Children's use of lexical flexibility to structure new noun categories

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Abstract

Because most common words have multiple meanings, children are often learning *new senses* of existing words, rather than entirely new words. Here, we explore whether children can use their knowledge of an existing word sense to constrain their interpretation of a new word meaning. Across two studies, we teach 3- and 4-year-olds and adults novel words for materials, and manipulate whether those words are also used flexibly, to label objects made from those materials. We find that participants of all ages assign markedly different interpretations to the object labels when they have a prior, material meaning: Rather than extending them to other objects of similar shapes, they extend them on the basis of shared material, thus overriding the well-documented *shape bias*. These findings suggest that language learners can use a word's prior meaning to learn about the structure of its new meaning.

Keywords: polysemy; lexical flexibility; word extension; word learning; shape bias

Introduction

A great deal of evidence in language development suggests that children constrain their guesses about the referents and extensions of new words through a variety of heuristics and biases (Clark, 1990; Markman, 1990). For instance, if children are told that a novel object is called a *dax*, they typically infer that *dax* will also refer to objects that are similarly shaped (Landau, Smith & Jones, 1988). This so-called *shape bias* arises early in acquisition, and is thought to play an important role in lexical development.

Of course, the shape bias is not sufficient for acquiring adult-like meanings for words, since the extension of many words meanings goes beyond shape. A single word can often apply to multiple items that vary in shape, but that share an underlying *essence* (e.g., natural kind terms like *bird*; e.g., Gelman & Markman, 1986), *intended function* (artifact terms like *chair*; e.g., Bloom, 1996), or *substance* (e.g., for mass nouns like *bread*). Consistent with this, in order to develop adult-like meanings for words, children are thought to draw on a variety of different cues – such as animacy, background knowledge, or functional affordances – to override the shape bias, and structure their new word meanings (Booth & Waxman, 2002; Jones & Smith, 1988; Kemler Nelson, 1995).

While previous studies have investigated how children learn the meanings of entirely new words, they have yet to address the fact that many of the new word meanings that children have to acquire are not associated with novel word forms, but instead with word forms they are already familiar with. This is because most words are not unambiguous, but are instead *flexible*: Most common words are polysemous and denote a variety of different senses of meaning (Nerlich, Todd, Herman & Clarke, 2003). The word *glass*, for instance, refers to both a transparent material and a drinking vessel made from that material. This phenomenon, which we refer to as *lexical flexibility*, is common both within languages and across languages. Further, lexical flexibility follows systematic patterns in English and in other languages: Multiple English words, for example, can label materials and objects made from those materials (*glass, tin*, etc.), animals and their meat (*chicken*, *lamb*, etc.), tools and functional uses of those tools (*hammer, saw*, etc.), and more (see Srinivasan & Rabagliati, 2015).

In the present studies, we investigate how children's biases about word meanings interact with lexical flexibility: How does a word's first-acquired meaning influence children's guesses about the extension of new, additional senses of the word? In particular, are additional word senses learned in isolation, or does a word's first meaning bias the application of constraints like the shape bias?

Consistent with the idea that the extension of new word senses is constrained by knowledge of other word senses, many historically-derived senses of words appear to be partially influenced by their historically-primary sense. This can be observed with the word *glass*, whose extended drinking vessel sense is defined by a combination of shape, function and material (and whose meaning thus differs from words like *cup,* which are defined by shape and function alone). Lending support to the idea that children's interpretation of new word senses could be constrained by their understanding of existing, already-learned senses, a recent body of work in language development indicates that even preschool-aged children understand the semantic relations that license lexical flexibility in their language. For example, children expect words to label animals and their meat, but not other thematically-related items (Srinivasan & Snedeker, 2014), and generalize patterns of lexical flexibility to new words (e.g., such that they expect new words to label tools and their functional uses; Srinivasan, Al-Mughairy, Foushee & Barner, 2017).

