ONTOLOGICAL CONSTRAINTS ON 2-YEAR-OLDS' INDUCTION OF WORD MEANINGS

by

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ABSTRACT

Babies learn much of their first vocabulary through ostensive definition. However, given a word that is defined through ostension, there are an infinite number of possible meanings of the word. For example, if a mother says "cup" while pointing to a cup, her pointing does not provide a basis for excluding meanings like "a kitchen object" or "an object with a flat bottom surface" or "an object 3/4 full of liquid" or "liquid" or "red", etc. Thus, the mapping between words and meanings should be impossible to achieve. Yet, children are experts at word learning. They learn words quickly (Carey and Bartlett, 1978; Heibeck and Markman, 1987; Oviatt, 1982) and often (Carey, 1982). Their success is due to the knowledge they have about language, the world, and their relationship in the form of constraints on the set of possible meanings.

A constraint was proposed that would provide a partial solution to the mapping problem. It states:

> When children hear a new word used to refer to an object (e.g., cup or dog), their first hypothesis about its meaning is the kind of object. When they hear a word used to refer to a non-solid substance (e.g., mud or sand) their first hypothesis about its meaning is the kind of substance.

This constraint has two parts. First, it specifies that information about ontological kind is relevant to word meaning. Second, it selects "kind of object" and "kind of non-solid substance" as the meanings of words, and it inhibits the mapping of other properties of objects and non-solid substances with words.

In the first three experiments 2-year-olds were taught novel words for unfamiliar objects and unfamiliar non-solid substances. They were then asked to select another referent of the word out of two choices. In the case of object words they chose an object of the same shape, size, and number as the original referent even though it was different in substance and color. In contrast, when they were given a non-solid substance word, they chose another example of the original substance ignoring the difference in shape, size, and number. The role of count/mass syntax in fixing word meaning was also examined. There was no relationship between the subjects' ability to produce count/mass syntax and their ability to use the object/substance distinction to constrain word meanings. Also, subjects who were given the novel noun in selective syntax were no better at determining the noun's meaning than subjects who were given the noun in neutral syntax. The fourth study examined the spontaneous speech of 4 children to test the hypothesis that solid substance words are late acquisitions. The fifth experiment focused on the applicability of the proposed constraint outside of the domain of language. Children were given a heavy object and asked to predict which of two other objects was heavy. They based their inferences on material kind and not object kind. The sixth experiment asked how children define object kind.

The main conclusion was that 2-year-olds do use the proposed constraint, but do not use count/mass syntax, to constrain their inferences about word meaning. However, there are certain situations in which children have difficulty determining the meanings of object words and non-solid substance words. It was argued that children use the constraint in those situations but are struggling with the specification of object kind and non-solid substance kind. Finally, although children used the proposed constraint on inferences of word meaning, they were not limited by it. When they were making nonlinguistic inferences, they had other systems available for the representation and comparison of objects.

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This thesis is dedicated to Tom, for all his love.

Introduction

The acquisition of word meanings is often considered an easy task because the final state is characterized as a mapping of words with meanings. However, this view is simplistic and uninformed. It is not clear that the final state is so simple; but, even if it is, the acquisition of the mapping poses a tremendous computational problem. This problem is due primarily to the nature of the evidence available to children about word meanings.

Children commonly learn words through ostensive definition. Children hear a word applied to a finite set of objects and need to determine the common property of the set that is relevant to the word's meaning. For every finite set of objects, there are an infinite number of common properties. For example, a finite number of cups could all be red things, cylindrically shaped things, small things, clay things, things that touch lips, things that need support, objects at three o'clock, cup things, smooth things, etc. Therefore, children must choose the correct property out of an infinite set of properties. Regardless of the number of examples that children are exposed to, the appropriate inference will never be uniquely determined.

Furthermore, Quine (1969) has demonstrated that some of the meanings in the infinite set of possible meanings could never be excluded through ostensive definition. For instance, every example of pointing to a rabbit is also an example of pointing to an undetached rabbit part. Therefore, "undetached rabbit part" can never be ruled out as a meaning of "rabbit" given only ostensive definition. Given that the set of possible meanings is infinite and contains incorrect meanings that cannot be rejected, it should be impossible to acquire even a single word.

However, there is evidence that children are very good at learning words. Young children can make an initial mapping of a word's meaning after hearing it only two times (Carey & Bartlett, 1978; Heibeck & Markman, 1987). 15-month-olds will comprehend a word and extend it properly to new objects after hearing it used only 24 times to label one object (Oviatt, 1982). And children learn nine words a day from their second to fifth years (Carey, 1978). There is a discrepancy between the difficulty of the task as suggested by the task description and the difficulty of the task as suggested by children's success rates.

The only way to resolve this discrepancy is to posit constraints that children bring to the task. That is, children must have prior knowledge of language, the world, or the relationship between the two that works with ostensive definition to limit the set of possible meanings from an infinite number to only one or two. Children's knowledge constrains the set of possibilities supplied through ostension.

One source of constraint could be the immaturity of infants' conceptual systems. That is, while it is true that any given set of objects has an infinite number of properties, maybe only a small subset of properties are accessible or salient to infants as the basis of induction. However, habituation and sorting studies show infants to be sensitive to any feature of the world that's been probed. For example, they can categorize by color (Bornstein, Kessen, & Weiskopf, 1976), speech sounds (Eimas, Siqueland, Jusczyk, & Vigorito, 1971), two dimensional shapes (Cohen, Gelber, & Lazar, 1971), objects (Ross, 1960), prototypical structure (Strauss, 1979), number (Strauss & Curtis, 1981), orientation (Wiener & Kagan, 1976), aspects of physical causality (Leslie, 1986), correlations among features (Cohen & Younger, 1985), etc. Therefore, in the case of word meanings, the immaturity of the cognitive system is not sufficiently constraining. The properties that infants can use for categorization need to be constrained such that only some of them are considered as possible word meanings.

A number of psychologists have proposed and defended various constraints. Each constraint restricts the set of possible word meanings to a certain degree, but cannot stand alone. A set of constraints will be necessary to fully enable the acquisition of word meanings.

Some of the constraints focus on the relationships between words. Eve Clark (1985) has proposed a constraint called lexical contrast. With respect to word learning the claim is:

> When children hear a new word, they select a meaning for the word that they do not already have encoded.

This constraint allows the extensions of two words to overlap. Therefore, words like "pet" and "dog" are acceptable. They have overlapping extensions, but not the same meaning. Ellen Markman and Gwyn Wachtel (1987) have proposed a similar constraint called mutual exclusivity. It states:

> When children hear a new word, they select a meaning for the word that has an extension that does not overlap with the extensions of all the other meanings they have encoded.

This constraint does not allow the pair of words "pet" and "dog" because there are dogs that are also pets, and therefore it could not be correct of the adult lexicon. However, it could be used effectively for a certain period of time by children. These constraints are important because they allow children to reject possible meanings of a new word on the basis of previously encoded meanings. Clark's constraint specifies that children can reject any meaning that is already encoded and Markman's constraint specifies that they can reject a meaning in which any member of its extension is also in the extension of a meaning that is encoded. However, when children do not know many words, these constraints are not very useful. And the constraints are only partially useful for adults. Adults only know a finite number of words at any one time. When they hear a new word, there are an infinite number of possible word meanings, but they can only exclude the finite set of meanings that they have encoded.

Frank Keil (1979) has proposed the M-constraint and the W-constraint. These constraints are based on a predicability tree that symbolizes which predicates span which terms. For a predicate to span a term, it must be possible for the predicate to be true of the term although it is not necessary for it to be true of the term. For example, "is green" spans both grass and daisies because both grass and daisies could be green. In fact, only grass is green. The constraint is:

> When children hear a new term, it must have a place on the predicability tree such that given any two predicates that span the term, P1 and P2, the sets of terms spanned by P1 and P2 must be equivalent or in a subset/superset relation.

These constraints affect word meaning because they specify which terms are allowable and which ones are not. Unfortunately, the predicability tree takes time to form branches. It does not even begin until children are approximately 5 years old. Therefore, it could not possibly constrain word meanings for children between 2 and 5 years of age when they are learning 9 words a day.

Other constraints have utilized the relationship between the syntactic properties of a word and the meaning of a word. Landau and Gleitman (1985) have proposed this constraint:

> When children hear a new verb, they use the subcategorization frames of the verb to specify the meaning of the verb.

This constraint is especially helpful in situations in which the children have limited exposure to the referents of the words. However, the constraint is only applicable to verbs. This specificity is not a criticism of the constraint, but it does mean that other constraints are necessary for other kinds of words.

Katz, Baker, and Macnamara (1974) claim that inferences about nouns are also constrained by syntactic information. Their constraint is:

> When children hear a new noun if the referent is animate or symbolic of animate beings then: 1. if the noun is a common noun, it refers to the class of things that the referent is a member of; and 2. if the noun is a proper noun, it refers to the original referent as an individual. When children hear a new noun if the referent is not animate or symbolic of animate beings, then it refers to the class of things that the referent is a member of.

For every noun one possibility is that it refers to only one referent as the name of that referent. This constraint specifies the conditions needed for that possibility to be correct. However, in the case of words that refer to classes, this constraint does not specify which class --of the infinite number of classes that include that object-- is the appropriate referent of the word.

Brown (1957) has proposed a constraint that is applicable to verbs and nouns. It is:

> When children hear a new verb, they take its referent to be an action. When they hear a new count noun, they take its referent to be an object. When they hear a new mass noun, they take its referent to be a substance.

The induction problem originally set up involved ostensive definition in a situation such that the child knew what the referent was but did not know what description of it corresponded to the word's meaning. However, usually it is not as clear what the referent is. Words are spoken in complex scenes which involve many objects, actions on those objects, and things inside the objects. This constraint helps direct the child to the referent. However, this constraint has a similar problem as the previous one. The mechanism that the child then uses to pick out the correct description of the action, object, or substance is not specified.

Waxman and R. Gelman (1986) have proposed a constraint that is based on the distinction between nouns and adjectives.

> When children hear a new noun, they think that it refers to a category at a basic level or a superordinate level of classification. When they hear a new adjective, they think it refers to a category at a subordinate level of classification.

When the child does know which object is being referred to, one problem is that the object can be described at different levels of abstraction. This constraint exploits a non-obvious relationship between form class and level. However, this constraint is also limited. It allows an infinite number of hypotheses at the appropriate level.

Markman and her collaborators have proposed a pair of constraints based on properties of the referents rather than properties of the words. The first is called the taxonomy assumption (Markman & Hutchinson, 1984). It is based on the distinction between thematic categories and taxonomic categories. Thematic categories are groupings of objects that are related by causality or events. For example, the category containing a knife and a cut apple is thematic because there is a causal relation between the members. Also the category containing a dog and a dog-bone is thematic because dogs and dog-bones take place in events together. Taxonomic categories are groupings of objects that are related by similarity. Examples are "red things" and "heavy things". Markman and Hutchinson propose the following constraint:

> When children hear a new word used to refer to an object, their first hypothesis about the meaning of the word is a taxonomic classification of the referent.

Markman's second constraint (Markman & Wachtel, 1987) is:

> When children hear a new word used to refer to an object, their first hypothesis about the meaning of the word is the whole object.

These constraints are very useful because they reject an infinite number of thematic categories as possible word meanings. However, an infinite number of taxonomic categories remain, even given the whole object constraint.

The constraints described so far are effective in constraining the set of possible word meanings to a certain degree. However, they are not powerful enough to complete the task, especially for very young children. For example, consider a two-year-old's situation when the word "cup" is ostensively defined. If the child does not yet know any words that name any aspect of the situation, then the child could not use lexical contrast or mutual exclusivity. The child is too young for the M and W constraints. Landau and Gleitman's constraint is only applicable to verbs. The remaining constraints (Brown, 1957; Katz, Baker and Macnamara, 1974; Markman & Hutchinson, 1984; Markman & Wachtel, 1987; Waxman and R. Gelman, 1986) would direct the child to select a meaning with an extension that was a taxonomic class of objects at the basic level or a superordinate level. However, an infinite number of meanings satisfy this description. For example, the word could mean "artifact that holds liquids" or "tool of a certain shape" or "tool of a certain size" or "kitchen equipment" or "indoor equipment" or "ceramic things", etc.

We have proposed the following constraint which addresses this limitation and, like Markman's constraints, is based on properties of the referents.

> When children hear a new word used to refer to an object, their first hypothesis about its meaning is the kind of the object. When they hear a new word used to refer to a non-solid substance (e.g., mud or sand), their first

hypothesis about its meaning is the kind of the substance.[1]

Some constraints, including this one, have two parts: the antecedent of the conditional (the basis) and the consequent (the inference). By "basis" I mean the kind of information that the children use to decide which meanings are correct. There is an infinite amount of information available at any one time. There is syntactic information, information about predication, information about color, etc. The basis of a constraint specifies which kind of information is used. In this case the basis makes explicit the role of the referent's ontological kind, as either a solid object or a non-solid substance. That is, it states that it is the ontological kind (at least for those two ontological kinds) that determines the inference that a child will make.

"Ontological kind" can be defined in different ways. I define "ontological kind" by referring to conditions for membership. The conditions that specify membership in a concept vary for different concepts. For example, for something to be a table, it needs to be move coherently through space and have stable boundaries among other things. Its color, material, and shape do not affect its tableness. However, for something to be gold, it needs to have a certain molecular structure. In other words, its material is essential and its coherence is not. Melted gold, which would not move coherently, is still gold. Some concepts do have the same conditions for membership: note that all objects (like

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1. This constraint is meant to be a member of a set of constraints including the others described. Therefore it is meant as an addition, not a contradiction. It is intended for use in situations in which the kind of object and the kind of substance are not yet encoded.

tables) have coherent motion and stable boundaries as conditions for membership and all substances have molecular structure as a condition for membership. But the conditions for membership are not the same for all concepts. If concepts are organized by kinds of conditions for membership, the resulting groups will be ontological kinds. Therefore, objects and substances are different ontological kinds.

I chose a subclass of the substances, the non-solid ones (e.g., mud) because solid substances (e.g., wood) are ambiguous. They are always in the form of objects. A particular piece of a solid substance, like an object, has distinct boundaries and moves coherently. These properties are irrelevant to the kind of substance, but do exist. This ambiguity could create confusion when children are dealing with solid substances and is examined in one of the experiments. Non-solid substances, on the other hand, do not have distinct boundaries and do not move coherently. They, therefore, are a less ambiguous contrasting class to objects.

The "inference" portion of a constraint consists of the actual meanings that the children give the words. For example, in some of the other proposed constraints the inferences are taxonomic kind, action, and superordinate level category. In this case the inferences are "kind of object" when the referent is an object and "kind of substance" when the referent is a non-solid substance. Therefore, this constraint causes the child to reject all the other properties of the object or substance --including the taxonomic properties-- as possible meanings of the word.

An important question remains: what is meant by "kind of object" and "kind of substance? This question can be answered by considering this phenomenon. If a number of adults were asked "What is this?" about an object, they could all give different answers, regardless of the number of adults asked. For example, two possible answers are "a red thing" or "a metal thing". But, instead, they all give the same answer (Anglin, 1977). That answer is the kind of the object. Similarly if the adults were asked what a particular non-solid substance is, they would all give the same answer --the kind of substance.[2] Another question is: how do children (or adults) determine the kind of an unfamiliar object and the kind of an unfamiliar substance? The proposed constraint does not address this question. Rather it credits children with that knowledge and addresses how they select those meanings out of all the possible meanings of words. That is, this constraint provides a partial solution to the mapping problem.

At first glance, "kind of object" may seem similar to the basic level (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). However, they are not exactly the same. The work on the basic level provides an analysis of the difference between descriptions of objects at different levels of abstraction. However, it does not distinguish different descriptions of objects at the same level, such as "red thing" versus "cup thing". I have not provided an analysis of either difference. However, I have

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2. Actually, the adults' answers depend on the situation in which the question is asked. They answer at a different level of abstraction when they are talking to children compared to when they are talking to adults. That is, in response to the query, more than one answer may be given; but, not more than a few and only one for each level. This should not be a problem for the child, because adults agree on a single response when talking to children and because the Waxman and R. Gelman (1986) constraint helps the children fix the level of abstraction.

defined "kind of object" more restrictively than basic level is defined. The kind of an object is not just any description of an object at a specific level of abstraction. It is a particular description of the object. The fact that an analysis of that description is elusive does not undermine its existence. The goal of the proposed constraint is not to further clarify the notion of "kind of object", but rather to specify how children select "kind of object" as the meaning of object words.

Three considerations support the proposed constraint. The first is that infants have a concept of object. Elizabeth Spelke and her collaborators (1985) have used the habituation paradigm to show that infants at four months use the following criteria to individuate objects. Any collection of surfaces that have stable boundaries, move coherently, have substance, and are spatiotemporally continuous are considered to be an individual object by the infant. One of the techniques they used was to have infants habituate to a visual scene with visual cues specifying the boundaries of a partially occluded object. Then the infants were presented with the object as a single object or the object as two objects. When the infants perceived the visual cues as specifying a single object, they dishabituated to the double object interpretation. This research demonstrates that infants have an object concept which, in part, specifies how objects are individuated. This ability is a prerequisite for the proposed constraint because the constraint requires children to determine whether the referent is an object or a non-solid substance. For children to know whether something is an object, they need, at least, to be able to pick out the objects in a visio-spatial representation of the world.

The second consideration is that young children use object words. Katherine Nelson (1973) has observed that 41% of infants' first 50 words are, in adult usage, object words. Infants are interested in words whose meanings are object kinds for adults. However, it is not clear what the words mean for the infants. They could be shape predicates. "Dog" could mean dog-shape the way that "round" means round-shape. Shape is relevant to object kind, but it is not identical. A throne and a bean bag have very different shapes and yet they are both the same kind of objects, chairs. Also, these data do not demonstrate how the words were acquired. We do not know by what possible laborious process the children arrived at the meanings.[3]

Although it is not always clear what children's words mean, the third consideration is that children reject meanings for object words that are clearly not object kind. Markman's and Hutchinson's research (1984) on the taxonomic constraint demonstrates that children reject thematic relations as meanings of object words. Baldwin (1986) showed that children also reject color as the meaning of object words. She labelled an object with a novel word and then asked which of two other objects was also a referent of the word. One object had the same form and a different color and the other object had the opposite features. The children selected the object of similar form. These findings follow from the proposed constraint. Again, we do not know if the children thought

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3. Huttenlocher & Smiley (1987) claim to have evidence that children think that object words refer to kinds of objects. However, they also do not demonstrate the process the children used to arrive at their meanings.

that kind of object, form, or something else corresponded to the meanings of the words. But we do know that they rejected thematic relations and color as meanings --as required by the proposed constraint.

In contrast to these supporting considerations, Quine (1969) has argued that the ontological distinction between objects and substances is not achieved until children have mastered the syntax of individuation and quantification. If Quine is right, the proposed constraint would not become available until late in the process of language acquisition. Children must first learn some nouns through a different means, learn the count/mass distinction over those nouns, and then learn the distinction between objects and substances. Only then could they use this constraint to learn the meanings of other words.

The following experiments were designed to see whether, in fact, the proposed constraint is used by young children. To review, the constraint is:

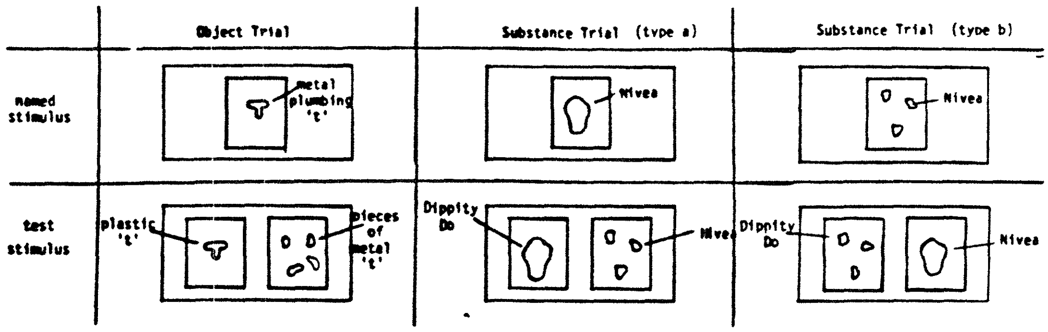
> When children hear a new word used to refer to a solid object, their first hypothesis about its meaning is the kind of object. When they hear a new word used to refer to a non-solid substance, their first hypothesis about its meaning is the kind of substance.

The first three experiments provide empirical evidence for the proposed constraint. Subjects were given novel words for novel objects and novel non-solid substances. The subjects then picked other referents of the new words. The design enabled an analysis of the constraint based on the subjects' response patterns. These experiments also addressed the relationship between syntactic information and the proposed constraint. The fourth experiment provided evidence for the constraint through an examination of spontaneous speech. Predictions follow from the constraint about which words children can and cannot learn. The relative use of each kind of word by children in natural environments was found and compared with the predictions. The fifth and sixth experiments accepted the constraint and asked different questions. Experiment 5 was concerned with the issue of scope. That is, the proposed constraint could be used only to support inferences about word meaning, or it could be used to support nonlinguistic inferences as well. Finally, the question of how children determine the kind of an object was examined in the sixth experiment. Children were tested to see if they considered various properties to be relevant to the definition of object kind. Different subjects were used in each experiment.

EXPERIMENT 1

We contrasted inferences about the meanings of object words with inferences about the meanings of non-solid substance words. One stimulus was named. Then two test stimuli were presented and the subjects were asked to infer which choice had the same name as the original. One stimulus shared the shape, size, and number of the original, but not its substance or color. The other shared the number and color of the original but not the shape size and number (Figure 1). In some trials the original stimulus was a solid object and in others it was a non-solid substance (as in gels and powders). In the object trials all test stimuli were solid objects. In the substance trials all test stimuli were non-solid substances. We predicted that the subjects would choose the object of the original shape, size, and number in the object trials but the substance of the original substance and color in the substance trials. These results would support both parts of the proposed constraint for the following reasons. If the basis of the subjects' inferences varies depending on the referent's ontological type, then the subjects must be distinguishing those ontological types and using the distinction in the determination of word meanings. Also, if children's words mean kind of object when the referent is a solid object and kind of substance when the referent is a non-solid substance, then children should project new words onto objects of the same kind and substances of

Figure 1--object and substance trials



the same kind (depending on the original referent) just as predicted above.

In addition we explored the possible role of count/mass syntax. There is a rough correspondence between the count/mass distinction and the object/substance distinction. Objects and count nouns are counted directly. It makes sense to talk about a single chair or three chairs. Similarly English enumerates count nouns directly, as in "a chair" or "three chairs". However, substances and mass nouns must be counted over portions. To discuss a single water or three waters is meaningless. Water is not divisible into individual waters. It must be partitioned by an external metric, as in bowls. Similarly English enumerates mass nouns over portions, as in "a bowl of water" or "three bowls of water". It is not the case that all count nouns are object words (e.g. "substance" and "gel") or that all mass nouns are substance words (e.g. "furniture" and "jewelry"). Rather, both the syntactic and conceptual systems are organized around the same distinction in individuation and quantification. That is, they each have a system for individuating and quantifying directly and a different system which relies on an external metric. However, if children assume the stronger correspondence, then they could use information about either the syntax or the semantics to infer properties of the other.

One role of count/mass syntax we explored derives from Quine's argument. According to Quine, infants who have not acquired count/mass syntax will not be able to use the distinction between objects and substances to determine word meanings. We tested this claim by analyzing the subjects' speech to see whether their production of count/mass syntax was related to their hypotheses about word meaning. If Quine is right, then children who do not know count/mass syntax should not differentiate the object trials from the non-solid substance trials. If Quine is wrong, then the subjects' knowledge of count/mass syntax should have no bearing on their inferences about word meaning in these experiments.

A second possible role of count/mass syntax is more direct. Young children may use information about the subcategorization of a particular noun to determine the meaning of that noun. This role is orthogonal to that described above. The possibility that children may use their representation of a syntactic distinction to acquire a conceptual distinction is very different from the possibility that children may use syntactic information about a particular noun to acquire semantic information about that noun.

Many psychologists have argued that children can use syntax to constrain inferences about word meaning. Roger Brown (1957) found that 4 and 5-year-olds assume newly heard mass nouns refer to substances and newly heard count nouns refer to objects. (although see Gathercole, 1986, for a slightly different interpretation). Katz, Baker, and Macnamara (1974) and S. Gelman and Taylor (1984) have found evidence that younger children use the distinction between common and proper noun syntax to constrain word meanings. And Landau and Gleitman (1985) and Naigles (1986) have argued that children use information about a verb's syntactic frames to determine the meaning of that verb. In the present study, we tested whether young children can use the subcategorization of a noun to help determine the meaning of that noun by comparing two conditions. In one the syntax specified the subcategorization of the noun as either count or mass. In the other neutral syntax was provided.[4] If children do use syntactic cues for determining word meaning, then the subjects in the selective condition should do better than the subjects in the neutral condition. If they do not use syntactic information when making inferences about meaning, then the subjects in both conditions should do equally well.

Method

SUBJECTS

In each group (neutral and syntax) there were 12 subjects, 6 girls and 6 boys. Their ages were from 1;10 - 2;3 (mean age, 2;1). They were recruited from the greater Boston area. Testing was begun with three other subjects but not finished. These three had no understanding of the task and could not complete a trial. Testing was conducted at the subjects' homes. The subjects' parents received $5.00 each for their participation.

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4. Note, however, that in both conditions the syntactic frame of the new word selected for a noun.

PROCEDURE AND STIMULI

Two experimenters ran each session. The primary experimenter (Ep) interacted with the subject and recorded responses. During the test phase of each trial, the Ep looked at the subject and not the stimuli. No indication was given as to the appropriateness of the subject's answers. After each response the Ep gave neutral comments, such as "O.K. Let's look at some more toys". The same precautions against experimenter bias were taken in all of the experiments. The other experimenter (Eo) organized the stimuli. A parent often observed, but was not involved.

