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Interactions between mutual exclusivity and lexical contrast in word learning

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I certify that I have read this thesis and that it is fully adequate to receive departmental honors in Symbolic Systems.

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Abstract

These studies examined how children use lexical contrast and mutual exclusivity to learn a new word. Previous research suggests that children are unable to use lexical contrast, in which a known word is contrasted with a new word in the same domain to help specify the domain of the new word: “That’s not green, it’s mauve.” Children hearing such phrases often mistakenly believe that “mauve” refers to an object’s shape or material rather than to its color. Only *corrective contrast* helps children to learn a color word, by using their own label for the new color in the contrast phrase: “That’s not [child’s label], that’s mauve.” We propose that children’s use of contrast is governed by mutual exclusivity, which prevents them from accepting two labels for a single property of an object. When children hear lexical contrast, they are unwilling to accept a second label for an object’s color because they believe they already know such a label. Only corrective contrast explicitly allows them to override this constraint and learn a new color label. Additionally, children who have a label for the object’s shape should exhibit a *shape familiarity effect*; they should be unwilling to accept a second label for an already-labeled shape and thus should learn a color term more readily. Experiment 1 tests these claims by teaching a new color word to a group of four-year-olds (n=72) in several conditions, each of which provided varying levels of information from corrective contrast and mutual exclusivity. Experiment 2 extended the results of Experiment 1 by examining the limits of the shape familiarity effect. We replicated earlier findings of children’s use of contrast and mutual exclusivity, as well as showing that children use either corrective contrast or the shape familiarity effect, not both, in learning a new color word.

Interactions between mutual exclusivity and lexical contrast in word learning

When children learn words, they acquire meanings for terms they hear in context. Often, children quickly and accurately eliminate certain incorrect hypotheses about a new word's meaning and "zoom in" on its correct meaning. In doing so, children must take into account a wide variety of linguistic and non-linguistic cues, including background assumptions about the world and their previous knowledge of other words (cf. Woodward and Markman, 1998). The current study aims to illuminate how children learn a new word by successfully applying multiple word-learning strategies and aspects of their previous knowledge to a single learning situation.

One source of information that may be helpful to children learning words is *lexical contrast*, which enables a listener to infer the meaning of a new word when it is contrasted with a known word (Carey and Bartlett, 1978). For example, on hearing, "this isn't red, it's chromium," a listener should be able to interpret "chromium" as a color term because it was contrasted with "red." Listeners should understand that the words used in the contrastive phrase are in the same lexical domain, the domain of color words.

Evidence from Carey and Bartlett (1978) suggested that young children can use lexical contrast to acquire at least the partial meaning of a new word. In this study, three-year-olds were taught a new color term using a contrastive phrase. Each participant saw two trays on the far side of a classroom. These trays were identical except for their color; one was red and the other was olive green. During the experiment's teaching phase, the child's teacher indicated the trays and said, "Bring me the chromium one. Not the red one, the chromium one." The new word, "chromium," is contrasted with a known color word, which should indicate to the child that the new word is also a color word. Children were later tested to assess whether they correctly mapped "chromium" to the color olive green. During the tests, children were asked to name the color of an olive-green swatch, to choose a chromium object out of an array of colored objects, and to tell whether "chromium" is a color word. Results indicated that children successfully learned this new color word, as indicated by comparing their performance with that of a control group on the same tests. Learning of this new word was fairly robust, with children showing evidence of remembering the meaning of "chromium" seven to 10 days after a single initial exposure to the word.

This study appeared to provide evidence that children can use lexical contrast to infer that a new word is in the same domain as a known word. However, later studies have shown that this word-learning situation is not as simple as Carey and Bartlett concluded. Recall that in the teaching procedure, children saw two trays that were identical on every dimension except color. Because of this, Heibeck and Markman (1987) argued that the *non-linguistic* cues from the situation strongly indicated that the new color was the appropriate referent of the new word. These researchers claimed that, since the two trays differed only in color, children's attention was drawn to color as a salient aspect of the objects. In other words, Carey and Bartlett may have obtained the same results even if children were not using information from lexical contrast to learn the new word in their task.

Heibeck and Markman (1987) provided evidence that the non-linguistic aspects of the situation were indeed driving Carey and Bartlett's (1978) results. In the Heibeck and Markman (1987) study, children aged two through four were introduced to a new color term in two different conditions. In both conditions, children saw two known objects that differed only in color. One of the objects was a familiar color, such as blue, and the other was an unfamiliar non-focal color, such as beige. In the experimental condition, which used the same procedure as Carey and Bartlett, the experimenter asked the children to "get the beige one, not the blue one." In the control condition, the experimenter asked children to "get the beige one, not the other one." This control condition did not provide any explicit linguistic contrast, so children could rely only on the implicit contrast between the objects to deduce the meaning of the new word. The researchers found no difference between these two conditions; both the experimental subjects and the control subjects correctly learned that "beige" referred to the object's color. Several other studies (Au, 1990; Au and Markman, 1987; Dockrell, 1981; Dockrell and Campbell, 1986) have also indicated that children ignore linguistic contrast and use non-linguistic aspects of the situation to succeed at learning a new color word. These findings run counter to Carey and Bartlett's claims that children find lexical contrast helpful in learning a new word.

