93%. Preliminary ANOVAs confirmed that there were no effects of order, side of presentation or sex of the infant on looking times. Subsequent analyses collapsed across these factors. To test the effect of the between-subjects variable stimulus type (object, sand), and within-subjects variables condition (baseline, test) and outcome (one, two) on looking times, we conducted a 2 x 2 x 2 ANOVA. There was a significant 3-way interaction (stimulus x condition x outcome), $F(1,30)=7.83, p<.01$. More focused, 2 x 2 ANOVAs revealed that this effect was due to the significant Condition x Outcome interaction in the object condition, $F(1,15) = 7.996, p<.02$ in the face of a failure of this interaction in the sand condition, $F(1,15) = 1.215$, *ns*. In the object condition infants looked longer at two objects with respect to their baseline preference. In the sand condition there was no such change in preference between the baseline trials and the test trials (see Figure 3).



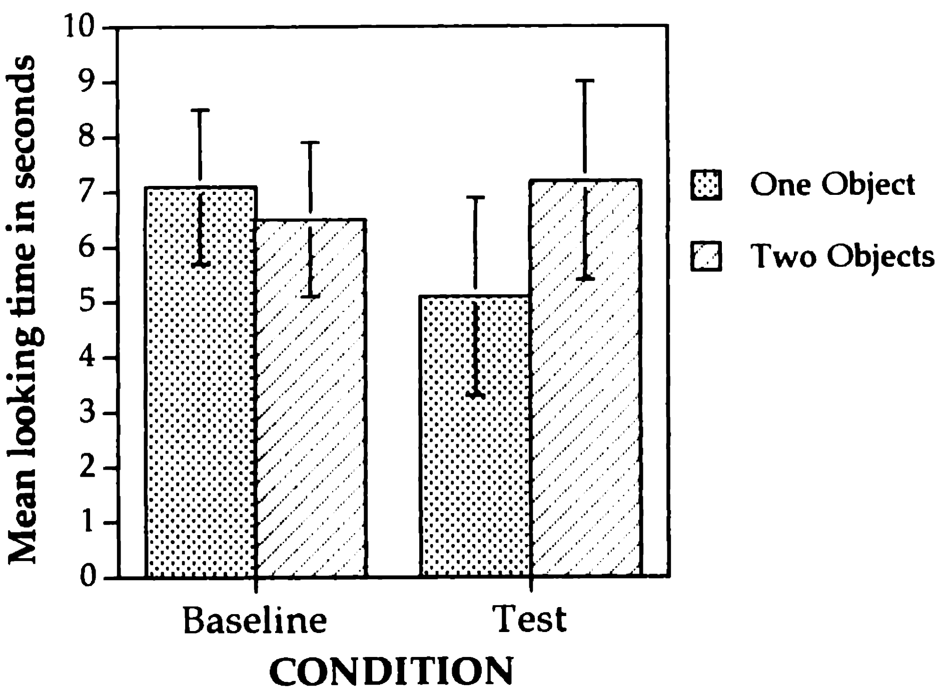


Figure 3. Looking time data for Experiment 2: (3a) sand condition and (3b) object condition

Infants clearly differentiated the outcomes of the test trials within each condition. A 2 x 2 ANOVA examined looking times on test trials only with respect to stimulus (object, sand) and outcome (one, two). The Stimulus x Outcome interaction was significant, $F(1,30) = 4.445$, $p<.05$.

These findings hold for individual babies as confirmed by non-parametric analysis. On the object test trials 13 out of 16 babies looked longer at the unexpected outcome of two objects, Wilcoxon $Z = 2.46$, $p<.02$. On the sand test trials, in contrast, 7 out of 16 babies looked longer at the outcome of one pile of sand, 8 looked longer at 2 piles and 1 looked equally long at both, Wilcoxon $Z = 1.06$, *ns*.

Discussion

As expected, babies in the Object condition established a representation of a single object and tracked it through time, expecting only one when the screen was removed. Even though the object was jiggled at the edge of the screen for the same amount of time that the sand was poured, babies did not assume that the object left portions of itself below. Success in this condition required that the infant trace the trajectory of a particular object through space and time. This finding is as expected given the evidence that infants represent objects as coherent individuals and given that infants use spatio-temporal evidence to individuate and trace identity (Hofsten & Spelke, 1985; Kellman & Spelke, 1983; Spelke et al., 1991; Xu & Carey, in press a).

The important result from Experiment 2 is that, contrary to the "miscategorization as object" possibility, infants clearly distinguished the sand from the object. Unlike the response in the object condition, in the sand condition infants did not expect only one pile of sand when the screen was removed. Thus, the infants in this study did not misconstrue sand as a flexible object which maintains its boundaries over time.

Although the infants differentiated the sand from the pile shaped object, it is not clear that they had any firm expectancy regarding sand. They were not surprised at the outcome of a single pile of sand, even though sand had been poured in two distinct locations. This failure is not informative however, because 8-month-old infants fail to add one object plus another object under the conditions of this experiment (Uller et. al., 1994).[6] We return in Experiment 4 to the question of how firm is the 8-month-old infant's understanding of sand as non-cohesive.

Unfortunately, the object condition in Experiment 2 is subject to the following objection: The study was designed to show that infants will make different inferences about objects and non-solid substances based on their cohesiveness or lack thereof. Yet subjects in Experiment 2 had explicit evidence that the object did not leave part of itself behind. Remember the procedure for Experiment 2: when the object was introduced it was partially lowered behind the screen and jiggled. At that point the infant had to judge whether the object remained complete or not. Subsequently, the object was raised to be moved to the other side. However when the object was raised it came into full view. Thus the infant had direct evidence that the object was still whole. Therefore there was no need to infer that there should only be one object sitting on the stage at the end of the trial. A stronger test of the claim that babies expect objects to cohere would require an inference that the whole object stays as a piece during the complex series of movements and jiggling. Experiment 3 provides such a test. Given the wealth of evidence that the principle of cohesion constitutes part of the infants knowledge about objects we expect infants to succeed in Experiment 3.

EXPERIMENT 3

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[6] Wynn's (1992) experimental protocol involves showing the infant an object, covering it with a screen, and then introducing a second object. Uller et al. (1994) replicated Wynn's results with the objects of the present study (the pile shaped objects). However if the screen is placed on the stage first before any object is introduced, 8-month-olds fail to expect two objects when one object is lowered behind the screen and then a second one is introduced and lowered behind the screen. See Uller et al. (1994) for an interpretation of this pattern of results.

Experiment 3 is a replication of the Object condition in Experiment 2. This time we were careful to keep the object partially hidden after it went behind the screen for the first time. To facilitate this we used a cylindrical elongated object which was covered in colored sand.

Method

Subjects

We tested 16 full-term infants (8 boys, 8 girls) at 8 months of age (M_{age}: 8 months, 6 days; SD = 10 days). Seven additional infants were excluded because of fussiness. Babies' parents were contacted and compensated as in previous experiments.

Materials and Set-up

The object used in this experiment was cylindrical. It measured 9 cm in height and 6 cm in diameter. The object was covered in bright green sand to make it attractive to infants. The cylinder was moved by means of a string attached to its top center. The stage was exactly as in Experiment 2.

The infants in Experiment 2 were observed "live" and also recorded using a hidden video camera. Data were collected by a primary observer during the experiment. After the experiment, another observer, who was blind to which experiment the baby participated in, measured looking time for half of the infants from the videotaped records.

Procedure

As in the object condition of Experiment 2 there are three sections in Experiment 3: an initial introductory exposure to the object, baseline/familiarization trials, and test trials. The introductory period served to introduce the babies to the novel object. The baseline/familiarization trials introduced infants to the apparatus and to the stage set-up and established whether they had an intrinsic preference for outcomes of one object or for outcomes of two objects. In the test trials subjects were required to trace the trajectory of the partially hidden cylinder.

Introductory exposure. As in Experiment 2 infants were familiarized with the object before testing began. Each infant played with the cylinder for 60 s.

Baseline/familiarization trials. The baseline/familiarization trials in Experiment 3 were exactly like those in the object condition of Experiment 2, except that there were two pairs of baseline trials in Experiment 3 as compared with three in Experiment 2. The first pair took place in full view and the second pair took place on a partially hidden stage. Each pair consisted of a single object trial and a double object trial. In the double object trials the objects were lowered simultaneously. There were two orders of baseline/familiarization trials (1-2-2-1 or 2-1-1-2). As before, objects were lowered halfway, jiggled for 5 s, and then lowered completely. Order of outcomes and the side of the floor on which the object was placed in single object trials were counterbalanced across subjects.

Test trials. In this study we were careful to design the test trials so that in order to be successful the subject had to make an inference based on the cohesional properties of objects. The experimenter never revealed the whole object once it was first partially hidden behind the screen. The test trials went as follows: First the experimenter showed the empty stage, then she introduced the screen. Next, she lowered the object and held it partially visible over the top of one end of the screen, jiggled it for 5 s, and moved it to the other end while it was still partially hidden behind the screen. There she jiggled it again for 5 s and lowered it onto the stage floor. The screen was then removed to reveal either one object ("possible outcome" for adults) or two objects ("impossible outcome" for adults). Should subjects infer that the object should not leave pieces of itself behind as it moves about, they will look longer at the impossible outcome of two objects.

Infants were shown six test trials, in one of two possible orders of outcomes (1-2-1-2-1-2 or 2-1-2-1-2-1). Order of outcomes and the side of presentation of the single object were counterbalanced across subjects.

Results

Inter-observer reliability for this experiment was 93%. ANOVAs revealed no main effects of side, order or sex of infant. We collapsed across these factors in subsequent analyses.

A 2 x 2 ANOVA was conducted comparing the effects of outcome (one, two) and condition (baseline, test) on looking times. There was no main effect of condition, $F(1,15) = .821$, *ns*, but there was a main effect of outcome, $F(1,15) = 9.249$, $p<.01$, indicating an overall preference for looking at the outcome of two objects over one object. However contrary to our expectation there was no Outcome x Condition interaction, $F(1,15) = .119$, *ns* (see Figure 4). This may appear to be a failure to replicate the results of Experiment 2, but a closer analysis of the data reveals a different picture.[7] There was no difference between looking at one object and two objects in the baseline trials, $F(1,15) = 1.445$, *ns*, whereas in the test trials, subjects looked longer at the impossible outcome of two objects than at the possible outcome of one object, $F(1,15) = 5.831$, $p<.03$. Experiment 3 thus replicates the finding for the object condition in Experiment 2.

These results are confirmed by non-parametric analyses. In the Baseline condition 10 out of 16 babies looked longer at the outcome of two objects, Wilcoxon $Z = 1.19$, *ns*. Whereas in the test condition 12 out of 16 babies looked longer at the impossible outcome of two objects, Wilcoxon $Z = 2.17$, $p<.03$.

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[7] Since more focused analyses are said to be "unprotected" given the non-significant interaction we applied the Bonferroni procedure to yield different alpha values for the intended analyses: baseline $\alpha = .01$ and test $\alpha = .04$.

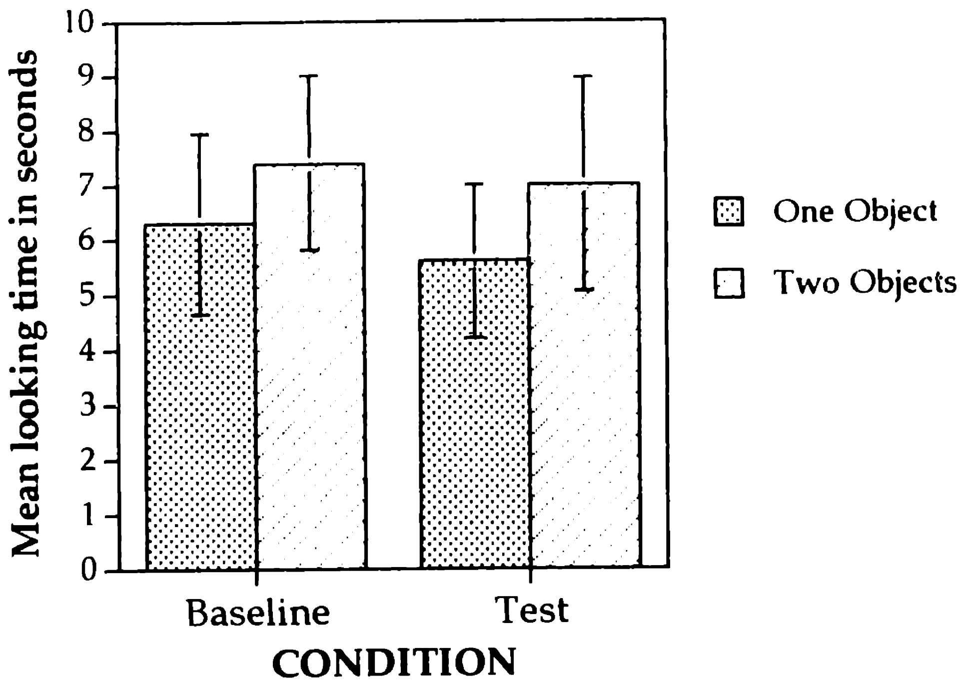

Figure 4. Looking time data for Experiment 3 (replication of the object condition of Experiment 2)

Discussion

The results of Experiment 3 confirm that 8-month-old infants expect objects to maintain their boundaries over time, even under conditions in which they are not in continuous perceptual contact with all of those boundaries. Unlike the sand condition of Experiment 2, the babies in Experiment 3 expected one object when the screen was removed, even though they had not seen the whole object raised above the screen. The results of the two experiments together confirm that babies of this age differentiate sand from objects with respect to cohesion. Apparently the experience provided them with sand during the exposure and familiarization trials of Experiment 2 provided sufficient evidence that sand, unlike objects, does not maintain its boundaries over time.

Experiment 2 showed that infants know that sand is not an object. Recall, however that the infants in the sand condition did not differentiate the two outcomes of the test trials. That is, whereas they did not expect only one pile behind the screen, they did not expect *two* piles either. As mentioned above, this failure could simply reflect the fact that under these conditions babies of this age cannot add 1 + 1 (Uller et al., 1994). It is also possible that babies of this age have not fully differentiated sand from objects. Adults know that it is not merely that sand may not cohere over time, it is in the nature of sand that it definitely does not cohere. Perhaps babies do not yet realize this.

Experiment 4 adapts the methodology of Spelke et al. (1993) to address this issue. Spelke et al. habituated infants to a stationary object. After habituation the object was grasped by a hand and the object either came up as a whole piece or separated into 2 pieces. Subjects looked longer at the outcome in which the object separated. In Experiment 4, infants are familiarized to a sand pile or the object resting on the stage. After familiarization infants see either the object or the pile of sand grasped from above. Given Spelke et al.'s results, we would expect babies in the object condition to be surprised when the "object" falls apart. Of particular interest is whether infants distinguish sand from objects in this respect. If infants know that sand does not cohere, those in the sand condition will look longer at the outcome in which a "pile of sand" moves together as an object.

EXPERIMENT 4

Method

Subjects

Forty-eight full-term infants (30 boys, 18 girls) were tested at 8 months of age (M_{age}: 8 months, 3 days; SD = 9 days). Thirteen additional infants were excluded because of fussiness, experimenter error or equipment failure. Infants were contacted and compensated as in Experiments 1, 2 and 3.

Materials

Stimuli were the same as in Experiments 1 and 2. The stage set-up was exactly as in Experiments 2 and 3. Infants were videotaped; there was one live observer and one videotape observer.

Procedure

Infants were randomly placed into one of three conditions (object, sand, and baseline) -- 16 infants per condition. In the experimental conditions (object, sand) there were three sections: an introduction to the stimuli, familiarization trials, and test trials.

Unlike Experiments 2 and 3, in the introductory section of the current study subjects were introduced to *both* stimuli. This was done for two reasons: 1) Every experimental subject saw both sand and the pile shaped object in the test trials; the introduction to the stimuli before testing began reduced the likelihood that subjects' looking times during the inconsistent outcomes are due to simple novelty of the stimuli. 2) In Spelke et al. (1993) it was found that in the absence of evidence from previous movement infants expect a stationary entity in a display to move together as a one piece. This means that babies should find the outcome where the entity falls apart to be intrinsically interesting. Given such a baseline preference, this makes it harder to get a result which depends on greater looking at the "fall apart" outcome in the test trials than in the baseline. Exposure to both the object and the non-coherent sand before testing should reduce this preference.

Object Condition, introductory exposure. Before the experiment began, every infant in the object condition was given a chance to manipulate both the object and some sand. The protocol was the same as in previous experiments except that each infant played with one stimulus for 30 s and then the other stimulus for the same amount of time. In addition, the sand was poured directly onto the baby's high chair tray instead of onto a plate since infants were occasionally distracted by the plate. The order of the presentation of the stimuli was counterbalanced across infants.

Object Condition, familiarization trials. First the Experimenter drew the infant's attention to the empty stage. Then a screen was introduced covering the stage floor and the lower half of the display. The experimenter next presented the object which was lowered until its bottom was hidden behind the screen but its top was still visible above the screen. The object was jiggled for about 5 s before being lowered to the stage floor behind the screen. The screen was then removed to reveal the object resting on the center of the stage floor and an open hand sitting stationary 25 cm above the object. Infants' looking to the display was measured. This was repeated six times. The presence of the open hand in the display served to desensitize the infants to the presence of a hand in the display, since the hand would grasp and move the object on the test trials.

Object Condition, test trials. Six test trials immediately followed the familiarization trials. These began just like the familiarization trials. The object was introduced, jiggled, and hidden behind the screen, and then the screen was dropped to reveal the hand above the object. This time instead of remaining stationary the hand reached down and grasped the object to move it. Two outcomes alternated: the object came as a coherent piece and was moved to a new location on the side of the stage ("possible outcome" for adults) or the object came apart like sand (having been replaced with a pile of sand) and a portion of the of the sand was moved to the side of the stage ("impossible outcome" for adults). The hand was then withdrawn, at which point the observer measured looking time to the resulting display where the displaced object or two portions of sand remained on the stage floor. This pair of outcome trials was repeated three times.

Subjects in the object condition saw a total of 12 trials (6 familiarization and 6 test). The side to which the stimuli were moved and the order of outcomes was counterbalanced across infants.

Sand Condition, introductory exposure. Subjects were introduced to both stimuli in counterbalanced order as in the object condition.

Sand Condition, familiarization trials. The sand condition paralleled the object condition. First the experimenter drew the infant's attention to the empty stage. Then the screen was introduced. The experimenter next brought into view a transparent measuring cup containing sand. The sand was poured behind the screen until the measuring cup was empty. Both the cup and the sand pouring from the cup were visible above the screen during the pouring event. The screen was then removed to reveal a pile of sand resting on the center of the stage floor and an open hand sitting stationary 25 cm above it. This familiarization event was repeated six times.

Sand Condition, test trials. Immediately following the familiarization trials came six test trials. The measuring cup containing sand was first introduced and then sand was poured behind the screen. Then the screen was dropped to reveal the hand above the sand pile. The hand reached down and grasped the pile of sand. The sand either fell apart, in which case a portion of it was moved to the side of the stage ("possible outcome" for adults), or was moved as a coherent piece (having been replaced by an object) to the side of the stage ("impossible outcome" for adults). The hand was then withdrawn at which point the observer measured looking time to the resulting display where the displaced object or two portions of sand remained on the stage floor. Note that these outcomes are identical to those in the object condition (see Figure 5 for a schematic representation of both outcomes). This pair of trials was repeated three times. Subjects in the sand condition saw a total of 12 trials (6 familiarization and 6 test). The side to which the stimuli were moved and the order of outcomes was counterbalanced across infants.

Baseline Condition, introductory exposure. Subjects were introduced to both stimuli in counterbalanced order as in the object condition and the sand condition.

Baseline trials. Subjects first saw the empty stage and then the screen was introduced to hide the stage. The screen was then removed to reveal a hand sitting 25 cm over a pile of sand or the pile shaped object. If the object was on the stage the hand reached down and grasped it and moved it to the side of the stage. If there was a pile of sand on the stage the hand reached down and grasped a portion of the sand which was moved to the side of the stage. The hand was then withdrawn and the infant's looking time was measured. At the end of the trial the stage was emptied and the screen was introduced again. Each infant in the Baseline condition saw alternating sand ("Fall-apart") and object ("Move-together") trials. There were a total of six such trials. The baseline trials are identical to the outcomes of the test trials in both the object and the sand condition. Order of trial type and direction of movement were counterbalanced across infants.