There were two conditions (neutral and syntax) and two types of trials (object and substance). Condition was a between subjects factor and trial type was a within subjects factor.

Each testing began with two familiar trials: one object trial and one substance trial. The purpose of these trials was twofold. First, the subjects were introduced to the procedure with stimuli that they would recognize and handle comfortably. Second, the subjects' responses to these trials demonstrated whether they already knew any object words and non-solid substance words. The familiar objects were a blue, plastic cup; a white styrofoam cup; and cup pieces. The non-solid substances were peanut butter and Play-doh. The two familiar trials were followed by eight unfamiliar trials: four object and four substance. Eight novel words were used: "blicket", "stad", "mell", "coodle", "doff", "tannin", "fitch", and "tulver".

An Unfamiliar Object Trial In The Neutral Condition

In an object trial the first stimulus presented was an unfamiliar object (Figure 1). Four different sorts of objects were used: apple corers (orange plastic and aluminum); plumbing fixtures shaped like a "T" (copper and white plastic); childhood toys often called cootie catchers or fortune tellers (orange acetate and silver paper) and honey dippers (wooden and clear plastic). The objects were given names. The Ep said, "This is my blicket". The Ep then continued to talk about the object using "my", "the", and "this" for determiners. She and the S manipulated the object. The object was placed to the side and two other sets of objects were presented directly in front of the subject. One set contained one object that was the same sort of object as the original but made out of a different material. For example if the original object was a metal "T", then the second object was a plastic "T". The other set of objects contained 3 or 4 chunks made of the same material as the original object. They were small and in arbitrary shapes. In the present example, they would have been 4 small pieces of metal. The Ep said, "Point to the blicket".

A Non-Solid Substance Trial (substance trial) In The Neutral Condition

Each non-solid substance was presented either in a single pile or in multiple piles (3 or 4) (Figure 1). The first stimulus presented was a substance in either of the presentation configurations. The Ep said, "This is my stad" and referred to the substance using only "my", "the", and "this" for determiners. The Ep and the S talked about the substance and played with it. In the presentation of test substances the S was shown 2 substances: the original and a novel one. The original substance was in the alternative configuration. The novel substance was in the configuration used originally with the named substance. The S was told, "Point to the Stad". There were four pairs of substances: 1) Dippity-do (a setting gel) and lumpy Nivea (a hand cream mixed with gravel); 2) coffee (freeze dried) and orzo (a rice shaped pasta); 3) sawdust and leather (cut into tiny pieces); and 4) Crazy Foam and clay. Of each pair one member was named and the other was used as the alternative to the original in the test presentation. Each member served in both roles across subjects.

The syntax used in the neutral condition did not indicate whether the new word was a count noun or a mass noun, only that it was a noun. However, if the subjects knew both count/mass syntax and its relation to objects and substances, then there were trials in the neutral condition in which the syntax gave evidence about the referent. Specifically, the substance trials in which the original substance was presented in multiple piles were of this sort. For example, "This is my glass" is nonselective. However, if the referent is many pieces of glass, then "glass" must be being used as a mass noun because only mass nouns are used with singular verbs when referring to multiple items.[5]

Object And Substance Trials In The Syntax Condition

In the syntax condition the determiners used when naming the original stimulus were selective for either count nouns or mass nouns. Otherwise the syntax trials were identical to the neutral trials, including the test question ("Point to the blicket"). In a syntax condition object trial the introductory statement by the Ep was "This is a blicket". The Ep used "a blicket" and "another blicket" in subsequent naming. In a substance trial in the syntax condition the Ep said, "This is stad". The Ep continued to omit determiners or use "some". These determiners were chosen because, in production, they are among the earliest selective determiners used by 2-year-olds (Gordon, 1982). Also, in comprehension, 3-year-olds can determine the subcategorization of a noun based on its

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5. Collection nouns are also used with singular verbs and refer to multiple items. Yet collection nouns do not have to be mass nouns. For example, "family" is a count noun that is used with a singular verb to refer to multiple items in the sentence: "Everyone in the family is here". If the subjects interpret the noun as a collection count noun and think that count nouns refer to objects, then they would do worse on the substance trials in which the substance is originally presented in multiple small piles. In contrast, if they interpret the noun as a mass noun and think that mass nouns refer to substances, then they would do better on those trials.

previous occurrence with one of these determiners (Gordon, 1985).

The following items were counterbalanced: the order of object and substance trials (S,O,O,S,S,O,O,S,S,O or O,S,S,O,O,S,S,O,O,S); the side of the correct response (R,L,R,R,L,L,R,R,L,L); the order of object types and substance types (e.g., ["T", corer] or [corer, "T"] and [Nivea, orzo] or [orzo, Nivea]); name - stimulus pairings (e.g., ["blicket" - "T"] or ["blicket" - orzo]); the specific object introduced within each object type (e.g., plastic or metal "T"); and the type of substance introduced within each substance pair (e.g., Dippity-do or Nivea).

Each subject was tested in two sessions. The two sessions were identical. There is evidence that the subjects treated the trials of the second session as independent from those in the first session. The probability of a correct response of trial Y in the second session given a subject's response on trial X in the first session was the same whether X = Y or X =/= Y (details of the analysis are in Appendix 1). This result does not imply that there was no consistency in the subjects' responses. In fact, if the subjects got trial X right in the first session, there was an 80% - 85% chance they would get trial Y right in the second session. The point is that it did not matter whether trials X and Y were the same or different. Their response to trial Y in the second session was not affected by their having experienced that particular trial in the first session.

The scoring was based on the following reasoning. The hypothesis is that the basis of children's inferences about word meaning depends on the ontological type of the referent. Evidence for this hypothesis would be provided if the subjects' projections varied depending on the ontological kind of the original referent. It was predicted that the subjects responses would support the hypothesis in the following way. In the object trials the subjects would think that the word referred to the object kind, ignoring changes in substance and color. And in the substance trials they would think that the word referred to substance kind, ignoring changes in size, number and shape.

Accordingly responses will be called "correct" if the choice matching shape and number is chosen in the object trials, and the choice matching substance is chosen in the non-solid substance trials. An object score and a substance score were found for each subject. Each score was the sum of correct responses on trials of the appropriate type.

Before and after testing the Ep played with the S. The entire period of involvement with the S was tape recorded. The play periods included reading books, playing with marbles, and talking. The subjects' noun phrases during the play periods were transcribed and organized according to noun subcategorization.[6] Occasionally during the test period the Ss spontaneously talked about a topic unrelated to the testing. The noun phrases from these productions were also transcribed and analyzed. The

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6. Many nouns have both count and mass interpretations. For example, "chicken" is used equally well as a mass noun, "Is there more chicken?", and as a count noun, "We have three chickens". However, there are other mass nouns that are used in count noun syntax, but the noun is not really a count noun. For example, "milk" can be used with mass noun syntax, "I want some more milk", or with count noun syntax, "This table needs three milks". But in the second sentence "three milks" is used elliptically to mean "three glasses of milk". The subjects' use of truly ambiguous nouns were not included in the analyses. The other nouns were included.

percents of types and tokens used in selective syntactic frames were calculated. The syntactic frames, or configurations, used were "a (noun)", "(noun)s", "some (noun)s", "the (noun)s", "(noun)" and "some (noun)". The first four select for count nouns, and the last two select for mass nouns. However, the percents of occurrences were calculated for all noun types in all frame types.

Competence with count/mass syntax can be defined in different ways. One definition is that competence is achieved when the child's use of determiners and plural endings differs depending on the noun-type. When children achieve this level of competence, they are using two different systems of individuation and quantification. It is this aspect of the count/mass distinction that corresponds to the object/substance distinction and that is relevant to Quine's argument. Therefore, a syntax score was found for each subject that reflected their ability to use determiners and plural endings differentially for the two kinds of nouns.

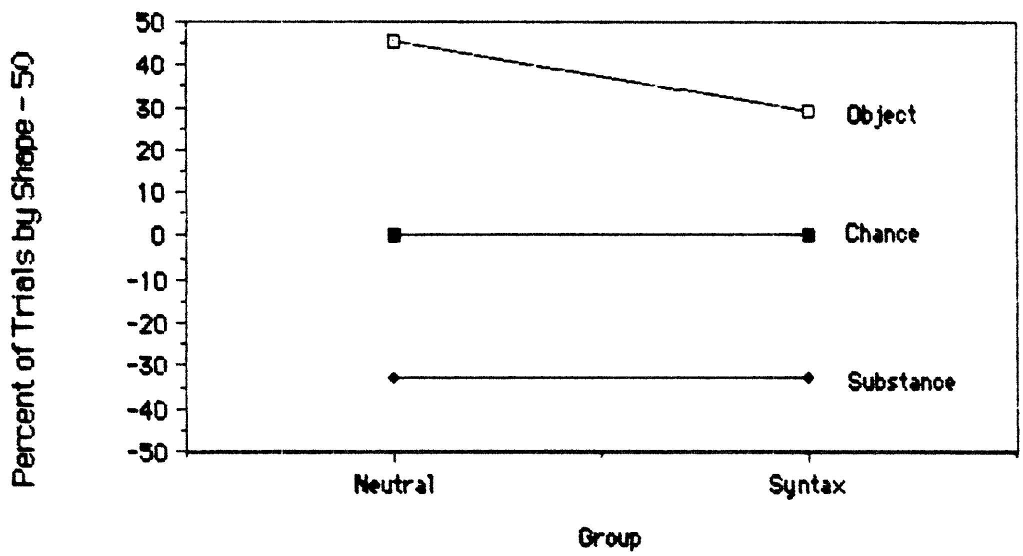
Results

Familiar Data

The familiar trials used cups and peanut butter and Play-dot. The subjects in the neutral group got 96% of the familiar object trials correct and 83% of the familiar substance trials correct. The subjects in the syntax group got 79% of the familiar object trials correct and 83% correct of the familiar substance trials correct. Chance is 50%. In Figure 2 the results are graphed as the percent of trials by shape minus 50. Therefore, the object score is represented as (object score - 50) but the substance score is represented as ((100 - substance score) - 50). Points above 0 indicate that the subjects chose the stimulus of the original shape, as predicted for the object trials. Points below 0 indicate that the subjects chose the stimulus of the original substance, as predicted for the substance trials. The further a point is from the 0 in either direction, the further it is from chance.

A 2-way repeated measure analysis of variance was carried out on the number of correct trials (i.e., not on the kind of score shown in Figure 2). It compared group (neutral x syntax) X trial type (object x substance). None of the main effects or interactions were significantly different from chance (all F's $< .79$, p's $> .39$). The subjects were better than chance on both kinds of trials (object: $t(23) = 8.351$, $p < .0000002$, 2-tailed; substance: $t(23) = 5.826$, $p < .00001$, 2-tailed). That is, they did equally well in the object trials and the substance trials and chose the correct answer in each case more often than chance.

Figure 2 -- Difference from Chance on Familiar Object
Trials and Familiar Substance Trials for the Neutral and Syntax Groups



Unfamiliar Data

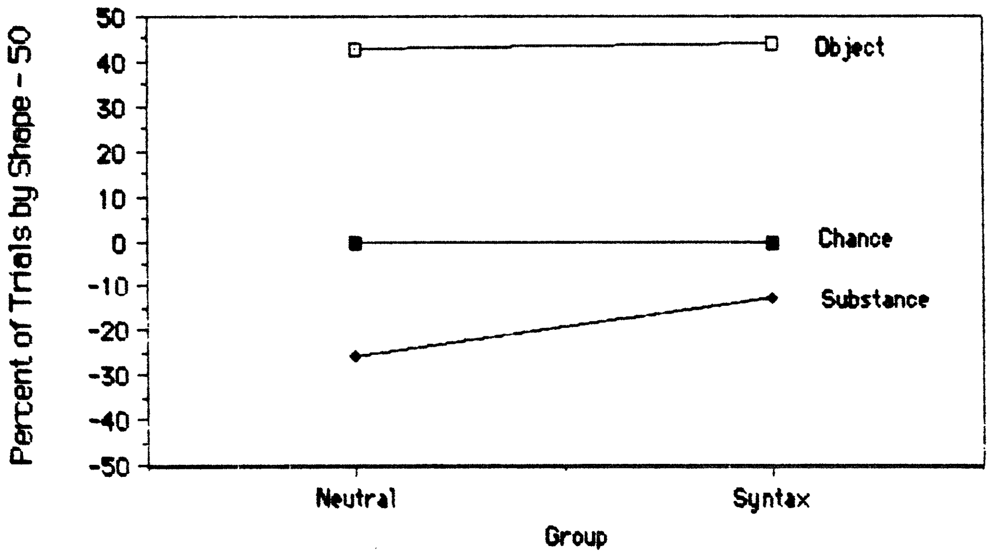
The subjects in the neutral group did 93% of the object trials correctly and 76% of the substance trials correctly. The subjects in the syntax group did 94% of the object trials correctly and 63% of the substance trials correctly (Figure 3). Chance is 50%.

A 2-way repeated measure anova compared trial type (o x s) X group (neutral x syntax). The only significant effect was trial type ($F(1,22) = 25.578$, $p < .00005$; all other F's < 1.8, p's $> .2$). The performance was better on the object trials than the substance trials. Performance on both the object trials and the substance trials was significantly better than chance (object: $t(23) = 23.3$, $p < .0000002$, 2-tailed; substance: $t(23) = 3.6$, $p < .002$, 2-tailed).

A separate anova compared the substance trials in which the substance was named in one big pile and the trials in which it was named in 3 or 4 small piles. There was not a significant difference ($F(1,22) = .226$, $p = .64$). Various other analyses were done comparing session, sex, stimulus item, stimulus order, and coding sheet. None of these effects were significantly different from chance (all F's < 2.2, p's $> .15$).

In sum, the children chose according to object type when the stimulus was an object and according to substance type when the stimulus was a non-solid substance. However, they were more consistent when the stimulus was a solid object than when it was a non-solid substance. They

Figure 3 -- Difference from Chance on Unfamiliar Object Trials and Unfamiliar Substance Trials for the Neutral and Syntax Groups



were neither facilitated nor hindered by the additional syntactic information.

Production Data

Productive competence was assessed for 22 of the 24 subjects. One subject was not yet talking and therefore had no productions to assess. Another subject had a cold --which greatly affected his desire to talk, but not his desire to do the experiment, which all children found fun.

On average the subjects used 67 count noun tokens and 7 mass noun tokens. 82% of the count nouns were singular. Of those, 57% were used with no determiner, 28% were used with "a", and 15% were used with "the". 80% of the plural count nouns were used with no determiner. 75% of the mass nouns were used with no determiner and 15% were used with "the". 73% of the mass noun types were non-solid substance words. 56% of those were food words. None of the mass noun types were solid substance words (e.g., "metal", "plastic", etc.).

For each subject the difference between the percent of count nouns used with count noun syntax and the percent of mass nouns used with count noun syntax was found. Also the difference between the percent of mass nouns used with mass noun syntax and the percent of count nouns used with mass noun syntax was found. The sum of the two differences was the subjects syntax score. The scores can range from -200 to 200. However, 96% of the errors were count nouns used without any determiners, rather than either kind of noun used with inappropriate determiners. And mass noun syntax allows determiners to be omitted. Therefore since the only errors are errors of omission (which are count nouns used in mass noun syntax) you might expect the lowest scores to be 0 ((0 - 0) + (100 - 100)). However, the subjects also used nouns in nonselective sentence frames, such as "the cat" or "the mud". These uses were not included in the computation of a syntax score. Therefore, if the subjects used more mass nouns in nonselective syntax than count nouns, they could get negative scores. For example, one subject had a score of -24. 2% of his count nouns were used with count noun syntax and 92% were used with mass noun syntax (omitting determiners). 0% of his mass nouns were used with count noun syntax and 66% were used with mass noun syntax. However, 33% of his mass nouns and 4% of his count nouns were used with neutral syntax. Therefore, his score is (2 - 0) + (66 - 92) = -24. Low scores, even negative scores, indicate a lack of differentiation between count and mass syntax. The higher the score is (above 0), the greater is the differentiation.

It is worth noting that improvement on this score is basically equivalent to improvement on the use of count noun syntax because 96% of the errors are errors of omission. In fact, each subject, on average, only made errors with 7% of the mass noun tokens compared to 48% of the count noun tokens.

The syntax scores ranged from -67 to 163. The neutral and syntax groups did not differ with respect to this score. The mean for the neutral group was 44 and the mean for the syntax group was 65 ($F(1,20)$ =

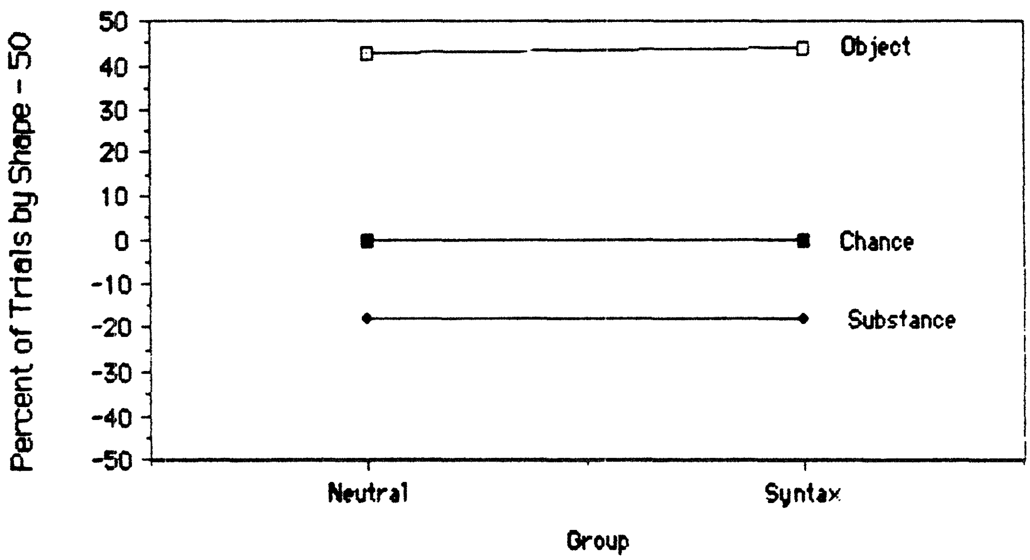
.6, p = .45).

A difference score based on the subject's ability to differentiate object and substance trials was also found for each subject. It was the difference between the percent of responses based on shape and number in the object trials (correct responses) and the same percent in the substance trials (incorrect responses). These scores ranged from 0 to 100. The correlation coefficient between the two kinds of difference scores (syntactic and semantic) is not significantly different from chance ($r = .07$, $p > .7$, 2-tailed).

The syntax scores were also used to separate the group of subjects into two groups according to count/mass proficiency. The median production score was used to divide the group. The effect of the syntax condition was then reevaluated using only the subjects who had the higher syntax scores. There were 5 subjects in the neutral group and six subjects in the syntax group. The neutral group did 93% of the object trials correctly and 68% of the substance trials correctly. The syntax group did 94% of the object trials correctly and 68% of the substance trials correctly (Figure 4). An anova comparing trial type X group revealed a significant effect of trial type only ($F(1,9) = 10.6$, $p = .01$; all other F's $< .02$, p's $> .9$).

In sum, there were three results. First, there was no difference in production skill between the neutral and syntax groups. Second, the ability to differentiate count/mass syntax did not correlate with the ability to differentiate objects from non-solid substances. Third, the subjects who were most skilled at count/mass syntax did not benefit in

Figure 4 -- Difference from Chance on Unfamiliar Object Trials and Unfamiliar Substance Trials for the Subjects in the Neutral and Syntax Groups whose Syntax Scores were Above the Median



the word learning task from the presence of selective syntax.

Discussion

The hypothesis was that children use this constraint when making inferences about word meaning:

> When children hear a new word used to refer to a solid object, their first hypothesis about its meaning is the kind of object. When they hear a new word used to refer to a non-solid substance, their first hypothesis about its meaning is the kind of substance.

This constraint has two parts:

Basis	Inferences about word meaning are based on the ontological kind of the referent, at least for the kinds solid object and non-solid substance.
Inference	The first hypotheses about word meanings are kind of object and kind of substance (depending on the ontological kind of the original referent, as stated above).

The results from this experiment support both parts of this constraint.

Basis

The subjects were given a task in which they were told the name of one stimulus and then asked which of two other stimuli shared the name. The two other stimuli had either the same shape or the same substance as the original but not both. The basis of the subjects' inferences varied depending on whether the original referent was a solid object or a non-solid substance. This result is consistent with the hypothesis that the subjects' inferences were based on ontological type.

Two claims about the role of syntax bear on this part of the constraint. First, Quine (1969) has argued that children learn the ontological distinction between objects and substances through the use of syntactic means of individuation and quantification. It follows from this position that only children who are using count/mass syntax should have a pattern of projection in this experiment indicating the use of the ontological distinction. However, even though many of the subjects were not using count/mass syntax at all, there was no correlation between use of the syntax and performance in this experiment. These results are in contrast to the prediction based on Quine's position. The ontological distinction between objects and substances is not learned through the syntactic distinction between count and mass nouns.

The second claim about syntax is that children use count/mass syntax as the basis of inferences about word meaning. A constraint with a syntactic base might look like this:

> When children hear a new word that is used in count noun syntax, their first hypothesis about its meaning is the kind of object. When they hear a new word that is used in mass noun syntax, their first hypothesis about its meaning is the kind of substance.

If children use this syntactic constraint, then those who are given the subcategorization of the noun should do better in this experiment than children who were not given that information. No such benefit was observed. That is, there was no difference in performance between the syntax and neutral groups.[7] This result is not surprising with the object trials since both groups were at ceiling. However, neither group was at ceiling in the substance trials and there was no difference between the groups with these trials either.

Also, there was no difference between performance on the substance trials in which the named substance was in one big pile or in multiple small piles. These latter trials gave added syntactic information since mass nouns, but not count nouns, are used with singular verbs to refer to more than one item at the same time.

It could be argued that many of the subjects did not know count/mass syntax yet and therefore could not be expected to benefit from its presence. To explore this possibility, we analyzed separately the performance of just those children who were best at count/mass syntax. This subgroup of subjects also did not show a benefit from the presence of syntactic information.

These data contrast those from other experiments that demonstrate children's use of syntax to constrain inferences about word meaning (Brown, 1957; S. Gelman & Taylor, 1984; Katz, Baker, and Macnamara, 1974; Naigles, 1986). In some of them the subjects were older than two years. In others, the syntactic and semantic distinctions were different from the ones investigated here. My argument is not that syntax is never used

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7. There was a nonsignificant difference between the two groups on the familiar object trials, but in the wrong direction.

as a source of constraint on possible word meanings. Rather, I suggest that count/mass syntax is not used by two-year-olds in deciding whether a word refers to a kind of object or a kind of substance.

In sum, the basis of inferences about the meanings of object and non-solid substance words appears to be the ontological kind of the referent. Syntactic information is not used as the basis of the acquisition of the ontological distinction or as the basis of inferences about the meanings of these kinds of words.

Inference

The inference part of the constraint is:

> When children hear a new word used to refer to an object, their first hypothesis about its meanings is the kind of object. When they hear a new word used to refer to a non-solid substance their first hypothesis about its meaning is the kind of substance.

The subjects' projections of word meanings were consistent with the proposed inferences. In selecting another referent of the word, they chose another object of the original object kind when the stimulus was solid and another substance of the original substance kind when the stimulus was non-solid. However, they were more consistent in the case of objects than non-solid substances. This difference does not negate the conclusion that they chose the substance or the original substance kind in the substance trials more often than chance. However, it is worth investigating the cause of the difference. Recall that the subjects did as well with the _familiar_ non-solid substance words as with the _familiar_ object words. Therefore, it may be that they are as capable of learning non-solid substance words as object words, but need more exposure to the non-solid substance words to get to the same level of competence. This could be because they have a bias to think that common nouns refer to objects. However, it could also be an artifact of this procedure. They may have had a bias to pick single things. In the object trials, the single object was always the correct object. In the substance trials, the single pile of substance was only correct half of the time. The fact that subjects were equally correct for single or multiple piles of a substance suggests that a single-object bias was not present. Nonetheless, it seemed worth testing the possibility more systematically (see Experiment 2).

The data are inconsistent with two other possible constraints:

> 1. When children hear a new word, their first hypothesis about its meaning is the function of the referents.

This is a reformulated version of Katherine Nelson's (1974) claim. The actions that the subject and experimenter did with each of the stimuli could have been done equally well with any of them. For example, any of the objects or non-solid substances were things that could be viewed, dropped, touched and smelled. The subjects may have imagined functions for the objects that could not have been functions of the pieces in the object trials. However, in the substance trials, both substances of a pair could have been used in the same ways. Therefore, the subjects could not have been inferring the referents' functions as the meanings of the words.

2. When children hear a new word, their first hypothesis about its meaning is the shape of the referents.

The subjects did choose the object of the original shape. But, this constraint can not be right because in the substance trials they rejected the substance in the original shape.

However, more specific constraints selecting shape as the meaning of a word may be possible. The following constraint is as consistent with the data as is our proposed constraint.

> When children hear a new word used to refer to <u>a solid object</u>, their first hypothesis about its meaning is its shape.

The inference about object words is shape rather than object kind. However, shape is often relevant to the kind of an object and therefore the two properties (shape and kind) are not independent. In contrast, shape is not relevant to the kind of a substance. Furthermore, the subjects recognized this difference in the relevancy of shape, as demonstrated through their differential responding to the object and substance trials. Subjects may think that the meaning of an object word is shape because of the relationship between shape and kind with respect to objects. Of, they may think that the meaning of an object word is the object kind.

Given either possibility the proposed constraint further delimits the set of possible word meanings given by the taxonomic constraint. The taxonomic constraint selects any taxonomic classification of a referent as the meaning of a word. The proposed constraint selects kind of object and kind of substance as the meanings of words, over the other taxonomic classifications. It achieves this power by differentiating kinds of taxonomic kinds and marking only some of them as possible word meanings.