Given these facts, it seems plausible that if children know one sense of a word, then they might use that knowledge to constrain their guesses about how that word should be extended. This could cause them to override the shape bias in some cases, and extend new word senses according to other criteria. Some preliminary evidence for this idea comes from a study by Yoshida and Smith (2003), who showed that the shape bias was increased if a novel object was labeled with a familiar name that was strongly associated with a characteristic shape (e.g., *ball*), compared to a familiar name that was associated with a substance. However, subjects in this previous study were learning novel exemplars for existing words – as opposed to novel *senses* of existing words – thus leaving open the role of lexical flexibility in structuring new semantic categories.

In the present studies, children and adults were first taught a novel name for a material. They were then presented a novel object made from the same material, and either learned that the object name was the same as the material name (both were called *gup*) or was labeled using a new, distinct word (the material was called *zev* and the object called *gup*). Our studies tested whether this manipulation of lexical flexibility affected participants' guesses about the extension of the object name – e.g., by making them more likely to privilege shared material as basis for extension in the flexibility conditions – using a forced-choice task (Study 1) and a more open-ended sorting task (Study 2).

Experiment 1

Adults and 3- and 4-year-olds participated one of three conditions: In the *flexibility condition*, the novel material and novel object were given the same label, and in the *unambiguous condition* they were given different labels. A final *material vs. object* condition tested whether participants learn distinct material and object senses of a flexible word, or instead a single vague meaning encompassing both objects and materials.

Methods

Participants

This study included 100 3- and 4-year-olds from the Berkeley area (Range: 3;0-4;11; Mean age = 4;0), split roughly evenly among the three conditions. 48 adults were also recruited from the UC Berkeley campus community, with 16 participating in each condition. English was the primary language spoken by all participants. Children were tested in lab, and at local preschools and museums; Adults were tested in lab or at designated locations on the UC campus. Children were given a small gift for participating, and adults were given either course credit or a small gift. 16 additional children participated but were excluded for failing catch trials administered at the end of the task (described below; n=12), parental interference (n=3), or experimenter error (n=1). Three adults were also excluded due to experimenter error. All participants were tested individually by a female experimenter.

Warm-up trials Participants completed three warm-up trials to ensure that they understood the task. The stimuli consisted of three sets of toy animals: two identical animals and one contrasting animal (e.g. two bears and a horse). In each warm-up trial, the experimenter placed one of the duplicate animals on the table, and named it (e.g. "Here is a bear!"), and then placed the remaining two animals and asked the participant to point to the other matching animal (e.g. "I want another bear. Can you point to a bear?").

Test Trials Participants completed four test trials. The trials varied depending on which of the three conditions the participant was in.

The stimuli consisted of four sets of novel objects. Each set included (1) a jar of small pieces of a *novel material* and a wooden spoon, (2) a *standard object* made out of the novel material, (3) a *material-match test object* that was made out the novel material, but was of a different shape than the standard, and (4) a *shape-match test object* that was the same shape as the standard, but was made out of a different material.

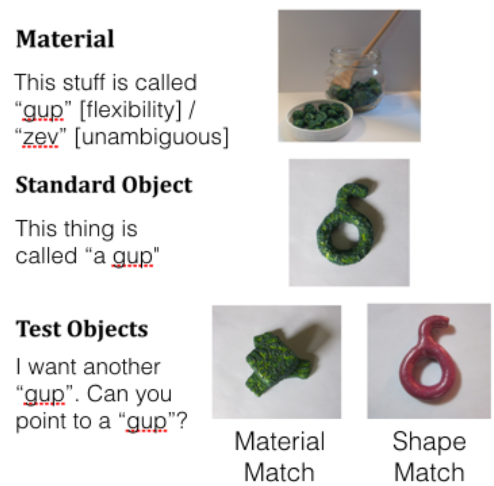

Figure 1: Example test trial from the polysemy and unambiguous conditions of Experiment 1. The novel material and standard object were given the same word in the polysemy condition and different novel words in the unambiguous condition.