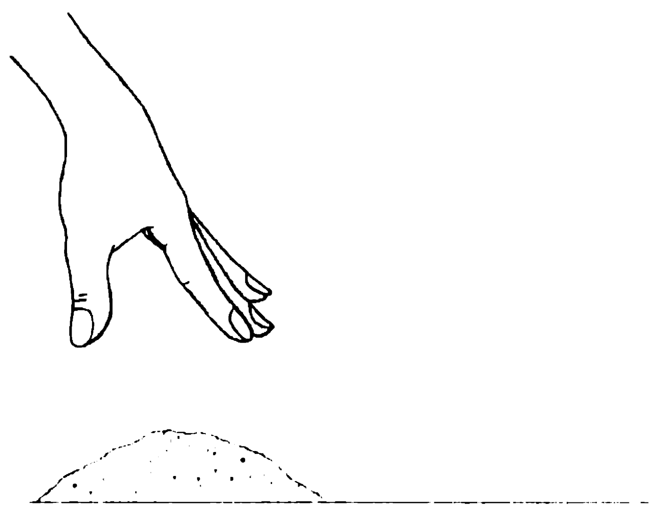

Figure 6 a. Familiarization display for object and non-solid substance condition

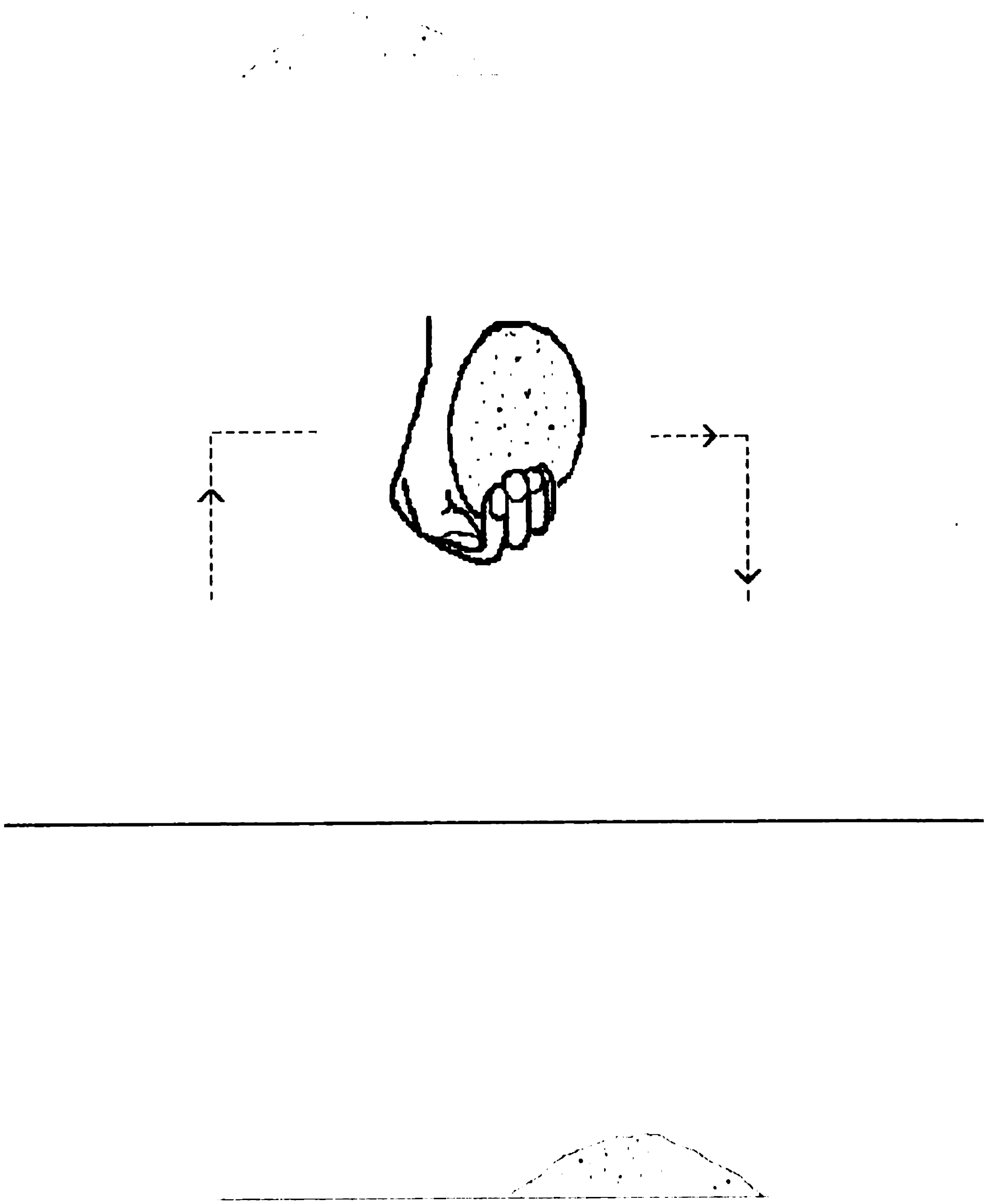

Figure 6 b. Move-together outcome

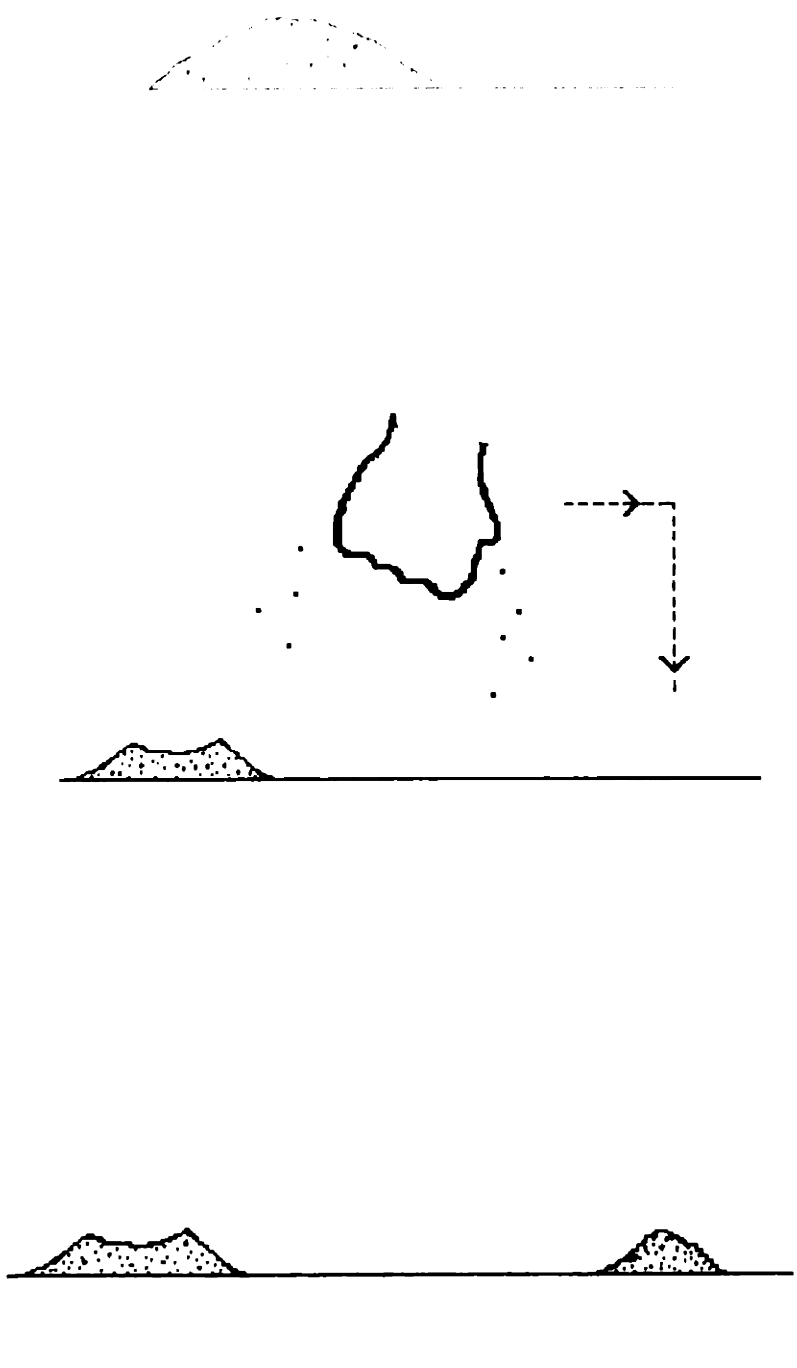

Figure 6 c. **Fall-apart outcome**

Results

Since the outcome trials for the object and the sand condition are identical, subjects' interpretation of these outcomes depend on the preceding familiarization trials. A direct comparison of the object and sand conditions can tell us whether infants distinguish objects from non-solid substances like sand. With respect to cohesion however, we can only determine whether infants know the particular cohesional properties of objects or sand by separately analyzing looking time to the outcome of the test trials in each condition with respect to infants' baseline preference.

Forty-five of the 48 babies were observed by one on-line observer and another trained observer who coded videotaped records of the experiment. Mean inter-observer reliability was 96%.

Preliminary ANOVAs established that there was no effect of order of test trials, order of baseline trials, side of presentation or sex of subject on looking times. The following analyses collapsed across these factors. We conducted a 3 x 2 ANOVA comparing the effects of condition (baseline, sand, object) and outcome (fall-apart, move-together) on looking times. There was no main effect of condition whereas there was a main effect of outcome, subjects overall preferred to look at the fall-apart outcome $F(1,45) = 11.089$, $p<.005$. However this preference is uneven as evidenced by the Outcome x Condition interaction $F(2,45) = 4.005$, $p<.03$ (see Figure 6).

Three planned comparisons were conducted.[8] Subjects' looking time at the fall-apart vs. move-together outcome was compared in each of the three conditions. Of special note is that subjects in the Baseline condition preferred neither outcome, $t(15) = 1.92$, *ns*. This result contrasts with Spelke et al. (1993) in which it was found that 3-month-old infants look longer at the outcome in which an apparent single object splits into two pieces. Our result suggests that introductory exposure to both the sand and the object and the familiarization

[8] The *MSE* from the 3 x 2 ANOVA provided the pooled S^2 for the tests of pairs of means.

with moving objects and poured sand reduced this a priori preference for the fall-apart outcome. However, infants did look longer at the impossible fall-apart outcome in the Object condition, $t(15) = 5.28$, $p<.001$. Finally, there was no preference for either outcome in the Sand condition, $t(15) = .23$, *ns*.

To determine whether infants expect objects to move as a whole we compared looking times in the baseline and object condition. A 2 x 2 ANOVA examined the effects of condition (baseline, object) and outcome (fall-apart, move-together) on looking times. Subjects looked marginally longer at the impossible outcome in the object condition compared to the baseline: Condition x Outcome interaction $F(1,30) = 3.517$, $p<.08$. However, all of the 16 infants in the object condition preferred to look at the fall-apart outcome whereas only 11 out of 16 infants in the baseline condition preferred that outcome, $p<.05$, Fisher Exact test (two tailed). This finding is as expected given that infants see objects as bounded coherent wholes (Spelke et al., 1993).

We also conducted a 2 x 2 ANOVA comparing the outcomes in the sand condition to the baseline condition. Subjects do not look any longer at the Move-together event in the sand condition than they do in the baseline condition, Condition x Outcome interaction: $F(1,30) = .565$, *ns*. In the sand condition 7 out of 16 infants preferred to look at the impossible move-together event; similarly 5 out of 16 infants did so in the baseline condition, ns, Fisher Exact test (two tailed).

To see whether babies differentiated the outcomes in the sand and the object conditions, these conditions were compared directly. A 2 x 2 ANOVA contrasting outcomes in the object and sand conditions indicates that while subjects overall preferred the fall-apart outcome, main effect of outcome, $F(1, 30) = 13.1$, $p<.002$; they distinguished outcomes depending on the familiarization stimulus, Condition x Outcome interaction, $F(1,30) = 10.495$, $p<.004$. There was no main effect of condition.

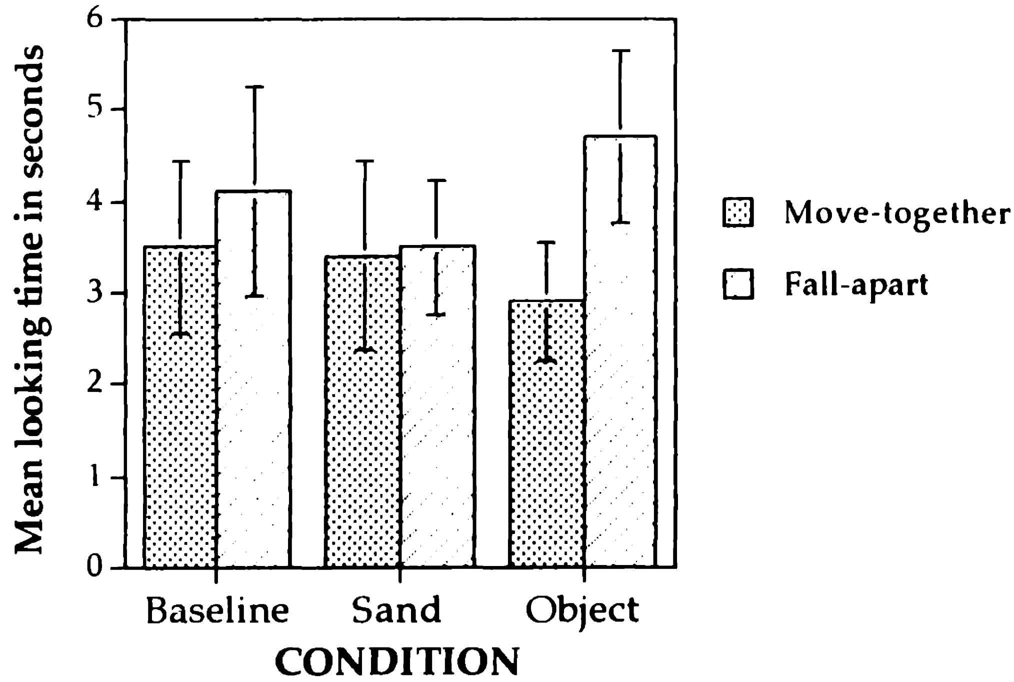

Figure 6. Looking time data for Experiment 4

Discussion

The introductory exposure to sand and to the pile shaped object succeeded in reducing a presumed (based on Spelke et al. , 1993) tendency to look longer when an apparent object comes apart upon being moved. Baseline babies had only a small and not statistically significant tendency to look longer at the fall-apart outcome than at the move-together outcome. Moreover, seeing the object lowered behind the screen prior to the familiarization trials led the babies in the object condition to establish a representation that there was indeed an object resting on the stage floor; every baby in the object condition looked longer at the impossible outcome trial in which the pile shaped object had been surreptitiously replaced by a pile of sand which came apart when grasped and moved. These results confirm those in the literature (as do the data from Experiments 2 and 3) that young infants represent objects as coherent wholes that maintain their boundaries as they move through space.

Experiment 4 confirms the conclusion from Experiment 2 that 8-month-old infants distinguish objects from sand. That is, even though the infants in the sand condition were familiarized to a hand suspended over a pile of sand, perceptually similar to an object, they had clearly attended to how that entity came to be where it was (by being poured from a measuring cup rather than by being lowered as a whole). Unlike the babies in the object condition, those in the sand condition were not surprised when the pile came apart upon being grasped.

The important result from Experiment 4 is that babies in the sand condition were also not surprised when the pile moved as a whole. Apparently, the introductory experience with sand, and seeing the sand poured from the measuring cup onto the stage, was not sufficient for the baby to establish a representation of a non-solid substance -- an entity that does not remain together when moved. In sum, they are capable of recognizing that sand *might* not cohere (thus differentiating sand from an object), but they have no definite expectation that sand *does* not cohere.

GENERAL DISCUSSION

The four experiments reported here support the third option outlined in the Introduction (that is, the "two types of physical entities" possibility); by 8 months of age, babies have split the domain of physical entities into at least two subtypes: OBJECTS and NON-OBJECTS. The "all bets are off" possibility was falsified by the finding in Experiment 1 that infants expect sand to satisfy one of the core principles of physical reasoning; they know that sand cannot pass through a solid barrier (see also Baillargeon's related findings with salt, in press). Furthermore the "miscategorization-as-object" possibility was falsified by the fact that babies do not expect sand to cohere under conditions in which they expect objects to cohere. That is, they know that objects do not leave portions of themselves behind as they move through space, but that sand may do so.

Experiments 2 - 4 confirm the many findings in the literature that infants expect objects to maintain their boundaries (Hofsten & Spelke, 985; Kellman & Spelke, 1983; Spelke, et al., 1993; Streri & Spelke, 1988). This is not surprising given that the subjects in the above studies are 8-months-old and somewhat older than subjects in previous experiments. However, unlike previous studies, the present experiments go beyond simply showing that infants use the coherence principle to identify something as an object. Experiments 2 and 3 show that infants are able to use the coherence principle to *reason* about objects as well.

To succeed in Experiment 3, infants must use information about the cohesional status of objects to make a judgment about whether there should be one object or two. Infants succeeded in the object case but they failed to use the non-cohesional properties of sand to make a quantificational judgment about how many piles of sand there should be in Experiment 2. Experiment 4 indicates that infants' failure in Experiment 2 is due to the fact that babies don't know the particulars of the non-cohesional properties of sand. Although 8-month-olds have differentiated objects from non-objects -- they know that sand is not an object and it *need* not cohere -- they have not yet formed a conception of sand as a kind of entity that cannot cohere. It is an open question at what age babies form the adult conception of sand as inherently non-cohesive. To this end experiments with 12-month-olds are currently under way in our lab.

There are two possible interpretations of the finding that 8-month-olds are not surprised when sand coheres when moved. First, babies have had very little experience with sand. Eight-month-olds are too young to have played with sand and many have never been to a beach. We informally surveyed the parents/guardians of the subjects in the sand conditions of these studies and many reported that their babies had never seen sand before; or if they had been in the presence of sand the babies did not play with it. It is possible that there are other non-solid substances that young infants have had more experience with (e.g. liquids, pureed food) and which, if used in studies such as Experiments 2 and 4, would lead to adult -like performance. That is, babies may have the concepts OBJECT and NON-SOLID SUBSTANCE but the brief exposure we provide them to sand is not sufficient to lead them to correctly categorize sand as a non-solid substance. Second, 8-month-olds may not yet have created the concept of NON-SOLID SUBSTANCE. We may have caught babies in the process of differentiating the category of PHYSICAL ENTITY into OBJECT/ NON-SOLID SUBSTANCE. If this is right, we might expect that younger babies would show evidence for the "miscategorization as object" possibility. This will be explored in further studies with the paradigm of Experiment 4 using younger infants.

We have much evidence that infants' earliest physical reasoning is articulated in terms of representations of objects and we now have evidence that by 8 months of age that domain of reasoning has begun to diversify. Given that 8-month-old infants have divided up their domain of physical reasoning into at least two kinds of physical entities -- OBJECTS and NON-OBJECTS -- we can say that the constraints on physical reasoning are not so tightly interdefined as to specify all and only objects in the domain. Should the domain be specified too strictly, no learning would be allowed and therefore no such split would be possible. The existence of partial inter-definedness is important because it is a structural means of apprehending interrelated phenomena. The recognition of relationships between prima facie unrelated phenomena is an important component of an explanatory framework (Carey & Spelke, 1994; Wellman & Gelman, 1992).

Finally, we note that the issue addressed in these studies -- how babies cope with representations that satisfy some, but not all, of the principles which determine the objects in the world and guide reasoning about them -- arises in another context as well. People and animals satisfy the principles of cohesion, solidity, but not the principle of contact. People may interact with others without touching. Spelke et al. (in press) show that by 7 months of age infants know this. Babies are surprised if the motion of one object is followed by the motion of another object when the two objects do not make contact, yet when the objects are people, infants have no such preference; that is, they do not expect the movement of one person to be dependent on physical contact with another person. Thus at 7-months babies have differentiated people from objects with respect to the principle of contact. What is not yet known is whether "all bets are off" with respect to the application of other principles of object reasoning, such as continuity, cohesion, and solidity, to people.

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Chapter 3:
On the Infant's Understanding of the Logical Distinction between Count Nouns and Mass Nouns

SUMMARY OF CHAPTER 3

Many languages make a distinction between count nouns and mass nouns. In English, count nouns may be preceded by words like "a", "another", "several" and "fewer" (e.g., "a dog", "fewer chairs") and mass nouns may be preceded by words like "much", and "less" (e.g., "much water", "less jam"). Only count nouns may be pluralized or be preceded by numerals. Mass nouns may appear in constructions such as "a piece of fruit" and cannot be pluralized.