In Experiment 2 two alternative explanations for the results of Experiment 1 are investigated. The first alternative concerns a distinction between the two kinds of trials that was ignored in this experiment. The second addresses an issue that was raised in the discussion. That is, it investigates whether the subjects' difficulty with the substance trials is due to a bias to pick single things.

EXPERIMENT 2

I have interpreted the data from Experiment 1 as supporting the claim that 2-year-olds use the ontological kind of the referent in constraining inferences about the meaning of a newly heard word. There are, however, alternative explanations for the data. Another difference between the two kinds of trials, besides ontological kind, could have been responsible for the pattern of response. The objects had complex shapes and the non-solid substances were put into simple piles. A plausible constraint that could account for the data is:

> When children hear a new word, their first hypothesis about its meaning is the most salient perceptual property of the referent.

This constraint follows from Eve Clark's (1973) early work on word meanings. She claimed that children's words had as meanings combinations of salient perceptual properties of the word's referents. In the first experiment, shape was likely to be the most salient perceptual property of the referents in the object trials. Therefore, according to this constraint, shape would have been chosen as the meaning of the object words. In contrast, since the shape of the non-solid substances was simple, it was not likely to be the most salient perceptual property of the referents in the substance trials. Rather, color or texture may have been the most salient perceptual property; and therefore, according to this constraint, would have been chosen as the meaning of the non-solid substance words. The results would have been the same, but the reason would be differences in shape complexity rather than ontological kind.

This constraint was tested in Experiment 2. The original procedure was used with new stimuli. The objects had simple shapes and the substances were put into piles with complex shapes. Ratings from adults were used to insure that the object shapes were not more complex than the substance shapes.

If the results of Experiment 2 follow the same pattern as the results of Experiment 1, then the constraint based on ontological kind will be supported. On the other hand, if the adult ratings on shape complexity predict the results, then the constraint based on shape complexity will be supported.

A second alternative explanation of the results of Experiment 1 is that children simply like to reach for whole things. This bias could not explain the results on the substance trials because the single pile was only correct half of the time. Therefore, it also does not account for the subjects' differentiation of objects and non-solid substances. However, it could explain the results on the object trials.

This bias was tested in a control condition of Experiment 2. The stimuli from the naming task were used with a new procedure. The subjects were given the test stimuli, in the absence of the naming event, and were asked to pick one of the choices. If the subjects are affected by this response bias, then they should choose the single object and the single pile of non-solid substance. If, also, they respond similarly in the naming task as they did in Experiment 1, then the bias could explain two results. First, it could account for the subjects' success on the object trials. Second, it could explain the subjects' relative difficulty with the substance trials compared to the object trials.

Method

SUBJECTS

There were 12 subjects, 6 males and 6 females, in each group. The mean ages were 2;1 (range: 1;10 -2;3) for the neutral group, 2;0 (range: 1;10 - 2;3) for the syntax group, and 2;2 (range 2;1 - 2;2) for the control group. They were tested at their homes and their parents were paid $5.00 each for their participation.

The adult subjects were 12 MIT undergraduates.

STIMULI AND PROCEDURE

Naming Task

The familiar objects were plastic and styrofoam cups, as in Experiment 1. The novel objects were made into the following forms: pyramids (wood and blue Super Sculpey[8]) pancakes (yellow wax and green plastic), kidneys (orange wax and purple plaster), and half eggs (grey styrofoam and red Super Sculpey). The familiar and novel non-solid substances were the same as in Experiment 1. The shapes are shown in Appendix 2. Note that the coffee/orzo and sawdust/leather pairs had simple piles for the multiple shapes. Those materials do not stay in small, complex shapes. The procedure was the same as in Experiment 1.

Adult Ratings

Line drawings were made of each novel stimulus. Each object kind had two drawings: one of itself and one of its pieces. The Crazy Foam/clay and the Nivea/Dippity Do substance pairs each also had two drawings: one of the large shape and one of the small shapes. The coffee/orzo and the sawdust/leather pairs only had drawings of the large shape since the

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8. Super Sculpey is a sculpting material, somewhat similar to clay.

small shapes were just simple piles.[9] Each object drawing was paired with the drawing of each substance in its large shape, resulting in 16 pairings. Each of the four drawings of the object pieces were paired with the two drawings of the substances in their small shapes, making another 8 pairings. Each pairing was on a separate sheet of a book. No drawing appeared on consecutive pages. The sides of the pictures were counterbalanced such that on half of the pages the object drawing was on the right side and on half of the pages it was on the left side. Each subject was tested individually. They read the instructions in Appendix 3 and then used a separate answer sheet to indicate which drawing in each pair they thought was more complex.

Control Condition

The subjects may have had idiosyncratic preferences for certain familiar things besides a general bias to pick whole things. We did not want them to develop obscure strategies for this task by generalizing from their preferences for known things. Therefore, we did not use any familiar stimuli.

The novel stimuli were the same as in the naming task. The subjects were shown the test pairs and asked "Which of these would you like to

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9. If line drawings had been made of the small shapes and compared with the drawings of the object pieces, the substance shapes may well have been rated as less complex than the object pieces for those substances. An item analysis of the non-solid substances will reveal whether the simplicity of those substance piles had an effect.

play with?" There was no naming event.

Results

ADULT RATINGS

The subjects chose the substance drawing as having the more complex shape in 97% of the large shape pairs and 79% of the small shape pairs. A difference score was found for each subject by subtracting the number of pairs in which the object drawing was chosen from the number of pairs in which the substance drawing was chosen. This score could range from -24 to 24. A 0 means that the subject chose objects and substances equally often. A negative score indicates that the subject chose more object drawings than substance drawings. A positive score indicates that the subject chose more substance drawings than object drawings. The average score was 19.8 which is significantly greater than 0 ($t(11) = 15.967$, $p < .001$, 2-tailed). No score was less than 8. A difference score can also be found for each pair by subtracting the number of people choosing the object drawing from the number of people choosing the substance drawing. These scores can range from -12 to 12. A 0 means that the object drawing and substance drawing of that pair were chosen equally often. A negative score means that the object was chosen most often and a positive score means that the substance was chosen most often. The mean score was 9.9 which is significantly greater than 0 ($t(23) = 11.264$, $p < .001$, 2-tailed). One score was -6, one was 0, and the scores of the other 22 pairs were greater than 8.

In sum, each substance was chosen more often than each object. Also, each subject chose substances more often than objects. The substances had more complex shapes than the objects.

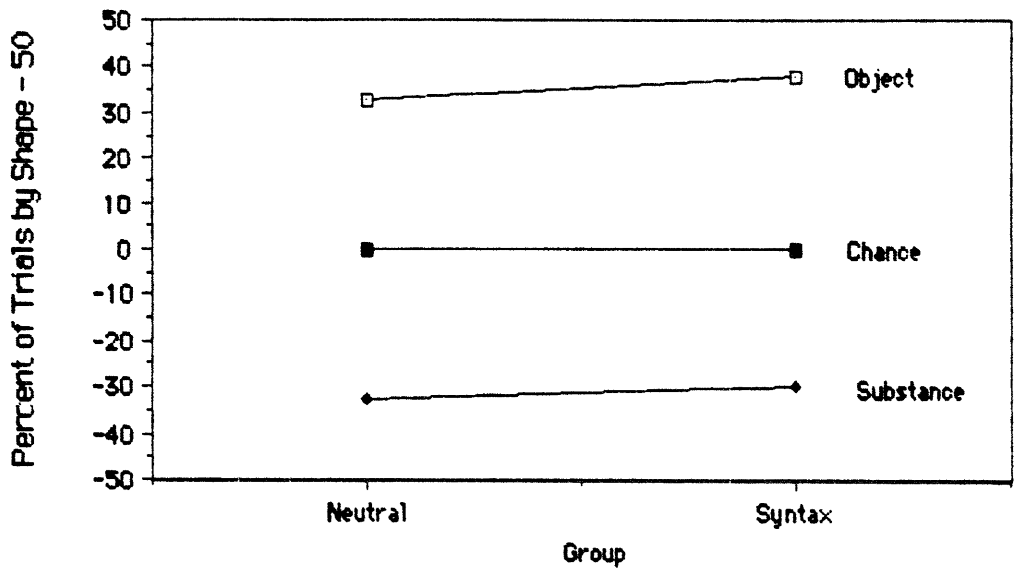
NAMING TASK

Familiar Data

The subjects in the neutral condition were correct in 83% of the object trials and 83% of the substance trials. The subjects in the syntax condition were correct in 88% of the object trials and 80% of the substance trials (Figure 5). A two-way ANOVA was done comparing trial type (object x substance) X group (neutral x syntax). None of the main effects or interactions were significant (all F's < 1.53, p's > .59). The subjects were better than chance on both the object and substance scores (object: $t(20) = 6.423$, $p < .000005$, 2-tailed; substance: $t(20) = 5.691$, $p < .00002$, 2-tailed).

In sum, the subjects were better than chance on the cup and peanut butter/Play-Doh trials and performed equally well on both kinds of trials. The neutral and syntax groups did not differ from each other.

Figure 5 -- Difference from Chance on Familiar Object Trials and Familiar Substance Trials for the Neutral and Syntax Groups



Unfamiliar Data

The subjects in the neutral group did 93% of the object trials correctly and 62% of the substance trials correctly. The subjects in the syntax group did 86% of the object trials correctly and 69% of the substance trials correctly (Figure 6). A two-way ANOVA comparing trial type (object x substance) X group (neutral x syntax) revealed a significant trial type main effect ($F(1,22) = 14.754$, $p = .001$). The group main effect ($F(1,22) = .004$, $p = .95$) and interaction ($F(1,22) = 1.449$, $p = .241$) were not significant. The subjects were better than chance on the object trials ($t(22) = 8.947$, $p < .0000002$, 2-tailed) and better than chance on the substance trials ($t(22) = 3.441$, $p < .005$, 2-tailed).

A three-way ANOVA was then done that added the factor, session (1 x 2), into the previous analysis. There were no additional main effects, but there was a session x trial type interaction ($F(1,22) = 5.955$, $p = .023$). The mean score in the first session was 92% for objects and 59% for substances. The mean score in the second session was 86% for objects and 71% for substances (Figure 7). A Newman-Keuls test revealed that the interaction is due to a significant difference between the sessions on the substance trials, but not the object trials. It also showed the trial type main effect.

A three-way ANOVA was conducted comparing experiment (1 x 2) X trial

Figure 6 -- Difference from Chance on Unfamiliar Object Trials and Unfamiliar Substance Trials for the Neutral and Syntax Groups

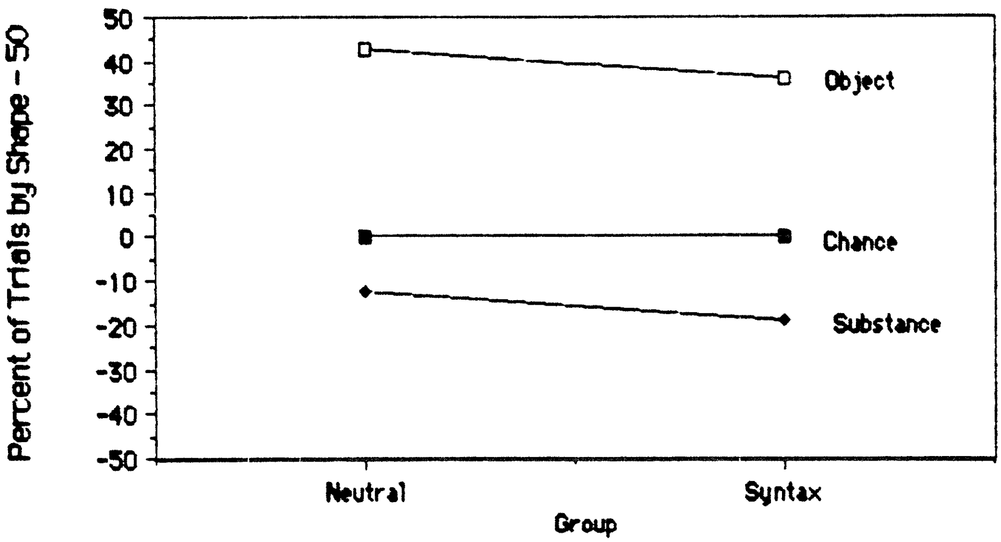
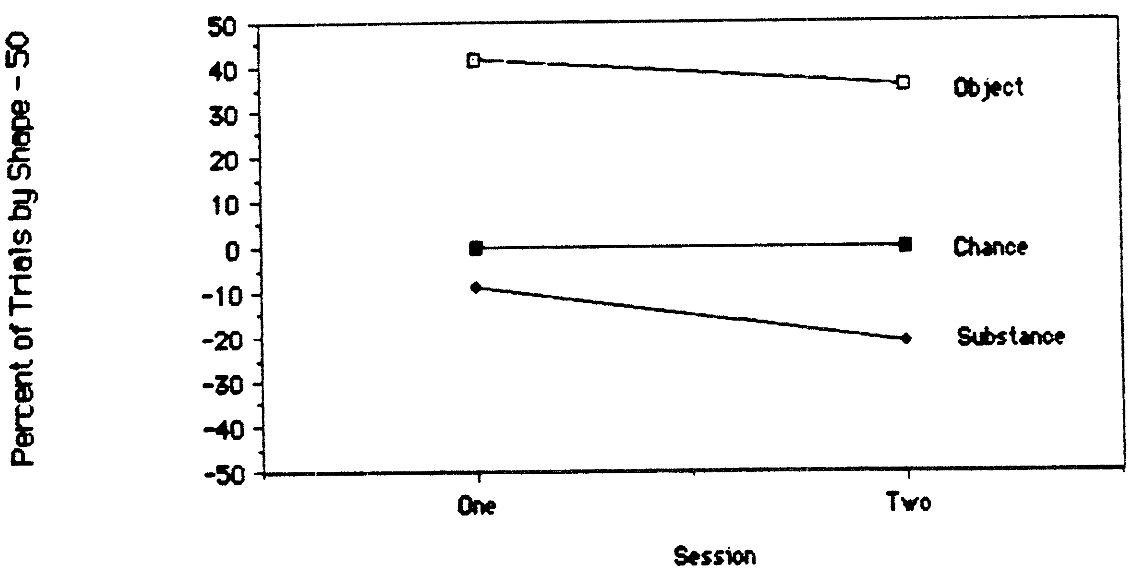


Figure 7 -- Difference from Chance on Unfamiliar Object Trials and Unfamiliar Substance Trials for Each Session



type (object x substance) X session (1 x 2). There was a trial type main effect ($F(1,46) = 36.012$, $p < .001$) and an interaction involving all three factors ($F(1,46) = 6.409$, $p = .015$). The improvement across sessions for the substance trials only occurred in Experiment 2. All other p's > .13. Another three-way ANOVA comparing experiment X trial type X group revealed only the trial type main effect.

A t-test on the effects of substance configuration (one big pile x 3/4 small piles) found a one-tailed significant difference ($t(22) = 1.686$, $p = .053$, 1-tailed). The mean scores were 55% for the single pile and 70% for the multiple small piles. Because the subjects improved on the substance trials across sessions, the effect of configuration was analyzed for each session independently. In the first session the mean scores were 48% for the single pile and 70% for the multiple piles. This difference was significant ($t(22) = 2.11$, $p = .046$, 2-tailed). In the second session the mean scores were 63% for the single pile and 69% for the multiple piles. This difference was not significant ($t(22) = .666$, $p = .512$, 2-tailed). All means except the mean for the single pile in the first session were significantly greater than chance; however, the mean for the single pile in the second session was only marginally greater (single pile, first session: $t(23) = .228$, $p > .8$, 2-tailed; multiple piles, first session: $t(23) = 2.853$, $p < .01$, 2-tailed; single pile, second session: $t(23) = 1.651$, $p = .058$, 1-tailed; multiple piles, second session: $t(23) = 3.193$, $p < .005$, 2-tailed).

The mean on the substance trials in which the named substance was in multiple simple piles was 63%. The mean on the substance trials in which the named substance was in multiple complex piles was 77%. These means cannot be compared statistically because the subjects did not receive each item in both types of piles. Therefore, although this factor was within subjects, there were insufficient data from each subject to meet the requirements of a parametric test such as the analysis of variance. In any case, the difference is in a direction opposite to the shape complexity hypothesis. In the trials in which the named substance was in multiple piles the subjects did better with the substances that had complex shapes than with the substances that had simple shapes. There were no effects of trial number, coding sheet, items, or sex (all F's $<$ 1.6, p's $>$ .22).

In sum, the subjects were better than chance on both the object trials and the substance trials, although they again did better with the objects than with the substances. There was no difference between the neutral and syntax groups. The subjects improved across sessions on the substance trials, but not on the object trials. This effect was only present in Experiment 2, not Experiment 1. Also, in the first session but not in the second session the subjects found the substance trials in which the substances were named in multiple piles easier than when they were named in a single pile.

Production Data

The subjects used an average of 111 count nouns tokens and 18 mass nouns tokens. Of the count nouns 86% were singular and 11% were plural.

Of the singular count nouns 71% were used with no determiner, 22% were used with "a", and 7% were used with "the". Of the plural count nouns 81% were used with no determiner. 87% of the mass nouns were also used with no determiner and 3% were used with "the". 90% of the mass noun types were non-solid substance words. 59% of those were food words. None of the mass noun types were solid substance words (e.g., "metal", "plastic", etc.).

A syntax score was found for 22 of the subjects. The other two subjects were not included due to recording difficulties. The score, calculated as in Experiment 1, indicates how well the subjects differentiated count nouns from mass nouns. As in Experiment 1, most of the errors were errors of omission (97%). On average, the subjects made errors with 5% of their mass noun tokens and 61% of their count nouns tokens.

The scores ranged from 10 to 148. The mean score was 58 overall, 49 for the neutral group, and 65 for the syntax group. The performance of the two groups did not differ ($F(1,20) = .906$, $p = .352$).

A semantic score was also found for each subject, as in Experiment 1. This score indicates how well each subject differentiated the two kinds of trials. The scores ranged from 8 to 100 (mean: 56). The correlation between the syntax and semantic scores was not significant ($r = .10$, $p > .6$, 2-tailed).

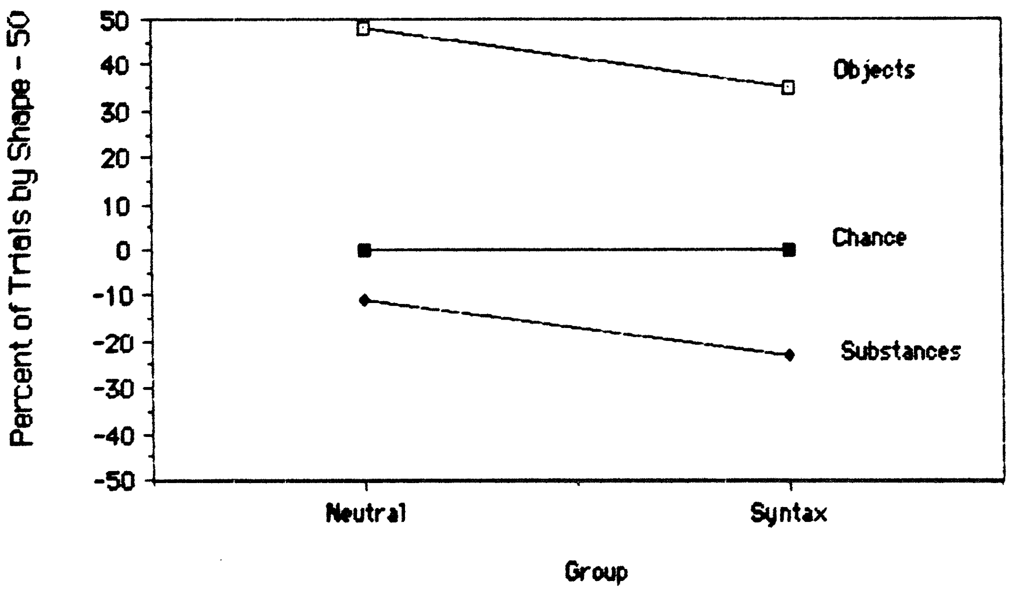
The naming results of the subjects who were better than the median on the syntax score were analyzed separately. There were 6 subjects in the neutral group and 5 subjects in the syntax group. The subjects in the neutral group did 98% of the object trials correctly and 61% of the substance trials correctly. The subjects in the syntax group did 85% of the object trials correctly and 73% of the substance trials correctly (Figure 8). A two-way anova comparing group by trial type was done. The main effect of trial type was significant ($F(1,9) = 4.791$, $p = .056$), but the other effects were not (group: $F(1,9) = .002$, $p = .963$; interaction: $F(1,9) = 1.085$, $p = .325$).

Thus the three results from Experiment 1 are replicated in Experiment 2. First, the neutral and syntax groups did not differ with respect to count/mass production. Second, the subjects' ability to differentiate object trials from substance trials was not correlated with their ability to produce count/mass syntax even though many of the subjects did not yet make the count/mass distinction. Third, even the subjects who were most proficient with count/mass syntax did not use it to constrain word meanings.

CONTROL CONDITION

A "whole object" score and a "whole substance" score were found for each subject. The whole object score was the percent of object trials in which the subject chose the single object. This kind of response would have been a correct answer in the naming task. The whole substance score was the percent of substance trials in which the subject chose the single pile of substance. This kind of response could have been correct or

Figure 8 -- Difference from Chance on Unfamiliar Object Trials and Unfamiliar Substance Trials for the Subjects in the Neutral and Syntax Groups whose Syntax Scores were Above the Median



incorrect in the naming task depending on the trial.

The average whole object score was 65% and the average whole substance score was 60% (Figure 9). These two means did not differ significantly from each other ($t(11) = .51$, $p = .62$, 2-tailed). Therefore, they were combined in the comparison with chance. The combined whole response was greater than chance ($t(23) = 2.672$, $p < .02$, 2-tailed).

The mean for the whole object scores (65%) was also compared to the mean on the object trials in the naming task (89%). These means are significantly different ($t(34) = 4.11$, $p < .0005$, 2-tailed).

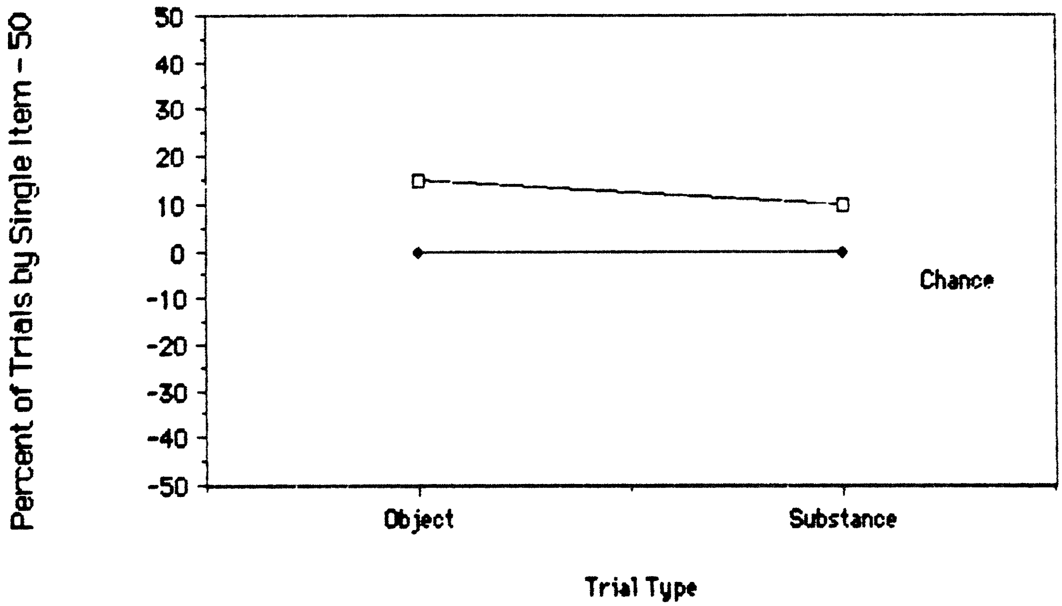
In sum, although there was a slight bias to select the whole item, it was the same for objects and substances. Furthermore, the presence of a naming event greatly increased the tendency to pick the whole object.

Discussion

The purpose of Experiment 2 was to determine whether a constraint based on ontological kind or a constraint based on shape complexity was responsible for the results of Experiment 1. The former constraint is stated as:

> When children hear a new word used to refer to a solid object, their first hypothesis about its meaning is the kind of object. When they hear a word used to refer to a non-solid substance, their first hypothesis is the kind of substance.

Figure 9 -- Difference from Chance on Object Trials and Substance Trials



A plausible constraint based on shape complexity, inspired by Eve Clark (1973), is stated as:

> When children hear a new word, their first hypothesis about its meaning is the most salient perceptual property of the referent.

The results of Experiment 2 support the ontological constraint. In Experiment 2 the substances had more complicated shapes than the objects. In Experiment 1 the objects had more complicated shapes. Yet, the results from the two experiments were practically superimposable. On the other hand, salient perceptual features did have a small effect on the subjects' inferences about non-solid substance words. It took the children some experience with the substance trials to recognize that the words had substance kind as their meanings. This delay was especially evident in the trials in which the named substance was in one big pile; that is, the trials in which the substance was most perceptually similar to an object. On those trials in the first session, even though the subjects could touch and manipulate the substances, they still were unsure of the words' meanings. When the substances were in small piles and could not be interpreted as a single object, the subjects knew that the substance kind was relevant. However, the effect of salient perceptual properties was weak. In the first session the subjects were at chance. They were not choosing the alternative with the same shape as the named substance. Also, the subjects were basing their responses on substance kind more often than chance by the second session, even in the trials in which the named substance was in a single pile. In sum, the subjects' responses were based on ontological kind, but they were weakly affected by an inappropriate salient perceptual property, shape.

This experiment also replicated the count/mass findings of Experiment 1. The subjects did not learn the ontological distinction through the count/mass distinction. They also did not use count/mass syntax to help constrain word meanings. The effect of substance configuration could be taken as counterevidence to that conclusion. However, that interpretation of the effect seems inappropriate. First, the effect was only in the first session. Why would the subjects lose a sensitivity with more experience? Second, the effect was not found in Experiment 1. The only difference between the two experiments in the substance trials was in the shapes of the substances. It seems that this difference in stimuli is probably the cause of the difference in results, as discussed above.