A second worry about the Carey and Bartlett study is that the olive color that they used was so salient to children that 35% of the control subjects chose olive green as the referent of "chromium," without having had any prior experience with the color or the word. Because of this, later studies used multiple colors in their tasks to avoid any such item effect. Unlike Carey and Bartlett, Heibeck and Markman (1987) taught several different novel colors to avoid the problem of having a single salient item carry their learning effect. They also used the same procedure to teach novel shape and texture terms, providing converging evidence that non-linguistic cues, not lexical contrast, helped children succeed in the Carey and Bartlett study.

In both Carey and Bartlett (1978) and in Heibeck and Markman (1987), the linguistic and non-linguistic information converged on a single hypothesis for the meaning of the new word. There is additional evidence that, when non-linguistic information is unavailable, children tend to ignore potentially useful information about the new word's meaning provided by lexical contrast. Au and Markman (1987) used a single object in their study, for example, a colored rattan square, so that the children would not have access to any non-linguistic contrast. These researchers theorized that children might be more likely to use lexical contrast in this case, when they could not rely on non-linguistic information to assign a meaning to the new word. They taught a new color word to three- and four-year-olds by asking the children to "get the mauve square," and then saying, "see, this is not red, and this is not green, this is mauve." Despite this helpful contrastive information, children were more likely to interpret "mauve" as a *material* term than as a color term. Au and Markman compared performance of children in this condition to performance of children in a control condition, who heard only the teaching phrase without the contrastive information: "see, this is mauve." There were no significant differences between children's interpretations of "mauve" in these two conditions. Children who heard explicit lexical contrast were equally likely to interpret the new word as a material term as children who heard no contrast. This provides further evidence that children fail to use lexical contrast to help them learn a new word.

These studies show that children's access to lexical contrast in word-learning situations is more complicated than Carey and Bartlett's initial analysis suggested. Children seem to base their hypotheses about new words on non-linguistic contrastive information. When such non-linguistic information was unavailable, they fail to use lexical contrast to help them correctly interpret the new word as a color term. This is a surprising result, since it suggests that children hearing "this isn't green, it's mauve" cannot use the well-known word "green" as a clue that color is an important dimension. Children seem to ignore this contrast information entirely.

Although children are unable to make use of lexical contrast in some situations, there is evidence that lexical contrast can sometimes be informative to children. One might think that one word used in the contrast phrase is as good as another, and that children will perform in the same way regardless of which familiar word they hear contrasted with the new term. However, subtle differences in the familiar word do matter to children; they will succeed or fail in the learning task depending on which familiar word is used.

Au and Laframboise (1990) distinguished three different types of lexical contrast: referential, semantic, and corrective. The teaching phrase used in the Carey and Bartlett (1978) study is an example of *referential contrast*, in which two terms of the same semantic domain are contrasted with the purpose of referring to or identifying an object: "the X one, not the Y one." *Semantic contrast* works in a similar way, involving a sentence of the form “it’s not X, it’s Y,” as used in Au and Markman (1987). Semantic contrast can only be used when a single object is present, unlike referential contrast, which involves a reference to two objects. *Corrective contrast* differs from these other two forms in that one of the terms used in the contrast phrase is the addressee’s label. A speaker would use a corrective phrase to indicate that the addressee’s term is wrong. For example, a child might mislabel a tiger as a cat, and an adult conversant could use corrective contrast to say, “That’s not a cat. That’s a tiger.”

The evidence discussed earlier has shown that young children do not understand or cannot make use of referential or semantic contrast. There is evidence, however, that children understand corrective contrast (Chapman, Leonard and Mervis, 1986; Au, 1990; Clark and Wong, 2002). Most relevant to the current study is work by Au and Laframboise (1990), which showed that three-, four-, and five-year-olds are able to make use of corrective contrast in the domain of color words. In a warm-up task, the experimenters elicited children’s own labels for the target color. They then taught a new color word by using corrective contrast; they contrasted the child’s own label for the color with the new word, for example, “it’s not purple [or whatever label the child provided], it’s mauve.” In this condition, children successfully learned that “mauve” was a color term. Au and Laframboise also ran conditions using semantic contrast and no contrast as a comparison. In their One Random Label condition, children heard the teaching phrase, “it’s not green, it’s mauve.” These children were unlikely to interpret “mauve” as a color term, preferring to interpret it as a shape term. Performance of children in this condition did not differ from that of children in a No Contrast control condition, in which no contrastive information was provided ("it's mauve"). The results from these two conditions replicate the findings of the Au and Markman (1987) study, in which children seeing a single object also ignored potentially useful information provided by semantic contrast.

Au and Laframboise offered several explanations for why children use corrective contrast more successfully than semantic or referential contrast in learning a new color word. They speculated that corrective contrast might be more pragmatically sensible, since a speaker has no reason to contrast a new term with a random term. They also suggested that the children in their task believed that they already had a name for the object's color. Children were therefore unwilling to accept a second label for this color, unless they heard explicit information that their color label was incorrect. Only corrective contrast provided them with such explicit information, which helped them to understand the new word more readily.