Beyond the use of different determiners, there is a logical distinction between these two types of nouns. Count nouns and mass nouns divide ("quantify") the world differently -- one into discrete units (count nouns) and the other either not at all, or into arbitrary portions (mass nouns). Clearly this has consequences for how we decide how many of whatever there are. We can see intuitively that we only enumerate what is available in discrete units; it follows that we need a means of specifying what the relevant units are in order to count them. Count nouns are a way to specify those units.

The natural construal of objects is as individuals, therefore objects are countable as such and we refer to objects using count nouns. The natural construal of non-solid substances is as arbitrary amounts (as in "some stuff") to which number is irrelevant. However as adults we know that it is possible to count portions of non-solid substances (*"one pile* of stuff"). Nevertheless, unlike objects, countable portions are not inherent in the kind of material being quantified. They are constructed for the moment based on volume, weight, the kind of container, or simple spatio-temporal discontinuities -- one cup, one fluid oz., one truckload, one pile, etc.

How early is the knowledge of this distinction manifested? There is much evidence that infants represent objects as individuals but there is a question about how infants construe non-solid substances. We hypothesized that infants might know that the physical differences between objects and non-solid substances have quantificational implications. Given that adults have a natural construal of non-solid substances as "some stuff" we proposed that if infants understood anything about the quantificational properties of non-solid

substances they would know that "stuff" is inherently uncountable. Using a procedure developed by Wynn (1992) we examined whether infants see portions of a non-solid substances (sand) as countable or uncountable.

Two experiments were conducted with 8-month-olds. In the first experiment there were two conditions: an object condition and a sand condition. The object condition was based on the Wynn (1992) "1+1" condition. The sand condition was identical to the object condition except that sand was poured instead of an object being lowered. We replicated Wynn (1992) in the finding that infants were able to set up an expectation that there were two hidden objects. However, babies did not expect two piles of sand in the sand condition. To rule out the possibility that the failure was due to babies' inability to keep track of the fact that sand was poured in two different places, in Experiment 2 we followed the same procedure except that the sand was poured behind each of two separate screens instead of a single screen. Infants also failed to expect two portions of sand in the second experiment. These results, in conjunction with other findings that babies can reason about non-solid substances as material entities subject to physical laws, suggest that babies have available a construal of non-solid substances to which number is irrelevant. The implications for children's language development and understanding of number are discussed.

INTRODUCTION

Many languages make a distinction between count nouns and mass nouns (Markman, 1985). In English, count nouns may be preceded by words like "a", "another", "several" and "fewer" (e.g., "a dog", "fewer chairs") and mass nouns may be preceded by words like "much", and "less" (e.g., "much water", "less jam"). Only count nouns may be pluralized or be preceded by numerals. Mass nouns may appear in constructions such as "a piece of fruit" and cannot be pluralized.[9] The word "advice" is a mass noun and thus sentences like "He has two advice" or "He has two advices" are unacceptable; whereas "opinion" is a count noun and "He has two opinions" is acceptable.

Beyond the use of different determiners, there is a logical distinction between these two types of nouns. Count nouns and mass nouns divide ("quantify") the world differently -- one into discrete units (count nouns) and the other either not at all, or into arbitrary portions (mass nouns). Clearly this has consequences for how we decide how many of whatever there are (see Quine, 1960; Macnamara, 1986, 1994, for a discussion of these issues). We can see intuitively that we only enumerate what is available in discrete units; it follows that we need a means of specifying what the relevant units are in order to count them. Count nouns are a way to specify those units.

Count nouns express concepts that provide criteria for individuation and identity. For example, the word "ball" is a count noun and knowing what "ball" means entails that we may distinguish one ball from another and that we can determine whether a particular ball is the same one we saw yesterday (see Xu & Carey, in press, for a more detailed discussion of these issues). To know what the word "ball" means is also to know that not every portion of a ball is also a ball. The implication for counting is as follows: We cannot answer "How many are on this page?" because we need a count noun to tell

[9] Mass nouns cannot be pluralized without changing the meaning from "stuff" to "kind of stuff." That is, "There are three fruits" can only mean something like there are apples, bananas and oranges.

what counts as one. Moreover, depending on the count noun you choose you may get different counts: "How many *words* are on this page?" vs. "How many *paragraphs* are on this page?". In sum, there is no answer to the question "How many ________ ?" without concepts like those expressed by count nouns; and because each count noun has it's own specifications for what counts as one, the answer you give is crucially dependent on the particular count noun you have chosen to insert into the sentence.

Mass nouns have a different status. It makes no sense to say that here is one water and there is another unless we are elliptically referring to portions of water which are themselves individuals (e.g., glasses of water). Similarly we cannot say that the water before us now is the same water we saw yesterday unless we have something like "body of water" in mind. Additionally, in contrast to the referents of count nouns, understanding what "water" means is to know that any portion of water is also water. With respect to number, it is impossible to reply coherently to "How many waters are here?" unless we say something like "There are four glasses (of water)." Notice that we have to insert mass nouns into phrases like "glass of _ " and "body of ___ " in order to talk about individual portions of mass quantified entities. Unlike objects, individuated *portions* are not inherent in the kind of material being quantified; these are constructed for the moment based on volume, weight, the kind of container, or simple spatio-temporal discontinuities -- one cup, one fluid oz., one truckload, one pile, etc. Part of our understanding of mass nouns is that alone they refer to entities that are not individuated and thus they do not support counting.

In summary, the availability of the linguistic contrast between mass nouns and count nouns reflects the fact that we have two fundamentally different ways of viewing the world. In one mode we reason about individuals, in the other we reason about non-individuated entities. An analysis of our intuitive understanding of objects indicates that we naturally see them as individuals and thereby countable. This construal of objects is contrasted with the number-irrelevant construal of non-solid substances like water and sand. Such substances are understood as non-individuated across different languages that entertain the count-mass distinction (Markman, 1985).

An important question is how we come to know this quantificational distinction. Quine (1960) proposed that we learn it by learning language; that is, by mastering the system of determiners (e.g. "a", "another", "some", "much") and then bootstrapping into the deeper distinction by which the assignment of determiners is constrained. An alternative to this view is that the knowledge which supports the distinction between individuals and non-individuals is in place before this system of determiners is mastered.

Children are able to distinguish between count quantified entities and mass quantified entities before they begin to use the determiners associated with count nouns and mass nouns. For example, 24-month-olds will take into account the number of portions when extending the meanings of a label learned of a novel object however they will ignore the number of portions when extending a label learned of a portion of non-solid substance (Soja, Carey & Spelke, 1991). Thus by two years of age children are able to use the physical differences between objects and non-solid substances to guide extension of word meaning. However these findings leave open the question of when in development this knowledge is first manifested.

The infant representation of objects

By now enough evidence has been amassed to answer this question at least part-way. Pre-linguistic infants represent the physical world in terms of objects that are bounded, coherent individuals. Infants as young as 5 months of age use the separation of surfaces in depth and the relative motion of surfaces to make inferences about object boundaries (Hofsten & Spelke, 1985; Kellman & Spelke, 1983). Babies expect objects to maintain these boundaries as they travel through space; that is, they do not expect objects to leave portions of themselves behind as they move (Spelke, Breinlinger, Jacobson & Phillips, 1993; Huntley-Fenner, Carey, Bromberg & Klatt, 1995). Indeed, babies will use spatio-temporal evidence not only to individuate objects but to make judgments of identity. This evidence suggests that the infant's representation of object has the logical properties of the adult representations of count nouns (Spelke, Kestenbaum, Simons & Wein, 1991; Xu & Carey, in press).

Further evidence that infants represent objects as individuals comes from the literature on the infant representation of number. It has been known for some time that babies are sensitive to differences in number (see Dehaene, 1992 for a review). Using the habituation-dishabituation paradigm researchers have shown that babies as young as 5 months of age can discriminate pictures of two objects from pictures of three objects, and pictures of three objects from pictures of four (for example Loosbroek and Smitsman, 1990; Strauss & Curtis, 1981).

Much of the research on the infant representation of number is consistent with a simple perceptual model of parallel individuation of visual discontinuities (Trick & Pylyshyn, 1994). However there is suggestive evidence that infants have a deeper understanding of number. Starkey, Spelke and Gelman (1990) found that 6 to 8-month-olds detect correspondences between the number of events presented aurally and the number of objects presented visually. Streri and Spelke (1988) found that 4-month-old infants will use haptic information about relative movement to make a judgment about whether they are handling one object or two and this judgment is reflected in their looking at displays of one and two objects. The fact that numerical knowledge may be compared across modalities casts doubt on a simple perceptual model.

Another piece of evidence that infants have a deep representation of number is due to Wynn (1992). She discovered that 5-month-old infants will construct in memory, over time, a representation of how many hidden objects there are in a display. This experiment is especially compelling because it unfolds over time thus implicating an iterative process, not unlike counting. We will describe this experiment in some detail because the present studies are in part a replication of Wynn (1992).

Wynn's experiment had two parallel conditions: an "addition" condition and a "subtraction" condition. In the "addition" condition she showed the infant a doll and placed it onto a stage. Next she raised a screen to hide the doll on the stage; then she introduced an identical doll and placed it behind the screen. Finally she removed the screen to reveal either one doll (impossible outcome) or two dolls (possible outcome). These events were repeated six times. Infants looked longer at the impossible outcome of one doll. Looking times in the addition condition were contrasted with those of babies in a "subtraction" condition. In the subtraction condition infants first saw *two* dolls on the stage, the dolls were hidden by the screen and then one of them was seen to be removed. In the case of the subtraction condition the impossible outcome was that of two dolls remaining on the stage. The babies in the subtraction condition looked longer at the outcome of two dolls than did the babies in the addition condition. Infants used the information about the removal and the insertion of dolls to infer how many hidden dolls there should be. This result has been replicated with 5-month-olds (Simon, Hespos, & Rochat, in press); and using a different procedure, with 8-month-olds (Uller, Carey, Huntley-Fenner, & Klatt, 1995).

The infant representation of non-solid substances

Non-solid substances may be construed either as "individuated portions of stuff" for the purposes of counting and measurement or as "some stuff" in which case number is irrelevant. However as adults we are disposed to represent non-solid substances as "some stuff", that is, without numerical considerations. Very little is known about the infant's understanding of non-solid substances. Recently researchers have examined infants reasoning about the physical properties of such substances. It was found that babies as young as 8 months of age do not expect sand to fall through a solid barrier (Huntley-Fenner et al., 1995). Indeed infants as young 5.5 months of age know that salt will not pass through the bottom of a container while it will fall through the bottom of a tube (Baillargeon, in press). While infants know that non-solid substances, like objects, are material entities; they also know that non-solid substances are different from objects. There is some evidence that babies as young as 8 months of age know that objects have different cohesional properties from non-solid substances (in this case sand) though infants' knowledge of the cohesional properties of sand is not fully developed (Huntley-Fenner, et al., 1995).

Despite the evidence that infants represent objects as individuals and distinguish them from non-solid substances, we are left with the question of whether this discrimination has quantificational consequences. We argued above that an important contrast between individuals and non-individuals is that only individuals may be counted. Should infants fail to count when presented with potentially countable portions of sand, there will be evidence that babies have available the construal of sand as "some sand" to which number is irrelevant.

Experiment 1 is modeled after Wynn (1992). We contrast a condition in which babies are expected to enumerate objects with a condition in which babies are given an opportunity to enumerate portions of sand. It is important to note that in the present studies each object was designed to look exactly like a portion of sand (see Figure 1). This ensured that the outcomes in the Object and the Sand conditions looked similar thus increasing the likelihood that any difference in the results is due simply to fact that one type of stimulus was poured onto the stage (sand) and the other was lowered onto the stage (object). Should infants succeed in counting in the sand condition there will be evidence that babies can represent individual portions of sand (along the lines of "pile of sand"). Such a result would leave open the question of whether infants distinguish between objects and non-solid substances with respect to quantification. Should infants fail to count portions of sand there will be evidence that babies use the fact that objects and non-solid substances have different physical properties to determine that one is countable and that the other is not. That is, babies like adults construe sand in terms of the number-irrelevant: "some sand."

EXPERIMENT 1

Method

Subjects

Thirty-two full-term 8-month-olds (19 boys and 13 girls) were tested (*M*: 8 months, 8 days; *SD* = 10 days). Thirteen additional infants were excluded because of fussiness, experimenter error or equipment failure. The infants' names were retrieved from the birth records in the Greater Boston area and their parents were contacted by letter and phone. Parents were compensated with token gifts (T-shirts, bibs and plastic cups).

Materials

Two types of stimuli were used in this experiment: a small portion of sand and a sand-pile shaped object. The object stimulus was roughly the shape of a flattened cone. It measured 15 cm in diameter at the base and 4.5 cm high at the center. The surface of the object was completely coated in glued on sand. To an adult, at a distance the object looked like a pile of sand. A piece of string was attached to the top center of the object allowing it to be raised and lowered without being held directly. The sand used as the non-solid substance stimulus was poured into a pile approximately the same size and shape as the object (see Figure 1).

In each of the experiments reported here the experimenter took care to ensure that the events involving the sand stimulus were similar to the events involving the object stimulus. For example, whenever the object was brought into view it was partially lowered towards a surface and then stopped and shaken in mid-descent before being placed onto that surface. This shaking was always exactly the point where, in the sand trials, a transparent container of sand was held to be poured. The timing of these events was matched so that lowering the object onto a surface from a given distance took exactly as long as pouring a comparable amount of sand onto that surface.

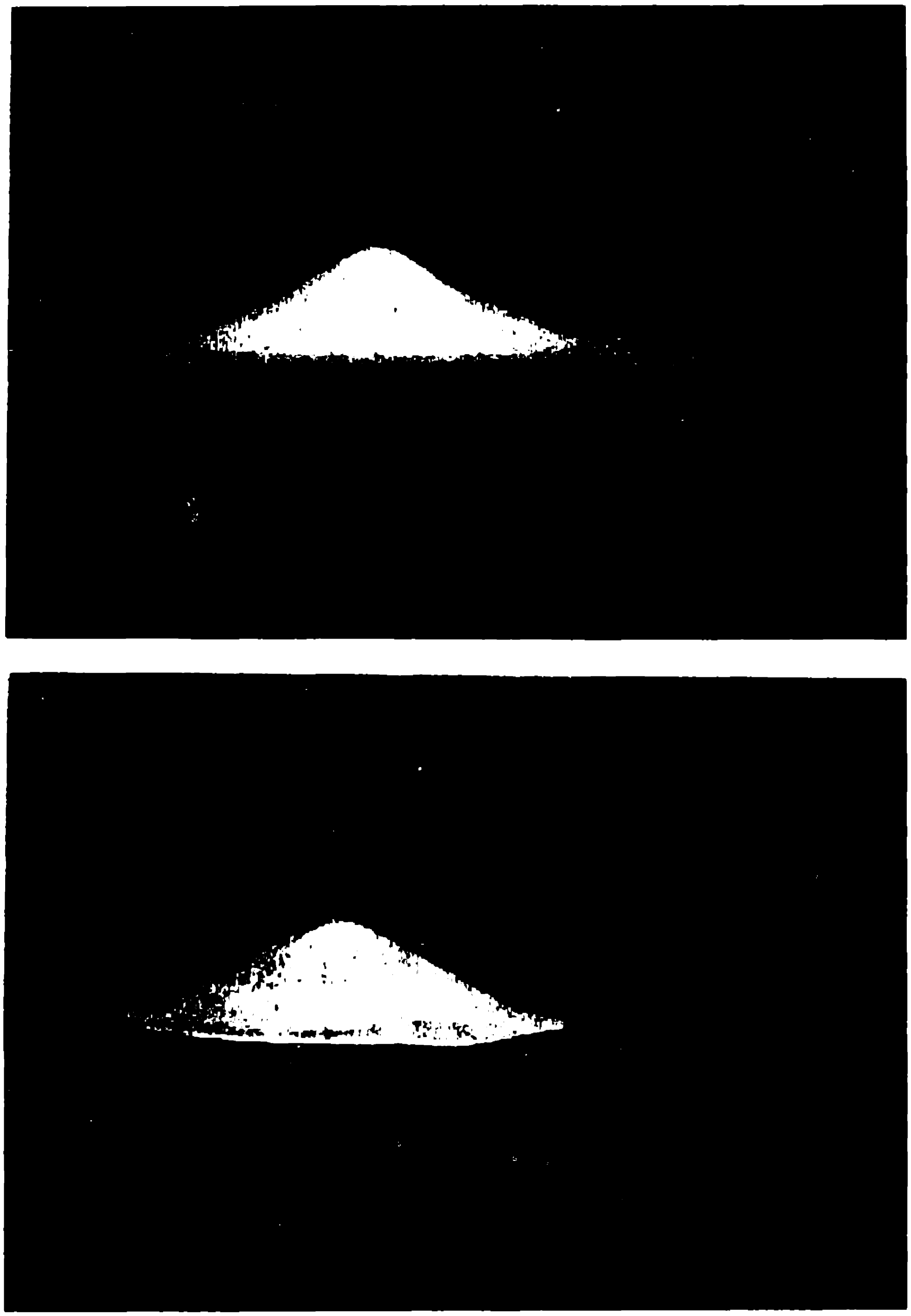

Figure 1. Photographs of the sand pile (top) and the object stimuli (bottom).

Setup

This experiment took place on a stage whose opening measured 38 cm x 88 cm x 34 cm and which was raised 100 cm from ground level. There was a black felt backdrop for the stage which hid the movements of the experimenter. Attached to the front of the stage was a screen which could be raised by the experimenter to partially obscure the display. The stage area itself was surrounded by black curtains from floor to ceiling. These curtains hid an observer who recorded looking time data and a video camera which recorded the subject. During the experiment, the lab was darkened and the stage was lit directly from above. The infant was lit indirectly by lamps in front of and on either side of the stage.

The infant sat facing the stage with its head about 70 cm away and it's eyes slightly above the floor level of the stage. The child's parent/guardian sat on the child's left facing away from the stage. Parents were instructed to interact with the baby as little as possible and to resist the urge to turn and look at the display. The live observer could see the infant through an invisible hole in the curtain. The observer could not see the stage however, and thus was blind to the details of the experimental manipulation.

Each live observer was highly trained and experienced; this observer measured looking time by pressing buttons connected to a computer. The computer signaled the end of each trial based on the recording of the live observer. Trials ended when the infant looked away for 2 continuous seconds having looked for at least 0.5 s before that. A second observer recorded looking time from the videotaped record of the infant. The match between the length looking time as measured by the live observer and the length of looking time as measured by the videotape observer is calculated as the inter-observer reliability and reported for each experiment in the Results sections below. A white noise generator masked any sound from the movements of the observer and the experimenter.

Procedure

Babies were assigned randomly to the sand Condition (n=16) or the object Condition (n=16). Each condition consisted of three sections (an introductory exposure, baseline/familiarization trials, and test trials). The introductory section served to acquaint infants with the experimental stimuli. The baseline/familiarization trials served to introduce infants to the stage on which the stimuli were placed. The looking times at the arrays of stimuli recorded during the baseline/familiarization session were used as an indication of the subjects' a priori preferences. In the test trials subjects were required to add one object/pile to another along the lines of Wynn (1992).

Stimulus (object, sand) was a between subjects variable but condition (baseline, test) and outcome (one pile/object, two piles/objects) varied within subjects. We will begin by describing the object condition and then we will describe the Sand condition.

Object Condition

Introductory Exposure. Each infant in the object condition was given a chance to manipulate the object stimulus. The experimenter held the object by its string for the infant to see. Then he walked towards the infant's high chair drawing the baby's attention before lowering the object onto the high chair tray. Babies often grasped the object spontaneously. The parent prompted the infant to manipulate the object if the infant was initially reluctant to touch it. Each baby handled the stimulus for 30 s.

Baseline/Familiarization Trials. There were two pairs of baseline/familiarization trials. In the first pair there was no screen and in the second pair a screen obscured the stage floor and the lower half of the display. Each pair of trials consisted of a "single object" trial and a "double object" trial.

During the first pair of trials, in the single object trial, the object was suspended by a string and lowered towards the stage floor. The object was stopped halfway down and the experimenter drew the infant's attention to the object by shaking it and calling out to the baby. Finally the object was placed on the stage floor; to get the infant's attention the experimenter tapped the object on the stage floor five times before letting the string go. Once the experimenter's hand was retracted from the display the observers were signaled by the experimenter to begin measuring looking time. In the double object trial two objects were lowered simultaneously; they paused halfway down, were jiggled for 5 s, and then simultaneously tapped on the floor of the stage before being released. Looking time was measured to the display of two objects on the stage floor.