Experiment 2 also examined the role of a possible response bias leading to the results of Experiment 1. The subjects may have been selecting the whole object in the object trials because they preferred reaching for whole things more than collections of things. However, although there did appear to be a slight bias in the control task, it could not account for the data in the naming task. First, the bias was not significantly different for objects and non-solid substances in the control. But in the naming task, the subjects' responses differed depending on the trial type. Second, the subjects did not pick the whole object nearly as often in the control as they did in the naming task. On the other hand, it is possible that this bias is partly responsible for the subjects' relative difficulty with the non-solid substance words in the naming task since it would have worked in the appropriate direction in the object trials, but not in the substance trials.

In Experiment 3 older subjects were tested to see if they also find the substance trials harder than the object trials and to see if they can use selective syntax as a source of information about word meaning.

EXPERIMENT 3

Experiments 1 and 2 show that young children project word meanings on the basis of the ontological kind of the referents of the word. However, there is still a question as to whether children can use information about count/mass subcategorization to constrain inferences about word meanings. It could be that children use both ontological information and syntactic information when acquiring new word meanings. In experiments 1 and 2 the lack of a difference between the neutral and syntax groups may have been due to the subjects' ignorance about count/mass syntax. Subjects who represent the relevant syntactic knowledge may be able to use it to constrain word meanings.

Gordon (1982) has shown that certain children were sensitive to the distributional properties of the determiners "a", "another", numerals, and plurals by the end of their first year or the beginning of their second year.[10] They understood the more subtle distinction that determiners are obligatory for singular count nouns, but not plural count nouns or mass nouns, between 2 1/2 and 3-years. Moreover, Dickinson (in press) has shown that 3-year-olds are at ceiling on the substance trials of the neutral condition of Experiment 1. Consequently, subjects of this

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10. Gathercole (1986) argues that Gordon has conflicting results and that two-year-olds do not yet represent count/mass syntax at all. However, Gordon (1982) effectively defends his original claim.

age or older could not improve on the substance trials, given the addition of syntax, regardless of their representational and processing capacities. Therefore, 2 1/2-year-olds were tested in Experiment 3. All of the subjects should have commanded some basic distributional properties that distinguish count nouns from mass nouns and would have had more time than the 2-year-olds to determine the relationship between syntax and semantics. Also, some of the subjects should have represented the role of obligatory determiners in the count/mass distinction.

The results of Experiment 3 will also indicate more clearly the developmental pattern of the subjects on the substance trials. 2-year-olds are just better than chance and 3-year-olds are at ceiling (Dickinson, in press). This experiment will demonstrate whether the improvement is gradual across the second year or sudden.

Method

SUBJECTS

There were 2 groups of 12 subjects. The mean age was 2;7 (range: 2;5 - 2;9) in each group. One other subject was dropped. He could not complete a single trial. The groups were evenly distributed across sex. The subjects' parents were paid $5.00 for their participation. Testing was conducted at their homes.

STIMULI AND PROCEDURE

The stimuli and procedure were the same as in Experiment 2.

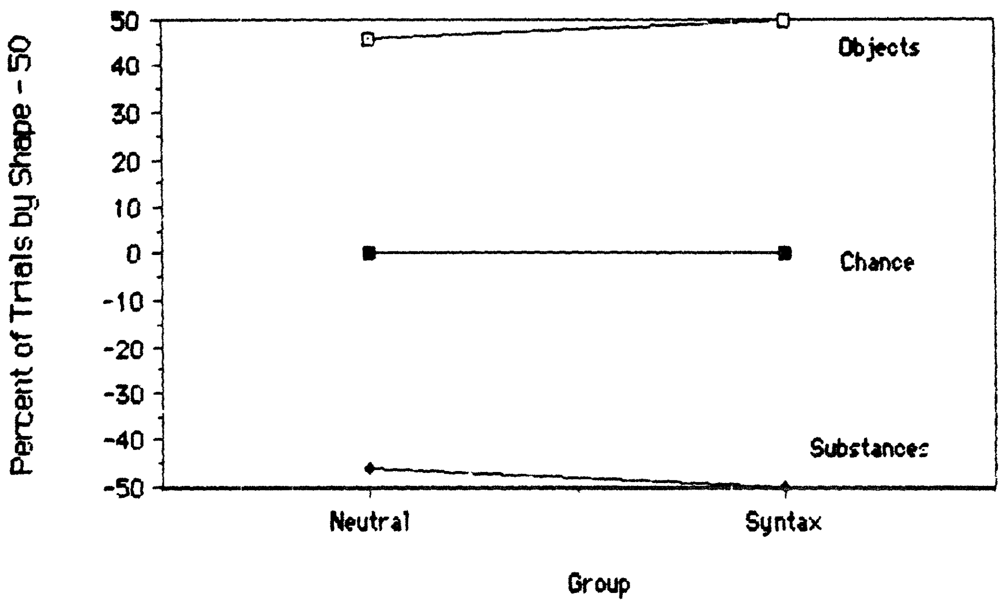
Results

Familiar Data

The subjects in the neutral group responded correctly on 96% of the object and substance trials. The subjects in the syntax group were correct on 100% of the trials (Figure 10). A 2 X 2 anova (trial type (object x substance) X group (neutral x syntax)) revealed no main effects or interaction (all F's < 2.6, p's $> .13$). The subjects' performance on both kinds of trials was significantly greater than chance (object: $t(23) = 23.006$, $p < .0000002$, 2-tailed; substance: $t(23) = 23.006$, $p < .0000002$, 2-tailed).

Unfamiliar Data

Figure 10 -- Difference from Chance on Familiar Object Trials and Familiar Substance Trials for the Neutral and Syntax Groups



The subjects in the neutral group did 93% of the object trials correctly and 79% of the substance trials correctly. The subjects in the syntax group did 90% of the object trials correctly and 91% of the substance trials correctly (Figure 11).

A two-way anova comparing trial type with group revealed no main effects or interactions (all F's < 2.4, p's $> .13$). The grand mean was significantly greater than chance ($t(23) = 17.398$, $p < .0000002$, 2-tailed).

A three-way ANOVA including the data from Experiment 2 compared the above two factors with age (2;1 x 2;7). It revealed trial type and age main effects (trial type: $F(1,44) = 14.833$, $p < .001$; age: $F(1,44) = 9.834$, $p = .003$) and a trial type X age interaction ($F(1,44) = 4.84$, $p = .033$) (Figure 12). A Newman-Keuls test showed that the younger subjects did significantly worse on the substance trials than on the object trials and than the older subjects did on both kinds of trials. There were no other significant differences.

An anova comparing the configuration of the named substance showed that the subjects' performance was not significantly different on the two kinds of configurations ($F(1,22) = .034$, $p = .854$). Other analyses were done comparing session, stimulus items, stimulus order, coding sheet, and sex. The only significant effect was with the object items ($F(3,69) = 3.466$, $p = .021$). The mean scores for the four object items were: pyramids: 96%, pancakes: 96%, half eggs: 90%, and kidneys: 81%. All of these scores are significantly greater than chance (all t's > 6.192, p's $< .000005$). All other F's < 1.28, p's $> .26$.

Figure 11 -- Difference from Chance on Unfamiliar Object Trial and Unfamiliar Substance Trials for the Neutral and Syntax Groups

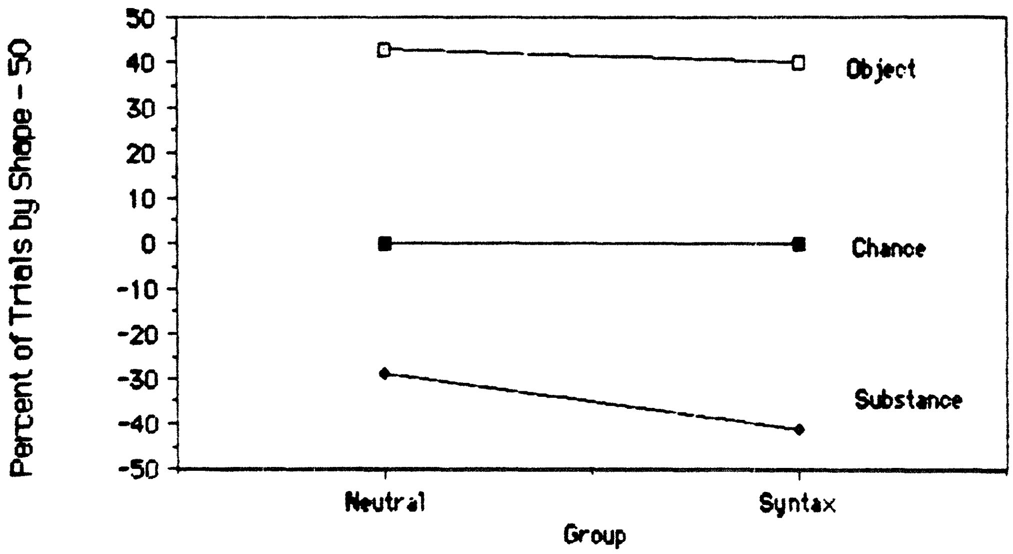
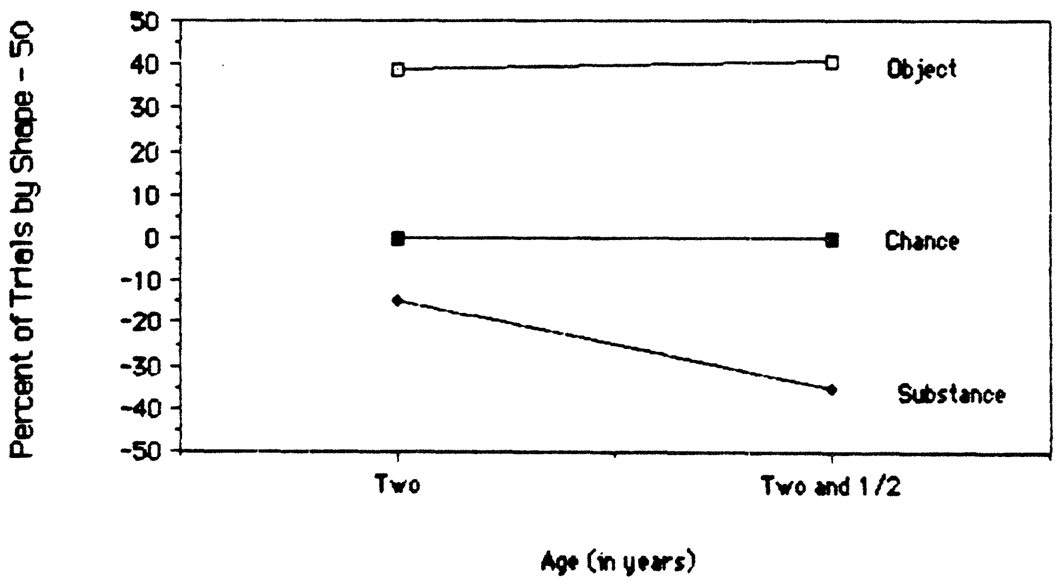


Figure 12 -- Difference from Chance on Unfamiliar Object Trials and Unfamiliar Substance Trials for the 2-year-olds and the 2 1/2-year-olds.



In sum, there was no difference between the object and substance scores and between the neutral and syntax groups. However, the subjects' near ceiling performance may have masked any differences. The subjects chose the object of the original object kind in the object trials and the substance of the original substance kind in the substance trials. The 2 1/2-year-olds did better than the 2-year-olds and their advantage was due to an improvement in the substance scores relative to the object scores. There was a difference in the subjects' performance in the object trials depending on the stimulus. However, they did choose the object of the original object kind more often than chance with each kind of object.

Production Data

On average, the subjects used 121 count noun tokens and 31 mass noun tokens. 83% of the count nouns were singular and 15% were plural. Of the singular count nouns 45% were used with no determiners, 42% were used with "a", and 12% were used with "the". 84% of the plural count nouns were used with no determiners. Of the mass nouns 83% were used with no determiners and 9% were used with "the". 85% of the mass nouns types were non-solid substance words. 51% of those were food words. There was one solid substance word, "wood". It was used by one subject 3 times and by two other subjects one time each.

A syntax score was found for each of the subjects'. The scores were computed as in Experiments 1 and 2. They indicate the subjects' differentiation of count and mass nouns. As with the younger subjects, 95% of their errors were errors of omission. The mean percent of errors with mass nouns was 4% and with count nouns was 37%.

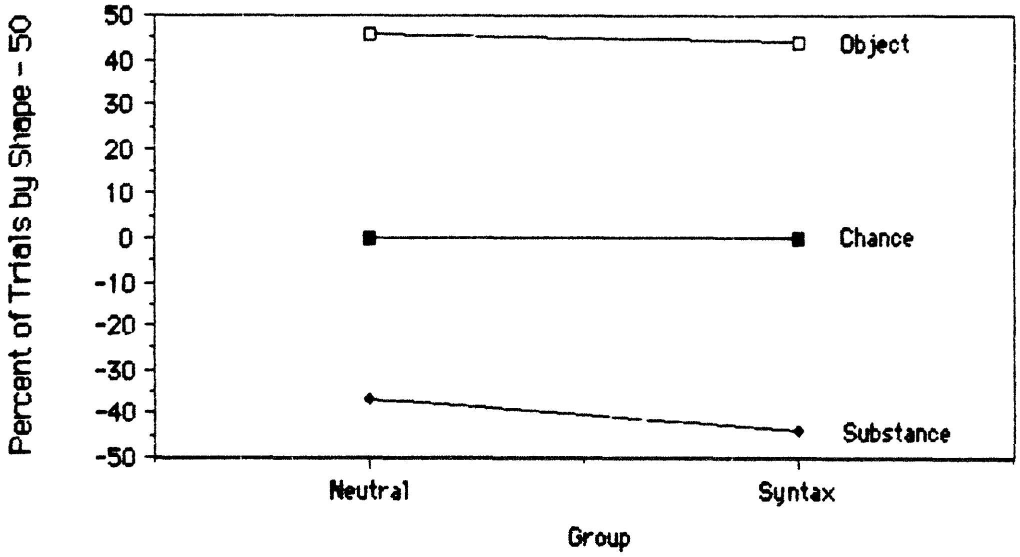
The syntax scores ranged from 0 to 159 (mean: 97). The mean for the neutral group was 100 and the mean for the syntax group was 95. The performance of the two groups was not significantly different ($t(22) = .245$, $p = .81$, 2-tailed).

Also, a semantic score was computed that indicates the subjects' differentiation of the object trials from the substance trials. These scores ranged from 13 to 100 (mean: 77). The correlation coefficient for these two scores was .387 which is marginally significantly different from chance ($p = .06$, 2-tailed).

The effect of selective syntax on the subjects' performance on the word learning task was reevaluated using only the subjects who scored higher than the median on the syntax score. The median score was 109.5. There were 6 subjects in each condition (syntax and neutral). The neutral group was correct in 96% of the object trials and 87% of the substance trials. The syntax group was correct in 94% of the object trials and the substance trials (Figure 13). A 2 X 2 anova comparing group by condition revealed no significant main effects or interactions (all F's $< .812$, p's $> .389$).

The performance of the 2 1/2-year-olds was compared with the performance of the 2-year-olds. The 2-year-olds had a mean of 58% on the syntax score and a mean of 56% on the semantic score. The difference between the two age groups on both kinds of scores was significantly

Figure 13 -- Difference from Chance on Unfamiliar Object Trials and Unfamiliar Substance Trials for the Subjects in the Neutral and Syntax Groups whose Syntax Scores were Above the Median



different (syntax score: $t(44) = 3.180$, $p < .005$, 2-tailed; semantic score: $t(44) = 3.130$, $p < .005$, 2-tailed).

In sum, the neutral group and the syntax group were equally proficient with count/mass syntax. On the other hand, the 2 1/2-year-olds as a whole were better than the 2-year-olds. There was a small correlation between the 2 1/2-year-olds' ability to differentiate count nouns from mass nouns and their ability to differentiate object names from non-solid substance names. There was no effect of selective syntax, even on the subjects who were most proficient at count/mass syntax; but, the difference was in the right direction.

Discussion

As in the previous experiments, the subjects chose the object of the original object kind on the object trials and the substance of the original substance kind on the substance trials. The strength of this finding is enhanced by its replicability with three different sets of subjects.

There were two differences between the results of this experiment and the results of Experiment 2. First, the 2 1/2-year-olds were better on the substance trials than were the 2-year-olds. By 2 1/2 subjects are no longer better at determining the meaning of object names compared to non-solid substance names. Also, the 2-year-olds improved on the substance trials across sessions but the 2 1/2-year-olds were as good in the first session as in the second. It is possible that the reason for this improvement is that the older subjects have overcome the effects of the bias to pick single things. It is also possible that they understand more clearly that shape is irrelevant to the kind of a non-solid substance.

Second, there was a small correlation between the 2 1/2-year-olds' command of the count/mass distinction and their command of the object/non-solid substance distinction. This pattern was not found for the 2-year-olds. This result cannot be interpreted as support for Quine's position because the younger subjects who already distinguished objects from non-solid substances did not show the correlation. However, it is possible that the subjects begin by representing both distinctions independently. Then, when they understand the relationship between the two distinctions, they use their knowledge of syntax to further elaborate their knowledge of semantics. In fact, it could be that the conceptual development that accounts for the subjects' improvement on the substance trials is a result of this sort of process. However, it is also possible that the reverse is true; that is, that further elaboration of the subjects' representation of syntax is due to their knowledge of semantics. For example, Gathercole (1986) has argued that the count/mass distinction is not complete until children are at least 7-years-old. Some of this more advanced knowledge may be acquired by the subjects through an analogy to their knowledge of semantics. The data do not favor either interpretation and it is equally possible that neither is correct. Neither follows from Quine's claims about the relationship between syntax and semantics.

As in the previous experiments the data also do not support the claim that children use syntactic information to constrain inferences about the meaning of particular words. There was no difference between the neutral and syntax groups even though these subjects were better at count/mass syntax than the 2-year-olds. In fact, when the 2 1/2-year-olds with the best command of syntax were evaluated separately, there was still no difference. However, there was a 12% difference between the two groups on the non-solid substance trials. The lack of a statistically significant difference could have been due to a ceiling effect rather than the knowledge of the subjects. Consequently, it would not be informative to test even older subjects with this task. One way to test the effect of syntax would be to use mass syntax in the object trials and count syntax in the substance trials. If the subjects can use syntactic information to help constrain word meanings, then their performance on both kinds of trials should move closer to chance.

The fourth experiment tests the proposed constraint from a different direction. It uses the spontaneous speech of Adam, Eve, and Sarah and Allison Bloom (Bloom, 1973; Brown, 1973; MacWhinney and Snow, 1985) as data. Specifically, the natural development of the lexicon is examined for effects of the constraint.

Experiment 4

The results from the first three experiments have supported the proposed constraint:

> When children hear a new word used to refer to a solid object, their first hypothesis about its meaning is the kind of object. When they hear a new word used to refer to a non-solid substance, their first hypothesis about its meaning is the kind of substance.

The experiments varied the stimuli used and the ages of the subjects. Experiment 4 tests the constraint through an examination of spontaneous speech.

The goal of Experiment 4 is to test a different prediction based on the constraint. All constraints have positive and negative effects on induction. The constraints enable certain inferences to be made while inhibiting others. The first three experiments have documented the positive effects of the proposed constraint: namely, that children are facilitated in learning object words (chair, book) and non-solid substance words ("water", "mud"). A negative effect of the proposed constraint is that children should have difficulty learning solid substance words ("wood", "metal"). Solid substances are always in the form of solid objects. According to the proposed constraint, children think that words said of solid objects have the object kind as their meaning and not the substance kind. Therefore, children should not be able to make the inference that a word has as a meaning solid substance kind. Experiment 4 examines this prediction by comparing children's use of solid substance words with their use of non-solid substance words. The effect of word frequency in the children's mothers' speech and in adult-adult speech is also examined.

Method

SUBJECTS

The corpora from Adam, Eve, and Sarah from Roger Brown (Brown, 1973) and Allison from Lois Bloom (Bloom, 1973) were examined. The corpora were accessed through the Child Language Data Exchange System (CHILDES) (MacWhinney & Snow, 1985). Adam and Sarah were followed from 2;3 to 5;2. Eve and Allison were begun at 1;6. Eve was recorded until 2;5 and Allison was recorded until 2;2.

PROCEDURE

The children's speech and the mothers' speech were examined exhaustively for use of solid substance words and non-solid substance words. The solid substance words probed were: "metal", "brass", "steel", "tin", "plastic", "glass", "wood", "stone", and "rubber". The non-solid substance words probed were: "sand", "Play-doh", "water", "powder", "dirt", "mud", "paint", "glue", "paste", "snow", "toothpaste", "shampoo", "clay", "milk", "juice", "peanut-butter", "butter", "ketchup", "jelly", "ice-cream", and "soup". The speech samples were blocked into 3 month periods.

Each word's frequency of usage in adult language was determined (Francis and Kucera, 1982). The effect of adult frequency on the subjects' usage was examined in the following way. If the average frequency of the non-solid substance words used by a subject was much greater than the average frequency of solid substance words used by that subject, then the non-solid substance words outside of the frequency range of the solid substance words were excluded. For example, if the set of non-solid substance words that Adam used had a higher average frequency in adult usage than the set of solid substance words that he used, then some of his non-solid substance words were excluded. The resulting subset of non-solid substance words closely approximated the solid substance words he used in the average frequency per type and token and in the range of frequency. Then his relative usage of each kind of word was reevaluated using the subset of the word type with the more frequent adult usage. Any effects discovered through these analyses could not be due to adult frequency.

Results

Adam

Figure 14 shows the number of tokens Adam used. In the period of recording Adam used solid substance words 50 times and non-solid substance words 640 times. He used non-solid substance words 112 times in the first 3 months of recording (note: recall that each point on the graph is one 3 month period). In contrast, he used solid substance words 15 times in the first 15 months of testing. At the beginning of the recordings he was already using non-solid substance words freely. At the same time he was not using any solid substance words. His "burst" of solid substance words came between 3;3 and 3;5 at which time he used them 11 times. When the sessions began (and Adam was using non-solid substance words) Adam was at stage 1 speech with an MLU of 1.75. At 3;3 (when he began using solid substance words) he was at stage 4 speech with an MLU of 3.7 (Brown, 1973).

An examination of the number of types Adam used reveals the same pattern (Figure 14). He used a total of 7 solid substance words and 20 non-solid substance words in the recording period. In the first 3 months he used 11 non-solid substance words and 0 solid substance words. He

Figure 14a -- Number of Tokens of Non-Solid Substance Words and Solid Substance Words used by Adam from 2;3 - 5;2

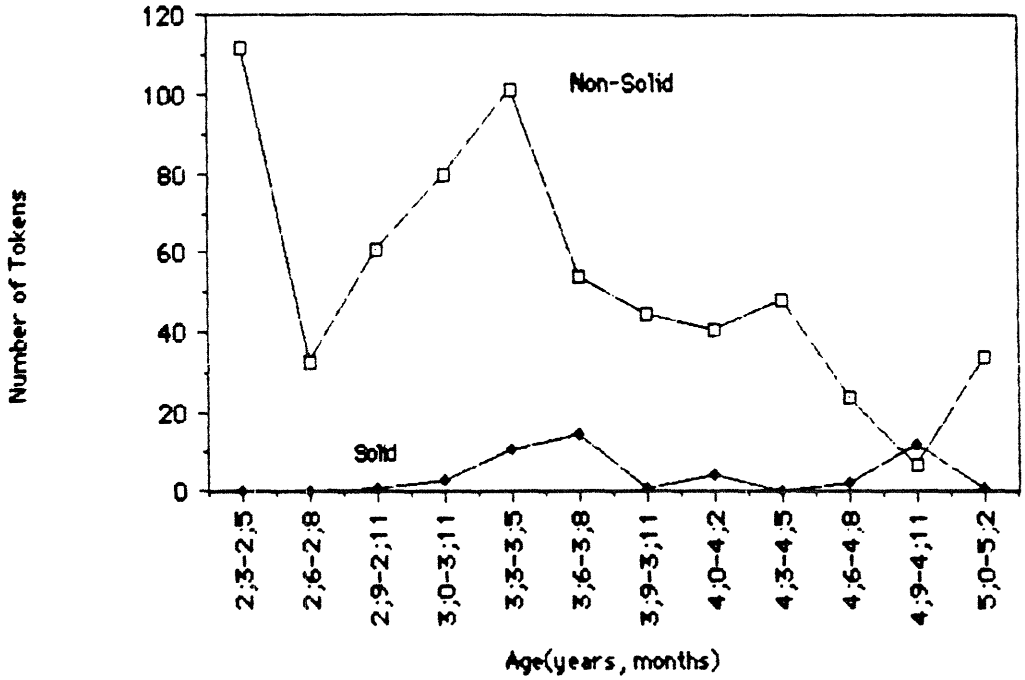
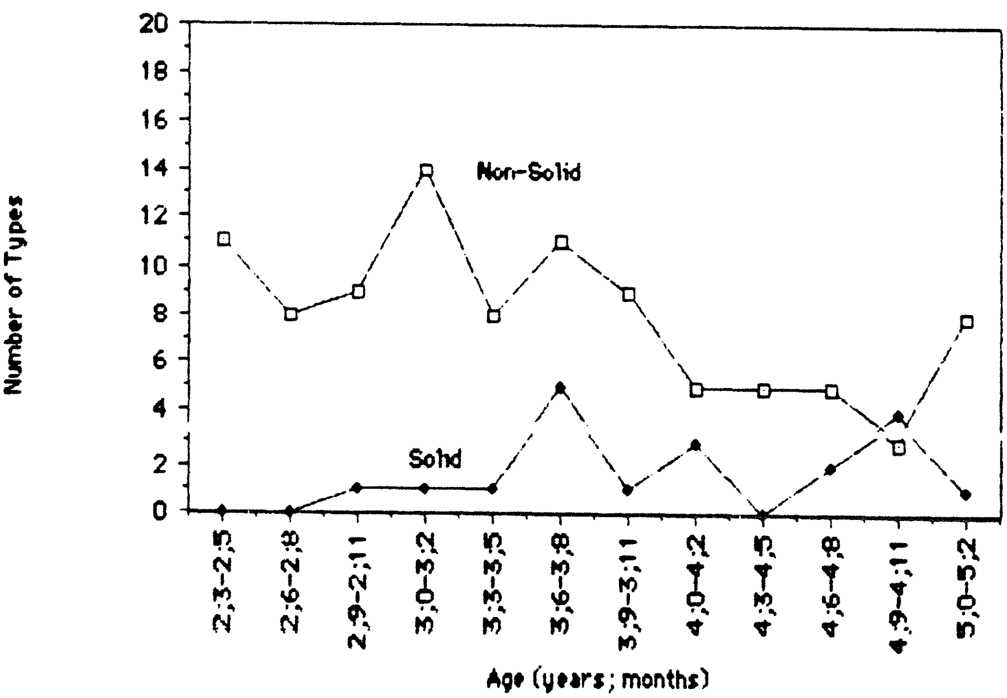


Figure 14b -- Number of Types of Non-Solid Substance Words and Solid Substance Words used by Adam from 2;3 - 5;2



used 5 solid substance words between 3;6 and 3;8. At that time he was bordering stage 5 with an MLU of 4.0 (Brown, 1973).