In other words, children's behavior in the Au and Laframboise study was consistent with the *mutual exclusivity constraint* (Markman, 1987; Markman and Wachtel, 1988; Markman, 1989; Markman, 1990). This constraint states that one should not accept a second label for an object or a property that already has a label. A similar constraint with a slightly different formulation is the principle of contrast (Clark, 1988; Clark, 1990), which states that all words contrast in meaning along some dimension, and children should therefore assume that every word applies to only one possible concept. These constraints help children to learn property terms for known objects. Essentially, they apply when children already have a name for the whole object and then hear a new word applied to the object. In this situation, they know that the new word cannot apply to the whole object because the whole object already has a name. They look for an as-yet-unnamed part or a property of the object to which they can apply the new word. To demonstrate children's usage of mutual exclusivity, Markman and Wachtel (1988, study 6) showed children a familiar object, such as a cup, or an unfamiliar object, such as a pair of tongs. They introduced a new term to the children while indicating the object: "See this? It's chrome." Children in who saw the cup interpreted "chrome" as a material term, and children who saw the tongs interpreted "chrome" as a label for the entire object.

Given this word-learning constraint as an explanatory tool, we can look at the lexical contrast findings in a new light. The underlying mechanism for lexical contrast seems to be a form of mutual exclusivity, which prevents children from accepting a second label for a single aspect of an object. For example, a child seeing a mauve-colored object could think, "that's purple." When the adult gives them semantic contrast information, "that's not green, it's mauve," the child might go through the following thought process:

I know that this object is not green; I thought it was purple.

Therefore, the information that this object is not green does not help me.

I need to figure out what "mauve" means.

By application of mutual exclusivity, "mauve" cannot be a color term because I already have a term for this object's color, namely, purple.

So mauve must refer to some other aspect of the object for which I do not yet have a name, such as its shape or material.

However, when the new word is contrasted with the child's own term for the object, as in corrective contrast, the thought process looks quite different. The adult says, "that's not purple, it's mauve," and the child thinks:

I thought that the object was purple.

She is telling me that it is not purple.

By application of mutual exclusivity, that color cannot have more than one name.

My label for this object's color is therefore incorrect.

This object's color is mauve.

Thus, by following mutual exclusivity, children are able to process contrastive information when it is a direct correction of their terms, and not otherwise. Most likely, children do not actually make this deduction consciously, but these processes provide a useful way to think about how they might settle on a meaning for "mauve."

This word-learning constraint also helps to explain children's performance in Au and Laframboise (1990) and Au and Markman (1987), in which children who heard semantic contrast interpreted the new term as referring to the object's shape or material, respectively. In the Au and Laframboise (1990) study, children were taught the new color term by seeing a novel shape: a trapezoid, crescent, or oval. These children believed that they already had a name for the object's color, so mutual exclusivity or the principle of contrast discouraged them from accepting a new label for this color. However, these children did not have a name for the shapes, so mutual exclusivity did not interfere with a shape interpretation for the new word. Au and Laframboise showed that children hearing semantic contrast, in which the new word is contrasted with a random color label, interpreted the new word as a shape term. But using corrective contrast, contrasting the novel color word with the child's own label for the color, significantly boosted the number of color interpretations for the new word. In this situation, corrective contrast gave the children explicit feedback that their label for the color was incorrect. This feedback enabled them to overcome the mutual exclusivity constraint and accept a new label for an already-labeled color.

Suppose, however, that the shapes used in such a task were familiar rather than unfamiliar. Now, according to mutual exclusivity, children should resist interpreting the new word as a shape term as well, because they already have a label for the object's shape. In the Au and Markman (1987) study, children learned the new word by seeing a square, a shape with which they were familiar and for which they had a name. Because children already had a name for this shape, they would not accept a second label for it, eliminating the hypothesis that the new word referred to the object's shape. Additionally, these children already had a term for the object's color and would reject a second label for the color, as described above. The only option left to these children was to interpret the new word as a term for the object's yet-unlabeled material, which is exactly what they did. Work by Hall (Hall, 1991; Hall, Waxman, and Hurwitz, 1993) has also demonstrated that children use the familiarity of an object to constrain their theorizing about a new word applied to that object.

Mutual exclusivity or the principle of contrast can therefore account for the puzzling findings of earlier studies: why children can use corrective contrast but not semantic contrast, and how children used non-linguistic aspects of the testing objects to draw incorrect conclusions about the meaning of the new words. As discussed above, corrective contrast incorporates both contrast and mutual exclusivity into a single phrase, using contrast to preempt a child's own label for the color. Semantic contrast does not accomplish this preemption, which forces children to apply mutual exclusivity to the object itself in assigning a meaning to the new word. Children's subtle and complex use of these two sources of information provides a good arena for studying how they weigh and integrate different sources of information when learning a new word. By examining word-learning situations such as these, we can extend our knowledge about why children find certain types of contrast more useful than other types, and which aspects of the non-linguistic information children find most useful in interpreting a new word.