The second pair of trials was the same except that the single object or the double objects were lowered behind the screen. Subjects were first shown that the stage floor was empty. Next a screen was raised into place which obscured the lower half of the display. In the single object trial, the infant's attention was drawn to a single object which was lowered towards the screen. This object paused halfway down so that its bottom was partially obscured by the screen while its top was visible. The infant's attention was drawn to the object which was jiggled for 5 s before it was lowered behind the screen towards the stage floor. The object was then tapped on the stage floor and released. Finally the screen was removed and the infant's looking time at the display was measured. In the double object trial the empty stage was shown and then hidden by the screen. Then two objects were lowered simultaneously towards the stage floor; they paused on the way down; were jiggled for 5 s while partially hidden behind the top of the screen; then they were lowered, tapped, and released. The screen was then removed and looking time at the two objects was measured. The baseline/familiarization trials involving a screen served to assure the babies that an object (or objects) lowered in a hidden trajectory lands where it (or they) should. They also provided a measure of the a priori preference for looking at one or two objects. The baseline/familiarization trials provided no information about what to expect on test trials.

There were a total of four baseline/familiarization trials -- one of each type. These trials alternated between one and two object outcomes in two possible orders (1-2-2-1 or 2-1-1-2). Order and the side of the stage floor to which the single object was lowered were counterbalanced across subjects.

Test Trials. Six test trials immediately followed the baseline/familiarization trials (see Figure 2a). Subjects were first shown the empty stage. Next an object was introduced and lowered onto one side of the stage. The object was stopped halfway down and jiggled for 5 s while the infant's attention was drawn to it. After it was jiggled it continued to be lowered until it hit the stage floor. The object was then tapped five times and released. After the object had landed on the stage the screen was raised into position hiding that object. Another object was introduced on the other side of the stage and lowered towards the screen. When this object reached the top of the screen it was stopped and dangled just behind the screen so that its top was visible. The second object was jiggled 5 s and then it was lowered behind the screen. When the object reached the stage floor it was tapped five times and released. The screen was then removed to reveal either one object (impossible outcome) or two (possible outcome). The single object in the impossible outcome was always that object which had been lowered into place in full view and furthermore happened to be on same side as in the concomitant single object baseline/familiarization trials. Since infants will have been familiarized with the single object before the test trials, longer looking at the familiar event during impossible test trials will indicate not perceptual novelty but a violation of an expectation.

Order of outcomes (possible first, impossible first), and the side on which the single object appeared in the impossible outcome were counterbalanced across infants.

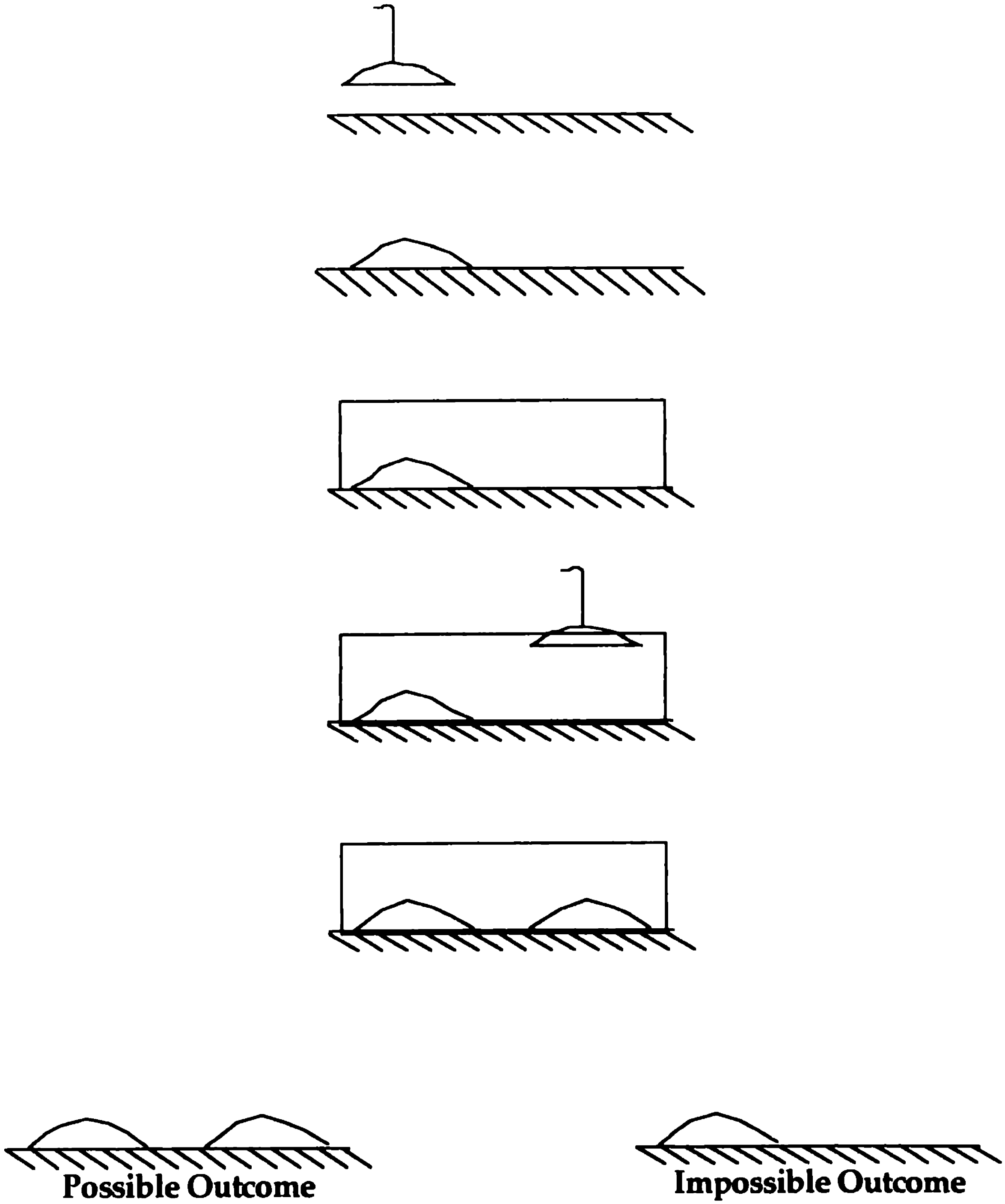

Figure 2a. Schematic of the test trial procedure for the object condition of Experiment 1.

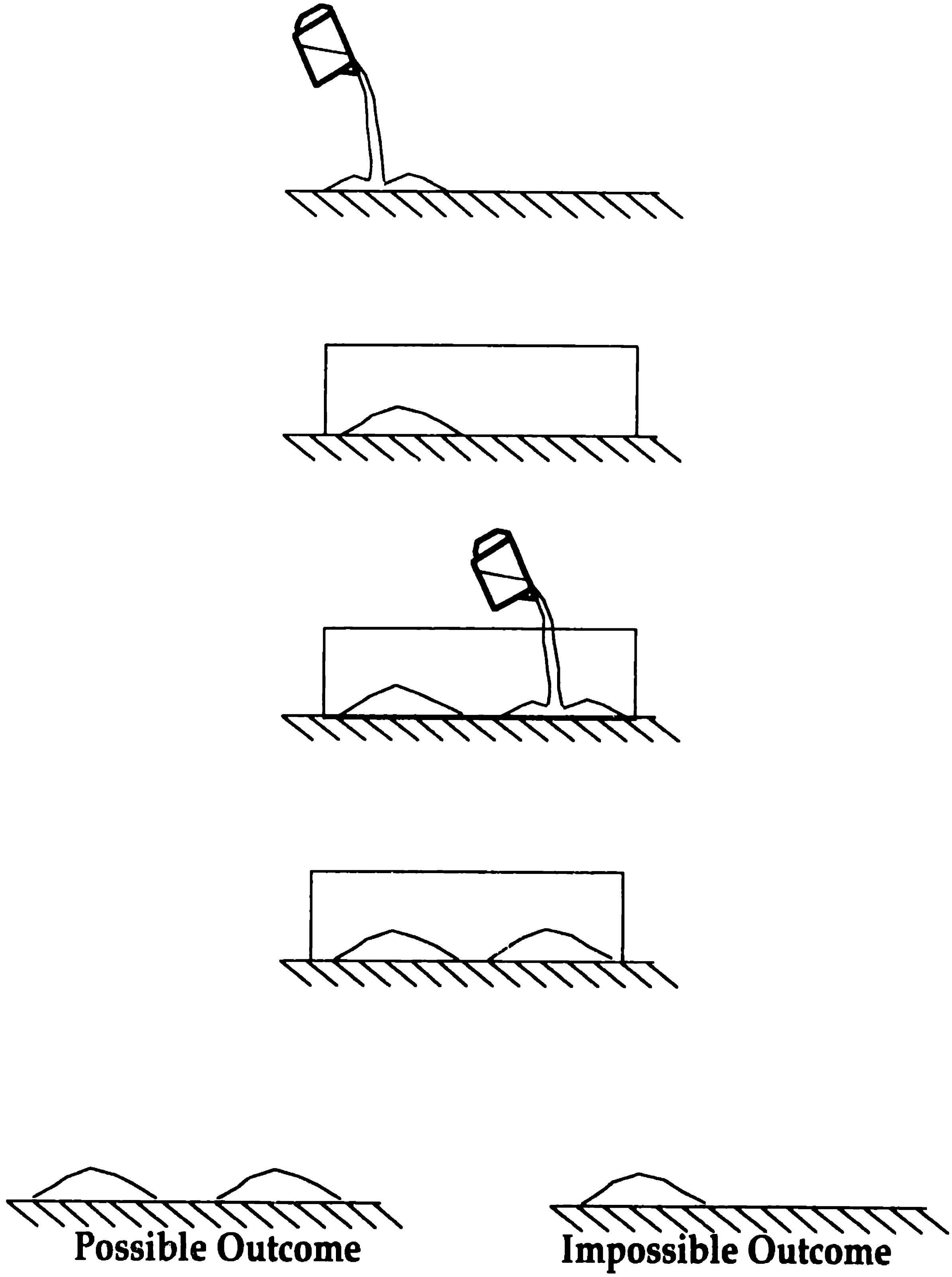

Figure 2b. Schematic of the test trial procedure for the sand condition of Experiment 1.

Sand Condition

Introductory Exposure. Each infant in the sand condition was given a chance to handle some sand. The experimenter held a transparent plastic measuring cup containing sand in one hand and an empty measuring cup in the other. He drew the infant's attention to the sand by pouring it back and forth between the measuring cups. Then he approached the infant's high chair and poured the sand onto the high chair tray. Babies often reached for the sand immediately. The parent prompted the infant to manipulate the sand if the infant was reluctant to touch it. Each baby handled the stimulus for 30 s.

Baseline/Familiarization Trials. The baseline/familiarization trials in the sand condition mirrored those in the object condition. There were two pairs of baseline/familiarization trials. In the first pair there was no screen and in the second pair a screen obscured the stage floor and the lower half of the display. Each pair of trials consisted of a "single pile" trial and a "double pile" trial. In single pile trials a hand holding a transparent measuring cup of sand was introduced into the display. The experimenter encouraged the infant to look and poured sand onto the stage floor. During the pouring, both the cup and the sand leaving the cup were fully visible. The sand formed a pile approximately the same size, shape, and color as the object in the object condition. The empty measuring cup was then withdrawn from the display. Once the measuring cup was no longer visible the observers were signaled to begin measuring looking time. The double pile trials involved two measuring cups containing sand. These measuring cups were introduced simultaneously and poured simultaneously onto the stage floor. Once each pile was the same size as the pile shaped object the empty measuring cups were withdrawn and looking time to the two piles of sand was measured.

The second pair of baseline/familiarization trials was similar to the first pair except that sand was poured behind a screen. In the single pile baseline/familiarization trial of the second pair subjects were first shown an empty stage and then the screen was raised in front of the stage. Next, a measuring cup containing sand was lowered and shown to the infant. The experimenter poured the sand behind the screen onto the stage floor. Both the measuring cup and the sand pouring from the cup were visible above the top of the screen. Finally the measuring cup was withdrawn and the screen was removed. Looking time at the display of the single pile of sand was measured. In the double pile trial of the second pair the infant was shown the empty stage and then a screen was raised. Next, two measuring cups of sand were introduced and sand was simultaneously poured from them behind the screen onto the stage floor. When the measuring cups were empty, they were withdrawn and the screen was removed. The looking time to the display of two piles of sand was measured.

There were a total of four baseline/familiarization trials in the Sand condition -- two without screens and two with screens. These trials alternated between one and two piles of sand in two possible orders (1-2-2-1 or 2-1-1-2). Order and the side of the stage floor on which the single pile was poured were counterbalanced across subjects.

Test Trials. Six test trials immediately followed the baseline/familiarization trials (see Figure 2b). Subjects were first shown the empty stage. Next a hand holding a transparent plastic measuring cup of sand was introduced and the sand was poured onto one side of the stage. The experimenter drew the infant's attention to the pouring sand. The pouring of the sand took just as long as the lowering of the object in the object condition. After the sand had been poured the screen was raised to hide the pile of sand on the stage floor. Next, a second measuring cup containing sand was brought into view just above the screen at the other side of the stage; and the experimenter poured the sand from the second cup behind the screen. Once all the sand had been poured from the second cup, it was withdrawn and the screen was removed. Subjects saw either one pile of sand (impossible outcome) or two (possible outcome). The single pile of sand in the impossible outcome was always that pile which had been poured in full view and also the side with which the baby was familiarized in the single pile baseline/familiarization trials.

Order of outcomes (possible first, impossible first), and the side on which the single pile appeared (impossible outcome) were counterbalanced across infants.

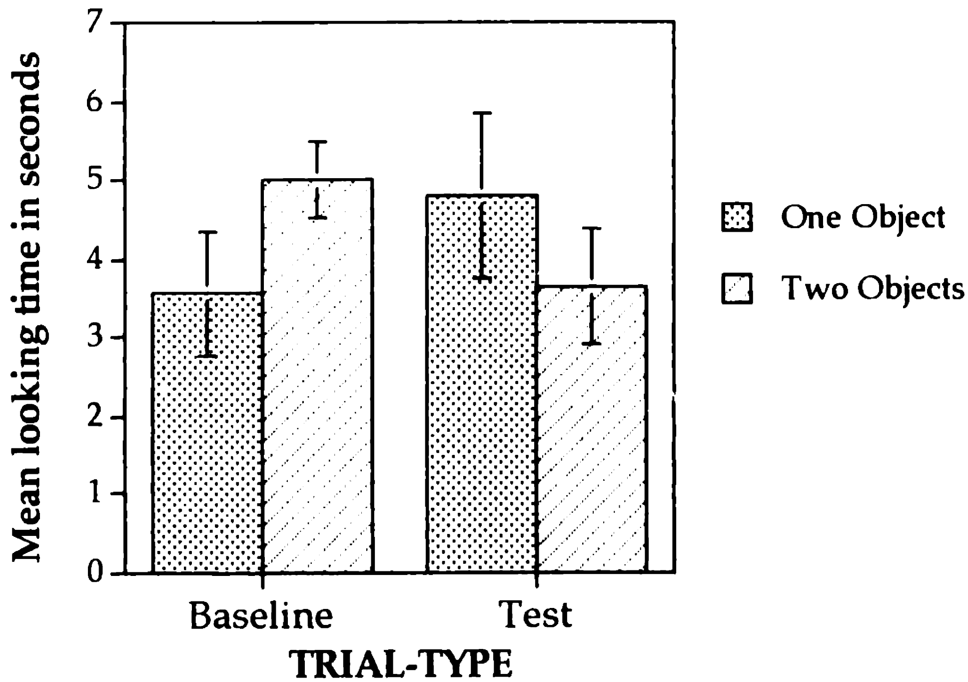

Figure 3a. Mean looking time data for the object condition in Experiment 1.

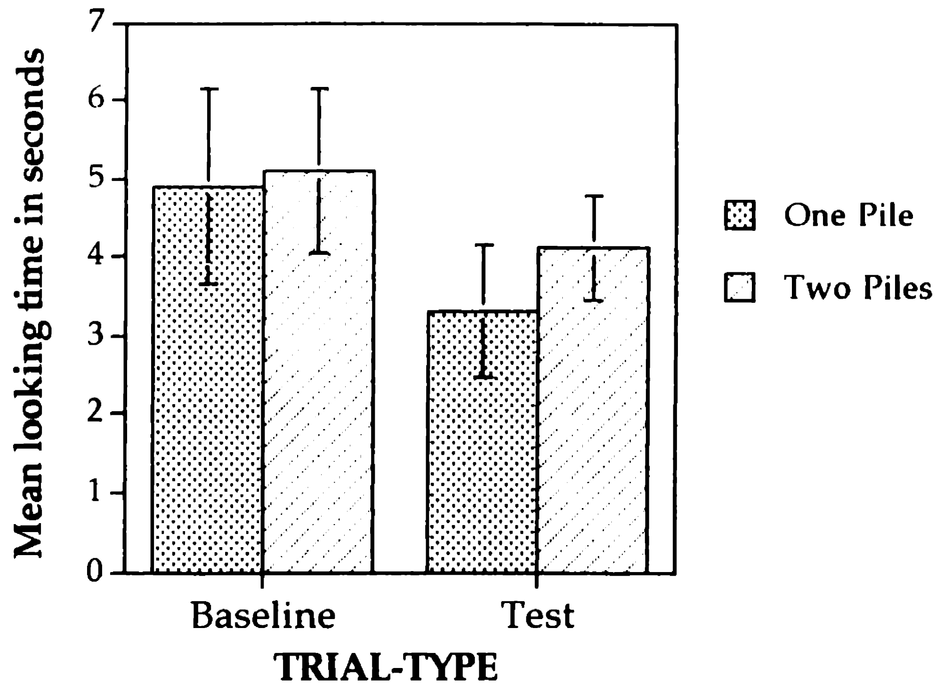

Figure 3b. Mean looking time data for the sand condition in Experiment 1.

Results

Looking by 28 of the 32 infants was measured by two observers. Mean inter-observer reliability was 93%.

In this Experiment and the experiments which follow alpha has been set at .05. Preliminary ANOVAs found no effects of order of outcome, side of outcome or sex of subject on looking times; subsequent analyses collapse across these variables. Figure 3 shows the mean looking times for the outcome of a single pile/object in each of the two conditions. A 2 x 2 x 2 ANOVA examined the effects of the between subjects variable condition (object, sand); and within subjects variables trial-type (baseline, test) and outcome (one pile/object, two piles/objects) on looking times. There was no main effect of condition, $F(1,30) = .02$, *ns*; trial-type, $F(1,30) = 3.37$, *ns*; nor outcome, $F(1,30) = 2.07$, *ns*. There was a significant three-way interaction (Condition x Trial-type x Outcome), $F(1,30)$

= 10.321, $p < .004$. More focused ANOVAs were conducted to investigate the source of this interaction.

The object condition was examined by a 2 x 2 ANOVA comparing the effects of trial-type and outcome on looking times. There were no main effects of trial-type or outcome but there was a Trial-type x Outcome interaction, $F(1,15) = 9.45, p < .009$. This interaction reflects the fact that subjects had a baseline preference for two objects, $F(1,15) = 7.94, p < .02$, but overcame that preference during the test trials where the outcome of the single object was impossible, $F(1,15) = 3.16$, *ns*. Subjects looked longer at the impossible outcome of the single object in each pair of test trials (Pair 1: $M_{imp} = 4.4$ s, $M_{poss} = 4.3$; Pair 2: $M_{imp} = 5.7$ s, $M_{poss} = 3.5$; Pair 3: $M_{imp} = 4.3$ s, $M_{poss} = 2.9$ -- see Figure 4).