When Adam did begin to use solid substance words, he seemed to use them appropriately and as nouns, not modifiers. His first use was "Dat rubber". In this case, it is not clear what he was referring to, however, he did use "rubber" as a noun. By 3;3 to 3;5 he used "wood" 11 times in phrases such as "piece of wood" and "some wood" referring to the wood on a hammer and a piece of wood mixed with his toys. In the next three month period he continued to use "wood" in the same context and also used "rubber" in the phrase "made of rubber" and "plastic" in the phrase f"why plastic come off?". In all cases the word was used as a noun and in the context of building things. These uses provide the clearest evidence that he is using the words to refer to the solid substances. At this time, he also could use solid substance words as modifiers. He used "stone" in 5 noun phrases as a modifier to the noun. For example, he said "a stone bug". For the rest of the recorded period, he continued to use solid substance words in the context of building or when discussing what different things were made of. He used the words both as nouns and modifiers, but mostly as nouns (overall: 33 times as a noun, 13 times as a modifier, and 4 times ambiguously).

His non-solid substance words were both food words and non-food words, but mostly food words. In the first three months he used 44 food words, 31 non-food words, and "water" 37 times (water is both). Overall he used 235 food words, 178 non-food words, and "water" 227 times.

Adam's solid substance words had adult frequencies between 12 and

110. The average frequency per token was 52 and per type was 51. A subset of his non-solid substance words had a frequency range of 12 to 103. The average frequency per token was 40 and per type was 42. The subset was formed by including all the non-solid substance words in the specified frequency range.

The difference between Adam's use of solid substance words and his use of the subset of non-solid substance words is less extreme than the differences found in previous comparisons. Yet, the same pattern is still present (Figure 15). His total use of the subset of non-solid substance words is reduced to 339 tokens and 11 types. In the first 3 months he used 65 tokens and 7 types. Recall that his use of solid substance words overall was 50 tokens and 7 types. He used none in the first 3 months.

Adam's mother also used solid substance words less frequently than non-solid substance words. In fact, her use of each kind of word directly parallels Adam's use (Figure 16). She used 5 solid substance words 35 times and 19 non-solid substance words 334 times in the recording period. In the first 3 months she used 1 solid substance word 2 times and 10 non-solid substance words 65 times. Adam's peaks in usage occurred at the same time as his mother's peaks.

Sarah

Sarah's results are very much like Adam's (Figure 17). She used

Figure 15a -- Number of Tokens of Non-Solid Substance Words in the Restricted Set and All Solid Substance Words used by Adam from 2;3 - 5;2

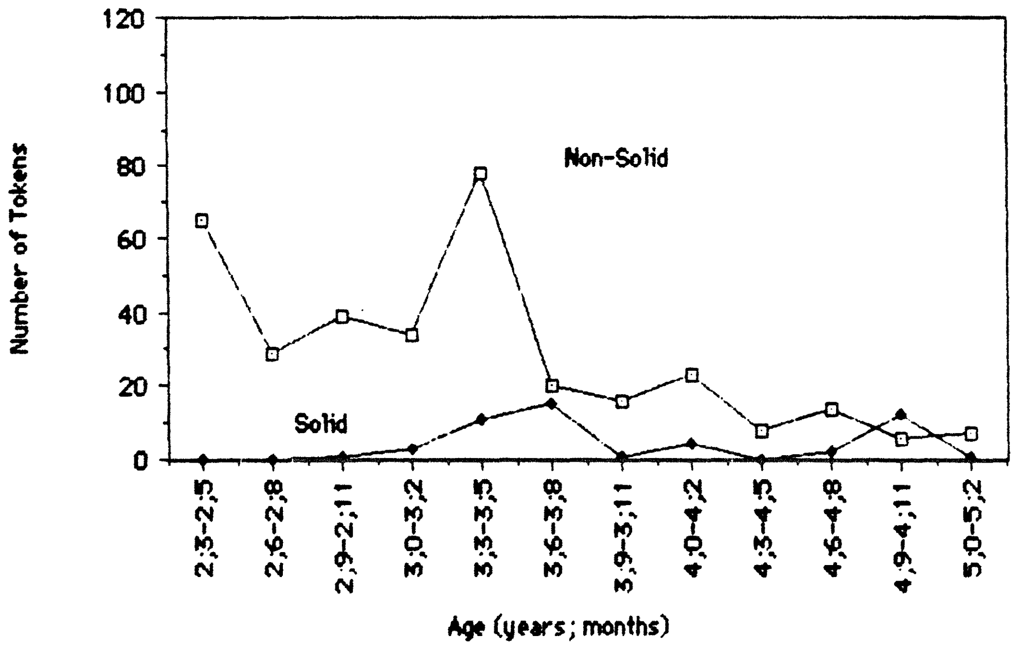


Figure 15b -- Number of Types of Non-Solid Substance Words in the Restricted Set and All Solid Substance Words used by Adam from 2;3 - 5;2

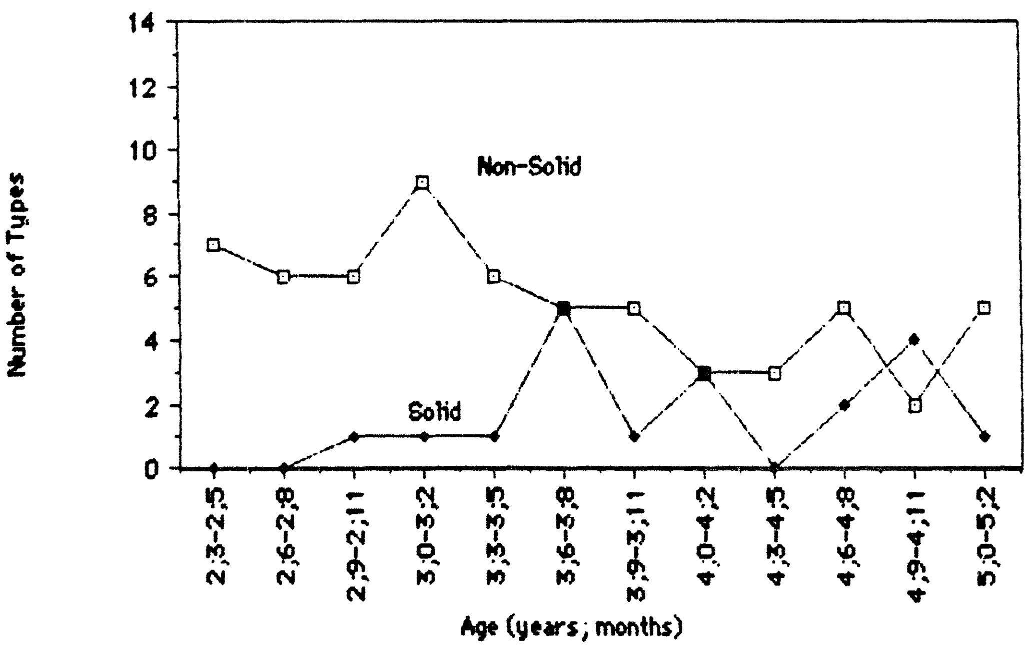


Figure 16a -- Number of Tokens of Non-Solid Substance Words and Soid Substance Words used by Adam's Mother when Adam was 2;3 - 5;2

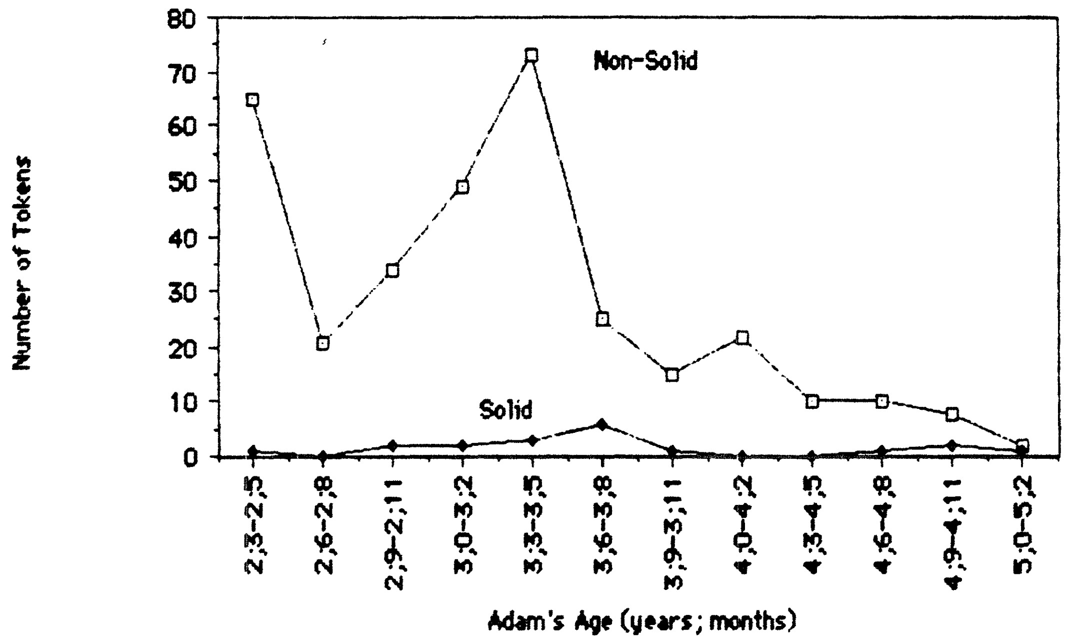


Figure 16b -- Number of Types of Non-Solid Substance Words and Solid Substance Words used by Adam's Mother when Adam was 2;3 - 5;2

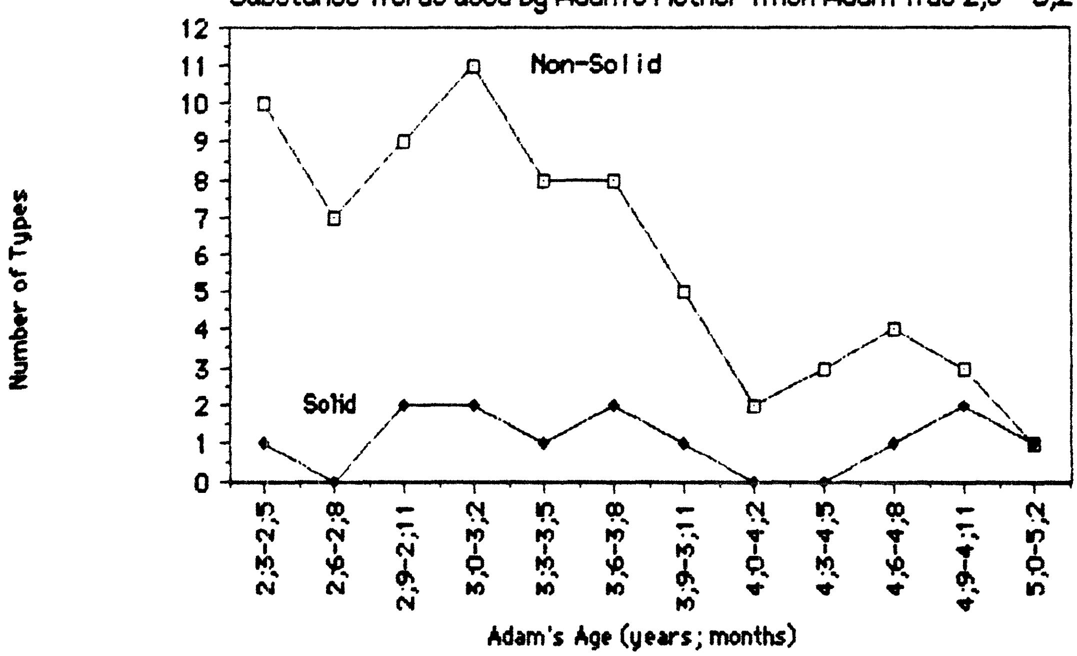


Figure 17a -- Number of Tokens of Non-Solid Substance Words and Solid Substance Words used by Sarah from 2;3 - 5;2

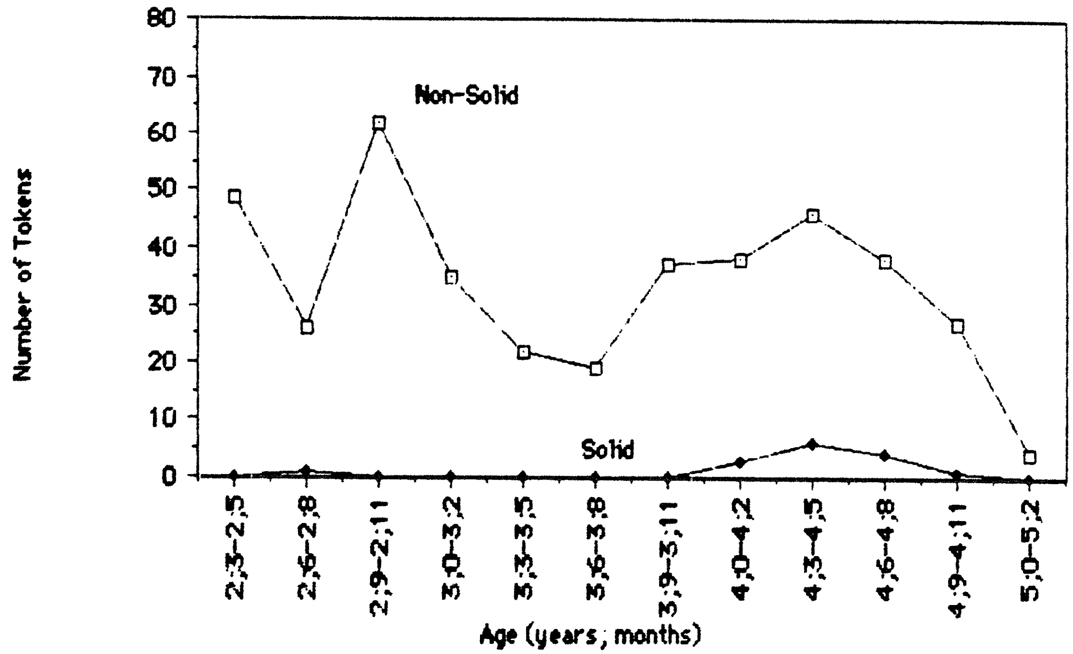
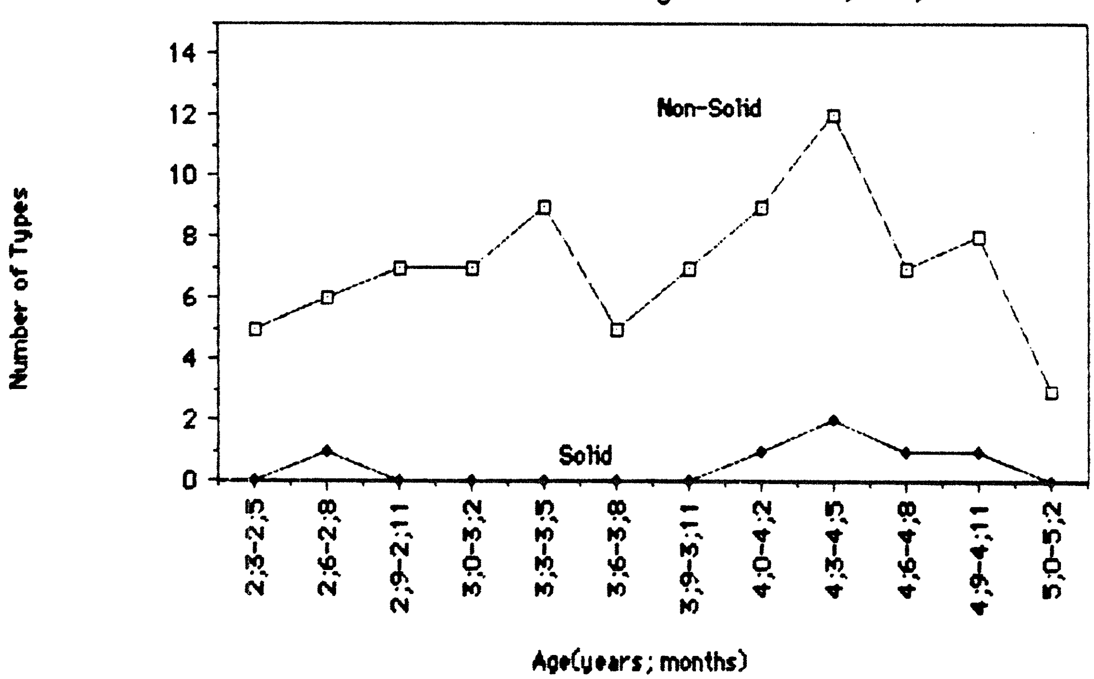


Figure 17b -- Number of Types of Non-Solid Substance Words and Solid Substance Words used by Sarah from 2;3 - 5;2



non-solid substance words 403 times and solid substance words 15 times in the recording period. She used non-solid substance words frequently in the first 3 months (49 times). At that time her MLU was around 1.9 and she was at stage 1 (Brown, 1973). Her "burst" (6 tokens) of solid substance words occurred between 4;3 and 4;5 at which time her MLU was greater than 4.0 and she was at stage 5 (Brown, 1973).

The pattern of Sarah's use of types is very similar (Figure 17). Overall she used 17 non-solid substance words and 3 solid substance words. In the first 3 months she used 5 non-solid substance words and no solid substance words. She never used more than 2 different solid substance words in a 3 month period.

Sarah's uses of solid substance words are more ambiguous than Adam's. In her earliest productions it is not clear if she was using the words as object words or solid substance words. For example, she said "a glass" but was referring to glass on a stove. In this case "glass" is a noun; but her use of count noun syntax suggests that maybe she meant "glass" as an object even though the referent was not a drinking glass. At 4;6 her use of "glass" was more clear. She said "want me to have it with some glass over it?" while drawing a picture of a car with glass on it. At this time, she seems to be using "glass" appropriately and again as a noun. However, she never used any solid substance words with the phrase "made of" or as a building supply. She also used other solid substance words ("wood" and "plastic"), but all of her uses were as nouns.

Her non-solid substance words were mostly food words and "water". In the first 3 months she used "powder" once and food words 48 times. Overall she used non-food words 103 times, food words 199 times, and "water" 101 times.

The adult frequency range of Sarah's solid substance words was 33 to 110. The average frequency per type was 71 and per token was 68. A subset of her non-solid substance words had an adult frequency range of 35 to 59. The average frequency per type was 45 and per token was 49. Figure 18 shows that she used tokens of the subset of non-solid substance words more frequently than tokens of solid substance words. She used the non-solid substance words 141 times and solid substance words 15 times overall. In contrast, her use of non-solid substance word types for the subset of non-solid substance words is only slightly greater than her use of solid substance word types (Figure 18). She used 5 different non-solid substance words and 3 different solid substance words. However, in each 3 month period her use of different non-solid substance words was greater than her use of different solid substance words.

Sarah's mother's use of the non-solid substance and solid substance words was similar to Sarah's (Figure 19). She used 18 non-solid substance words 463 times and 5 solid substance words 10 times in the recorded period. She used 10 non-solid substance words 70 times in the first 3 months. She used no solid substance in the first 3 months. She never used solid substance words more than 3 times in a 3 month period. The peaks and valleys in her usage of both kinds of words match the peaks and valleys in Sarah's usage.

Figure 18a -- Number of Tokens of Non-Solid Substance Words in the Restricted Set and All Solid Substance Words used by Sarah from 2;3 - 5;2

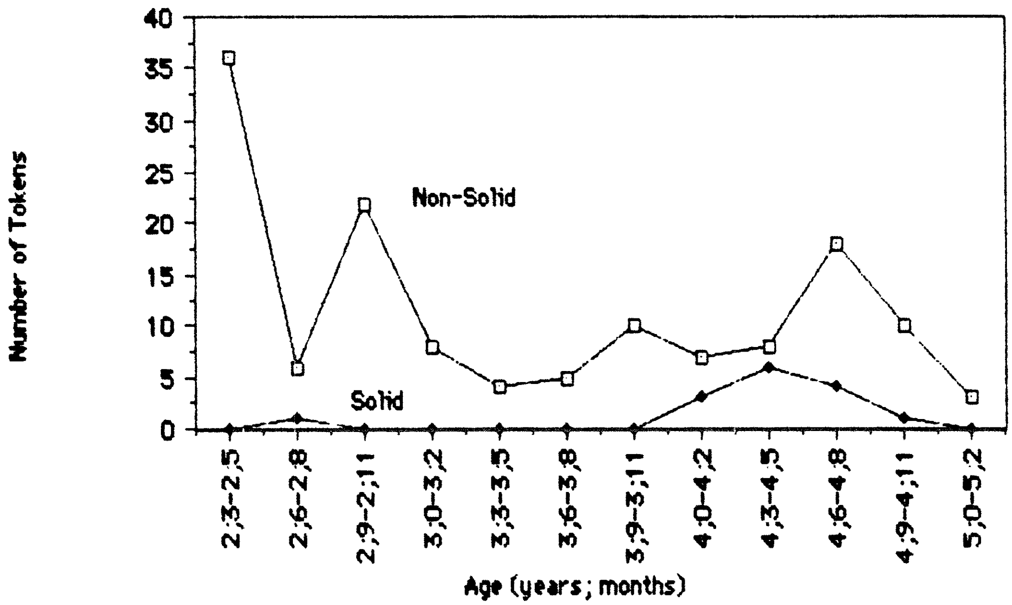


Figure 18b -- Number of Types of Non-Solid Substance Words in the Restricted Set and All Solid Substance Words used by Sarah from 2;3 - 5;2

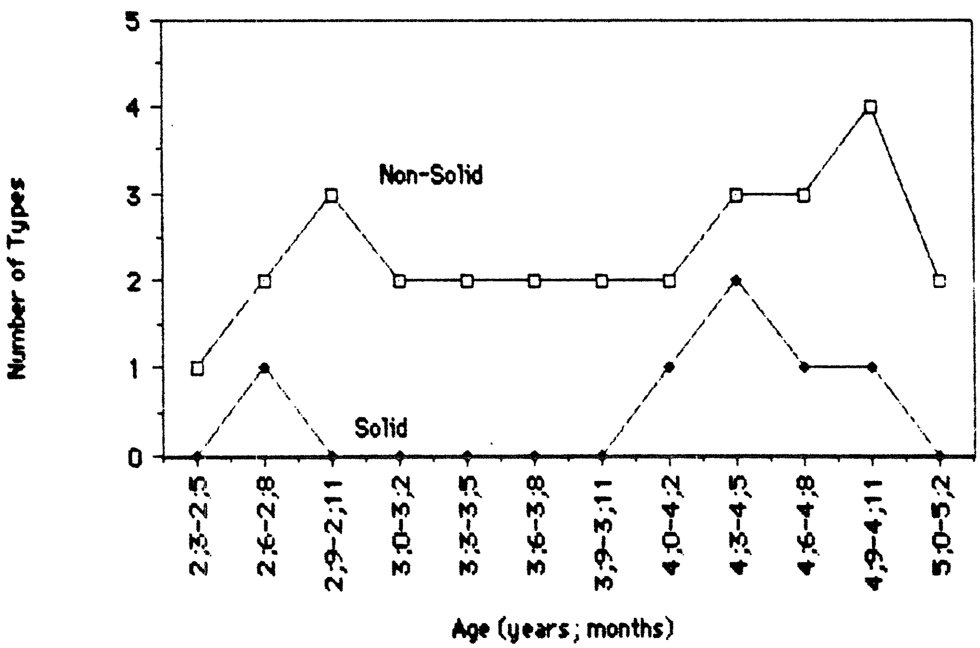


Figure 19a -- Number of Tokens of Non-Solid Substance Words and Solid Substance Words used by Sarah's Mother when Sarah was 2;3 - 5;2