In each test trial (Fig. 1), the experimenter brought out a jar of novel material and a wooden spoon. The experimenter labeled the material with a novel word, using mass syntax (e.g. "This stuff is called *gup*. This stuff is called *gup*. I have half a jar of *gup* here.") and then stirred the material with the spoon and scooped some of it out of the jar to emphasize that it was a material. The name given to the material varied depending on the condition: The material was labeled with the same novel word (e.g. *gup*) that was later used to label the standard object in the flexibility condition, and was given a different name (e.g. *zev*) in the uanmbiguous condition (Fig. 1).

Next, the experimenter brought out the *standard object* and named it (e.g. "Now look at this thing! This thing is called a *gup*."), and illustrated that it was an object by using count syntax and attributing a vague function to it ("I have two *gups* and I use them in my garage."). Then, the experimenter brought out the two *test objects* – the *material-*

match object and the *shape-match* object (in the flexibility and unambiguous conditions) – and asked the participant to extend the label for the standard object to one of the two test objects, using count noun syntax ("I want another *gup*. Can you point to a *gup*?"; Fig. 1). We expected that if participants use a prior sense of the word to constrain their interpretation of a new word sense, they should be more likely to override a shape bias–which typically arises when a count noun labels a rigid object (Landau et al., 1988)–and choose the material-match object in the flexibility condition.

The *material vs. object* condition was conducted to test whether participants who learned that the material and object were given the same word (e.g., when both were labeled *gup*) in fact learned two distinct senses of the word (as opposed to a single word that can label both materials and objects). To test this, at test participants were asked to choose between the material-match object and a pile of the material. We reasoned that if subjects had learned a novel object sense of the critical word, they would choose the material-match more often than the pile of material, since the request at test employed count syntax (Can you point to *a gup*?), and thus a request for an individual.

Catch trials Finally, participants completed three *catch trials* at the end of the task to ensure that they had sustained their attention throughout the study. In these trials, the experimenter labeled a novel object with a novel word, and then asked participants to point to which of two subsequent objects could be labeled by the word. One of the choice objects was identical, and the other differed in shape and material. Participants who failed to correctly respond on at least two out of the three catch trials were excluded.

Results

Our results are consistent with the idea that the meaning of one word sense guides children's guesses about subsequent senses. As indicated in Figure 2, children in the flexibility condition extended the name of the standard object to the material-match object (70% of trials; *SE* = 4%), and were more likely to do so than children in the unambiguous condition (27% of trials; *SE* = 4%), as revealed by a linear model ($\beta = -1.86$, $SE = 0.27$, $z = -6.79$, $p < .001$). Thus, while children in the unambiguous condition exhibited the robust shape bias documented in prior work (Landau, Smith, & Jones, 1988), children in the flexibility condition overcame this bias and extended the new word sense according to material, rather than shape.[1] This tendency to select the material-match object could not be explained by a failure to learn distinct senses of the flexible word (i.e., to learn both a material *and* object sense of the word), as children in the material vs. object control condition reliably selected the material-match object over the pile of material on 83% of trials (*SE* = 3%) of the time. This suggests that children understood that the experimenter was requesting an object using the object sense of the novel word at test, as opposed to simply re-using the material word they had first been trained on.

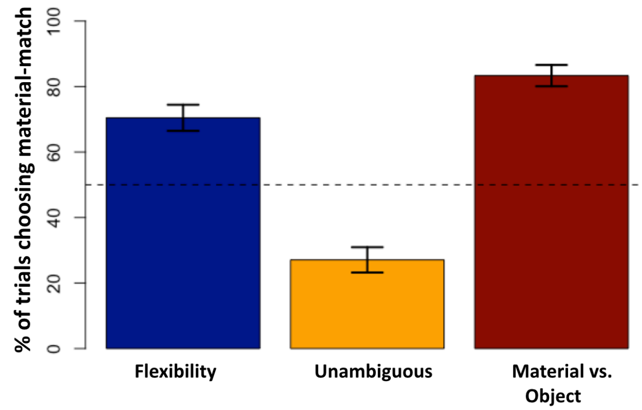

Figure 2: Percentage of trials in Experiment 1 in which children chose the material-match object across conditions. Error bars show +/- 1 SE. Dashed line shows 50% mark.