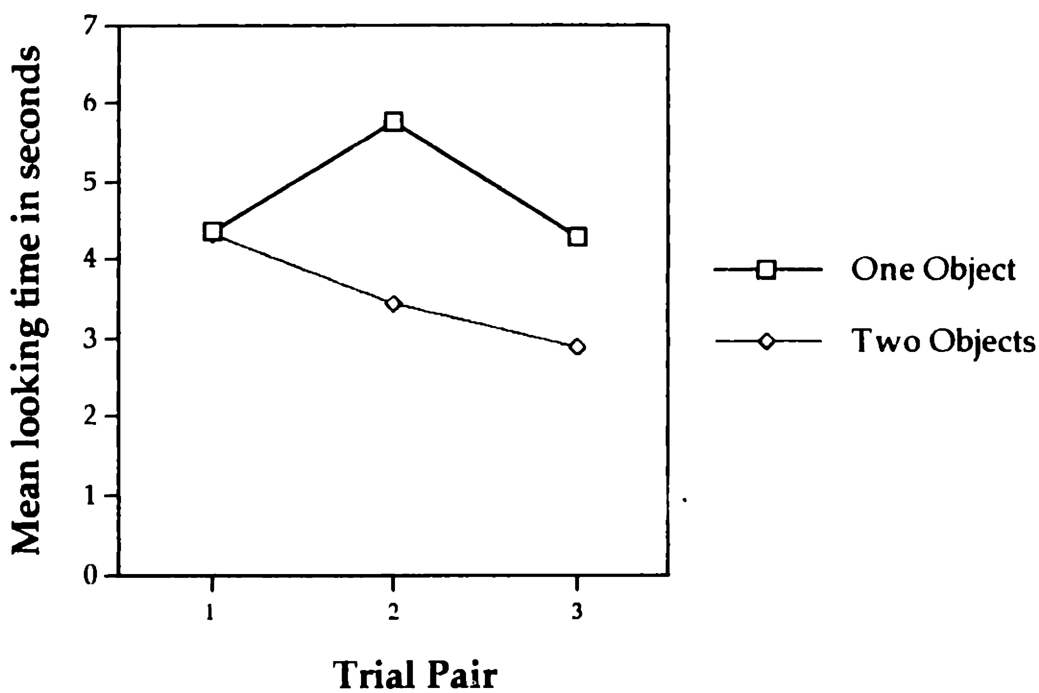

Figure 4. Mean trial by trial looking time data for the test trials only in the object condition of Experiment 1

The sand condition was examined by a 2 x 2 ANOVA comparing the effects of trial-type and outcome on looking times. There was no main effect of outcome but there was a main effect of trial-type, $F(1,15) = 4.97, p < .05$; subjects looked longer at the displays during the baseline trials than during the test trials (see Figure 3). Since the test trials, as a block, followed the baseline trials this result reflects the fact that subjects were becoming less interested in the displays over time. That subjects become bored as the experiment continued suggests that they did not find the "impossible" outcomes interesting. This is indeed the case; in contrast to the object condition, there was no Trial-type x Outcome interaction, $F(1,15) = 1.26$, *ns*.

A 2 x 2 ANOVA (outcome x condition) contrasting looking times during the test trials between conditions indicates that subjects were more interested in the impossible outcome during the test trials of the object condition than during the test trials of the sand condition. There were no main effects of outcome or condition but there was an Outcome x Condition interaction, $F(1,30) = 10.22, p < .003$. Thus the three-way interaction above may be attributed to infants preference for the impossible (single object) outcome during the object condition test trials contrasted with the lack of such a preference (for the impossible single pile outcome) during the sand condition test trials.

This conclusion is supported by non-parametric statistics. In the object condition 11 out of 16 subjects preferred the outcome of a single object (in that case the impossible outcome) during the test trials compared with 2 out of 16 in the baseline trials, Wilcoxon $Z = 2.74, p < .007$. In the sand condition only 5 out of 16 subjects preferred the impossible outcome, of the single pile of sand. This is no different from the baseline trials, where 7 out of 16 subjects preferred the single pile outcome, Wilcoxon $Z = 1.16$, *ns*.

Discussion

The Object condition of Experiment 1 replicates Wynn's finding (1992) that infants will build a representation of some number of hidden objects over time. This supports the claim that infant judgments of number are not the result of the application of a simple perceptual mechanism. However infants fail to enumerate hidden portions of sand. This failure is striking since the displays of sand on the stage are almost identical to the displays of the objects on the stage. If one assumes that the infant builds a representation of the hidden objects in memory somewhat like a visual image of those objects then it is remarkable that infants succeed in constructing a representation of 2 distinct shapes that are the result of lowering but fail to construct a representation of the same shapes that were the result of pouring. We will return to this issue in the General Discussion. This confirms the hypothesis that even for infants there is something special about the representation of objects that makes them countable; and that whatever that is does not hold of sand. That is, not only do infants distinguish between objects and non-solid substances but this distinction has implications for what can be counted.

The finding that there are circumstances under which infants will not represent a set of distinct shapes as countable suggests that the infant's knowledge of number is akin to our own wherein we need to specify individuals in order to count. However when faced with the challenge of the sand condition one would expect adults and children to invent individuals in order to count them. Adults have available notions like PILE OF STUFF which are spatially defined individual portions of a non-solid substance. Without seeing the sand actually land on the stage adults would have been able to infer that the pouring event resulted in a pile of sand immediately beneath where the pouring happened and thereby further infer that there were, in total, two piles of sand hidden behind the screen.

There are two possible reasons why the 8-month-olds in the sand condition failed: 1) they do not have notions like PILE OF STUFF available, that is, they only construe sand as "some stuff" / "some sand"; or 2) they were confused about whether the second pouring event happened over the same location as the first. Since notions like PILE are spatially defined, knowing the location of the second pile is crucial to determining whether there should be one pile or two.

Experiment 2 is designed to give subjects more information about where the second portion of sand is being poured. In Experiment 2 we used multiple screens to provide evidence that each pile of sand was poured in a different location. Researchers have found that 5 and 6-month-old infants are able to remember where an object is hidden for up 70 s when the object is hidden behind one of multiple screens (Baillargeon, de Vos & Graber 1989; Wilcox, Rosser & Nadel, 1994). In addition, multiple screens help the baby to individuate locations in order to build a representation of countable objects (Uller et al.; 1995). In Experiment 2 we replicated the Sand condition of Experiment 1 using two brightly colored screens instead of a single black screen. The goal is to help the baby to individuate locations thereby helping them to build a representation of separate and thus countable piles. Before testing, babies are introduced to the screens and are shown that there are two separate screens with a space in between them. Should infants be helped in individuating portions of sand by the two screens we would conclude that babies do have notions like PILE available but that they have an impoverished representation of location and need explicit spatial cues in order to individuate locations.

EXPERIMENT 2

Method

Subjects

Sixteen full-term 8-month-olds (9 boys and 7 girls) were tested (*M*: 8 months, 0 days; *SD* = 8 days). Seven additional infants were excluded because of fussiness, experimenter error or equipment failure. Infants were contacted and compensated as in Experiment 1.

Materials and Set-up

The materials and set-up are exactly as in the Experiment 1, except that the single screen was replaced with two screens each measuring 35 cm x 35 cm. These screens were both colored bright orange and contrasted with the dark blue of the stage floor and the black backdrop. When placed on the stage the two screens were separated by a distance of 16 cm. The screens were introduced and withdrawn by the experimenter through the top of the stage.

Procedure

The procedure was identical to that of the Sand condition in Experiment 1. There was an introductory section, followed by a baseline/familiarization trials, and a series of alternating test trials.

Unlike the subjects in Experiment 1, subjects in Experiment 2 were introduced to the screens after the introductory section and before the baseline/familiarization trials. The subject was first shown an empty stage, then the two screens were lowered into place, side by side on the stage floor. The experimenter drew the infant's attention by calling out to the baby as the screens were lowered. Once the screens were on the stage the experimenter introduced a set of keys. The keys were passed from left to right behind the screens; from the outside edge of the left screen, pausing between the screens, and exiting at the outside edge of the right screen; then the keys were passed in the opposite direction. After this event the screens were removed and the baseline/familiarization trials were begun.

Introductory Section. As in the Sand condition of Experiment 1 each subject was given a chance to play with a portion of sand for 30 s.

Baseline/Familiarization Trials. The baseline/familiarization trials in Experiment 2 paralleled those in the Sand condition of Experiment 1. There were two pairs of baseline/familiarization trials. The first pair happened in full view while the second pair was partially hidden behind the two screens. Each pair consisted of a single pile trial and a double pile trial. In the double pile trials of the second pair the sand was poured simultaneously behind the two screens. There were two orders of baseline/familiarization trials (1-2-2-1 and 2-1-1-2). Order and side of the single pile trials were counterbalanced across subjects.

Test Trials. Six test trials immediately followed the baseline/familiarization trials (see Figure 5). Subjects saw one pile of sand poured in full view. Then both screens were lowered onto the stage simultaneously. One screen hid the pile of the sand and the other was on the other end of the stage. The experimenter held the screens in different hands, as he lowered them, so the screens moved somewhat independently despite the fact that they were lowered onto the stage at the same time. After the two screens were in place the experimenter poured sand behind the screen that did not occlude the first pile of sand. Finally the screens were simultaneously removed to reveal either one pile of sand (impossible outcome) or two (possible outcome). Looking times at the outcomes were measured. Each infant saw an alternating series of test trials (possible first, impossible first). As in Experiment 1, the side of the impossible outcome was the side on which the infant had seen sand poured in the single pile baseline/familiarization trials. Order of test outcomes and side of the single pile (impossible) outcome were counterbalanced across subjects.

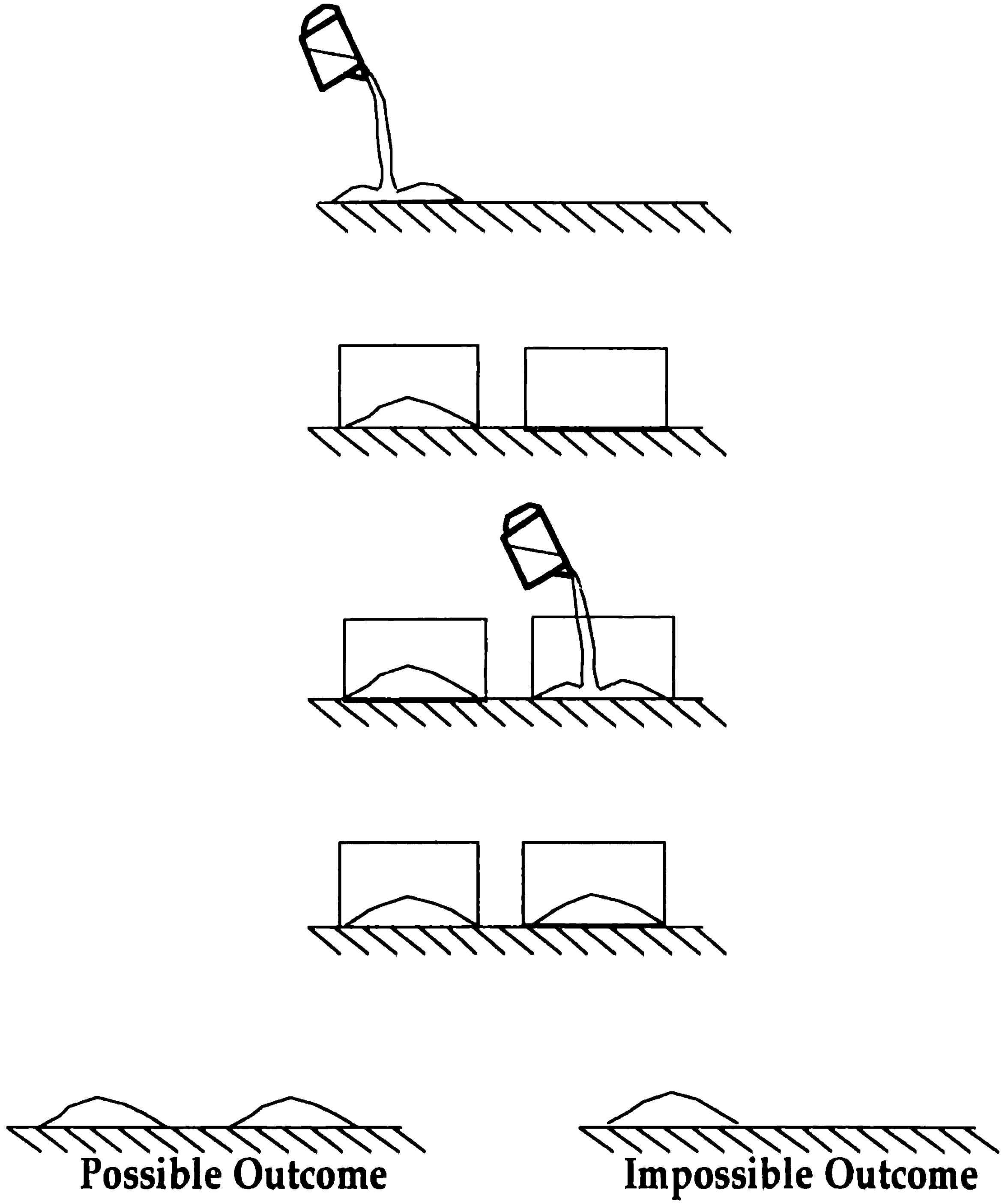

Figure 5. Schematic of the test trial procedure for Experiment 2.

Results

Looking by 11 of the 16 babies was measured by two observers. Mean inter-observer reliability was 91%.

Preliminary ANOVAs found no effects of order of outcome, side of outcome and sex of subject on looking times. Subsequent analyses are collapsed across these variables.

A 2 x 2 ANOVA contrasting the effects of outcome (one pile, two piles) and trial-type (baseline, test) on looking times was conducted. There was no main effect of outcome but there was main effect of trial-type, $F(1,30) = 7.99$, $p < .02$. As in the sand condition of Experiment 1, subjects looked longer during the baseline trials than they did during the subsequent test trials. Subjects found both possible and impossible test trials in Experiment 2 equally uninteresting; there was no Trial-type x Outcome interaction, $F(1,15) = .78$, *ns* (see Figure 6).

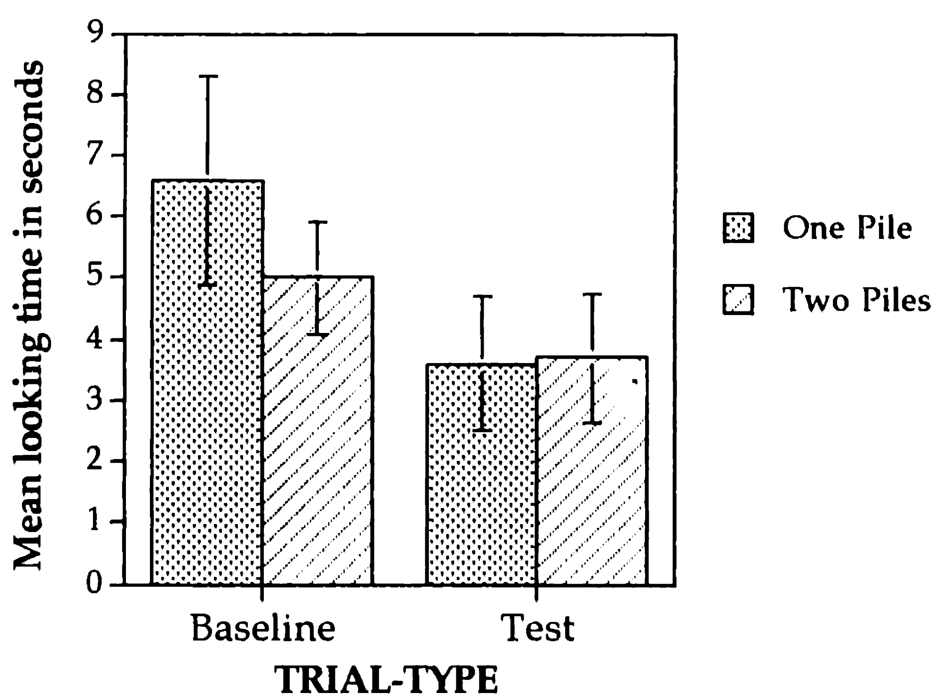

Figure 6. Mean looking time data for Experiment 2.

The above pattern of results should sound familiar, it is exactly the same as the sand condition in Experiment 1. A 2 x 2 x 2 ANOVA (Experiment -- sand condition Experiment 1, Experiment 2 --, Trial-type, Outcome) revealed no interactions and no main effects except for the "habituation" effect: subjects become bored over time in both experiments; main effect of trial-type, $F(1,30) = 12.32$, $p < .002$.

The multiple screens in Experiment 2 did not help subjects individuate portions of sand. It follows that the results of Experiment 2 should contrast with those of object condition in Experiment 1. A 2 x 2 x 2 ANOVA was conducted (Experiment -- object condition in 1, Experiment 2 --, Trial-type, Outcome). There were no main effects or interactions except for two 1) the "habituation" effect: subjects became more bored over time across both experiments; main effect of trial-type, $F(1,30) = 4.42$, $p < .05$. 2) There was an Experiment x Trial-Type x Outcome interaction, $F(1,30) = 5.34$, $p < .03$. Subjects in the object condition of Experiment 1 preferred the impossible outcome in the test trials with respect to the baseline trials whereas subjects in Experiment 2 did not.

These findings are supported by non-parametric statistics. In Experiment 2, eight out of 16 subjects preferred the baseline outcome of one pile of sand; the same as in the test condition, Wilcoxon Z = .21, *ns*. Whereas as reported above, in contrast to Experiment 2, a greater number of subjects in the Object condition of Experiment 1 preferred the impossible outcome of a single object in the test trials than in the baseline trials, Wilcoxon Z = 2.74, $p < .007$.

Discussion

Infants failed to build a representation of two piles of sand even when they were given explicit information about where those two piles of sand were hidden. This is surprising given the wealth of evidence that infants can use hints about location, in the form of multiple screens, to remember where an object is hidden and how many objects are hidden (Baillargeon et al., 1990; Wilcox et al., 1994; Uller et al, 1995). The failure to enumerate in Experiment 2 thus represents not a shortcoming of memory or a misjudgment about pouring location but a failure to encode individual portions of sand as such. Experiment 2 confirms the finding of Experiment 1 that infants see counting as irrelevant to sand. Given that infants so readily represent the number of objects in a hidden array, infants' refusal to enumerate portions of sand in Experiments 1 and 2 is evidence that for infants the distinction between non-solid substances and objects is one that has quantificational force.

Given the similarity between the array of objects in Experiment 1 and the arrays of sand in Experiments 1 and 2, the failures in Experiments 1 and 2 suggest that babies will only count what is quantified as an individual. Should this be true it suggests that the infant's knowledge of number draws not merely on the perception of a discontinuity but on deeper conceptual resources; that is, concepts which provide criteria for individuation and identity.

GENERAL DISCUSSION

Experiments 1 and 2 support the view that infants by 8 months of age understand the distinction between objects and non-solid substances as one that has quantificational force. Experiment 1 confirmed the finding that objects are countable entities (Wynn, 1992) and demonstrated that infants know that there is a number-irrelevant construal of non-solid substances like sand.

This finding has implications for the research on the infant representation of number. Some have suggested that infants make judgments about number by simply parsing a visual array into perceptual individuals (Trick & Pylyshyn, 1994; Dehaene & Changeux, 1993). In such proposals the countable entities are carved out of the world by preattentive visual processes on the basis of discontinuities (color, brightness, texture, etc.) which mark boundaries. The alternative to this view we owe to Frege (1884/1953); he pointed out that judgments of number depend on the count noun under which we are quantifying the array. Thus a set of white playing cards spread out separately on a black background may present 52 different bounded discontinuities but they can be counted as 1 deck, 4 suits, etc.

In Experiment 1, care was taken to design the object stimuli so that they would have the same shape, color and texture as the sand stimuli thus presenting similar discontinuities. Under one view infants should make judgments of number on the basis of a modular, preattentive representation of discontinuities. Since the arrays of objects and piles presented similar discontinuities they should have been counted the same. This was not the case, infants paid attention to the origin of the discontinuities (whether poured or lowered) and counted objects but not piles of sand. This is consistent with the alternative view that in order to count we must specify what the countable individuals are. We know that infants represent objects as individuals and thus in the case of Experiment 1 the countable individuals must have been objects.

It should be pointed out that what is being argued is not that infants cannot enumerate discontinuities. That is, infants can probably be habituated to repeated displays of some number of piles of sand (lets say 2), and subsequently dishabituated to a different number of piles of sand (lets say 3). In that case the infant is not called upon to reason about sand as such in order to count. Infants might count pouring events or resulting blobs neither of which involves thinking about sand. The crucial point of Experiment 1 is that infants tracked objects, held them in memory and counted them but that they did not track the portions of sand and hold them in memory in the same way. In the case of the objects they were tracking numerically distinct entities. In the case of the sand they were tracking something like "some sand" to which number is irrelevant.