In particular, we do not know how or to what extent children can integrate information from these two cues in any single word-learning situation. Au's previous work (Au and Markman, 1987; Au and Laframboise, 1990) has indicated to a certain extent what happens when children have access to helpful information from both corrective contrast and mutual exclusivity. Neither of these studies were complete tests of this interaction, however. Au and Markman (1987) used only familiar shapes as their stimuli, and Au and Laframboise (1990) used only novel shapes.

Our study was designed to incorporate these findings into a single study, by fully crossing the possible types of contrast with both familiar and unfamiliar shapes. We predicted that children would learn the new color word most successfully when they hear their own label contrasted with the new word and when the shape they see is familiar to them. Corrective contrast will help children to understand that the new word refers to a color, as shown by Au and Laframboise (1990). Mutual exclusivity will prevent children from interpreting the new word as a shape term when they see familiar shapes, as in Au and Markman (1987). Children should have the most trouble learning a color word when there is no lexical contrast and when the contrast uses a random color word, following the results of previous studies. They should also have difficulty interpreting the new word as a color term when the shape is unfamiliar because shape is a viable alternate interpretation for the novel word in this condition. This study extends our knowledge about how children integrate the mutual exclusivity constraint and lexical contrast to correctly infer the meaning of a new word.

Methods

Design

In this study, we used a modified version of Au and Laframboise's (1990) procedure to probe children's performance when presented with these two word-learning cues. We gave children information about a new word in six different conditions. These six conditions came from a 2 x 3 design, crossing shape familiarity (familiar vs. unfamiliar) with types of lexical contrast (corrective, semantic, and none).

We used two different types of shapes in this study, Familiar and Unfamiliar. In the Familiar conditions, children already knew the shapes' names. We predicted that they would be more likely to interpret the new word as a color term in these conditions, since a shape interpretation would be unavailable to them. In the Unfamiliar conditions, we predicted that children would be more likely to apply the new term to the object's shape. These Unfamiliar Shape conditions were a direct replication of the Au and Laframboise study. We fully crossed these shape types with three types of contrast: corrective contrast (which we call Child's Own Contrast), semantic contrast (Random Contrast), and No Contrast. We predicted that children would be more likely to correctly interpret the new word as a color term in the Child's Own Contrast conditions than in the conditions using the other two types of contrast.

Some of our conditions pit predictions about the new word's meaning from mutual exclusivity against those from contrast. For example, in the Unfamiliar Shape/ Random Contrast condition, mutual exclusivity encourages children to interpret the new word as a shape term, while contrast indicates that the new word refers to a color. In other conditions, specifically those that use corrective contrast, mutual exclusivity and contrast work together to indicate a meaning for the new word.

After a warm-up phase, in which children were probed for their knowledge about their target shape, color, and material, we presented the new term in a contrastive phrase (this isn't X, it's Y). We then used three tests to assess the child's interpretation of the new term: a generalization array, a co-hyponym task, and a color-identification task. The first two of these tasks were repeated for a total of five tests per child.

Participants

Seventy-two four-year-olds (mean age 4;5, range 4;0 to 4;11) participated in the study. There were 37 females and 35 males, all attending a university-affiliated preschool. All children were tested in quiet rooms at the preschool, separate from their own classrooms.

Stimulus Materials

In this procedure, we taught three novel colors, which we labeled "mauve" (purple/red), "celadon" (green/yellow), and "infantry" (blue/gray). Each target color appeared on each of four shapes, two familiar to children this age and two unfamiliar. The familiar shapes were a triangle and a square, and the unfamiliar shapes were a hexagon and a trapezoid. Each child saw only one of the 12 possible target objects. All targets were about cut out of high-quality artboard and painted.

In addition to the targets, we made a series of other objects to use in the tests and in he warm-ups, which will be described below with the relevant test. See the Appendix for a full list of all study materials.

Procedure

There were six conditions: Familiar Shape/Child's Own Contrast, Familiar Shape/ Random Contrast, Familiar Shape/No Contrast, Unfamiliar Shape/Child's Own Contrast, Unfamiliar Shape/Random Contrast, and Unfamiliar Shape/No Contrast. There were twelve children in each condition, approximately counterbalanced for gender and age. Target color and target shape were also counterbalanced across conditions.

A researcher invited children out of their preschool classrooms individually to "play a game" in another room. Once seated at opposite sides of a small table, the researcher administered a warm-up test, a teaching procedure for the new color, and a series of tests to determine how the child extended the new word.

An example will help to illustrate the procedure more clearly. We examine a child in the Unfamiliar Shape/Child's Own Contrast condition who learned the word "mauve" and whose target shape was a hexagon.

Warm-up

First, there was a brief warm-up to assess the child's knowledge of the target material, shape, and color. The warm-up was designed to elicit children's own labels for their target colors to use in the contrast phrase. In our example, the researcher showed the child a mauve artboard circle and asked, "What color is this?"; a white artboard hexagon and asked "What shape is this?"; and a white jagged-cut piece artboard and asked, "What kind of stuff is this? What is this made out of?" The order of these warm-up questions was counterbalanced across subjects.