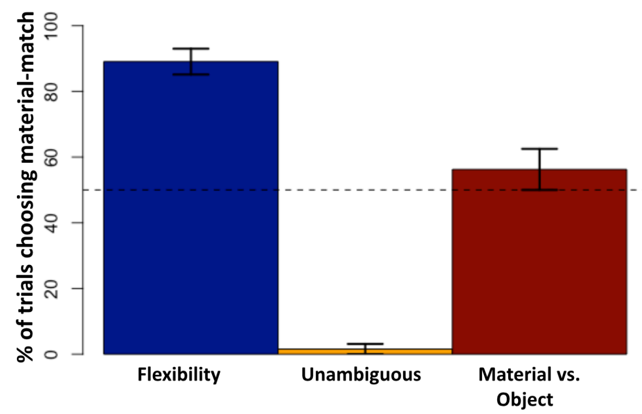

Figure 3: Percentage of trials that adults chose the material-match object across the conditions of Experiment 1. Error bars show +/- 1 SE. Dashed line shows 50% mark.

Adults (Fig. 3) showed a similar pattern of word extension choices to children in the flexibility condition, and extended the name of the standard object to the material-match object on 89% of trials (*SE* = 4%), significantly more than they did in the unambiguous condition (2% of trials, $SE = 2\%$; $\beta = -6.24$, $SE = 1.08$, $z = -5.76$, $p < .001$). Unexpectedly, however, adults did not show the same pattern of choices as children in the material vs. object condition, and only chose the material-match object on 56% of trials (*SE* = 6%). This surprising result leaves open whether adults differentiated between the two senses of the word as clearly as children.

Discussion

Experiment 1 showed that lexical flexibility allows children to override semantic heuristics like the shape bias: When a label for an object had previously also been used to label a material, then children's guesses about the further extension

[1] This model did not detect a significant effect of age, which was treated as a continuous variable ($\beta = 0.03$, $SE = 0.02$, $z = 1.43$, $p = .15$)

of that object label were less reliant on shape, compared to a condition in which different labels were given to the object and material. Importantly, the additional material versus object control condition provided evidence that children did not simply conflate the "object" and "material" senses of this novel word into a single vague meaning: When asked to choose "a *gup*" from an object and a pile of material, children consistently chose the object. Thus suggests that children understood that while one sense of the word *gup* referred to a kind of material, another sense of the word (identified with count syntax) referred to an object. Surprisingly, adults behaved a chance in this condition, and we return to this result in the General Discussion.

What, then, is the status of the shape bias when children learn an additional sense under these conditions? In particular, did the participants believe that shape was entirely irrelevant to the meaning of the second sense, or did they simply privilege material when they were forced to choose between an item that matched in material (but not shape) and an item that matched in shape (but not material)? One possibility left open by the results of Experiment 1 is whether children in the flexibility condition might have chosen to extend the novel label for the object only to other items that matched in *both material and shape*, had they not been forced to choose between a material match and shape match (a limitation of the 2-alternative-forced-choice task used in Experiment 1).

Experiment 2

Here, we employed a more open-ended task, giving participants more choice in how they determined the extension of the newly-learned words. 4-year-olds and adults were taught a label for a novel material and a label for a novel standard object, just as in the flexibility and unambiguous conditions of Experiment 1. Then, participants were shown an array of new objects that varied in shape, material, and size from the standard object, and were asked to classify which of these additional objects could be labeled by the same word as the word for the standard object (Fig. 4). As in Experiment 1, we varied whether the newly-learned object and newly-learned material shared a label. Using this method, we were interested in whether participants in the flexibility condition would restrict word extension to only items of the same shape *and* material as the standard.