Experiment 2 was designed to give infants a hint that there were distinct entities resulting from the two pouring events. Individuated portions of non-solid substances may be defined by their location. What makes a particular pile of sand an individual is that it is in a different place than any other portion of the same material. The two screens in Experiment 2 served to define two distinct places. If infants understood that location could serve to individuate non-solid substances they should have succeeded in that condition.

Infants failure to use the information provided by the two screens is noteworthy considering that multiple screens help 8-month-olds to individuate objects (Uller et al., 1995). This striking pair of failures raises the possibility that 8-month-olds may not have conceptions like INDIVIDUAL PORTION of NON-INDIVIDUATED ENTITY available. Adults would have succeeded without ever seeing any piles of sand simply by knowing that stuff in two distinct locations makes two portions. Had they never seen sand before the Experiment, recognizing that the stimulus does not cohere, they would they would have invented something like PILE of SAND which is an instance of the concept: INDIVIDUAL PORTION of NON-INDIVIDUATED ENTITY and counted that. Infants failure to construct such a representation in Experiments 1 and 2 suggests that the parent concept: INDIVIDUAL PORTION of NON-INDIVIDUATED ENTITY was not available to be instantiated.

In summary, adults can entertain two conceptions of non-solid substances, either as portions or as "some stuff." Infants' failure to count piles of sand suggests that babies reason about sand in such a way that number is irrelevant. This is akin to the adult conception of sand as "some stuff." Babies appear not to entertain the alternate construal that "some stuff" could be "one pile of stuff." The above experiments raise interesting questions about the infant's understanding of the physical properties of non-solid substances. We showed each subject a few times that pouring sand from a cup results in a pile shaped entity of the same material. Perhaps infants were not familiar enough with the pouring process to make the inference that pouring behind a screen would result in an enduring pile shaped entity behind that screen. Alternatively, infants may have been unable to track the portion of sand as it was transformed from a cup of sand into a pile of sand. Such transformations from one kind of thing into another occur in nature (tadpole - frog, caterpillar - moth) but at a very different time scale. Future experiments are being designed to explore these possibilities.

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Chapter 4:
The Effect of the Whole Object Bias on Preschoolers' Understanding of Collective Nouns

SUMMARY OF CHAPTER 4

There is much evidence that children's inductions about word meaning are influenced by a "whole object bias." That is, children have a tendency to assume that novel words refer to kinds of whole objects. Such a tendency is invaluable when the word being learned in fact refers to a kind of object but it will hurt lexical acquisition otherwise. Indeed, there is evidence that children adhere to this bias to their detriment when learning syntactically marked proper names (Hall, 1991), mass nouns (Soja, 1992) or names for parts of objects (Markman & Wachtel, 1988). Given such a bias, one type of word which should be hard to learn is the collective noun. These words refer to kinds of discrete individuals grouped together (e.g. family, army, forest, flock, etc.). The current paper is the first systematic study of the meanings children assign to the earliest collective nouns in their vocabulary.

Three experiments were conducted. In the first, 3- and 4-year-olds and adults were asked to count objects held by groups of people. For example, subjects were shown a drawing of 3 people holding two balloons apiece and asked "How many balloons do the people have?". For adults this in an ambiguous question: "Each person has 2 balloons" or "They have 6 balloons in all" unless the word "people" is replaced with the collective noun "family." When asked "How many balloons does the family have?" the answer can be only "Six." While adults knew that collective nouns entailed an obligatory collective response, 3 and 4-year-olds made substantial errors even on familiar collective nouns (30%). Two further experiments confirmed that preschoolers often misinterpret collective nouns as referring to individual whole objects. We asked 2 to 4-year-olds to identify the referents of collective nouns and superordinates by choosing one of three cards (a familiar individual whole object, a group of familiar objects or an unfamiliar object distractor). As predicted, evidence for the misinterpretation of collective nouns was found. Subjects of both ages often picked the single familiar object when probed with a collective noun (40%). Some subjects even described arrays of objects as arrays of collections: e.g. 4 soldiers - "a lot of armies." These findings are

consistent with young children's reported difficulty learning novel collective nouns (Bloom & Kelemen, 1994). The implications of these results for the hypothesis that superordinate categories are sometimes represented as collections (Markman & Seibert, 1976; Markman 1989) is discussed.

INTRODUCTION

Any account of the acquisition of word meaning, like an account of any inductive process, must specify the mechanisms by which candidate hypotheses are kept within psychologically manageable limits. This insight has led to a rich variety of proposals concerning constraints on possible word meanings that children bring to the task of acquiring a lexicon. In general these proposals invoke knowledge in the word learner of a relationship between types of meaning and lexical categories (kinds of objects -- count nouns, non-solid substances -- mass nouns, properties -- adjectives, relations -- verbs; e.g. see Brown, 1957; Pinker, 1984). In this paper we will focus on the representations that children assign to count nouns.

There is much evidence that from at least 2 to 3 years of age children expect count nouns ostensively defined over objects to refer to kinds of individual whole objects. That is, that they reject alternative interpretations of novel count nouns as referring to particular individuals, properties of objects, the substances of which objects are composed, events in which the objects participate, or any of a host of other conceivable candidates (Hall, 1991; Landau, Smith & Jones, 1988; Macnamara, 1982; Markman & Hutchinson, 1984; Markman & Wachtel, 1988; Soja, Carey, & Spelke, 1991; Taylor & Gelman 1988; Waxman, 1990). This expectation has been dubbed the "whole object assumption." Here we take the whole object assumption to have two parts -- that count nouns refer to *kinds* of *individual whole objects*.

This assumption raises a problem, namely that children must learn the meanings of count nouns that don't refer to kinds of objects; for example, collections like families and forests, abstract entities like ideas, and sounds like drumbeats. A whole object assumption may mislead word learners. Indeed, a testament to the salience of objects is that preschoolers will ignore pragmatic evidence that a speaker using a novel word intends to refer to the type of material of which an object is made or a part of an object. In such cases, subjects will often infer that the novel word picks out a kind of whole object (Landau, et al., 1988; Markman & Wachtel, 1988). Moreover, despite a manifest sensitivity to syntactic cues, toddlers and preschoolers will often override syntax to interpret a novel word as picking out a kind of object (for evidence with proper name syntax see Hall, 1991; with mass nouns, Soja, 1992; and with adjectives, Hall, Waxman, & Hurwitz, 1993). This tendency of children to override syntactic and pragmatic cues for a non-object interpretation of a novel word in favor of the whole object interpretation has led some to argue that very young children are generally biased to interpret all words as picking out kinds of objects (Waxman & Markow, 1995; Hall, et al., 1993).

Despite this object bias, children's early count nouns include labels which adults use for kinds of non-objects (Nelson, 1988; Nelson, Hampson & Shaw, 1993). Some of these words may have been misanalysed by children as labeling kinds of whole objects but this seems unlikely for words like "minute" and "nap." Furthermore, it has been shown that preschoolers will use their knowledge of count/mass syntax to individuate portions of a non-solid substance (Soja, 1992) and to quantify an ambiguous sequence of sounds either as discrete (count noun) or as undifferentiated noise (mass noun -- Bloom, 1990). Evidently, preschoolers have the capacity to attend to non-objects as possible referents of a novel count noun.

Studies showing that preschoolers are capable of learning novel count nouns to refer to non-objects have been limited to the contrast between count nouns and mass nouns. Yet the whole object bias poses a problem even once canonical mass noun interpretations (kind of stuff) are ruled out. For example, as mentioned earlier, there are collective count nouns like "forest" and "army" which pick out multiple objects, and words like "handle" which pick out parts of objects.

Clearly children eventually become adults who know meanings of count nouns which do not label kinds of whole objects, so there must be a way of overriding the whole object bias. One proposal for how this is accomplished comes in the form of a constraint on meaning known as Mutual

Exclusivity: "Each object ... could have only one category label and each label could refer to only one category of objects." (Markman & Wachtel, 1988, p. 122).

Mutual Exclusivity (ME)

The belief that each object belongs to a unique kind, has the effect of attenuating the whole object bias once the child already knows a label for some kind to which an object belongs (Markman & Wachtel, 1988). Children learn labels for basic level kinds before any others (Mervis & Crisafi, 1982; Rosch, Mervis, Gray, Johnson & Boyes-Braem, 1976; see Markman, 1989 for a recent review). Under ME, the assignment of an object to a basic level kind and the learning of that kind's concomitant label should block future assignments of that object to another kind, thereby preventing the learning of additional labels for talking about that object.

In support of ME, there is consensus in the literature that the whole object bias is reduced when the object being labeled with a novel word is familiar or already labeled. Markman and Wachtel (1988) established that 3-year-old children who already know one label for an object are more likely to interpret a second count noun applied to that object as referring to a part of the object than are those who do not already know a label for the kind of object. Similarly, preschoolers are more likely to interpret a mass noun as referring to the material of which an object is made, or a proper name as referring to a particular individual, or an adjective as picking out a property, in the presence of a familiar object than an unfamiliar one (Hall, 1991; Markman & Wachtel, 1988; Prasada, 1993, 1995).[10]

Unfortunately, as a solution to the problem presented by the whole object bias, ME is itself problematic. ME is false; there is no one-to-one correspondence between kinds and objects. In light of this, evidence is presented that preschoolers have difficulty learning certain kinds of words

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[10]A possible alternative to ME is that once children learn count/mass syntax they may reject the
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because of ME, e.g., superordinate and subordinate kind terms (Markman, 1989; but see Waxman, 1990). It is argued that superordinate words (e.g., "animal" and "toy,") are misanalysed upon first being learned: 2-year-olds and young 3-year-olds often will deny that a single dog is "an animal", or a single doll is "a toy" (Macnamara, 1982); and when asked to put "a toy" or "an animal" in a box some put several at once (Callanan & Markman, 1982).

The Collectivization Hypothesis

The finding that children will reach for groups when asked for "an animal" is curious. Collection words like "forest," "family" and "army" label individuated groups of whole objects and learning such meanings entails violating the whole object bias. Nevertheless, Markman and Seibert (1976) argued that preschool children may avoid talking about a single object using two different labels by conceptualizing a given object simultaneously as e.g., "a dog" and as "a part of an animal." Consequently, words like "animal" are sometimes learned as collective nouns. That is, "animal" is interpreted as referring to a kind of group which includes cows, dogs and cats rather than a kind such that each cow, dog, and cat is a member of that kind.

In support of this view, Markman and Seibert (1976) argued that the (meronymic) relationship among the objects in a collected group (e.g., forest, fleet) is more transparent than the (taxonomic) relationship among the individual members of a superordinate category. Thus collections ought to be more "psychologically coherent" than superordinates. Evidence comes from the finding that Piagetian class inclusion tasks (often failed by children under 8-years-old) are solved by 4 and 5-year-olds if posed in terms of collections: "Who would have more pets? Someone who owned the baby pigs or someone who owned the family?" rather than if posed in terms of count superordinates: "Who would have more pets? Someone who owns the big

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whole object bias in favor of non-spatio-temporal criteria (e.g., Prasada, 1995) pigs or someone who owns the animals?". We will refer to the idea that children avoid violations of ME by invoking a collective interpretation of superordinates as the "Collectivization hypothesis."

The Collectivization hypothesis raises an interesting conflict -- it pits ME against the whole object bias. Though Markman and Seibert (1976) did not argue the following point, the implication of their proposal is that the child is more likely to avoid violating ME than to avoid the violating whole object bias. Collection words are count nouns which label not kinds of individual whole objects, but kinds of groups.[11] Thus according to the whole object bias they should be harder to learn, not easier. The experiments and arguments presented in this paper will help to distinguish among three possible states of affairs: 1) The *Collectivization hypothesis:* Superordinates and collections are represented alike as collected entities (Markman, 1989; Markman & Seibert, 1976; Markman, Horton & McLanahan, 1980); 2) the *Object-as-individual hypothesis:* Collections are sometimes taken to refer to individual whole objects; 3) the *Continuity hypothesis:* Superordinates are distinguished from collections and collection words are learned as picking out kinds of groups.[12]

Hypothesis (1) is supported by the evidence discussed above, that children will refuse to call a dog "an animal" while still referring to a pile of dogs, horses, cows, etc. as "animals." Hypothesis (2) predicts that a collection word will often be misanalysed as a kind label for the individual objects that make up the collection. For example, "forest" is a count noun, and a simple ostensive indication of a forest invariably includes examples of trees, so the whole object assumption could lead the child to violate ME and assume that

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[11] Of course not all collection words label groups of *objects* (e.g. trinity, pantheon, vocabulary) but for the purposes of the present discussion, we will consider those that do as affected by the whole object bias.

[12] There are two different versions of this hypothesis: Children may well have the capacity to represent collected individuals but not demonstrate that knowledge because they rarely get the right kind of evidence. Alternatively children may not have the full range of possible individuals available to adults: (e.g. entities like portions of non-solid substances, collected groups, etc.) and thus these are not contemplated as possible referents of count nouns.

"forest" refers to some kind of tree. Hypothesis (3) predicts that there should be few errors of either type, if any.

There are two pieces of evidence in the literature which bear on Hypotheses (1) and (2) above. First, in support of the Object-as-individual hypothesis, Shipley and Shepperson (1990) reported that 3-year-olds, when asked to count the "teams" or the "families" in an array, counted the individual people instead. Second, Smith and Rizzo (1982) investigated the meanings that preschoolers and first-graders assigned to collection words and superordinates by asking them to identify whether sets of objects (including singletons) could be referred to either by a collection word or by a superordinate. It was found that occasionally children accepted a superordinate label as identifying only a group of objects and not singletons (9%). These are very few errors but they are similar to those reported by Macnamara (1982) and Callanan and Markman (1982) and they are consistent with the Collectivization hypothesis. Smith and Rizzo also found that children occasionally accepted a collective label for a singleton (10% of responses). These errors are consistent with the Object-as-individual hypothesis.

These small numbers of errors hardly make the case for Hypotheses (1) and (2) above but two things should be noted. First, Smith and Rizzo's subjects were beyond the 2.5- to 3-year-old age range at which some children refuse to call a doll "a toy." Second, some of the "collective" stimuli Smith and Rizzo used are arguably not collections at all (e.g. "sandwich", "garden", and "traffic jam").

Apart from the Smith and Rizzo study there has been little research on the meanings young preschoolers have assigned the collection words in their lexicon. In the current paper, we intend to ascertain whether young children know that the individuals picked out by collection words quantify over groups. In addition, we will examine whether collection words are contrasted with count superordinates which quantify over individual whole objects. It is predicted that children guided by the whole object bias will sometimes misinterpret collections as referring to individual whole objects. It will be argued that in contrast to the Collectivization hypothesis this may make collection words harder to learn than count superordinates.

EXPERIMENT 1

The clearest way to determine how someone is quantifying over a group is to ask them to count; thus it makes sense to ask children to count collections. As mentioned above, Shipley and Shepperson (1990) found that 4 and 5-year-olds had difficulty counting collected objects (teams, families, "kinds", etc.) as "one." It was argued that children make such errors not because they don't understand what they are being asked to count, but because in implementing the counting procedure, they are disposed to enumerating individual whole objects. As a way of avoiding this problem we adopted a procedure from Miyamoto and Crain (1991).

Miyamoto and Crain asked preschoolers and kindergartners to count objects held by groups of people (see Figure 1). For example, children were shown a drawing of three people holding two balloons apiece and asked "How many balloons do the people have?". The syntactic structure and the context of the sentence led many children to give the distributive answer: "Two" (as in "two each"). However Miyamoto and Crain found that children switched this preference when given appropriate pragmatic and syntactic context. One way to force the collective reading of such questions is to use a collection word. For example, when asked "How many balloons does the family have?" the answer can only be collective: "Six." Given the Miyamoto and Crain finding that young children are often disposed to give the distributive answer ("Two" rather than "Six") when probed with a basic level count noun, we hypothesized that children who understand collection words might switch from a distributive response to a collective one when probed with a collection word. In addition should they interpret words like "animal" as labeling collections they should also switch their preference when probed with a count superordinate.

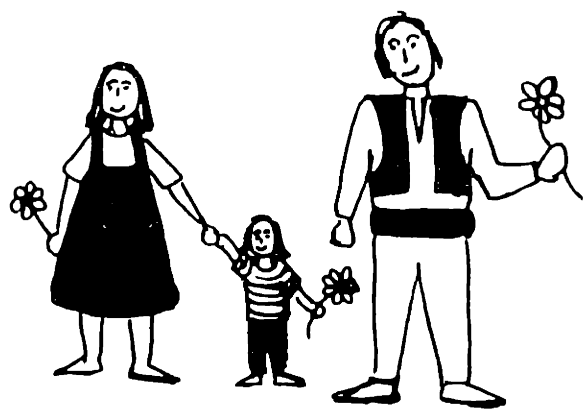

Figure 1. Example of Miyamoto & Crain style stimuli.

Method

Subjects. Subjects were 18 MIT undergraduates and 18 preschoolers ranging in age from 2;6 and 4;10 (M_{age} = 3;9). Some of the preschoolers were tested on object stimuli and others were tested on drawings: object stimuli (n=8, M_{age} = 3;7) and picture stimuli (n=10, M_{age} = 4;0). All of the adult subjects were tested on drawings.

Materials. Adult subjects were presented with drawings of groups of objects (4" x 6") whose labels corresponded to each of 4 word types (basic level, count superordinate, mass superordinate, and collection word -- see Table 1). The labels were chosen on the basis of a search in the CHILDES database (Bates, Bretherton, & Snyder, 1988; MacWhinney & Snow, 1985; MacWhinney & Snow, 1990). All of the words were found to be in the vocabulary of children 3-years-old and younger. The superordinates and collection words used in this experiment and the experiments below are the most common of these words in the vocabularies of young children.

The objects in the drawings each had either one or two other objects on them or beside them (e.g., books on chairs, worms in apples); or if people were pictured they were depicted holding objects (e.g., balloons). Some of the children saw the same drawn stimuli as the adults, the others were presented with actual objects corresponding to the drawn stimuli. Like the drawings, these objects each had other objects (one or two) associated with them (e.g., bells on cows, bugs on apples, books on chairs). It was hypothesized that since the task involved counting and was somewhat more like a test than a game, the children might be more engaged by the object stimuli than by the drawings and thus be more likely to demonstrate their knowledge.

Table 1. Stimuli for Experiment 1. Each subject was tested on only two of the basic level labels. Otherwise every subject was tested on the full list of superordinate and collection word labels shown here.

Basic Level	Count Superordinate	Mass Superordinate	Collection Word
cow, rabbit, apple,	animal	fruit	army
house, chair,	building*	furniture	family
building block,	toy	money	forest
tree, turtle, plane			

*Those children who saw actual objects were asked to count over "vegetables" (carrots) instead of "buildings."

Procedure. All of the children were given a pretest after Wynn (1990) to determine whether they understood the rudiments of counting. Subjects were first asked to "count", i.e., spontaneously generate the list of number words as high as they could go. Next they were given small numerosities of objects (1 - 3) and asked to count them. Finally they were asked to put one, two, or three objects into a bag. Those subjects who did not pass the pretest were not included in the rest of the experiment.

Adults and those children who were presented with drawings saw the stimuli in a random order. The procedure was the same for both adults and children. For each drawing the experimenter gestured to the objects and labeled them using either a basic level word, a count superordinate, a mass superordinate, or a collection word. For example (count superordinate): "Do you see what I have here? Look at the animals. Do you see the animals?". Then the experimenter drew the subject's attention to a subset of the objects (e.g., collars on rabbits) by saying: "Look at the collars. Do you see the collars on the animals?". After the subject's attention was drawn to all of the relevant details in the drawings the subject was asked to count: "How many collars do the animals have? How many collars are on the animals?".

Children who saw actual physical objects were engaged in a similar procedure. Each group of toys was placed one at a time on a table between the experimenter and the child. The toys were labeled using either a basic level word, a count superordinate, a mass superordinate, or a collection word. For example (collection word): "Look at the army. Do you see the army?". Next the child's attention was drawn to other objects in the array (e.g., flags held by each soldier). "Look at the flags. Do you see the flags?". Finally the experiment asked the child to count by saying "How many flags does the army have?".

Results and Discussion

Subjects responses were coded either as collective or distributive. Subjects' counting was not always accurate but since subjects were able to count at least to three it was clear whether they were counting distributively ("one-two, one-two, one-two") or collectively (one, two, three, ...). The first analysis examined the effect of the object stimuli vs. the picture stimuli on children's counting. We conducted a 2 x 4, repeated measures ANOVA examining the effects of stimulus type (object, picture) as a between subjects factor and word type (basic level, count superordinate, mass, superordinate, collection word) as a within subjects factor on the proportion of collective responses. There was a marginal effect of word type, $F(3,48) = 2.52$, $p < .07$. But there was no main effect of stimulus type, $F(1,16) = 1.09$, *ns*; nor was there a Stimulus x Word Type interaction, $F(3,48) = .449$, *ns*. Future analyses will collapse across stimuli treating all the preschoolers as belonging to the same group.