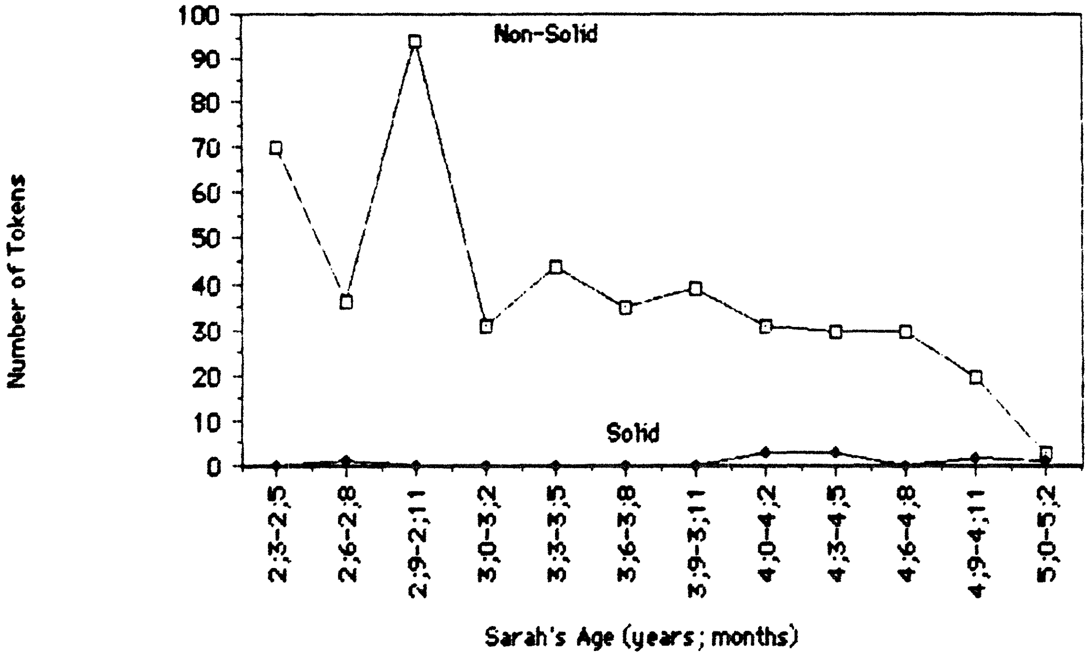
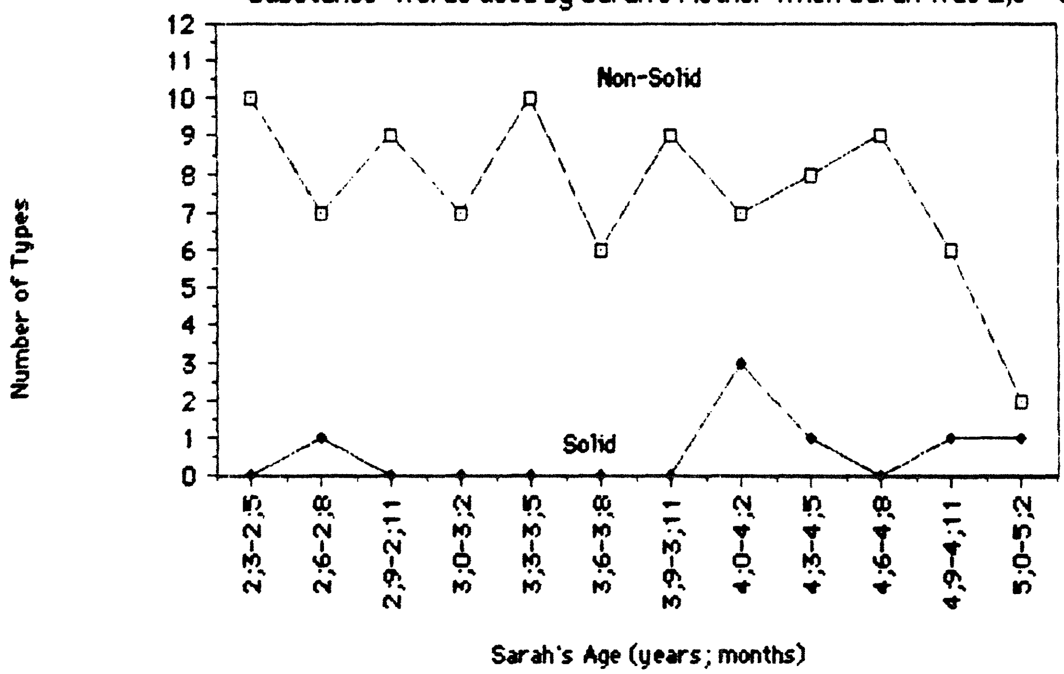


Figure 19b -- Number of Types of Non-Solid Substance Words and Solid Substance Words used by Sarah's Mother when Sarah was 2;3 - 5;2



Eve

Eve used 12 non-solid substance words 358 times and 1 solid substance word ("rubber") 3 times overall (Figure 20). In the first 3 months she used 9 non-solid substance words 106 times and no solid substance words. She never had a burst of solid substance words. In the first session she was 1;6, had an MLU of 1.5, and was not yet at stage 1. At the end of her recordings she was 2;5, had an MLU of 4.2, and was at stage 5 (Brown, 1973).

Two of the three times Eve used "rubber" were in the phrase "rubber pant". She seemed to be using the word correctly and as a modifier. However, it is not completely clear what it meant for her. The whole phrase might have referred to a kind of pant and not the material. The third time she used "rubber" was in the sentence "That a rubber". She was referring to the eraser at the end of a pencil. She was using the word as a noun, but it is very possible that she had the meaning of "eraser" encoded by the word "rubber".

She used non-solid substance words for foods and non-foods, but mostly for foods. In the first three months she used 86 food terms, 6 non-food terms, and "water" 14 times. Overall she used food terms 296 times, non-food terms 36 times, and "water" 26 times.

Her solid substance word had an adult frequency of 16. One of her non-solid substance words ("soup") also had an adult frequency of 16

Figure 20a -- Number of Tokens of Non-Solid Substance Words and Solid Substance Words used by Eve from 1;6 - 2;5

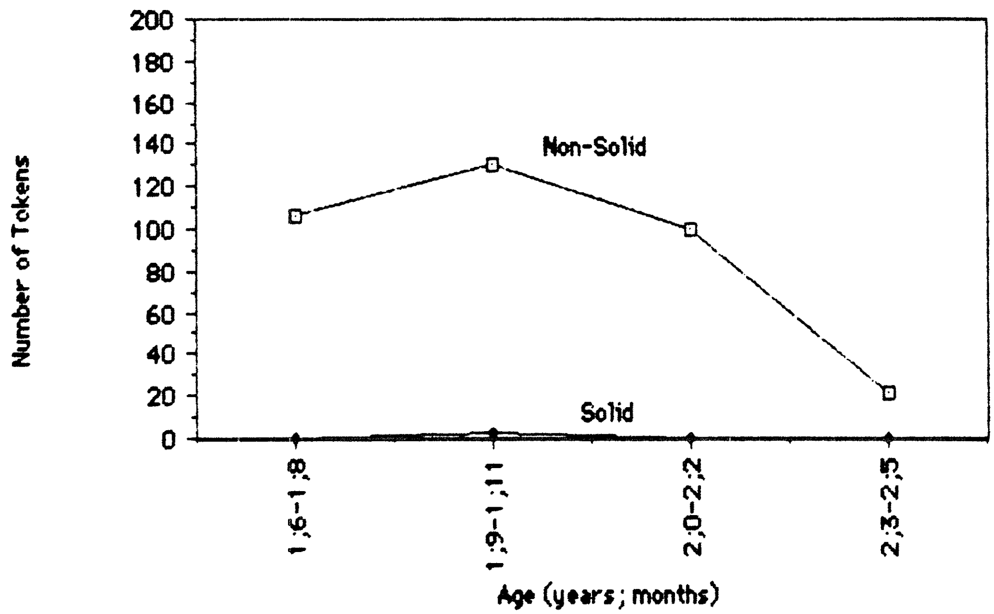
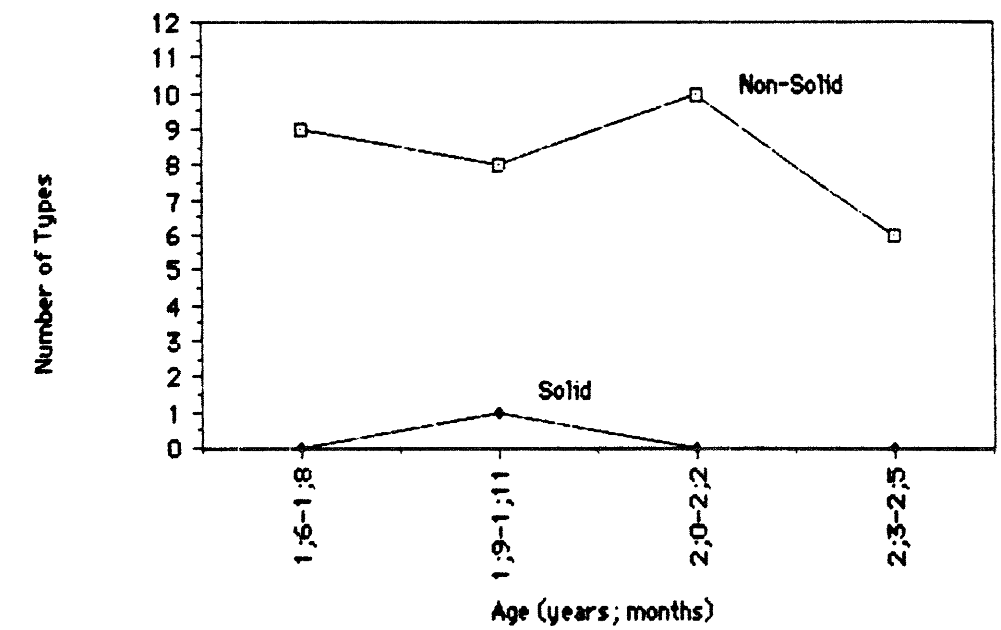


Figure 20b -- Number of Types of Non-Solid Substance Words and Solid Substance Words used by Eve from, 1;6 - 2;5



(Figure 21). She used "soup" earlier and more frequently than "rubber". She used "soup" 53 times and 23 times in the first 3 months. She used "rubber" 3 times and not until the second 3 months.

Eve's mother used 13 non-solid substance words 337 times and 1 solid substance word 1 time (Figure 22). She used 8 non-solid substance words 115 times in the first 3 months and no solid substance words. Her pattern of usage can be superimposed with Eve's.

Allison

Allison did not use any solid substance words (Figure 23). She used 4 non-solid substance words 47 times overall and 1 of them 5 times in the first 3 months. Since Allison did not use any solid substance words, it is impossible to pick a nonempty subset of non-solid substance words in a comparable range. At the beginning of her recordings she was not yet at stage 1.

The words Allison used were: "juice" (42 times), "ice-cream" (3 times), "water" (1 time), and "snow" (1 time).

Allison mother also did not use any solid substance words (Figure 24). She used 5 non-solid substance words 82 times. Her use of non-solid substance words is different from Allison. Allison began with 6 tokens and increased steadily to 26 (across 3 3-month periods). Allison mother used 23 tokens in the first 3-month period, increased to 34, and fell back down to 25.

Figure 21 -- Number of Tokens of Non-Solid Substance Words in the Restricted Set and All Solid Substance Words used by Eve from 1;6 - 2;5

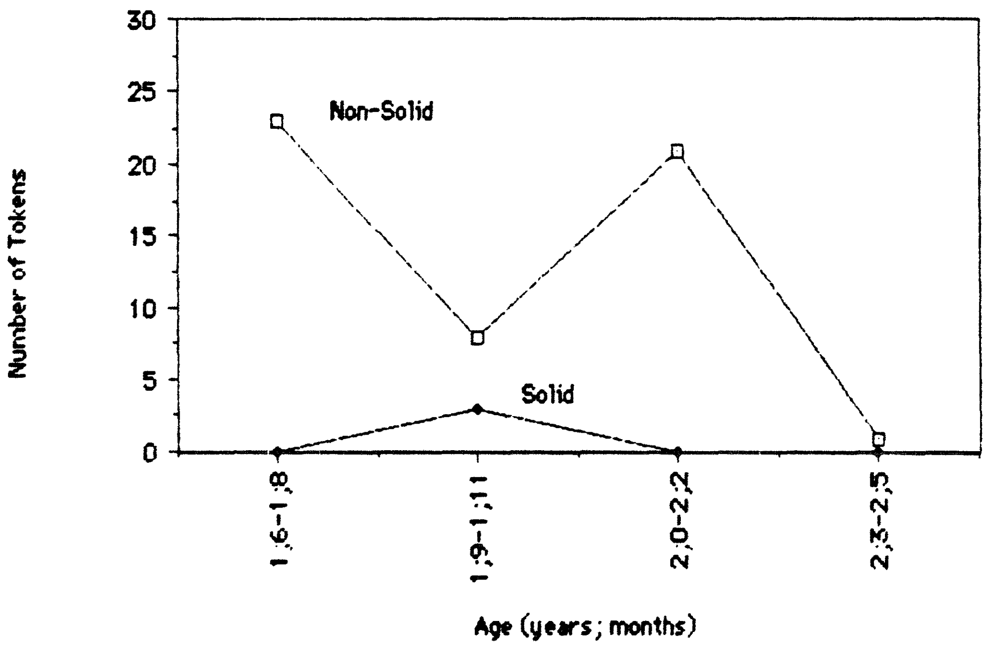


Figure 22a -- Number of Tokens of Non-Solid Substance Words and Solid Substance Words used by Eve's Mother when Eve was 1;6 - 2;5

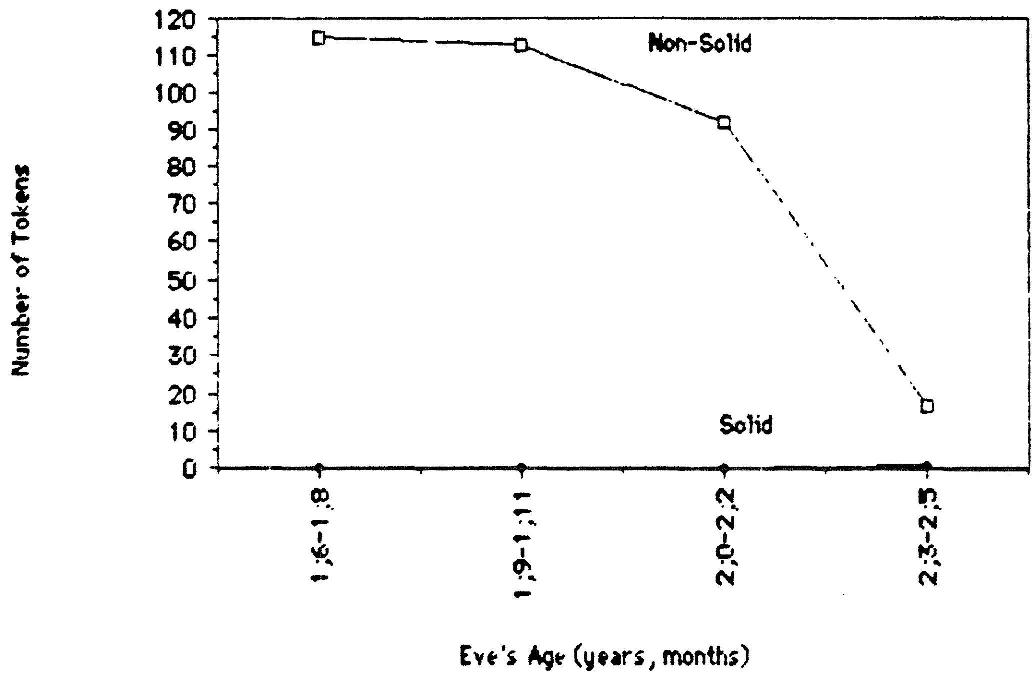


Figure 22b -- Number of Types of Non-Solid Substance Words and Solid Substance Words used by Eve's Mother when Eve was 1;6 - 2;5

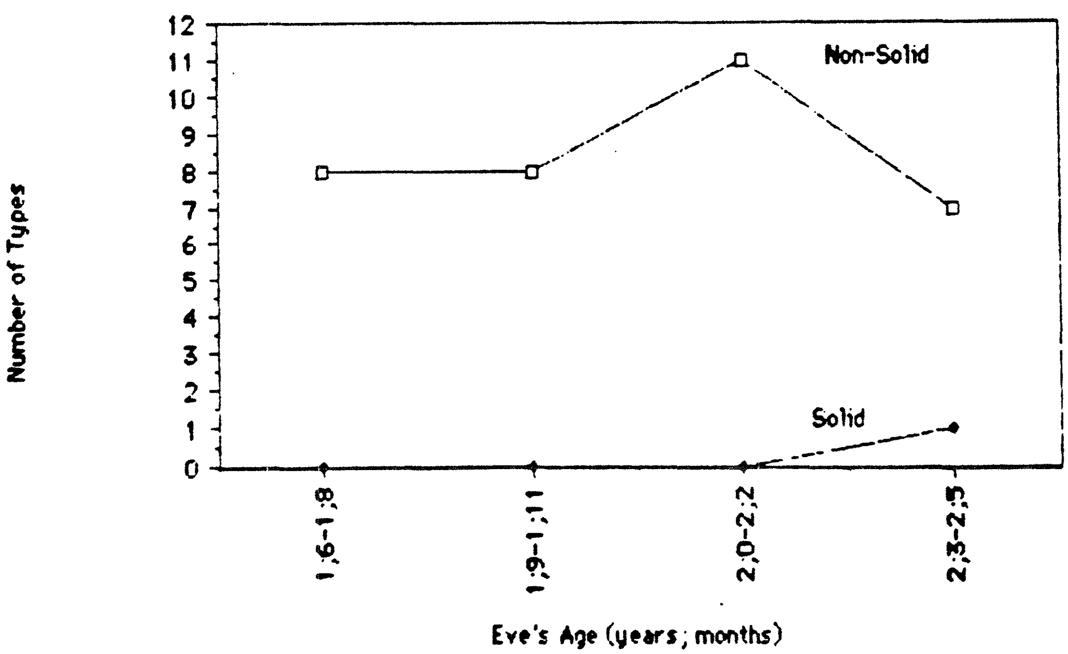


Figure 23a -- Number of Tokens of Non-Solid Substance Words and Solid Substance Words used by Allison from 1;6 - 2;2

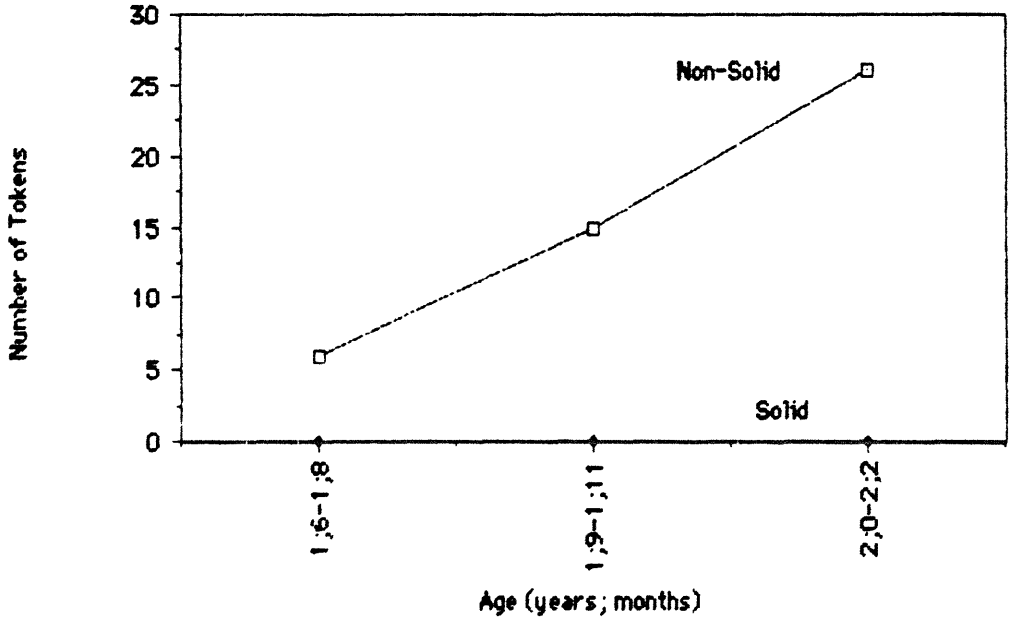


Figure 23b -- Number of Types of Non-Solid Substance Words and Solid Substance Words used by Allison from 1;6 - 2;5

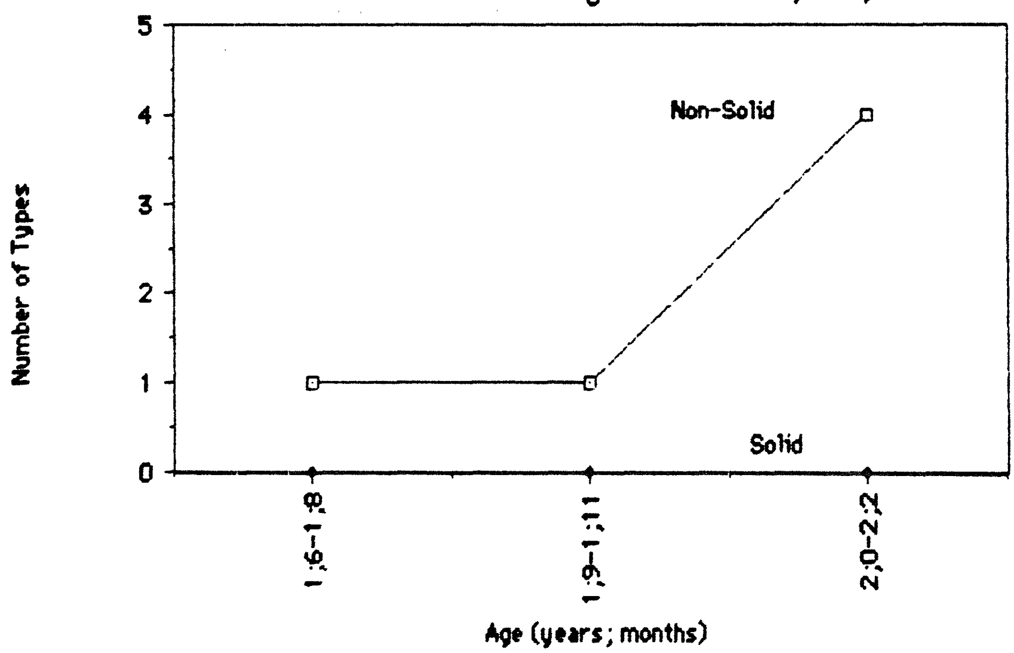


Figure 24a -- Number of Tokens of Non-Solid Substance Words and Solid Substance Words used by Allison's Mother when Allison was 1;6 - 2;2

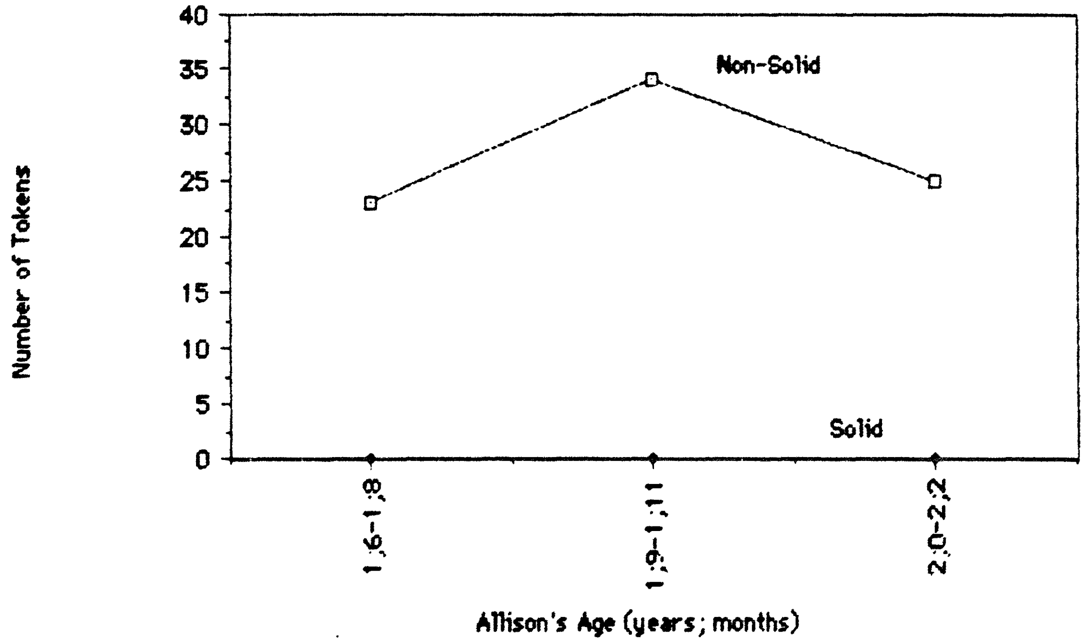
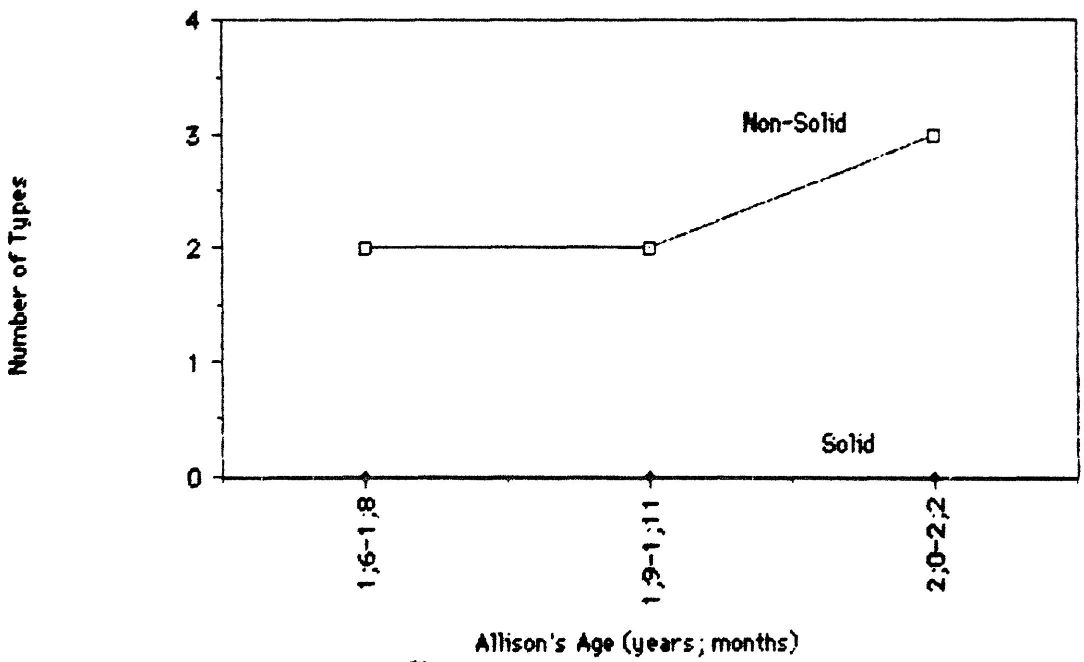


Figure 24b -- Number of Types of Non-Solid Substance Words and Solid Substance Words used by Allison's Mother when Allison was 1;6 - 2;2



Discussion

Each of the children used non-solid substance words earlier and more frequently than solid substance words. From these data I conclude that children learn solid substance words later than non-solid substance words. This conclusion may be flawed, however, because it could be that children did not have the opportunity to use solid substance words in the recording sessions, but did use them in other situations. However, there is empirical evidence against that possibility. David Dickinson (1986) examined children's comprehension of solid substance words. He found that only 64% of the 3 1/2-year-olds comprehended "glass" and only 46% comprehended "wood". 36% of the subjects did not know any solid substance words at all. Similarly, in the first three experiments none of the 2-year-olds used any solid substance words and only 3 of the 2 1/2-year-olds used one. In contrast, all the subjects used many non-solid substance words.