Methods

Participants

Participants were recruited from the Berkeley area as described in Experiment 1. Experiment 2 included 32 4-year-olds (Range: 4;0-4;11; Mean age = 4;6), divided evenly between the flexibility and unambiguous conditions. 33 adults also participated (17 in the flexibility condition; 16 in the unambiguous condition). English was the primary language spoken by all participants. Three additional children participated, but were excluded for failing the initial warm-up trials (n=2), or due to parental interference (n=1). All participants were tested individually by a female experimenter either at a children's museum or at designated locations on the UC Berkeley campus.

Materials and procedure

Warm-up trials Participants completed three warm-up trials. Participants who failed on two or more of these trials were excluded. The stimuli consisted of three sets of toy animals. Each set included three animals from a single category and two animals from contrasting categories (e.g. three horses, a cat, and a fish). In each trial, the experimenter brought out a toy animal and told the participant what is was (e.g. "Here is a horse!"). The experimenter then put the animal into a plastic box and told the participant that the box was for the target animals (e.g. horses). The experimenter then placed the animal on the table with the other four animals and asked the participant to sort all of the animals (e.g. horses) into the box and all the animals that were not in that category, into a plastic bowl.

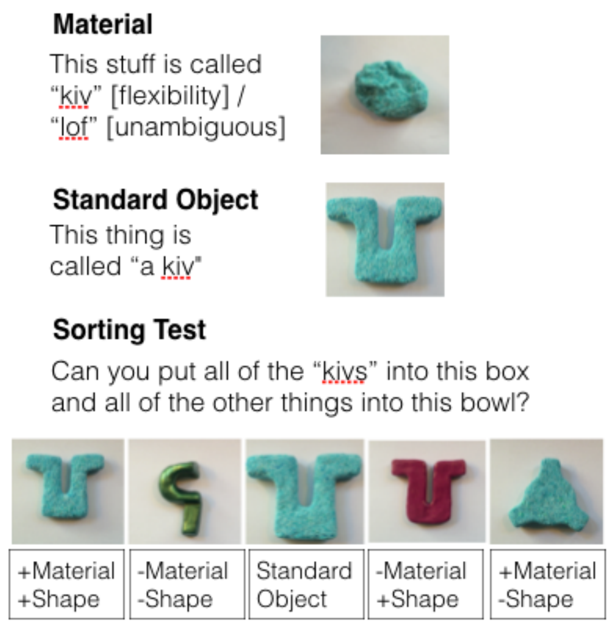

Figure 4: An example test trial from Experiment 2. Participants sorted five objects as belonging to the target category or not. The novel material and standard object either received the same label (flexibility condition) or different labels (unambiguous condition).

Test Trials In each of the four test trials (Fig. 4), participants were first introduced to a novel material (but instead of pieces of a solid material, novel non-solid materials were used). As before, participants were then shown a standard object that was made out of the same novel material. Then, participants were asked to sort a set of five objects (four test objects plus the standard object itself) as either belonging to the target category or not. The four test objects varied in whether they matched the standard object in material and shape. In total, participants were asked to sort: (1) a +Material/-Shape Object that was made out the same material, but was a different shape than the standard, (2) a –Material/+Shape Object that was the same shape as the standard, but was made out of a different material, (3) a +Material/+Shape object that shared the same material and shape as the standard, but was smaller, (4) a –Material/-Shape object that contrasted with the standard in both shape and material, and finally (5) the Standard Object itself.

In each test trial, the experimenter took out a jar of novel material. The experimenter told the participant the material's name (e.g. "This stuff is called *kiv*.") and then stirred the material with the spoon and then scooped and/or stretched the material, and took some material out of the jar (This was to underscore fact that the novel material was indeed a material). The name of the material varied depending on the condition, as before: In the flexibility condition, the material was labeled with the same novel word that was later used to label the standard object, and in the unambiguous condition was given a different name.