Some of the children exhibited response biases. That is, 6 out of 18 children always counted collectively. There were no distributively biased children.

An overall 2 x 4 ANOVA was conducted examining the effects of age (adults, children) and word type on the proportion of collective counting. There was no main effect of age, $F(1,34) = 2.961$, *ns*; but there was a main effect of word type, $F(3,102) = 10.805$, $p < .001$; there was also an Age x Word type interaction, $F(3,102) = 2.77$, $p < .05$. Two focused one-way ANOVAs revealed that the overall Age x Word type interaction was due to the fact that adults clearly differentiated among different word types with respect to collective counting, effect of word type: $F(3,51)=9.85$, $p < .001$; whereas, as mentioned above, preschoolers only had a marginal tendency in this direction, $F(3,51) = 2.6$, $p < .07$.

The main effect of word type for the adult subjects was due to the fact that in the obligatory collective counting context -- i.e., when probed with a collection word -- adults counted collectively 100% of the time. Planned post hoc comparisons of mean collective responses confirm that adults distinguished the collection word trials from all other trials and that they did not distinguish the other types of trials from each other. In contrast children did not distinguish any of the word types (including collection words) from each other. The Object-as-individual hypothesis predicts that collection words are especially difficult for children to learn. A post-hoc comparison of responding on collection word trials revealed that children counted collectively less often than adults in the obligatory collective context, $t(34) =$

3.73, p<.001 (see Table 2). As suggested by the lack of an overall age effect, none of the other age comparisons by word type are significant.

Table 2. Data for Experiment 1

Word Type	**Proportion Collective**	
	Adults	*Children*
Basic Level	.53	.54
Count Superordinate	.65	.46
Mass Superordinate	.69	.50
Collection Word	1.00	.67

Adults clearly distinguish collection words from other types of words in that they understand that collection words quantify over groups. Adult subjects were more likely to count collectively when probed with a collection word than when probed with a basic level word or with a superordinate.

Preschoolers showed a slight tendency towards differentiating collection words from words referring to kinds of individual whole objects (see Table 2). Such a tendency is what one might expect under a Continuity hypothesis. Nevertheless the Continuity hypothesis still leaves unanswered why children erroneously counted distributively 1/3 of the time in the obligatory collective context. This is especially notable in light of the fact that several children were collectively biased to begin with. The failure to count collectively in an obligatory context is consistent with the Object-as-individual hypothesis in that it may signal misanalyses of collection words like "army", "family", and "forest" as picking out kinds of individual whole objects.

With respect to the Collectivization hypothesis it appears that preschool children are less likely to count collectively when probed with a count or mass superordinate than when probed with a collection word (50% for superordinates overall vs. 67% for collection words). That is, superordinates are not treated as labels for collections. In addition, the Collectivization hypothesis predicts that subjects would be more likely to count collectively when probed with a superordinate than when probed with a basic level word. This was not the case (basic level vs. count superordinates: $t(17) = 1.45$, *ns*; basic level vs. mass superordinates: $t(17) = .57$, *ns*). With respect to quantification, count and mass superordinates pattern with basic level words and not with collection words. These two pieces of evidence suggest, contrary to the Collectivization hypothesis, that subjects are not treating words like "animal" and "furniture" as collection words.

It is clear that even at the late age of 3.5-years-old, children have yet to sharpen their understanding that collection words label kinds which quantify over groups quantify over groups. It is of interest that one of the subjects spontaneously referred to the group of identically dressed soldiers as "A lot of armies." This suggests that some preschoolers have really misanalysed words like "army" as picking out individual whole objects. Nevertheless, it is as yet unclear whether children's occasional failure to count collectively in an obligatory collective context is evidence that they have misinterpreted the collection words in their vocabulary. The children in Experiment 1 were slightly older than those who make the errors reported in support of the Collectivization hypothesis (Callanan & Markman, 1982; Macnamara, 1982). In Experiment 2 we directly tested knowledge of the collection words in the vocabulary of younger children.

EXPERIMENT 2

Toddlers' and preschoolers' knowledge of collection words and count superordinates was probed in Experiment 2 by a picture identification task. In this experiment 2- to 4-year-olds were asked to choose from an array of three choices. They were asked for the picture with "one X" where X was either a count superordinate, a collection word, or a novel word. To keep the task short we did not probe children with basic level words or mass superordinates.

The arrays of pictures were constructed so that there was always a group choice and a two singleton choices available. One of the singleton choices and the members of the group in the group picture were always familiar objects from a single superordinate category. It was determined through pretesting that children could readily name the elements in those pictures. Should children distinguish between collection words and superordinates with respect to whether they quantify over groups or individual objects, they should choose the group when probed with a collection word and the familiar singleton when probed with a count superordinate. The remaining singleton was a drawing of a novel object which, through pretesting, it was determined that preschoolers could not name (see APPENDIX A for a complete list of stimuli used in Experiment 2). Should children be unfamiliar with any of the probe words, ME predicts that they should choose the novel object distractor. Choice of the novel object is therefore an index of children's familiarity with a probe word. Should it turn out that children make an *incorrect* choice but not pick the distractor, there will be evidence that the probe word is familiar but misanalysed.

Method

Subjects. Eighty Boston area toddlers and preschoolers were tested in local day care centers and at our Cambridge, MA lab. The children were divided into two groups by age. The younger group (n=40) ranged from 2;6 to 3;6 (M_{age} = 3;0). The older group (n=40) ranged from 3;7 to 4;10 (M_{age} = 4;0).

Stimuli. Stimuli were drawings on 4" x 6" cards. Five sets of cards were designed for each of two word classes (collection words: army, bunch, class, family, forest; and count superordinates: animal, building, tool, toy, vegetable). Each set of stimuli consisted of an array of three cards (see Figure 2 for an example). Each subject was tested on three items from each word class. The remaining 4 stimulus sets were used in novel word trials ("blicket", "dax", "zav", "wug").

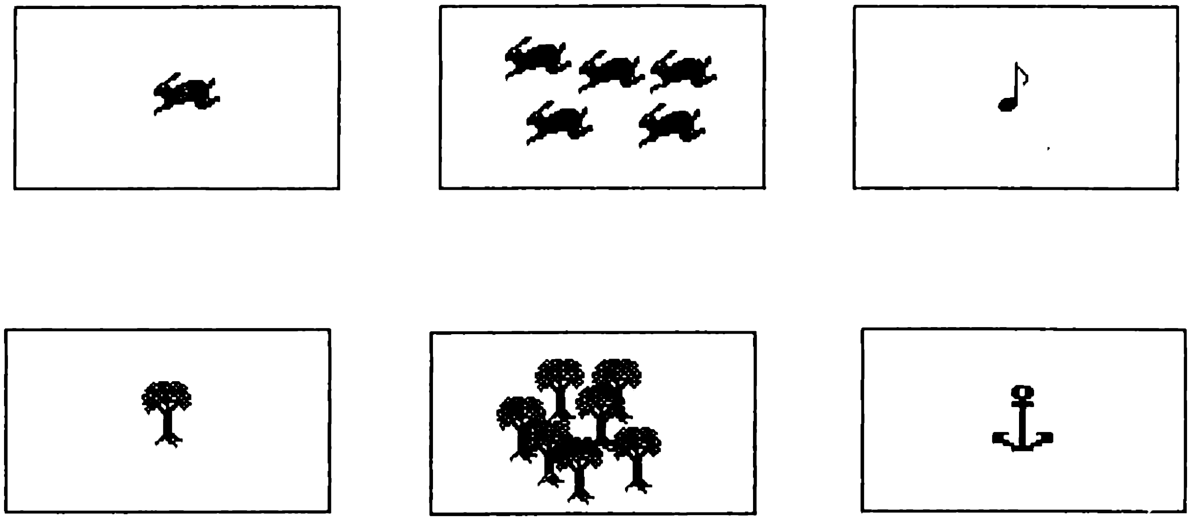

Figure 2. Schematic drawing of the stimulus sets for the count superordinate: "animal" (top) and the collection word: "forest" (bottom) used in Experiment 2.

Procedure. Subjects were told that they were going to play a game with a puppet who likes to eat cards. There were 4 practice trials to teach subjects the basics of the game. Each practice array of three cards consisted of pictures of familiar objects and the practice probe words were their basic level labels ("hat", "ball", "book", "apple"). For example, children were asked to "Give [the puppet] the card with one ball on it." Practice trials were repeated when the child did not make the correct choice; this rarely happened. To inform children that sometimes the correct choice consisted of a card picturing multiple objects, half of the time the target card had more than one object on it and half of the time it did not. The practice trials in which the target card pictured the target among multiple objects might contribute to collectivization responses. However, the practice arrays also included one case where the card with the singleton target (e.g. one ball) was contrasted with a card containing more than one exemplar of the target (e.g., two balls, and one dog) and another card containing an unrelated but familiar object (e.g., one snake). In that case subjects always chose the card with the single exemplar of the target (e.g., one ball).

Upon completion of the practice trials, subjects were presented with each experimental stimulus set one at a time. The experimenter drew attention to the cards by showing them and saying "See that", the cards were then turned over and shuffled three-card-monte style. The subject was then asked to give the puppet the card with "one X on it", where "X" was either a count superordinate, a collection word, or a novel word. To make sure that the subject was focusing on the question, they were asked to repeat the probe word to the experimenter. After the probe word was uttered, the experimenter turned the cards face up all at once, repeated the question, and allowed the subject to choose.

There were a total of 10 experimental trials per subject: 3 collection words trials, 3 count superordinate trials and 4 novel word trials. The experiment was designed so that across subjects all of the arrays would be probed with a novel word and with either a count superordinate or a collection word. This design allowed us to measure for each array the distribution of subjects' responses when the probe was a novel word. Given a particular array, we may compare choices when the probe was a superordinate or a collection word to choices when the probe was a novel word thereby determining whether the superordinate or collection word was familiar or unfamiliar.

Stimuli were blocked by word-type. Blocks were ordered so that the novel word trials either preceded or followed the collection word and superordinate trials. The order of the superordinate trials and the collection word trials was counterbalanced in turn, for a total of four different orders by block. The order of words within blocks was randomly varied.

After the Puppet task we probed subjects' understanding of collection words more deeply. Subjects were asked to define the collection words they were exposed to in the course of the study. We asked, for example, simply "What is a family?"

Results and Discussion

Errors. Subjects' responses were coded for errors. When the probe word was a count superordinate subjects' choice of the single familiar object was coded as correct. When the probe was a collection word only the group choice was coded as correct. When the probe was a novel word, given the evidence for ME and related principles (Clark, 1983; Markman & Wachtel, 1988), subjects were expected to choose the distractor, hence distractor choices were coded as "correct."

Table 3. Error data for Experiment 2

Word Type	**Proportion Correct**	
	Young	*Older*
Count Superordinate	.81	.83
Collection Word	.44	.52
Novel Word	.68	.75

A 2 x 3 repeated measures ANOVA with age (young, older) as the between subjects factor and word type (count superordinate, collection word, novel word) as the within subjects factor was conducted on the error data. There was no main effect of age, $F(1,78) = 1.69$, *ns*; nor was there an Age x Word Type interaction; $F(2,156) = .27$, *ns*. However there was a main effect of word type; $F(2,156) = 31.47$, $p<.001$. Subjects did best when probed with a count superordinate and worst when probed with a collection word (count superordinate: 82% correct; novel word: 72% correct; collection word: 48% correct). Planned post hoc comparisons indicate that these means are significantly different from each other (see Table 3).

Clearly subjects have not learned count superordinates and collection words equally well. Subjects made many more errors when probed with a collection word than when probed with a count superordinate. The Continuity hypothesis cannot account for why subjects make errors 52% of the time when probed with a collection word. Additionally, under the Collectivization hypothesis collections are psychologically coherent and relatively easy to represent. This hypothesis predicts that there should be more errors when subjects are probed with a count superordinate than when they are probed with a collection word; however, the reverse is true.

The "errors" for collection words and count superordinates for the moment are undifferentiated between cases where the probe word is completely novel, in which case subjects chose the distractor, and those cases where the probe word is familiar but misanalysed. The arguments for the Collectivization hypothesis and the Object-as-individual hypothesis depend on showing that errors are not due to simple unfamiliarity. To this end we shall now turn to a detailed analysis of the distribution of subjects' responses.

Table 4. Choice proportions by probe type when asked to give a puppet the card with "one X on it."

Word Type	**Proportion Choice**					
		Young			*Older*	
	Single	*Group*	*Distractor*	*Single*	*Group*	*Distractor*
Superordinate	.81	.14	.05	.83	.15	.02
Collection	.34	.43	.23	.33	.51	.17
Novel	.23	.09	.68	.19	.04	.76

Choices. There was no difference between the younger and older children's responses for any of the probe words (see Table 4 above). We conducted three 2 x 3 ANOVAs, one for each possible choice of cards (single familiar, group, distractor) examining the effects of age (young, older) and word type (count superordinate, collection word, novel word) on the choice of each kind of picture.[13] There was no main effect of age in any of the three ANOVAs: single familiar, $F(1,34) = .013$, *ns*; group, $F(1,34) = .291$, *ns*; distractor, $F(1,34) = .581$, *ns*. Nor were there any Age x Word Type interactions: single familiar, $F(2,34) = .037$, *ns*; group , $F(2,34) = .291$, *ns*; distractor, $F(2,34) = .22$, *ns*. Each analysis yielded a main effect of word type, indicating that subjects' choice of each kind of card was affected differently by the probe words (single familiar, $F(2,34) = 57.87$, $p<.001$; group , $F(2,34) = 20.7$, $p<.001$; distractor, $F(2,34) = 96.58$, $p<.001$). Choices are examined in detail, collapsing across ages below.

Three one-way ANOVAs were conducted examining the distribution of choices for each word type. As noted in the discussion of errors, subjects when probed with a novel word picked the distractor most often (72%); main effect of choice: $F(2,38) = 176.56$, $p<.001$. Of special note is that despite the effect of ME driving subjects to pick the distractor when probed with novel word, subjects often chose the card picturing a familiar object in violation of ME (21%). These violation are especially telling when one considers that under the Collectivization hypothesis subjects might have avoided violations of ME by choosing the group when probed with a novel word. Choice of the group when probed with a novel word was less frequent than choice of the single familiar object (7%), $t(19) = 5.3$, $p<.001$, suggesting, contrary to the Collectivization hypothesis, that subjects were more willing to violate ME than they were to choose the group as a candidate interpretation of a novel word.

There was also a main effect of choice when subjects were probed with a count superordinate, $F(2,18) = 445.69$, $p<.001$. Again as noted in the discussion of errors, subjects chose the single familiar card most often when probed with a count superordinate (82%). Among the errors we see that subjects chose the group of familiar objects (15%) more often than the distractor (3%), $t(9) = 5.2$,

[13] We were unable to conduct a 2 (age) x 3 (choice of card) x 3 (word type) ANOVA because each subject was probed with the same number of collection words and count superordinates thus there was no variance between those word types.

$p<.007$. Given that subjects often choose the distractor when probed with a novel word, the relatively high choice of the group when probed with a count superordinate suggests that occasionally subjects were familiar with the words but wrong about whether they quantified over groups or individual whole objects. This misanalysis, though infrequent, is predicted by the Collectivization hypothesis.

Finally, the effect on Choice when subjects were probed with a Collection Word was examined. Despite the fact that there is an apparent tendency to choose the Group card (47%) more frequently than the Single Familiar card (33%) or the Distractor (20%), this difference was not significant, $F(2,18) = 2.16$, *ns*. However, this pattern of data should not be taken to indicate random responding for two important reasons: First, random responding would due to unfamiliarity with the probe word; we know from the novel word trials that choice of the distractor will predominate in such a case and this is not the pattern we see here. Second when one looks at the collection words individually there are three distinct patterns (See Table 5).

Table 5. Subjects choices when probed with a Collection word broken down by word. The modal choice for each word is boxed (Object-as-individual errors: double line; Correct choice: single line).

Word	Choice		
	Single	*Group*	*Distractor*
army	34	5	9
bunch	7	16	25
class	5	34	9
family	10	38	0
forest	23	20	5

For two of the collection words ("army" and "forest") choice of the Single Familiar card predominates. This is consistent with the misanalysis predicted by the Object-as-individual hypothesis. In contrast, subjects correctly pick the group card when probed with "class" and "family". Finally, when subjects were probed with "bunch" they often picked the distractor indicating that were unfamiliar with the word (as applied to flowers tied together in a bundle). Subjects understood some collection words but the words they did not understand were either unfamiliar ("bunch") or misanalysed ("army, "forest"). In the process of figuring out what different collection words might mean, subjects will entertain that these count nouns pick out kinds of whole objects.

That all collection words are not equally well (or poorly) mastered is reflected in the following analysis. In Table 6, we indicate subjects' misanalyses by parceling out from errors, the effect of simple unfamiliarity. Every array of cards was probed by a novel word and either a count superordinate or a collection word. For a given array of cards, responses due to unfamiliarity are predicted by the distribution of responses when the probe word was novel. Occasionally when the probe word was novel subjects chose the single familiar object or the group, thus such choices are not always evidence of misanalyses. In Table 6 we have listed the likelihood that subjects will make a choice that looks like a misanalysis given that the probe word is in fact novel. Those proportions are compared to putative evidence for misanalyses, namely the proportion single familiar choices out of total errors (collection) and proportion of group choices out of total errors (count superordinate).

Table 6. Ratio of choices coded as "misanalyses" over total errors. Proportions given in the novel word columns are a benchmark measure of the probability of apparent misanalyses given complete unfamiliarity with the probe word.

Stimulus Array	Group/Group + Distractor		Stimulus Array	Single/Single + Distractor	
	Novel word	*Superordinate*		*Novel word*	*Collection*
animal	.04	.89	*army*	.33	.79
building	.04	.88	*bunch*	.07	.22
tool	.15	.71	*class*	.21	.36
toy	0.0	.64	*family*	.10	1.0
vegetable	.21	1.0	*forest*	.26	.87
TOTAL	11/123 (.09)	35/43 (.81)	TOTAL	29/148 (.20)	89/137 (.65)

In Table 6 we see evidence that when children make errors in the choice task they are not making the choice one might predict if the words were simply unfamiliar. Consistent with the Collectivization hypothesis is that when probed with count superordinates subjects make more errors then would be expected from simple unfamiliarity with the probe word, $t(9) = 18.371$, $p<.0001$. When probed with collection words the result is the same, $t(9) = 9.148$, $p<.0001$. Note however that despite the fact that subjects had equal opportunity to make both kinds of errors, there are many fewer example of collectivization errors (35) than there are of errors driven by the whole object bias (89).

Definitions of Collection Words. Many subjects were unable to finish the study beyond the Puppet task. Of the 40 younger children who completed the first part of the experiment we succeeded in encouraging only 21 younger children to complete the definitions as well. Of the 40 older children 30 completed the definitions.

It was rare for children to give full-fledged definitions when asked but we could often use their answers to infer how the relevant category was conceptualized. For example subjects most often gave interpretable one word answers (Experimenter: "What is an army?" Subject: "Soldiers.").

We coded children's responses into 4 mutually exclusive categories. See Table 7 below. Here are examples of the kinds of responses we received. Plural: subject answered "What is an army?" by saying "*they* march." Location: subject referred to a class as "a *place* where . . .". Object Interpretation: subject defined bunch as "a flower." All responses which indicated that subjects did not understand the word or that they did not understand what they were being asked to do are grouped in Table 7 as "Uninterpretable." These include Semantic Associate: subject mentioned related word like "teacher" for class; Repetition: subject repeated word to be defined; and responses like "I don't know".

Table 7. Number of responses by category when asked to define a collection word. Note the different n's by age.

	Category of Response	**Younger** (n=21)	**Older** (n=30)
Interpretable	*plural*	10	39
	location	6	5
	object interpretation	7	7
Uninterpretable	*semantic associate*	10	7
	"I don't know"	15	14
	repetition	1	4
	irrelevant	14	14
	Total # of Responses	63	90

Not surprisingly the younger children who knew fewer collection words and were less adept at giving definitions gave more uninterpretable responses than older children. About 68% of the time they said "I don't know", gave nonsensical answers, or mentioned a semantic associate when asked to give a definition. Older children in contrast did so only 43% of the time. Since these answers are uninterpretable we will exclude them from any further analyses.