Given that solid substance words are learned later than non-solid substance words, the cause of the phenomenon must be evaluated. Is it due to the proposed constraint or another factor? Two possible factors are adult-adult frequency and adult-child frequency.

The effect of adult-adult frequency was examined in the following way. Analyses of the productions of Adam, Eve, and Sarah were conducted in which the higher frequency of non-solid substance words was taken into account. The non-solid substance words with extreme frequencies were excluded. For each child the remaining non-solid substance words were in the same frequency range as the child's solid substance words.

The results demonstrate that adult-adult frequency may have some role in determining the words children acquire but is not the only factor. When frequency was equated all results were less striking. However, adult-adult frequency can not account for all of the results. Even with the frequencies equated, there was still a difference between the children's use of non-solid substance words and solid substance words. Each child used the subset of non-solid substance words earlier and more frequently than solid substance words.

However, the role of frequency may be more important than suggested by this argument. It could be that when adults are talking to children they use solid substance words even less frequently (relative to non-solid substance words) than when they are talking to other adults. In that case the pattern of children's productions could be reflections of adult usage to children. This, in fact, seems to be the case. The adult patterns seem to be identical to the children's patterns in the speech samples.

An important question is: What is the direction of causation? Does the lack of solid substance words in adult speech account for children's difficulty with solid substance words (lack of exposure) or is the reverse true (maternal sensitivity)? If a lack of exposure is the reason for children's nonuse of solid substance words, then they ought to use them, given appropriate exposure.

This possibility has been tested, but it is not clear what kind of exposure would be appropriate. Dickinson (in press) tried to teach children solid substance words. He used the procedure from Experiments 1 through 3 with 2 minor changes. First, his objects were shaped like chunks of material, rather than real objects. Second, the introduction of the word was, "This is made of blicket". 4 and 5-year-olds did think that the word referred to the material, but 3-year-olds did not. S. Waxman (personal communication, June 24, 1987) has argued that the children may need to hear the words used as modifiers, not nouns. This experiment has not been done. However, in these recordings solid substance words are learned as nouns before they are learned as modifiers. Adam and Sarah, the only children who knew more than one solid substance word, learned them first as nouns. In fact, Sarah, by 5-years-old had still not used any as modifiers. Adam did use solid substance words as modifiers, but not as frequently as he used them as nouns. Another possibility (S. Waxman, personal communication, June 24, 1987) is that children would only learn solid substance words in situations in which the substance is relevant. This hypothesis has also not been tested experimentally; however, it is worth noting that there are some natural experiences in which solid substances are relevant. For example, when children are banging objects to create noise and when they break objects, the material is essential. In those situations you might expect the mothers to use the words and the children to learn them given this hypothesis. However, children do not learn solid substance words until they are 3 or 4-years-old.

If children's difficulty with solid substance words is due to a lack of ability, then the adults' nonuse of solid substance words could be due to their sensitivity to their children's competencies. There is evidence that mothers, when referring to objects, use different words with children than with adults in order to avoid using words the children would not understand (Anglin, 1977, Mervis & Mervis, 1982). Similarly, the mothers' suppression of solid substance words may have been caused by their recognition that their children would not comprehend solid substance words.

In conclusion, as predicted by the proposed constraint, young children are delayed in learning solid substance words. However, the reason for the delay is not necessarily the constraint. The delay could be due to a lack of exposure to the words.

If the delay is due to the constraint, then another question is: to what degree does the constraint inhibit projection over solid substances? It could be that the constraint is effective because it specifies which concepts can be named. If so, then young children should be able to make nonlinguistic inferences over solid substances. On the other hand, the constraint could be effective because it specifies which concepts can support <u>any</u> inductive inference. If this is the case, then young children should not be able to make any inferences over solid substances. This issue is addressed in Experiment 5.

EXPERIMENT 5

The purpose of the first four experiments was to support the proposed constraint. The fifth and sixth experiments accept the constraint as psychologically real and address additional questions. The fifth experiment attempts to answer the question: is the constraint used only to constrain inferences about word meaning or is it used to constrain any cognitive inference? It could be that it applies to the induction of any property, not just the induction of word meanings. For example, it could be that the constraint should be stated more broadly:

> When children are making any inductive projection from a solid object, their projection is based on the object's kind. When they are making any inductive projection from a non-solid substance, their projection is based on the substance's kind.

This formulation implies that children have a single similarity space underlying all inductive projection over physical entities. It is organized around kinds of objects and kinds of non-solid substances. That is, objects are seen as similar if they are the same kind of object and non-solid substances are seen as similar if they are the same kind of substance.

Experiment 5 tests this cognitive constraint. The subjects were asked to make projections about the heaviness of objects. The relative weight of an object is determined by the material that the object is made out of and its size, but not the kind of the object. This experiment asks whether young children realize the role of material or are fixated on object kind. They were also given a naming task with the same objects in order to see if they could vary the basis of their projections over the same set of objects.

Pilot testing revealed that 2 1/2-year-olds could not succeed on the naming task. Consequently, this experiment was run on 3-year-olds. The task is slightly different from the naming task of Experiments 1 - 3 and those differences could account for the difference in results. This possibility is examined in the discussion and in the next experiment.

Method

There were two tasks: a weight task and a naming task. The order of the tasks was counterbalanced across subjects. There was also a pretraining of the word "heavy" which directly preceded the weight task. The orders were: naming, pretraining, weight; or pretraining, weight, naming.

SUBJECTS

There were 8 subjects. The mean age was 3;3 (range: 3;0 - 3;5). They were tested individually at their day care centers in an empty room.

STIMULI

In the pretraining for the weight task a pair of objects were used in each trial. The objects of a pair were the same size, but had different shapes, different materials, and different weights. In the two main tasks quadruples of objects were used. Each quadruple had two shapes and two materials, such that each shape was paired with each material. Also the two materials were very different in weight. Some of the objects were weighted to satisfy this criterion. The size of the four objects within a quadruple was the same. There were eight trials in each task. No shape or material was used in more than one set of stimuli, resulting in 16 shapes and 16 materials. See Appendix 4 for pictures of the objects and a list of the materials. The same eight sets were used in the weight task and the naming task.

PROCEDURE

Pretraining for the Weight Task

The subjects were first introduced to Pokey, a horse, and told that Pokey likes heavy things. They were given the two objects of one pair and asked which was the heavy object. They were then reminded that Pokey likes heavy things and were asked to give the heavy object to Pokey. If the subjects chose the incorrect object, they were corrected. The experimenter felt the objects and said, "Hmmm ... I'm not sure, why don't you think about it again." He then returned the objects to the subject for another judgment. When the subjects chose the correct object in their first judgment for four trials in a row, the weight task began.

Weight Task

The subjects were given two objects of one set, (O1,M1) and (O2,M2) (read as OBJECT 1, MATERIAL 1 and OBJECT 2, MATERIAL 2), and were asked to give Pokey the heavy toy. If the subjects picked the wrong object, the experimenter said, "Hmmm ... I'm not sure, why don't you think about it again." The other toy was put to the side, still in the subjects' view. The subjects were then shown (O1,M2) and (O2,M1) (but could not touch them) and were asked to predict which object was heavier. There were eight weight trials.

Naming Task

The subjects were introduced to Gumby, a man, and were told that Gumby likes some of the toys that they would be playing with. Again, the subjects were given two objects, (O1,M1) and (O2,M2). One of the objects was put to the side, still in the subjects' view. The other object was named and described as a favorite of Gumby's. For example, the experimenter said, "This is my mindert. Gumby really likes the mindert. Can you give the mindert to Gumby." As in the weight task, the other two objects, (O1,M2) and (O2,M1), were presented (visually, only) and the subjects were asked, "Which is the mindert?" There were eight naming trials.

It was predicted that the constraint the subjects use in naming is not a general purpose cognitive constraint, but a constraint on naming. Therefore, the subjects should be able to make projections over material kind when appropriate. Accordingly, in the weight task responses that were based on material kind were considered correct and in the naming task responses based on object kind were considered correct.

Results

Weight Pretraining

6 of the subjects made no errors on the weight judgments in the pretraining. 2 of the subjects made one error.

Weight and Naming Tasks

The mean score on the weight task was 66% and the mean score on the naming task was 67%. The performance on both tasks was significantly greater than chance, but the difference on the naming task is only of one-tailed significance (weight: t(7) = 2.828, p = .028, 2-tailed; naming: t(7) = 2.091, p = .04, 1-tailed). In order to see whether there was a difference between the subjects' approach to the two tasks, the scores from the two tasks needed to be calculated in the same way. Therefore the percent of trials in which the subject chose according to shape was found for both tasks. This score is the same as the percent correct for the naming task but equals 100 minus the percent correct for the weight task (Figure 25). An anova run on these scores demonstrates that the subjects' performance on the weight task was significantly different from their performance on the naming task ($F(1,7) = 10.113$, $p = .015$).

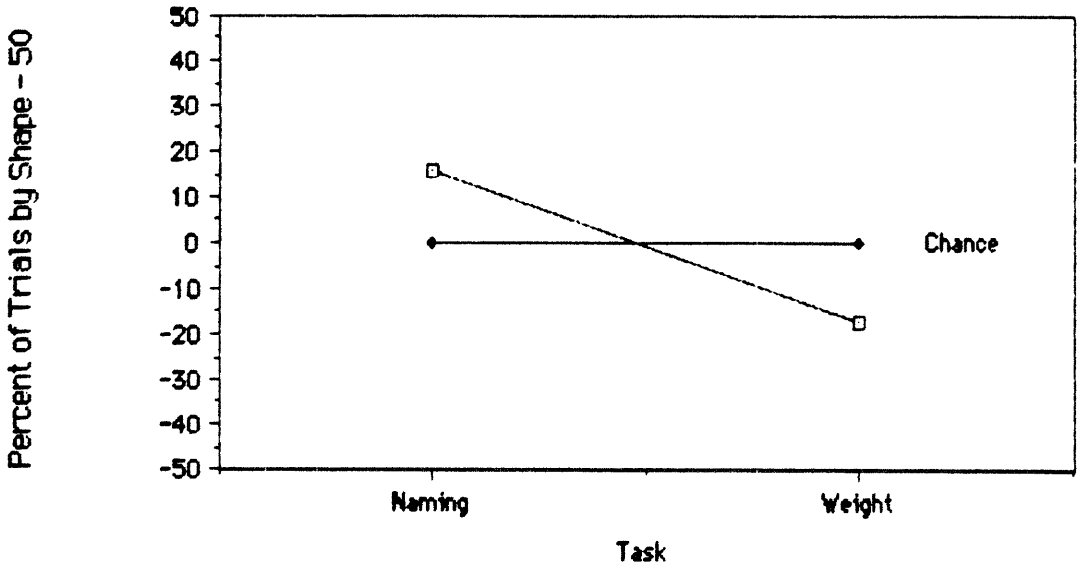
A 2 X 2 anova using the original naming and weight scores was run to examine the interaction between the order of the tasks and the kind of the task. There were no significant effects (order: $F(1,6) = .189$, $p = .679$; tasks: $F(1,6) = .021$, $p = .889$; interaction: $F(1,6) = .021$, $p = .889$).

Other anovas comparing the items and the order of the items within a condition revealed no significant effects (all F's < 1.825, p's $> .104$).

Discussion

The subjects were able to base inductive projection on different properties depending on the nature of the projection. When asked to make

Figure 25 -- Difference from Chance in the Weight Task and the Naming Task



predictions about the relative weights of objects, they based their inferences on the materials of the objects and not their shapes. In contrast, when asked to predict which of two objects had the same name as another object, they based their inferences on the shape of the objects or the object kinds.

Therefore, the proposed constraint can not be stated as a general cognitive constraint. It does not govern all inductive inference. Children must have at least 2 similarity spaces underlying inductive projection. In one the similarity of two objects is determined by the relationship between the kinds of the objects. In the other the similarity of two objects is determined by the relationship between the material kinds of the objects.

One question that arises from this data is why are the 3-year-olds so much worse on this naming task than the naming task in Experiments 1 - 3? In those experiments the subjects were only introduced to 1 object initially. In this experiment they were introduced to 2 objects, but one was ignored and one was named. Another, probably more important difference, is that in the original naming task the same-material alternative was 3 or 4 small pieces of an object. In this experiment the same-material alternative was another whole object. The subjects may well have known that pieces of an object were not be the same kind of thing as a whole object. If so, then the original naming task would have been very easy. In Experiment 5 the subjects could not have used that kind of information to decide which objects were the same kind. The subjects may not be very good at determining object kind under these conditions. In Experiment 6 this issue is further investigated.

EXPERIMENT 6

To repeat, the proposed constraint is:

> When children hear a new word used to refer to a solid object, their first hypothesis about its meaning is the kind of object. When they hear a new word used to refer to a non-solid substance, their first hypothesis about its meaning is the kind of substance.

This constraint addresses the mapping problem. Given any particular object, it presumes that children already know the kind of the object as well as other properties of the object. The role of the constraint, then, is to specify which property is mapped onto a word used to name that object. Similarly, given any non-solid substance the constraint specifies which property of the substance is mapped onto a word used to name the substance. It does not address how children develop a representation of the various properties of the substance. Another question is: how do children determine what an object's kind or a non-solid substance's kind is?

Two pilot studies have addressed this question with respect to objects. In the first, 2 1/2-year-olds were given the naming task of Experiment 5. An object was named for them and they were asked which of two other objects had that name. One object had the same shape as the named object, the other object had the same material as the named object. The subjects were at chance. Even the 3-year-olds that were tested in Experiment 5, although better than chance, were only at 67% correct. It is clear from Experiments 1 - 3 that 2 1/2-year-olds know that the meaning of a word used to refer to a solid object is the object's kind. Therefore the subjects' inability to choose either object consistently suggests that they were confused about the defining properties of the object kind. In other words, they knew that the meaning of the word was the object's kind, but did not know whether the object kind was defined by shape, material, or some other property.

This conclusion seems contradictory to the results of Experiments 1 - 3. However, there is an important difference in the naming tasks between those experiments and this pilot. In the original procedure, the same-material choice was in 3 or 4 pieces. The subjects may have rejected that stimulus because they knew that an object was not the same kind of thing as a collection of pieces, regardless of any similarity. Given this knowledge, the subjects did not need to know that shape was more important than material in determining object kind to succeed on the task. In the pilot, as in experiment 5, both test stimuli were single objects. Either object could have been the same kind of object as the original depending on how "kind of object" was defined.

It may seem that the spontaneous speech data suggest that young children do not think that words refer to solid substances. But, it could be that the subjects thought that the word (in the pilot) referred to an <u>object</u> made out of a certain substance. For example, they would not have inferred that the word meant "metal", but they may have inferred that the word meant "metal object". The word would have still referred to the object kind, but the object kind would have been specified by a material. In fact, there are words in the adult lexicon with this property. For example, the word "rug" has as a meaning a kind of object, not a kind of substance. Yet, not any floor covering can be a rug. A piece of plastic that covers part of a floor is not a rug because it is made out of the wrong kind of material. A piece of woven material of the same size, color, shape and used in the same way would be considered a rug because of its material.

That pilot study suggests that 2 1/2-year-olds are not sure which features are most relevant to object kind: shape or material. A different pilot study indicates that under certain circumstances children are sure which features define object kind. The second study had the same procedure as the first. The difference was in the stimuli. The object with the original material was irregularly shaped and small, like a chunk of an object. The subjects recognized that differences in either regularity or size specified differences in kind of object. It is not the case that size indicates object kind. A tremendous chair and a tiny chair are both the same kind of object. However, regularity is relevant to object kind. Something that is regular is often a purposefully designed artifact. Something that is irregular is often an arbitrary piece of a substance. Usually an arbitrary piece of material and an artifact are not the same kind of object. Consequently, we hypothesized that young children use regularity, but not size, to specify kind of object.

In this experiment we attempted to replicate the two pilot studies and also determine whether young children can use regularity (independently of size) as an indicator of object type.

Method

SUBJECTS

There were 12 boys and 12 girls ranging in age from 2;5 to 2;8 (mean age: 2;6). They were tested individually at their homes. The parents of each subject were paid $3.00 for their participation.

PROCEDURE

The S was given one object and its name. For example, the E said, "This is my tulver". The S and the E then played with the object and the E continued to name it using "my" and "the" for determiners. Then that object was put to the side, still in the S's view, and two new objects were presented. The E said, "Can you find the tulver here?"

There were three different conditions and four trials within each condition. Each S received all three conditions. The trials were blocked by condition. The order of the conditions was counterbalanced across subjects.

One object was named for the subject. Then two other objects were presented. One had the original shape and one had the original material. The size and style of the material choice varied across conditions

STIMULI

Each trial involved four objects. The objects had two shapes (S1, S2) and two materials (M1, M2) crossed with each other. Therefore, the four objects were (S1,M1); (S2,M2); (S1,M2); and (S2,M1). In each trial 3 of the 4 objects were used. The objects that were used were counterbalanced across subjects; but the particular form of counterbalancing depended on the condition. Twenty-four different shapes and twenty-four different materials were used. Therefore, in each trial two new shapes and two new materials were presented. The shapes and materials are pictured and described in Appendix 5.

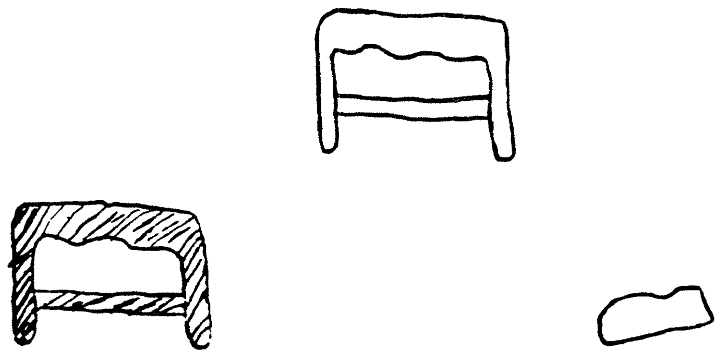
Double Object Condition

Both shapes of a set were regular; that is, they both seemed like artifacts. They were also both the same size as the named object (Figure 26). Each object served as the named object, the shape choice, the material choice, and the unused object across subjects.

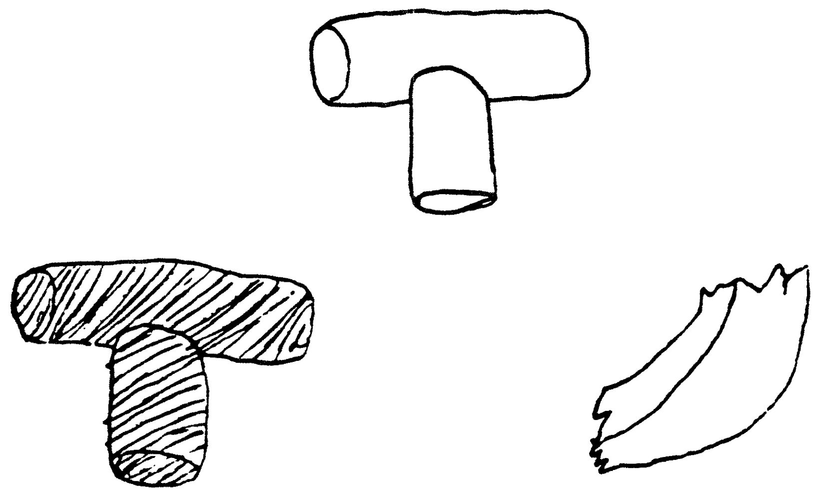
Little Piece Condition

Figure 26--Examples of stimuli in the little piece condition, the big piece condition, and the double object condition

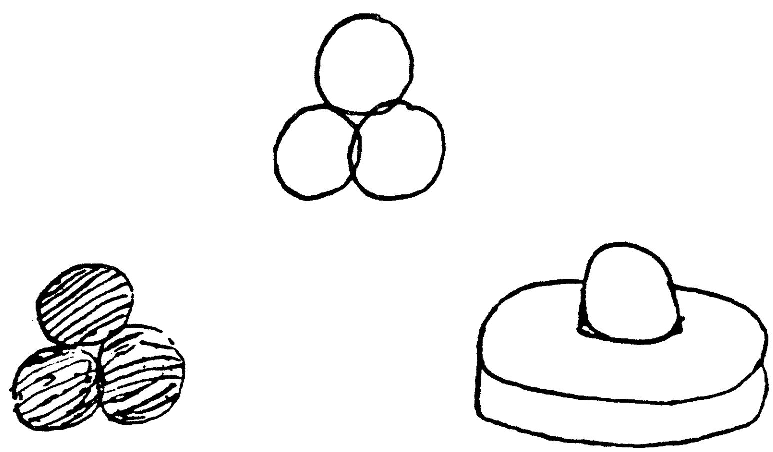
little piece condition



big piece condition



double object condition



In each trial one of the shapes was an artifact-type shape. The other shape was a chunk-type shape. The two chunk-type objects were smaller than the two artifact-type objects (Figure 26). Each of the objects with artifact-type shapes were used as the named object across subjects. For a particular subject the artifact-type object that was not named and the chunk-type object of the original material were used as the test objects. The chunk-type object that had a different material than the named object was not used for that subject.

Big Piece Condition

This condition was identical to the little piece condition except that the two objects with the chunk-type shape were the same size as the other two objects (Figure 26).

The subjects' choices were coded as correct if they respected shape and ignored material since shape is more relevant to object kind, at least in the case of artifacts. It was predicted that the subjects would do well in the big piece and the little piece conditions in which the incorrect object was shaped as a chunk. It was also predicted that they would do poorly in the double object condition in which the incorrect object was shaped as an artifact.

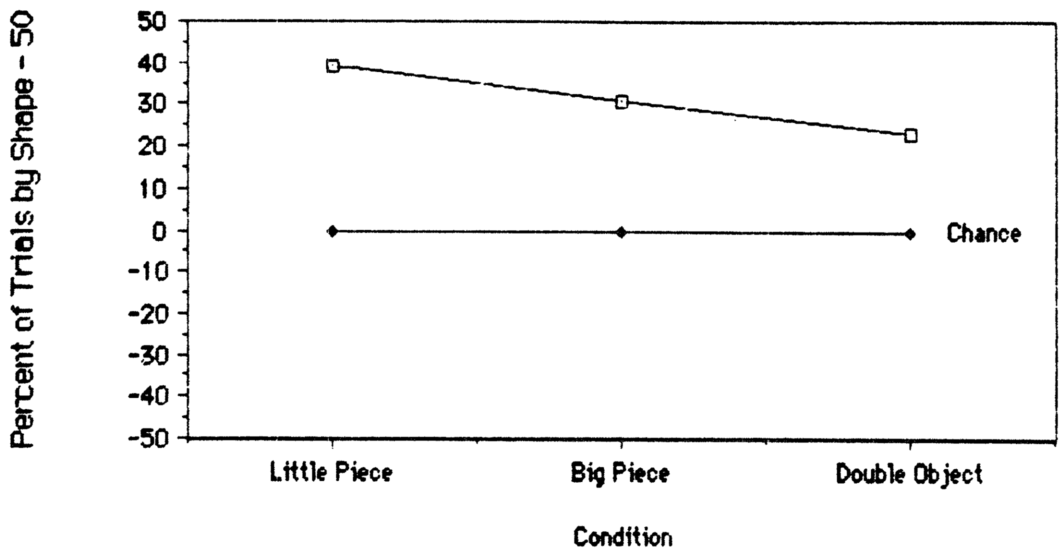
Results

The subjects' performance was 89% correct in the little piece condition, 81% correct in the big piece condition, and 73% correct in the double object condition (Figure 27). Chance is 50%. The subjects' performance in each condition was significantly greater than chance (little piece: $t(23) = 12.25$, $p < .0000002$, 2-tailed; big piece: $t(23) = 6.08$, $p < .000005$, 2-tailed; double object: $t(23) = 4.70$, $p < .001$, 2-tailed).

A one-way anova comparing the conditions revealed a significant main effect ($F(2,46) = 4.488$, $p < .017$). This indicates that the performance on the little piece condition was significantly different from the performance on the double object condition. Subsequent t-tests indicated that the performance on the big piece condition was not significantly different from the performance on the little piece condition ($t(23) = 1.44$, $p > .1$, 2-tailed) or the performance on the double object condition ($t(23) = 1.4$, $p > .1$, 2-tailed).

A 6 X 2 anova was conducted comparing the order of the conditions by the conditions. The only significant effect was the condition main effect, as previously revealed. The order and interaction effects were not significant (order: $F(5,18) = .511$, $p = .765$; interaction: $F(10,36) = 1.446$, $p = .2$).