Teaching

Then the researcher showed the child the target object: a mauve artboard hexagon. Because this child is in the Child's Own Contrast condition, the researcher taught the word by saying, "See this? This is mauve. It's not purple [or whatever label the child gave in the warm-up], it's mauve. Can you say mauve? Very good. See, it's not purple, it's mauve." The child was given an opportunity to handle the object for a moment.

Immediately following teaching, children participated in three types of tests: a generalization task, a co-hyponym task, and a color-identification task.

Generalization Array Task

First, children saw a generalization array, which consisted of four objects on a tray. These objects were (1) the target which the child learned on, (2) a color-associate, an object that was the same color as the target but a different shape and material, (3) a shape-associate, which was the same shape as the target, but a different color and material, and (4) a material associate, which was the same material as the target, but a different color and shape. For the child in our example, the array could consist of the mauve artboard hexagon (target), a mauve plastic square (color-associate), a yellow plastic hexagon (shape-associate) and a brown artboard circle (material-associate). The researcher asked, "Can you find a mauve one here?" If the child found one, by pointing to it or handing it to the researcher, she prompted, "Can you find another mauve one?" This questioning continued until the child denied that there were any mauve ones. The array was then cleared from the table. By analyzing which objects children picked, we can determine what they think the new word means. For example, a child who picked only the target and the color-associate would be credited with interpreting the new word as a color term.

Co-hyponym Task

The second test began immediately after the first test ended. This test was a co-hyponym task, designed to probe to which aspect of an object the new word refers. Children saw a single object in this task, a wooden circle painted either orange or black, so that it differed from the target on the relevant dimensions of color, shape, and material. The researcher asked, "Is this mauve?" If the child incorrectly answered "yes," the object was removed and the next test was administered. If the child correctly answered "no," the researcher probed, "It isn't mauve because it's…" using a rising intonation to signal that the child should complete the sentence. Children who completed the sentence with a color word would indicate that they thought the new word referred to a color. If the child in our example responded by saying, “a circle,” this child would be credited with thinking that “mauve” was a shape term.

Children then saw a second generalization array consisting of entirely new objects with the exception of the target, and then a second co-hyponym task with a wooden circle of a different color than the first.

Color-Identification Task

After these repetitions of the tests, children saw a color-identification task. This consisted of an array with three corduroy pentagons, each painted one of the target colors. These objects matched the target object only in color, not in shape or material. The researcher asked, “Can you find a mauve one here?” This test examined if the child could identify his target color. In the case of children who interpreted the new word as a shape term or a material term, they should deny that there were any mauve objects in the array.

The order of objects in the generalization arrays and the identification array, which objects appeared in which array, and which co-hyponym object was seen first was counterbalanced across subjects. The order of tests did not vary, so that each child always saw the first generalization array, then a co-hyponym task, then a second array, then a second co-hyponym task, and finally the color-identification task. We decided to administer the arrays and the co-hyponym task twice to see how robust children’s interpretations were and if they would remain constant across probes with different objects. We administered the identification task only once and after the other tests because it “gave away the answer,” so to speak. The identification-array objects had only the color in common with the target, and we reasoned that this could bias the children towards thinking that the new word labeled a color.

Each child learned only one new word. Each session was videotaped and lasted from five to 10 minutes.

Results

In this study, we taught each child a new color word in one of six conditions, each of which combined a shape type (Familiar or Unfamiliar) with a type of contrast (Child's Own, Random, or None). We predicted that children would be more likely to learn the color word in the Familiar Shape conditions compared to the Unfamiliar Shape conditions, because in these conditions mutual exclusivity would block a shape interpretation of the new word. We also expected to replicate Au and Laframboise's (1990) finding that children are more likely to learn a color word in the Child's Own Contrast conditions compared to conditions using the other two types of contrast. We expected that children who both saw a familiar shape and heard Child's Own Contrast would perform better than children who only had access to one of these cues. Children who saw neither of these cues, as in the Unfamiliar Shape/Random Contrast and Unfamiliar Shape/No Contrast conditions, should be the least likely to interpret the new word as a color term.

Color interpretations

Each participant saw five tests: two generalization arrays, two co-hyponym tasks, and one color-identification array. In order to be counted as having a color interpretation for the new word in the generalization arrays, children had to choose only their target object and its color-associate. In the co-hyponym task, children had to respond to the prompt, "It's not [color] because it's…" with the color of the co-hyponym object. In the identification array, children had to pick only the swatch corresponding to their target color. To obtain an overall score for each child, we examined each test to see whether the child's response conformed to our criteria for a correct color response. If so, the child received a score of 1 for that test, 0 otherwise. Each child thus obtained a total score ranging from 0 (no color responses on any test) to 5 (color responses on every test). The average scores per child in each condition are shown in Table 1 and Figure 1.

There were no differences in performance by gender as revealed by a 2 x 3 x 2 (shape type x contrast type x gender) ANOVA, $F(1, 60) = 0.19$, $p > 0.10$.