Next, the experimenter brought out the standard object and named it, using count syntax (e.g. "This thing is called a *kiv*."). The experimenter then brought out the four test objects and said "Some of these are *kivs* and some are not *kivs*." and then asked the participant "Can you put all of the kivs into this box and all of the other things into this bowl?"

Results

The results from the more open-ended task of Experiment 2 paralleled those of Experiment 1. In particular, participants were more likely to privilege material in their extensions in the flexibility than in the unambiguous condition. Consistent with this, children in the flexibility condition were more likely to sort the +Material/-Shape object (61%, SE = 6%) as a member of the target category than children in the unambiguous condition (14%, SE = 4%; $\beta = -2.25$, SE = 0.44, $z = -5.11$, $p < .001$). In contrast, children in the unambiguous condition were more likely to show a shape bias, and sort the –Material/+Shape object (88%, SE = 4%) as a member of the target category than children in the flexibility condition (38%, SE = 6%; $\beta = 2.46$, SE = 0.46, $z = 5.37$, $p < .001$). Meanwhile, children in both the flexibility and unambiguous conditions almost always sorted the Standard Object (Flexibility: 98%, SE = 2%; Unambiguous: 100%) and +Material/+Shape Object (Flexibility: 98%, SE = 2%; Unambiguous: 100%) as members of the target category, and almost never sorted the –Material/-Shape Object as a category member (Flexibility: 2%, SE = 2%; Unambiguous: 0%).

To examine whether individual children were internally consistent in their sorting, we coded the data in terms of their *categorization strategies.* Strategies were defined using a 75% cut-off: Participants who used the same strategy for 3 or 4 of the test trials were classified as having that categorization strategy, but were otherwise coded as *other*. As indicated in Figure 5, children in the flexibility condition more often sorted objects using a *material-based strategy* (i.e., sorting all three of the objects that matched in material as being part of the target category), than children in the unambiguous condition. In contrast, a *shape-based strategy* (i.e., sorting all three of the objects that matched in shape as part of the target category) was more prevalent in the unambiguous condition.

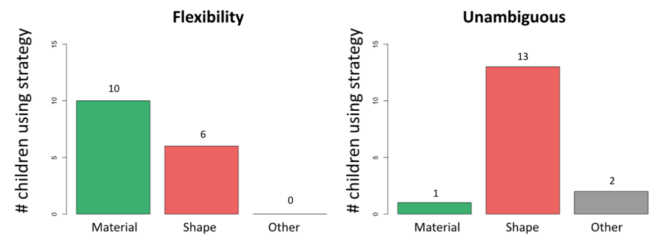

Figure 5: Categorization strategies of children in the flexibility condition (left) and unambiguous condition (right).

Adults showed a similar pattern of choices to children. Participants in the flexibility condition were more likely to sort the +Material/-Shape object (74%, SE = 5%), as a member of the target category than adults in the unambiguous condition (5%, SE = 3%; $\beta = -4.03$, SE = 0.65, $z = -6.19$, $p < .001$). In contrast, adults in the unambiguous condition were more likely to show a shape bias, and sort the –Material/+Shape object (81%, SE = 5%) as a member of the target category than adults in the flexibility condition (19%, SE = 5%; $\beta = 2.91$, SE = 0.44, $z = 6.54$, $p < .001$). No adults in either condition sorted the –Material/-Shape as a member of the target category, and all but one participant sorted the Standard object and +Material/+Shape object as a member of the target category.