Figure 27 -- Difference from Chance in the Little Piece, Big Piece and Double Object Conditions



One way anovas were run on each condition to examine item effects. The only significant effect was found for the items in the big piece condition (big piece: $F(3,69) = 6.749$, $p < .0009$; little piece: $F(3,69) = .451$, $p = .717$; double object: $F(3,69) = .657$, $p = .581$). The means for each item, A, B, C, and D, in the big piece condition were 58%, 79%, 92%, and 96%, respectively. A Newman-Keuls test reveals that the main effect was due to a significant difference between the performance on item A and the performance on the other items. There were no other significant differences between the items.

We tested the hypothesis that the subjects did worst on item A because the shapes used were more alike than the shapes of the other items. The materials of item A were aluminum foil (that was pressed into solid shapes) and rubber (that was carved from erasers). The shapes may have been more alike than in the other items because they were confined to the overall dimensions of a large eraser. No similar restrictions were placed on the shapes of the other items. Adults were shown pairs of objects from each item in the big piece condition and were asked to rate their similarity. The scale used was from 1 (very, very similar) to 5 (not similar at all). The adult subjects made comparisons about the similarity of shape ((S1,M1) and (S2,M1) or (S1,M2) and (S2,M2)); the similarity of material ((S1,M1) and (S1,M2) or (S2,M1) and (S2,M2)); and overall similarity ((S1,M1) and (S2,M2) or (S1,M2) and (S2,M1)). Note that there are two pairs of objects that can be compared for each type of similarity. Each subject made both comparisons. The two scores were then averaged for each subject. Twenty-four subjects rated both pairs for all three types of similarity for all 4 items, resulting in 24 comparisons each.

The mean scores for items A, B, C, and D on the shape comparisons were 3.0, 3.08, 3.17, and 3.77, respectively. A planned contrast testing the prediction that the shapes of item A were more alike than the shapes of the other items was significant ($F(1,69) = 11.28$, $p < .002$).[11] The mean scores for the items on the overall comparisons were 4.44, 4.79, 4.60, and 4.9. A planned contrast testing the prediction that the objects of item A were more similar overall than the objects of the other items was also significant ($F(1,69) = 10.223$, $p < .005$). The mean ratings for the material comparisons were 2.17, 2.08, 2,13, and 1.79. The same contrast with respect to material was not significant ($F(1,69) = 1.607$, $p > .2$).[12]

Because the shapes of item A were significantly more similar than the shapes of the other items and because the (child) subjects did significantly worse on that item than the others, the analysis of the differences between the conditions was redone without item A. The mean for the big piece condition was 89% (Figure 28). The main effect for

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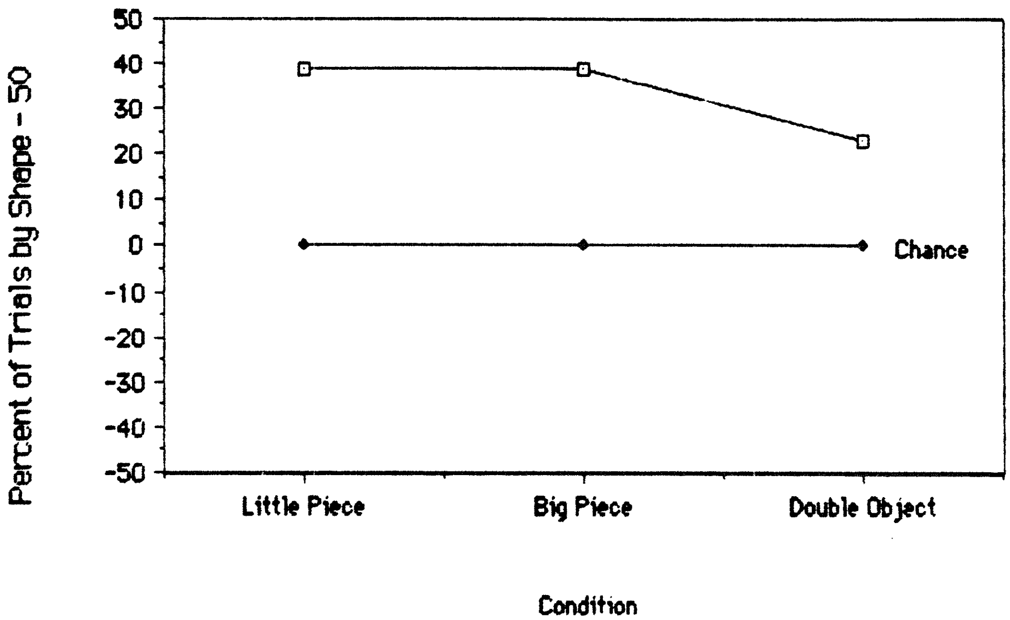
11. It is clear from looking at the means that item D is more different from the other items than is item A. However, we were not concerned with the differences in similarity among items B, C, and D. Rather we were testing the prediction that the shapes of item A were more similar than any others.

12. Note, that in this case item A has the highest score. The contrast, however, drops the sign of the weights in the calculation of the mean square and therefore really tests the prediction that the material (or shape or overall similarity) of item A was more extreme (either similar or different) than the materials (or shapes or overall similarity) of the other items.

Figure 28 -- Difference from Chance in the Little Piece, Big Piece and Double Object Conditions, without Item A in the Big Piece Condition



condition still significant ($F(2,46) = 5.193$, $p = .009$). A preplanned contrast was done to test the prediction that the subjects would do equally well on the little piece condition and the big piece condition; but worse on the double object condition. The contrast was significant ($F(2,46) = 10.015$, $p < .005$).

Other anovas showed that there were no effects of sex, the particular object named, and the order of the objects within a condition (all F's < 1.572, all p's > .226).

In sum, the subjects responded as if shape was more relevant to the meaning of an object word than material in all three conditions. However, certain other properties also affected their inferences. They were more certain of their categorizations when the alternative object was a chunk rather than another artifact. On the other hand, differences in size did not affect their decisions.

Discussion

These results are not completely as predicted. When faced with a new object, 2 1/2-year-olds could determine whether another object of the same shape or another object of the same material was the same kind of object. They must have recognized that shape is more relevant to object kind than material, even in the two artifact condition. This result is contrary to the pilot result with 2 1/2-year-olds using the materials from Experiment 5.

The results also suggest that the subjects recognized a different aspect of object kind. They recognized that an object --as in an artifact, not just any solid thing-- and a chunk of material would not be the same kind of thing. This is clear because they did best in the conditions in which the incorrect object was chunk-like rather than artifact-like.

It could be argued that this result is due to a strategy of selecting the object that had the least number of differing properties with the named object, ignoring the kinds of the properties. In this experiment, the correct choice always differed from the named object by one property, material. Therefore, according to this reasoning, any differences between the tasks must have been due to the relationship between the incorrect object and the named object. The greater the difference between the incorrect object and the named object, the easier the task should have been. In the double object condition the wrong answer differed in shape from the named object; but in the pieces conditions the two objects differed in shape <u>and</u> in "artifact-ness". The children may have been better at the pieces conditions merely because the wrong answers had fewer properties in common with the named object than in the double object condition.

However, there are two reasons why this argument fails. First, in the little piece condition the two objects also differed in terms of size, but the subjects did not do better in this condition than in the big piece condition. Second, the subjects were better than chance in the double object condition even though the two choices each differed from the named object by one property (either shape or material). The subjects could not have been simply counting the number of differing properties in a theoretical vacuum. They must have been relying on a theory of object kind that considers shape and artifact-ness to be relevant to the definition of a kind of object.

GENERAL DISCUSSION

These experiments addressed three questions:

1. Do children use the proposed constraint as part of their solution to the mapping problem?

2. Is the proposed constraint a constraint on word meanings or a cognitive constraint used in all inferences over physical entities?

3. How is "kind of object" defined for children?

I will discuss the data from the experiments as they pertain to each of these questions.

Question 1: Do children use the proposed constraint as part of their solution to the mapping problem?

The constraint has many parts. The first part is that children base their inferences about word meaning on the ontological kind of the referent, at least for the kinds solid object and non-solid substance (examples of non-solid substances are mud and sand). In the first three experiments the subjects' response patterns consistently supported this aspect of the constraint. The basis of their inferences varied depending on the ontological kind of the referent. They based their inferences on the shape, size, and number of the referent when it was solid, ignoring substance and color. In contrast, they based their inferences on the substance and color of the referent when it was non-solid, ignoring shape, size, and number. The replicability of these data across Experiments 1 and 2 are especially significant because the salient perceptual features of the stimuli differed. The complexity of the shapes as a function of stimulus type (object or non-solid substance) was manipulated. In Experiment 1 the objects had more complex shapes, and in Experiment 2 the non-solid substances had more complex shapes. Yet the subjects differentiated the two kinds of stimuli similarly in both experiments.

The next part of the constraint is that children think that when a word is used to refer to an object, it has as a meaning the kind of object. The data from the first three experiments were also consistent with this part of the constraint. In the object trials the children did choose another object of the original object kind. However, as was discussed in Experiment 1, these data are equally consistent with a different interpretation. The subjects may have thought that the meaning of the word was the referent's shape, but only in the case of words that referred to objects.

Although the data from Experiments 1 - 3 do not support one interpretation over the other, the data from Experiments 5 and 6 do. If the subjects thought that the meaning of an object word was the shape of a referent, then they should have done equally well in the naming task of Experiment 5, all three conditions of Experiment 6, and the object trials of Experiments 1 - 3. After all, the shape of the named object was identical to the shape of the correct choice in every case. But the subjects did not do equally well. In Experiment 5 and in the double object condition of Experiment 6 they were better than chance, but they were not near ceiling. In the other conditions of Experiment 6 and in the first three experiments, they were practically at ceiling. Given the "shape" interpretation, this difference in the results is unexplained. However, if the subjects thought that the meaning of an object word was the object kind of a referent, then their performance could have varied depending on the condition. Object kind is not necessarily defined by one property. If shape <u>and other properties</u> define object kind, then their performance could have varied depending on the properties of the test choices in the naming tasks. That is, given the "object kind" interpretation, the difference in performance is explainable. It could be that the subjects knew in each condition that the meaning of the word was object kind But were not always able to determine which two objects were the same kind. That is, it could be that their definition of object kind was not always sufficient for categorization. Therefore, the results of Experiments 1 - 3, 5, and 6, together, support the claim that children infer that object words mean kind of object.[13]

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13. This argument assumes that the subjects found the test choices equally discriminable across the conditions. If the similarity of the shapes of the test choices varied such that the two objects of a pair in the harder conditions were more similar than the two objects of a pair in the easier conditions, then the results of Experiments 5 and 6 would also not differentiate the two interpretations. An experiment I suggest later

The final piece of the constraint is that children think that when a word is used to refer to a non-solid substance, it has as a meaning the kind of substance. The data from Experiments 1 - 3 support this part of the constraint. In the substance trials the subjects chose the substance of the original substance kind.

However, the 2-year-olds were not as good at determining the meaning of non-solid substance words as they were at determining the meaning of object words. And in the first session of the second experiment the uncharacteristically complex shapes of the substances further confused the subjects --even though they could manipulate the substances. The trials in which the substances were in a single complex pile and looked most like an object were especially difficult. On the other hand, there is evidence that the subjects knew non-solid substance words. They were 80% - 83% correct in the familiar trials, and most of their mass nouns were non-solid substance words. There is also evidence that other 2-year-olds know some non-solid substance words. Adam, Sarah, and Eve used many of them at the beginning of their recordings which was at 2;3 for Adam and Sarah and 1;6 for Eve. Allison used them sparingly at 1;6, but more often by 2;2.

A possible explanation for the subjects' relative difficulty with non-solid substance words in the naming task is that they used the proposed constraint but were also affected by a response bias. The subjects demonstrated, in the control condition, that they preferred

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in the discussion could provide more evidence.

reaching for single things over multiple things. This bias would have a detrimental effect on the substance trials relative to the objects trials because it leads to the correct answer in the object trials, but not always in the substance trials. However, it does not explain the subjects' extra difficulty in the first session of the second experiment.

A possible explanation of that additional confusion is that the subjects knew that the meaning of the word was the kind of substance but had not completely determined the defining properties of non-solid substance kind.[14] Non-solid substances have various properties. For example, they are coalescent, they do not have characteristic shapes, they often have smells, certain non-solid substances are sticky or wet, etc. The subjects may have had a definition of non-solid substance kind that was sufficient for the acquisition of some non-solid substance words. However, it may also have been partially incomplete with the effect that when the subjects saw a salient uncharacteristic property on a non-solid substance, they would have been temporarily confused. This explanation can account for the subjects' diminished performance in the first session and their return to normal by the second session.

One way to test this explanation would be to do an experiment using naming tasks, like the ones of Experiment 6. Various properties of non-solid substances could be manipulated to determine which properties

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14. This explanation is analogous to the explanation of the subjects' difficulty in inferring the meaning of object words under certain conditions.

the subjects considered relevant to non-solid substance kind. 2-year-olds could be compared to 2 1/2-year-olds. The 2 1/2-year-olds in Experiment 3 were as good on the substance trials as on the object trials. Data demonstrating that the younger subjects responded, generally, like the older subjects but were more swayed by inappropriate factors would support the proposed explanation of the subjects' difficulty in Experiment 2.

The constraint also has implications for the acquisition of solid substance words (e.g., "wood" and "metal"). It specifies that a word said of a solid object has the object kind as a meaning. Since solid substances are in the form of solid objects, the object part of the constraint inhibits the mapping of words with solid substance kind. The analyses of the spontaneous speech of Adam, Sarah, Eve, and Allison demonstrated that young children do use few solid substance words. However, before this result can be taken as support for the constraint, it has to be shown that this is not due to another factor. It was demonstrated that the frequency of solid substance words in the adult lexicon is not responsible. And it was argued that the frequency of the words used by the mothers to their children, although highly correlated with the children's usage, is also not the reason. However, a critical experiment has not been done. Subjects need to be taught the solid substance words in a situation in which the kind of substance of an object is relevant to the child's interaction with the object. Also, the words need to be given as modifiers, not nouns. If the children do learn solid substance words in that kind of experiment, then their difficulty in their natural environment must be due to a lack of exposure to the appropriate conditions for acquisition. On the other hand, if the subjects still fail to learn the words, then the argument that children cannot learn solid substance words is quite strong. In that case their difficulty would provide even more support for the proposed constraint.

If children do have difficulty learning solid substance words, another question is: do they have a conceptual problem or a linguistic problem? That is, can they make any inferences over solid substances? The results of the weight task demonstrate that young children can make projections over solid substances when asked to make predictions about weight. Therefore, they can represent the concept "metal" or "metal object", for example. Their trouble is in mapping the concept with the word. The constraint supports the mapping of words with kinds of objects and words with kinds of non-solid substances. But, conditional on the results of the experiment suggested above, it inhibits the mapping of words with kinds of solid substances.

Given that children do use the proposed constraint as part of their solution to the mapping problem, we can ask about the relationship between the constraint and count/mass syntax. It could be, as Quine argued, that children are not able to make the ontological distinction until they are making the syntactic distinction. If so, then children's use of the constraint would hinge on their knowledge of count/mass syntax. Once acquired, the syntactic distinction would no longer bear on the constraint. The data from the 2-year-olds in the first two experiments demonstrate that count/mass syntax does not have this role. Subjects who did not yet have the syntactic distinction used the constraint effectively and as well as subjects who did have the distinction. In contrast, the 2 1/2-year-olds in the third experiment did show a correlation between their use of count/mass syntax and their use of the constraint. But, the interpretation of that result is unclear. It does not undermine the fact that 2-year-olds who did not have the syntactic distinction were not prevented from using the constraint.

Another role for count/mass syntax is as an additional constraint on inferences of word meaning. However, the data argue against this role for count/mass syntax as well. Subjects in Experiments 1 - 3 who were given count/mass syntax did no better than subjects who were given nonselective syntax. Gordon (1985) has compared the roles of the two distinctions in order to examine inferences about the syntactic properties of a new word. He also demonstrated the independence of syntax and semantics. Subjects used syntactic properties as the primary source of information for inferences about other syntactic properties. However, he found that semantic information could support syntactic inferences. That conclusion resulted from conditions in which either there were only semantic cues or the semantic cues and the syntactic cues were in conflict. The parallel conditions were not done in these experiments. It is possible that such conditions would demonstrate that syntactic information can support inferences about semantics, as well as the reverse.

Question 2: Is the proposed constraint a constraint on word meanings or a cognitive constraint used in all inferences over physical entities?

Experiment 5 addressed this question. The subjects based inferences about weight on solid substance kind, not object kind. However, the incorrect answer was a single object. It could be that children can only base similarity on material kind when material kind is considered as a property of objects. Or it could be that children can only base inferences on object kind, but sometimes they define object kind by the material of the object. In either case, young children would always think that two single objects were more alike than one of the objects and a collection of pieces of the material of that object, regardless of the kind of inference. If so, then the proposed constraint is a general cognitive constraint.

In order to demonstrate that children can base inferences on material kind and not object kind, it needs to be shown that under some set of circumstances children find pieces of an object and the object as more similar than two objects of the same kind, but different materials. Hilary Schmidt (1987) has this sort of evidence. Subjects were presented with trials similar to the object trials of Experiments 1 - 3. However, the stimuli had smells that corresponded to the materials. The subjects smelled the first object and were asked to predict which of the alternatives would have the same smell. In some trials both alternatives were single objects. In the other trials the same-material alternative was in pieces. The subjects chose the same-material alternative in both cases. In other words, they grouped an object of a certain material with pieces of that material rather than another object of the same kind.

The weight results and Schmidt's results demonstrate that young children can make nonlinguistic inferences based on solid substance kind. However, they do not imply that the proposed constraint is purely linguistic. There could be other nonlinguistic inferences that also depend on this constraint. What is clear is that children have at least two different similarity spaces for objects. Their reason for using the proposed constraint when making inferences about word meaning is not because they only have one way of representing and comparing objects. Rather, it is because the representation of objects used by the proposed constraint is the most appropriate for mapping with words.

Question 3: How is "kind of object" defined for children?

Experiments 1 - 3 and 6, as well as addressing the mapping problem, also address a preceding stage in the process of determining word meanings. When children hear a new word used to refer to an object, before they face the mapping problem, they need to determine the kind of the object. The results of the first three experiments demonstrate that 2-year-olds know that an object and pieces of an object are not the same kind of object, even if they are the same material and the same color. In other words, they know that for something to be a certain kind of object, it must *be an object*.

The data from Experiment 6 further specify which properties children use to define object kind. When children need to sort objects by kind and the only properties available as the basis of their sorting are shape and material, they can use shape as the defining feature. However, the subjects were not as consistent with their classifications as when there were other distinguishing properties. Another factor that the subjects considered relevant was the regularity of the shapes of the objects. Objects with regular shapes tend to be artifacts that are built with a purpose. Objects with irregular shapes tend to be chunks of material that are a result of accidents or by-products of the building of an artifact. The subjects knew that an artifact and a chunk were not the same kind of an object. On the other hand, the subjects did not think that any property that differentiated the objects was a defining feature. They were aware that size did not affect object kind. In sum, the subjects had a concept of object which considered shape and artifact-ness as relevant to the definition of object kind.

It would be useful to have more experimental conditions in which the role of size and artifactness are evaluated. Other properties that may be relevant to object kind could be tested as well, such as the function of objects. Also it is important to have some conditions in which the two objects of the same kind do not have the same shape. If 2-year-olds give the two objects the same name, then that would be the clearest evidence that they do not think that the meaning of a word used to refer to an object is the object's shape.

The acquisition of the mapping between words and meanings would be an impossible task for even a single word without constraints contributed by the learner. Yet, 2-year-olds are experts at learning words. They must have considerable knowledge of language, the world, and their relationship in the form of constraints. In this work I have proposed one constraint and have presented evidence from empirical work and spontaneous speech that supports it. I have also begun to address two related questions. First, how does the constraint fit into the rest of the cognitive system? And second, how do children represent an important prerequisite concept?

By talking with young children, we know that they solve the mapping problem, somehow. In fact, they succeed so easily, it is often difficult to recognize that there is a problem. By doing this sort of investigation, we begin to understand the nature of their very elegant solution.

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Appendix 1

The question of the independence between the trials of the first and second session was only asked for the substance trials. Performance was so good on the object trials that the question is moot.

For each subject a 2 X 2 matrix was set up comparing the response to each trial, X, in the first session with each trial, Y, in the second session.

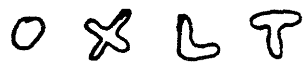
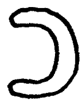
		second session (trial Y) ✓	X
first session (trial X)	✓	a	b
	X	c	d

There were 16 matrices in all. X = Y in four of them and X =/= Y in the remaining 12. Two summary matrices were made. The four 2 X 2's in which X = Y were collapsed to make one and the other 12 were combined to make the other. The former demonstrates the relationship between the response to trial X in the first session and the response to trial Y in the second session when X = Y. The latter shows the same relationship when X =/= Y. a/(a + b) is the probability that given trial X is right in the first session, trial Y will be right in the second session. b/(a + b) is the probability that given trial X is right in the first session, trial Y will be wrong in the second session. c/(c + d) is the probability that given trial X is wrong in the first session, trial Y will be right in the second session. d/(c + d) is the probability that given trial X is wrong in the first session, trial Y will be wrong in the second session. These probabilities can be compared for the two 2 X 2's. The can not be statistically compared, however, because the same information went into each matrix and, therefore, they are not independent. For each probability the difference is .13 or .05 between the two matrices.

		X = Y	X =/= Y	difference
probability that given trial X is right in the first session trial Y will be right in the second session	$\frac{a}{a+b}$	.85	.8	.05
probability that given trial X is right in the first session, trial Y will be wrong in the second session	$\frac{b}{a+b}$	.15	.2	-.05
probability that given trial X is wrong in the first session, trial Y will be right in the second session	$\frac{c}{c+d}$	.42	.55	-.13
probability that given trial X is wrong in the first session, trial Y will be wrong in the second session	$\frac{d}{c+d}$	.58	.45	.13

These differences seem sufficiently small enough to consider the response made to a particular trial in the second session no more dependent on the response made to the same trial in the first session than to the response made to any other trial in the first session. In other words there is no reason to think that the results would be different if new stimuli had been used in the second session.

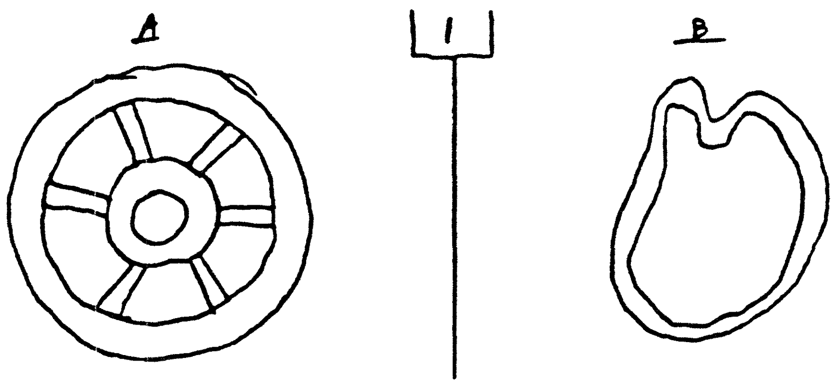
Appendix 2
Shapes of non-solid substances in Experiment 2

	single shape	multiple shapes
Play-doh peanut butter		
Dippity do Nivea		
clay Crazy foam		
orzo coffee		
sawdust leather (in very small pieces)		

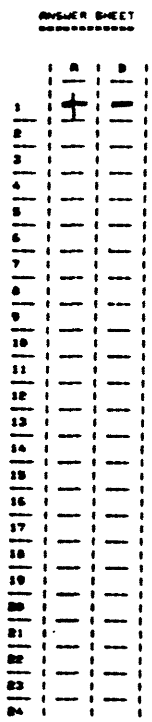
Appendix 3

You are going to be looking at pairs of pictures. The picture on the left is designated as "A". The picture on the right is designated as "B". Compare the pictures in terms of their complexity. On your answer sheet put a plus "+" in the box that corresponds to the picture that you feel is more complex. Put a minus "-" in the box that corresponds to the picture that you feel is less complex.

For example, you could see this:



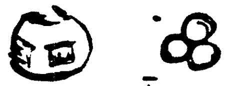
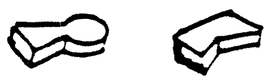
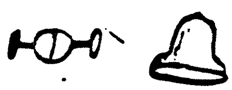
If you consider "A" to be more complicated than "B", then you should mark your answer sheet like this:



If you have any questions, ask me before you continue. Otherwise turn the page to see the first pair of pictures and put your answers on the separate answer sheet. Feel free to take as much time as you need.

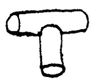
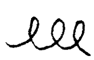
Appendix 4

Stimuli in Experiment 5

Quadruplet#	Objects	Materials
#1		rough styrofoam (white) smooth styrofoam (white)
#2		wood papier mache (grey)
#3		clay green modeling material
#4		wax (brown) sponge (yellow)
#5		sandpaper (black) felt (white)
#6		iron plastic (white)
#7		charcoal plastic (clear)
#8		sculpting material (tan) plaster (white)

Appendix 5

Stimuli in Experiment 6

Item		Objects	Materials
little piece condition			
A		"C" shaped	whipped wax cardboard
B		cootie catcher	foil paper cellophane
C		vegitable peeler	plastic metal
D		pie slicer with ball at handle	sawdust[2] paper mache[1 2]
big piece condition			
A		circle-triangle	erasor aluminum foil
B		odd donut	wax plaster
C		plumbing "T"	copper plastic
D		honey dipper	clear plastic wood
double object condition			
A	 	three spheres solid hat	styrofoam sand[2]
B	 	stick dome	papermache[1] brittle plastic
C	 	coil plate with rudder	modelling grass[2] clay
D	 	odd saddle joined pyramids	couscous[2] dryer lint[2]

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1. The paper mache in the little piece condition was made with strips of paper bags. The paper mache in the double object condition was made with bought shredded material.
2. These materials were glued to or stuck on hardened clay.