To test for age differences, we split the data into a group of younger children (age 4;0 to 4;5, n=39, mean age = 4;3) and a group of older children (age 4;6 to 4;11, n=33, mean age = 4;8), and we ran a 2 x 3 x 2 (shape type x contrast type x age) ANOVA. This test revealed no main effect of age, $F(1, 60) = 2.31$, $p > 0.10$.

There was a significant main effect of color label, which will be discussed later.

The total scores were analyzed by a 3 x 2 (contrast type x shape familiarity) ANOVA. This analysis revealed a significant main effect of shape familiarity, $F(1, 66) = 4.62$, $p < 0.05$, with children in the Familiar Shape conditions giving more color responses ($M=2.22$, $SD=2.34$) than children in the Unfamiliar Shape conditions ($M=1.31$, $SD=1.83$). As predicted, children interpret the new word in a way that is consistent with mutual exclusivity. Those children who saw a familiar shape rejected the hypothesis that the new word could refer to this object's shape, making them more likely to think that the word referred to color.

The 3 x 2 ANOVA also revealed a main effect of contrast type, $F(2, 66) = 11.0$, $p < 0.001$. Children in the Child's Own Contrast conditions gave significantly more color responses (M=3.12, SD=1.94) than children in the Random Contrast conditions (M=1.42, SD=2.08), $t(46) = 2.94$, $p < 0.01$. Additionally, children in the Child's Own Contrast conditions gave significantly more color responses than children in the No Contrast conditions (M=0.75, SD=1.70), $t(46) = 4.51$, $p < 0.001$. There was no significant difference in color responses between children in the Random Contrast and No Contrast conditions, $t(46) = -1.21$, $p > 0.10$. This result replicated Au and Laframboise's (1990) finding about children's use of lexical contrast: children hearing their own term contrasted with the novel term gave more color responses than children who heard a random label contrast or no contrast.

We also found a significant interaction between shape familiarity and contrast type in the 3 x 2 ANOVA: $F(2, 66) = 3.29$, $p < 0.05$. This indicates that our prediction that two cues would have an additive effect was incorrect; there is no additive interaction between these cues. Instead, we found that the type of contrast matters only when the shape is unfamiliar. In the Unfamiliar Shape conditions, children have the possibility of interpreting the new word as a shape term, since this interpretation is not blocked by mutual exclusivity. Children who see unfamiliar shapes and who hear Child's Own Contrast, but not the other two types of contrast, are able to correctly interpret the new word as a color term. When the shape is familiar, mutual exclusivity interferes with the possibility of interpreting the new word as referring to the object's shape, so children focus on a color interpretation regardless of what type of contrast they hear. For these children, the Child's Own Contrast does not help them further towards a color interpretation. It seems that children are using either the familiarity of the shape or corrective (Child's Own) contrast to succeed at this task.

This analysis is borne out by follow-up t-tests, which revealed no significant difference among the color interpretations of children in the Familiar Shape conditions who heard different types of contrast. Children who saw a familiar shape performed at the same level regardless of what type of contrast they heard (all p's > 0.10). There was a significant difference between the Familiar Shape/Random Contrast condition and the Unfamiliar Shape/Random Contrast condition, and a marginally significant difference between the Familiar Shape/No Contrast condition and the Unfamiliar Shape/No Contrast condition (all p's < 0.10). In other words, when the contrast was unhelpful in interpreting the new word, children who saw familiar shapes performed better than those who saw unfamiliar shapes did.

There was no difference between children's color interpretations in the Familiar Shape/Child's Own Contrast condition and the Unfamiliar Shape/Child's Own Contrast condition: $t(22)= -0.73$, $p > 0.10$. This is a further indication that children used only shape familiarity or Child's Own Contrast, not the co-occurrence of these, to interpret the new word. Children in both of these conditions were most likely using the helpful information in the contrast phrase to drive their interpretations.

We did find significant differences between children who saw an unfamiliar shape depending on contrast; those who heard Child's Own Contrast performed significantly better than those hearing Random Contrast or No Contrast (both p's < 0.001). These results support our prediction that those children who have access to neither of the two cues perform most poorly at learning a color word.

Our analyses revealed a significant main effect of color label, $F(2, 54) = 6.24$, $p < 0.01$, as shown by a 2 x 3 x 3 (shape type x contrast type x color label) ANOVA. Follow-up t-tests showed that children who learned the word "mauve" were significantly more likely to give a color-name interpretation than those who learned "celadon" or "infantry." There was also a significant interaction between shape type and color label, $F(2, 54) = 3.21$, $p < 0.05$. Children in the Familiar Shape conditions who learned the word "mauve" were significantly more likely to give color interpretations than children who learned "celadon" ($t(22) = -3.0$, $p < 0.01$) or "infantry" ($t(22) = -3.1$, $p < 0.01$). However, this pattern was limited to the Familiar Shape conditions and did not hold true for the Unfamiliar Shape conditions. There was no significant interaction between contrast type and color ($F(4, 54) = 0.35$, $p > 0.10$), and there was no three-way interaction ($F(4, 54) = 0.61$, $p > 0.10$). We have no ready explanation for this pattern of results.

In sum, children interpreted the new words as referring to a color only in certain conditions: when they heard their own label as a contrast, and when they saw a familiar shape, although this was especially true for those children learning "mauve." Having access to both of these cues did not improve performance; children seemed to base their interpretations on one or the other of these cues.