All of the percentages below refer to only the subset of the total responses (from younger = 23 responses, from older = 51 responses) that are interpretable. Of these responses the plural answer is predominant. Of the children who gave interpretable definitions, both younger (43%) and older (76%) children often say things like "Soldiers" when asked "What is a army?" and "Trees" when asked "What is a forest?". Older children were almost twice as likely to do so as were younger children, even though we saw above that there were no age differences by age in the Puppet task.

Object-interpretation responses provide evidence that children have misanalysed some collection words. Such errors were infrequent but younger subjects made the error more often than older children (30% vs. 14%). As you might expect, those children who made this error were also likely to choose the single familiar object when probed with the collection word at issue (6/7 responses for both ages). Consistent with the word by word data we presented above, object-bias errors were not distributed equally among all collection words (see Table 8 for breakdown; see APPENDIX B for excerpted transcripts). Most children did not understand the word "army" though younger children made other errors as well.

Table 8. Number of times subjects gave object bias responses when asked to give definitions of collections. Number in parentheses is error frequency.

Younger (n=6)	Older (n=7)
army (4)	army (6)
bunch (1)	forest (1)
family (1)	
forest (1)	

Finally, children in both age groups sometimes responded as though being queried about a location, especially for "forest" and "class." These collection words differ from the others in the task in that for each of these words also label a location. Younger children gave location responses proportionately more often than older children (26% vs. 10%). It isn't clear that these responses were errors at all. At the very least thinking that "forest" or "class" picks out a location is not strictly consistent with the Object-as-individual misanalysis. The location responses taken together with the plural responses are both plausibly correct and make up a total of 69% of interpretable responses for younger children and 86% for the older children. Only when children are asked to give definitions of collection words is there a hint of an age difference with respect to the Object-as-individual hypothesis. This may have to do with the task rather than the word type -- older children may do better at giving definitions of collection words simply because they do better at giving definitions in general.

Summary. Contrary to the Continuity hypothesis it is clear that preschoolers are still working out the quantificational properties of some count superordinates and collection words in their vocabularies. However it is not that case that 3- and 4-year-olds treat all count superordinates and collection words alike. So far we have convergent evidence which suggests that children have misanalysed some collection words as predicted by the whole object assumption (in particular "army" and "forest"). Children picked a single object instead of a group when probed with a collection word and some children occasionally described the collected entity as an individual whole object. Additionally, contrary to the Collectivization hypothesis, preschoolers made fewer errors when probed with a count superordinate than when probed with a collection word suggesting that collection words are not easier to conceptualize than count superordinates.

There is some evidence for the Collectivization hypothesis. Subjects chose the group when probed with a count superordinate more than expected given the novel word trials. Nevertheless, two problems remain: First, children are more likely to violate ME than they are to collectivize a novel word, this suggests that the force driving collectivization of superordinates is not the attempt to avoid a ME violation. Second, it seems unlikely that preschoolers misanalyse collection words while simultaneously using a collective analysis to interpret novel count superordinates. We will return to these points in the General Discussion.

EXPERIMENT 3

In Experiment 2, we asked children to give a card with one forest on it when there was no card with more than one forest available to choose. This may have been pragmatically infelicitous. Usually when an adult asks for "the X with one Y on it" he is intending to distinguish between the cases where X has one Y and X' has more than one Y. When the probe word was a count superordinate that contrast was available and subjects often correctly picked the card with the single familiar object. However, because there was no such contrast when the probe was a collection word, the collection word trials were infelicitous. Moreover, had subjects been choosing on the basis of pragmatics alone they would give the experimenter a card with one object where that card is contrasted with another card having more than one of the same object. Thus the card of choice would be the card with the single familiar object pictured on it. Such responses would inflate the single familiar object choosing across the board thereby increasing errors associated with the Object-as-individual hypothesis and decreasing Collectivization errors. In Experiment 3 we changed the stimulus array by replacing the distractor cards with cards picturing two groups. There are no novel word trials in this experiment. If the objection on the basis of pragmatics is accurate we should see an overall reduction in the rate of single familiar choosing.

Method

Subjects. Subjects were 48 Boston area 3- and 4-year-olds divided into two groups by age. Twenty-eight 3-year olds ranging from 3;1 to 3;10 (M_{age} = 3;6) and twenty 4-year olds ranging from 4;0 to 5;3 (M_{age} = 4;6).

Stimuli. Stimuli were similar to those in Experiment 2. We replaced the distractor card with a card picturing two groups of familiar objects. Each array consisted of three cards: one with a single familiar object, another with a single group of familiar objects and a third with two groups of familiar objects (see Figure 3). Care was taken to emphasize the separation between groups on the card with two groups pictured. Each array of three cards contained exemplars from a single superordinate category (see APPENDIX C). Subjects were tested on the same five collection words and five count superordinate words, as Experiment 2. There were no novel word trials in this experiment.

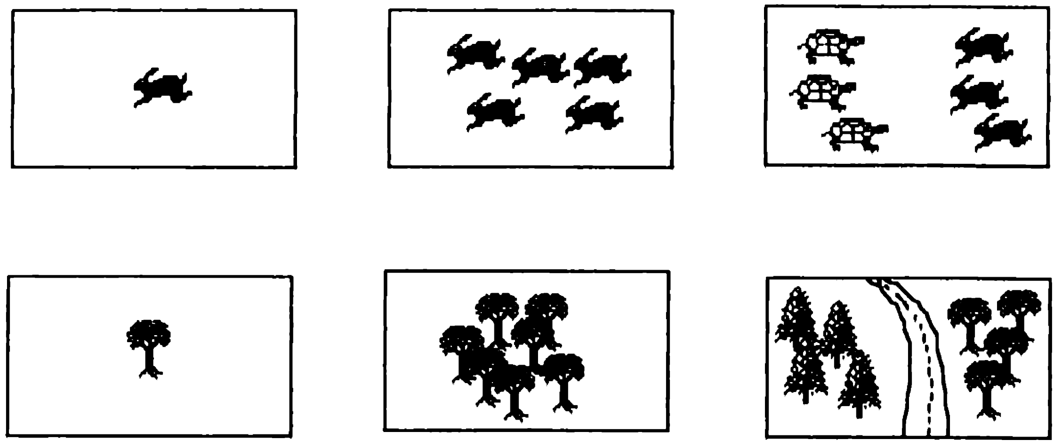

Figure 3. Schematic drawing of the stimulus sets for the count superordinate: "animal" (top) and the collection word: "forest" (bottom) used in Experiment 3.

Procedure. The procedure was the same as in Experiment 2. There were four practice trials preceding the experimental trials where all of the choices were familiar and the probe words were their basic level labels. The practice stimuli were the same as in Experiment 1. Each subject was tested on a total of fourteen different trials, including practice and experimental trials. Stimuli were blocked by word type and subjects were always probed with collection words before count superordinates.

Results and Discussion

Errors. Subjects' responses were first coded for errors (see Table 9). As in Experiment 2, when the probe word was a count superordinate subjects' choice of the single familiar object was coded as correct. When the probe was a collection word, choices of both the single group and the double group cards were coded as correct. This was done because it became clear during testing that despite the fact that there were spatial cues and non-spatial cues to grouping, subjects did not always see the double group card as containing two groups. For example, in the case of "family", in addition to being spatially separated, the two groups were individuated by skin color. Some children may not have made use of this cue. In addition, in the case of "forest" the two groups were individuated by being spatially separated and consisting of different kinds of trees.[14] The effect of the current coding is that subjects have a greater chance of making a "correct" choice when probed with a collection word than when probed with a superordinate; thus making it harder to get evidence for the Object-as-individual hypothesis.

Table 9. Error data for Experiment 3

Word Type	**Proportion Correct**	
	Young	*Older*
Count Superordinate	.86	.98
Collection Word	.58	.72

A 2 x 3 repeated measures ANOVA with age (young, older) as the between subjects factor and word type (count superordinate, collection word, novel word) as the within subjects factor was conducted on the error data. There was a main effect of age, $F(1,46) = 12.82$, $p<.001$, older subjects did better than younger (3-Year-olds: 72% correct, 4-year-olds: 85% correct); and there was a main effect of word type, $F(1,46) = 31.42$, $p<.001$. That is, despite the fact that subjects had more opportunities to make a "right" choice when probed with a collection word there were more errors on collection words than on count superordinates (collection words: 64% correct; count superordinates: 91% correct). There was no Age x Word Type interaction, $F(1,46) = .037$, *ns*.

To determine whether there was any effect of the felicitous pragmatics of Experiment 3 on subjects' choices we compared error data across the two

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[14] Understanding a collection word is precisely the problem of knowing what to count as "one." Children's failure to recognize the double group cards as containing two groups suggests that they do not understand these words as adults do. Of course the possibility remains that children may know that a particular collection contains more than one object of a certain kind before they learn exactly what the (conventional) constraints on membership might be.

experiments. A 3-way ANOVA examining the effects of age (younger, older), word type (count superordinate, collection word) and experiment (2, 3) on errors was conducted. There were no main effects or interactions except for the main effect of word type, $F(1,32) = 19.4$, $p<.001$; subjects made more errors overall when probed with collection words (57% correct) than when probed with count superordinates (87% correct). There was a marginally significant trend towards there being fewer errors overall in Experiment 3 (78% correct) than in Experiment 2 (65% correct), $F(1,32) = 3.89$, $p<.06$.

It is possible that the trend towards fewer errors in Experiment 3 was not due to the felicitous pragmatics. Rather it may have been due to the fact that there were no distractor cards to choose from, and that subjects had a 2/3 chance of being correct when probed with a collection word in Experiment 3 contrasted with a 1/3 chance in Experiment 2. Thus the proportion of correct responses for collection words might have been inflated independently of the effect of the pragmatics. The best test of the argument from pragmatics is the following: since felicitous pragmatics help reduce single familiar object choices, subjects ought to be especially helped in the collection word trials of Experiment 3 as compared with the count superordinate trials. This was not the case, there was no Experiment x Word Type interaction, $F(1,32) = .436$, *ns*. Thus subjects' erroneous choices of the single familiar object in Experiment 2 were not likely due to infelicitous pragmatics.

Table 10. Choice data for Experiment 3

Probe	**Proportion Choice**					
	3-year-olds			*4-year-olds*		
	Single Familiar	*Single Group*	*Double Group*	*Single Familiar*	*Single Group*	*Double Group*
Superordinate	.85	.09	.06	.98	.02	0
Collection	.42	.36	.21	.28	.61	.11

Choices. The distribution of responses in Table 10 indicate again that collection words and count superordinates are differentiated. However there are data consistent with both the Collectivization hypothesis and the Object-as-individual hypothesis. In Experiment 3 subjects sometimes chose a group card when probed with a Count Superordinate (3-year-olds: 15%, 4-year-olds: 2%), albeit less often than they chose the single familiar object when probed with a collection word (3-year-olds: 42%, 4-year-olds: 28%). This result is consistent with the finding in Experiment 2 that subjects make both kinds of errors but that Collectivization errors are rarer than Object-as-individual errors. Finally, the errors predicted by the Object-as-individual hypothesis happen to violate ME. In the context of a possible group choice, these errors show that subjects are willing to violate ME despite the availability of a kind of group interpretation. In sum, subjects' collectivization errors when probed with a count superordinate are not driven by an attempt to avoid violations of ME.

GENERAL DISCUSSION

The experiments reported herein provide support for the Object-as-individual hypothesis: that for preschoolers, collection words sometimes pick out kinds of objects instead of kinds of groups. Furthermore, they argue against the claim that children's occasional collectivization of superordinates is driven by an attempt to avoid violations of ME.

In support of the Object-as-individual hypothesis, it was found in Experiment 1, that 3- and 4-year-olds sometimes counted over collections as though they quantify over individual whole objects rather than groups. Moreover, contrary to the Collectivization hypothesis, the pattern of responses when children were asked to count using superordinates was no different from that when subjects were asked to count using basic level labels.

In Experiments 2 and 3, it was found that 3- and 4-year-olds often chose a single familiar object when asked to give a picture containing "one X" where "X" was a collection word. In the case of Experiment 2, these errors were made in a context where there was an opportunity to choose a completely unfamiliar object. An analysis of subjects' choices when probed with a novel word confirmed that subjects errors when probed with a collection word were not the result of simple unfamiliarity with the collection word. Clearly subjects have misanalysed some collection words as referring to individual whole objects instead of groups of objects. Occasionally subjects articulated this misconception by referring to a soldier as "an army", or saying that a forest is "a tree." When such statements occurred they were consistent with subjects' choices when asked to choose from an array of pictures. Experiment 3 ruled a pragmatically based interpretation of subjects errors in Experiment 2; and confirmed that subjects will often pick an individual object when asked for a collection.

In addition to the finding that collection words are sometimes misanalysed as labeling kinds of objects, it was found that superordinates are sometimes taken to refer to groups. In Experiments 2 and 3, subjects occasionally chose a picture of multiple objects when asked for "one animal." Such choices were probably evidence of misanalyses rather than unfamiliarity because they were more frequent than predicted when probe was a novel word. Given that it is unlikely that subjects are driven to a collective representation of superordinates by ME, it is not clear how such misanalyses might arise.

There are two possibilities. First, Macnamara (1982) suggested that when young children take superordinates to refer to groups it is not that superordinates are interpreted as collections, but that they are interpreted as pluralities which refer to an assortment of kinds. The second possibility has to do with the way children are taught superordinates and collection words. Perhaps children receive different forms of misleading evidence in the course of learning each kind of word. We will discuss each of these potential explanations below.

First of all let us clarify Macnamara's suggestion. Consider that all plurals are ambiguous: The word "dogs" has different senses in the following sentences.

(1) All dogs were easily domesticated.

(2) All dogs are well fed.

In (1) the word "dogs" refers to different kinds of dogs (POODLE, HUSKY, RETRIEVER, etc.). In (2) the word "dogs" refers to individual animals (Rover, Fido, Rex, etc.). Macnamara argued that since children often hear words like "toys" or "animals" only in the plural: "Pick up your toys!" they misconstrue superordinate plurals like "toys" as referring only to a multiplicity of kinds (see Shipley, 1991 for a related discussion). In support of this account Macnamara reported asking 2-year-olds to label a clear plastic bag of assorted plastic animals and a different bag of just dogs. He found that 19/20 of the 2-year-olds called the bag full of assorted animals "animals" but only 11/20 would do so for the bag full of dogs only. He ruled out the possibility that children simply prefer to use the most specific label by appealing to children's reluctance to call an unfamiliar animal "an animal."

Under Macnamara's analysis we would expect preschoolers to be better able to interpret superordinate terms applied to a multiplicity of kinds. Data in Experiments 2 and 3 can be brought to bear on this issue: The superordinate trials in those studies were ambiguous. Since the single group cards were always homogeneous, when subjects chose the card with "one animal" on it, they had the option of getting the card with one *kind* of animal even though that card had more than one object pictured. This happened infrequently despite the genuine ambiguity. Subjects rarely looked quizzical or confused when asked to choose "one animal." Moreover one would expect that the presence of the card with the double group in Experiment 3 would make this ambiguity even more salient thus driving up choices of the single group when the probe was a superordinate. However subjects choices of the single group actually decrease rather than increase in the pragmatically felicitous context of Experiment 3 (15% vs. 6%).

An alternative to the Macnamara hypothesis is that children are taught superordinates and collection words differently, and these differences result in the misanalyses we report above. Callanan (1985) reported that parents of 2- to 4-year-olds taught superordinates differently than they did basic level words. When teaching superordinates parents sometimes labeled individual objects saying things like "This is a vehicle." However, they also anchored their labels to the basic level (see also Markman, et al., 1980), for example, "A bus is a vehicle." Often parents labeled an entire group of assorted toys saying, "These are machines" and that sometimes they incorrectly gave misleading labels saying "Furniture's a group", or "All of them together are vehicles." Drawing the child's attention to the group could result in a collectivization of superordinate terms. If this is the case, children may misanalyse count superordinates not because they want to avoid violating ME but because of phenomena having to do with the way superordinates are taught.

In contrast, the proposed misanalysis of collection words is argued to result from the kinds of assumptions children make about possible meanings when learning novel words. Mere sensitivity to syntax does not give the word learner enough information about the kinds of things the speaker might be referring to. Thus learning that "blicket" is a count noun still leaves open the possibility that blicket might refer to entities individuated on the basis of spatio-temporal criteria (e.g., objects, portions of non-solid substances) or more abstract criteria. To recover the meaning of the novel count noun the word learner must rely on extra-linguistic means of picking out salient candidates. Other researchers have found, in trying to teach novel collection words to preschoolers and adults, that it is not a trivial matter to give cues that the speaker intends to refer to a group of whole objects rather than the individual objects themselves (Bloom & Kelemen, 1994).

The experiments in this paper confirm the central role that the child's conception of objects has in determining the candidates for count noun meanings. Indeed within the first year of life babies understand objects to be inherently individuated and the infant representation of objects yields enumerable entities with the logical properties of count nouns (Huntley-Fenner & Carey, 1995; Starkey, Spelke, & Gelman, 1990; Strauss & Curtis, 1981; Wynn, 1992; Xu & Carey, in press). Thus objects kinds are particularly salient candidates for the meanings of count nouns.

We argue that those children who misanalyse particular collection words know *something* about the collection word in question, namely that it is a count noun and thus labels a kind of individual, but not that the individual quantifies over groups of objects. For instance the child who misanalyses "forest" might know that the count noun "forest" refers to an individuated entity and that forests have something to do with trees but not that the relevant individual consists of a group of trees.

This leaves open the possibility that there might be contexts under which children correctly infer that a novel count noun picks out a group of whole objects. For example, preschoolers learn "family" and "class" relatively early. This suggests that the Continuity hypothesis is accurate in so far as it is a claim that preschoolers have the *capacity* to conceptualize groups of whole objects as individuals. However, merely invoking continuity does not explain the range of phenomena we have reported here. These studies show that groups of objects are certainly not the first hypothesis that comes to the preschooler's mind when hearing a novel count noun and that kinds of individual whole objects are especially compelling meanings for novel count nouns.

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APPENDIX A.

Stimuli for Experiment 2

Probe	Choice		
	Familiar Object	*Familiar Group*	*Unfamiliar Object*
animal	rabbit	3 rabbits	quaver
building	skyscraper	3 skyscrapers	bellows
tool	hammer	3 hammers	mortarboard cap
toy	block	3 blocks	neuron
vegetable	carrot	several carrots	balance
army	soldier	several soldiers in line	kayak paddle
bunch	flower	several flowers	ankh
class	young boy	people in room with desks blackboard and teacher	corkscrew
family	baby	parents and child dressed alike	cricket bat
forest	pine tree	several pine trees	clam

APPENDIX B.

"Object interpretation" responses from the definitions in Experiment 2

YOUNGER

What is an army?

GA, 3;1 "A soldier."

CA, 3;0 "Tinman."

ZN, 3;3 "A soldier."

JB, 3;0 "He plays the game. He plays the song. He puts the gun over his shoulder."

What is a bunch?

CA, 3;0 "A flower."

What is a family?

HC, 2;11 "A baby."

What is a forest?

HD, 3;2 "Like a tree, like snow."

OLDER

What is an army?

LA, 3;8 "A soldier."

ME, 4;1 "A soldier."

AF, 3;9 "A soldier."

KD, 3;9 "A soldier."

CG, 4;0 "A soldier."

AC, 4;4 "Army is a soldier with a thing in his hand." [rifle]

What is a forest?

AL, 4;3 "One tree, one frog."

APPENDIX C.

Stimuli for Experiment 3

Probe	Choice: *Single Familiar Card*	*Single Group Card*	*Double Group Card*
animal	rabbit	3 rabbits	3 rabbits and 3 turtles
toy	block	3 blocks	3 balls and 3 dolls
vegetable	carrot	3 carrots	3 carrots and 3 ears of corn
tool	hammer	3 hammers	3 hammers and 3 screwdrivers
building	skyscraper	3 skyscrapers	3 skyscrapers and 3 churches
army	soldier	soldiers in a line	2 lines of soldiers in different uniforms facing each other
forest	pine tree	pine trees	pines and oaks separated by a river and field
family	baby	2 parents and child dressed alike same hair color	dark-skinned family and light-skinned family each consisting of 2 parents and a child
class	boy	people in room with desks blackboard and teacher	two such rooms separated by a wall
bunch	flower	group of flowers with same color and shape	2 groups of flowers of different colors and shapes