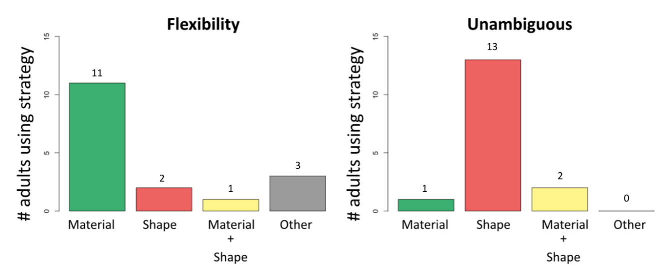

Figure 6: Categorization strategies of adults in the flexibility condition (left) and unambiguous condition (right).

Finally, similar to the children, most adult participants in the flexibility condition sorted objects using a material-based strategy, while most in the unambiguous condition used a shape-based strategy. Only three adults (1 in the flexibility condition, 2 in the unambiguous condition) employed a *material- and shape-based strategy*, constraining the target category to only the standard object and the +Material/+Shape object. Note that this third, more conservative strategy was never used by children.

Discussion

While Experiment 1 showed how lexical flexibility can reduce reliance on the shape bias, Experiment 2 explored the nature of that reduction. We found that, in the presence of lexical flexibility, both children and adults tended to extend new meanings based on a single feature – material – rather than through a combination of multiple features, such as shape and material (only 1 out of 16 adults in the flexibility condition used the shape & material strategy), even though the task of Experiment 2 was open-ended enough to allow this strategy to emerge.

This reliance on material when extending the object labels in some ways conflicts with how flexible material words are used in languages. For instance, although the object senses of words like *glass* and *tin* are defined partially by material (a wooden box is not a "tin"), they label specific kinds of objects that are defined by shape and function (not all artifacts made of tin can be called "tins"). One reason that children and adults in the flexibility condition may not have used shape in their strategies is because we did not provide specific information about the functions of the standard objects; Such information could constrain hypotheses about the likely shapes – and functional affordances – of kind members (Kemler Nelson, 1995).

General Discussion

How do children make inferences about the structure of new lexical categories? Guided by the fact that most common words are polysemous, our studies explored whether children's understanding of one meaning of a word would affect how they interpreted a subsequent meaning for that word. Two experiments demonstrated that, after children and adults learned that a substance name could also be used to label an object, they were less likely to extend that name according to shape, and instead privileged material.

These findings are consistent with a recent proposal (Srinivasan & Rabagliati, 2015) that lexical flexibility plays an important functional role in language development, in facilitating the acquisition of the lexicon. By this account, it may be more difficult for children to learn an unambiguous lexicon in which each meaning has its own word, compared to one in which words label multiple meanings in predictable ways. Consistent with this idea, the present studies show that children's knowledge of an initial word sense can facilitate their learning of a second word sense.

Our findings also raise a host of interesting questions for future research. Some questions concern the precise meanings that children learned in our task. For instance, when children learned that *gup* could label both a material and an object, did they actually learn separate and conventionalized senses? Or did they simply realize that it was possible to "coerce" the meaning of *gup* from a material sense to a portioned object sense (cf. ordering *two coffees*, Frisson & Frazier, 2005). Experiment 2 provides some evidence for the latter account, as children (and adults) were willing to extend the newly learned object name to any other object made of the material, regardless of its shape. This might also help make sense of why adults were at chance in choosing between the material-match object and pile of material in Experiment 1: Adults may have thought that the flexible "object" label could apply to any individual made of the material, and may have been more flexible than children in construing a pile of material as an individual.

Although we have only explored our hypothesis in the context of materials and objects, our results hold implications for how lexical flexibility might shape conceptual development more broadly. While prior research has focused on how children use labels as 'invitations' to group items into common categories, our findings show that children understand that labels can pick out items from distinct, but related categories. In particular, by attending to lexical flexibility, children could use naming practices to draw inductive inferences about the structure of the world. For instance, just as *hammers* are used for *hammering* and *shovels* for *shoveling* children could reason that something called a *dax* that supports *daxing* is probably designed for that function, and that all *daxes* should support this function.

Acknowledgments

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