Those children who did not interpret the new word as a color term had the option of interpreting the new word as referring to a shape. We used the same method for determining color interpretations to analyze whether children interpreted the new word as a shape term.

Shape interpretations

Children were counted as having a shape interpretation if they chose their target and the shape-associate in the generalization arrays; if they responded to the co-hyponym prompt by saying “it’s a circle” or “it’s round;” and if they denied that there were any [target word] objects in the identification array. As with the color interpretations, each child received a score from 0 (no shape-interpretations on any task) to 5 (shape-interpretations on all tasks).

We predicted that children would be more likely to interpret the new word as a shape term in the Unfamiliar Shape conditions than in the Familiar Shape conditions. When children did not have a label for their shape, mutual exclusivity did not interfere with interpreting the new word as a shape term. We also predicted that there would be more shape interpretations in the Random and No Contrast conditions, because children in the Child’s Own Contrast conditions would interpret the word as a color term.

A 3 x 2 (contrast type x shape familiarity) ANOVA on the total shape interpretations supports both of these predictions. We found a significant main effect of shape type, $F(1, 66) = 5.63$, $p < 0.05$, with children in the Unfamiliar Shape conditions giving significantly more shape responses ($M=2.28$, $SD=1.92$) than children in the Familiar Shape conditions ($M=1.25$, $SD=2.10$). This supports our hypothesis that children obey the mutual exclusivity constraint. Those children who already had a name for their shape were less likely to interpret the new word as a shape label than those who did not know the name of their shape.

The ANOVA also revealed a main effect of contrast type, $F(2, 66) = 6.57$, $p < 0.01$. Children in the Child's Own Contrast conditions gave significantly fewer shape responses ($M=0.67$, $SD=1.46$) than children in the Random Contrast conditions ($M=2.46$, $SD=2.06$, $t(46) = -3.47$, $p < 0.01$) and children in the No Contrast conditions ($M=2.17$, $SD=2.20$, $t(46) = -2.78$, $p < 0.01$). There was no difference between performance in the Random and No Contrast conditions $t(46) = -0.47$, $p > 0.10$. Thus, children who heard a random label contrast or no contrast were significantly more likely to interpret their word as a shape term than children who heard their own label in the contrast.

There was a marginally significant interaction between shape type and contrast type, $F(2, 66) = 2.50$, $p < 0.10$. This indicates that children who heard Child's Own Contrast tended not to interpret their new word as a shape term, regardless of whether the shape is familiar or unfamiliar. Children who heard the other two types of contrast, however, tended to rely on shape familiarity to assign a meaning to the new word. Those children who saw an unfamiliar shape tended to interpret the new word as a shape term, while those who saw a familiar shape tended to interpret the new word as a color term, as discussed above.

A 2 x 3 x 2 (shape type x contrast type x age) ANOVA showed no effects of gender on children's shape interpretations, $F(1, 60) = 2.86$, $p > 0.10$.

We also found no significant main effect of age, $F(1, 60) = 2.01$, $p > .10$, as revealed by a 2 x 3 x 2 (shape type x contrast type x age) ANOVA. However, we did find a significant three-way interaction between shape type, contrast type, and age: $F(2, 60) = 3.51$, $p < 0.05$. This interaction suggests that the two age groups use different strategies to apply a shape interpretation to the new word. To determine this, we performed separate 2 x 3 (shape type x contrast type) ANOVAs on the shape responses of the younger and the older group. For the younger children, the ANOVA showed no significant main effects of shape type ($F(1, 33) = 1.82$, $p > 0.10$) or of contrast type ($F(2, 33) = 2.50$, $p > 0.05$). However, the younger children did show a significant interaction between these two variables ($F(2, 33) = 4.59$, $p < 0.05$). This suggests that neither the information from shape familiarity nor the contrast information is sufficient for the younger children to attach a shape interpretation to the new word. These children need to integrate information from both sources in order to interpret the word as a shape term. The ANOVA on the older children's data showed no significant main effect of shape type ($F(1, 27) = 2.77$, $p > 0.10$) and no significant interaction ($F(2, 27) = 0.91$, $p > 0.10$). For the older children, there was only a significant main effect of contrast type ($F(2, 27) = 4.05$, $p < 0.05$). This suggests that older children tend to use only the information present in the contrast phrase to interpret the new word as a shape term.

As predicted, therefore, children's shape interpretation data shows that they are more likely to interpret a word as a shape term if the shape is unfamiliar and if the contrastive information is not helpful, as in the Unfamiliar Shape/Random Contrast and Unfamiliar Shape/No Contrast conditions. When the shape is familiar or when they hear a Child's Own Contrast, children correctly interpret the new word as referring to color, not to shape. This data is a mirror image of children's color interpretations; in the conditions where children are unable to interpret the new label as referring to a color, they tend to apply the new term to their object's shape. The shape interpretation data also reveals what may be an interesting developmental trajectory: younger children seem to need both cues when making a shape interpretation, while older children can rely only on contrast in their interpretations.

Material Interpretations

In addition to color and shape, children could also interpret the new word as referring to material. We did not expect many material interpretations, since all of the target objects were made of cardboard. Because most children had a label for this material, we reasoned that children would be unwilling to accept a second label for the material, following mutual exclusivity. Indeed, only two children gave material responses to all five tests, and only five children gave any material responses at all. The majority of these material responses were from children in the Familiar Shape/Random Contrast and the Familiar Shape/No Contrast conditions. In these conditions, children were not able to interpret the new word as a shape term, since the target shape already had a name. Some children may have been reluctant to interpret the new word as a color term, since they believed they already had a name for the object's color. The only possible interpretation left to these children would be a material interpretation. Due to the extremely small number of total material interpretations relative to the number of color and shape interpretations, we did not perform further analyses on this data.

Consistency

It is important to note that a child might have an inconsistent interpretation of the new word, giving a color interpretation in some tasks and a shape interpretation in others. For example, a child might have a score of 2 for color and 3 for shape, indicating that this child gave a color interpretation for two of the tests and a shape interpretation for the other three tests. We wanted to determine whether children were interpreting the new word consistently, and in which conditions they were doing so. Since there were five tests, we counted children giving 4 or 5 color responses as having a consistent color interpretation, and children giving 0 to 3 color responses as being inconsistent. We then split these scores by condition and used a chi-squared test to determine in which conditions children were giving the most consistent answers (see Table 2).

In the Child's Own Contrast conditions, there was no difference in consistency if children saw a familiar or unfamiliar shape. Both when the shape was familiar and when the shape was unfamiliar, six children were consistent and six were inconsistent. That is, children were equally likely to be consistent when they heard their own label in the contrast, no matter the shape type. In the Random Contrast conditions, children were significantly more likely to have a consistent color interpretation if they saw a familiar shape than if they saw an unfamiliar shape, $\chi^2(1) = 8.00$, $p < 0.01$. When the shape was familiar, six children were consistent and six were inconsistent. However, when the shape was unfamiliar, no child qualified as consistent; all 12 children in this condition were inconsistent. We obtained similar results from the No Contrast conditions, although these were only marginally significant, $\chi^2 (1) = 3.43$, $p < 0.10$. When the shape was familiar, three children were consistent and nine children were inconsistent. When the shape was unfamiliar, all 12 children were inconsistent and no child was consistent. These consistency measures provide converging evidence that children can use only Child's Own Contrast information to interpret the new word as a color term, not the other two types of contrast. When such useful contrast is not available, they then rely on information from shape familiarity.

Discussion

In this study, we examined children's use of lexical contrast and mutual exclusivity in a word-learning task, as well as the interaction between these cues. Studying such interactions provides a reply to the Carey and Bartlett (1978) study, which claimed that children could successfully use lexical contrast to learn a new color word. Later studies, such as Heibeck and Markman (1987) and Au and Markman (1987), showed that children's use of contrast is more complex than the original Carey and Bartlett finding suggested. According to these later studies, children successfully learn a color word only when non-linguistic information is available to guide them. Otherwise, children are unable to make use of lexical contrast. Instead, they posit meanings for the new words that do not overlap with labels they already know, consistent with predictions from mutual exclusivity. Work by Au and Laframboise (1990) showed that children could successfully use corrective contrast, but not semantic contrast, to narrow down the meaning of a new word. When such helpful contrast was absent, children in their study failed to learn that the new word was a color term. These previous studies showed to a certain extent how children integrate contrast and mutual exclusivity, but the current study is the first to provide a complete test of the interactions between these two cues, integrating and extending these previous findings.

These previous studies showed that children can use only a single type of contrast, corrective or Child's Own contrast, in learning a new color word. Our results replicated these findings; children consistently interpreted the new word as a color term when they heard their own label contrasted with the new label. Children's use of corrective contrast in this way was our most robust finding, holding constant across age, gender, and item.

When children heard a random label contrast or no contrast at all, they tended to rely on information from the object's shape to help them arrive at a meaning for the new word. Their hypotheses about the new word's meaning depended on the familiarity of the shape they saw, consistent with the predictions from mutual exclusivity. If children obey mutual exclusivity in their theorizing about a new word, they should be unwilling to accept a second label for a familiar shape. Thus, when children see a familiar shape and hear a new word, they should be more likely to interpret the new word as a color term. Conversely, when children see an unfamiliar shape, they should be more likely to interpret the new word as a shape term, since a shape interpretation is not blocked by mutual exclusivity in this condition. We found, as predicted, that children do use mutual exclusivity to constrain their hypotheses about the meanings of words. Children gave more color interpretations when the shape was familiar and more shape interpretations when the shape was unfamiliar. This finding integrates the results from Au and Markman, (1987) and Au and Laframboise (1990), which used only familiar shapes and only unfamiliar shapes, respectively.

This shape familiarity effect was not quite as clear-cut as our results from contrast, however. This effect seemed to be carried more by those children learning “mauve,” and it did not appear as reliably with children learning the other two color words. We do not have a ready explanation for this effect. “Mauve” has only one syllable, while “celadon” and “infantry” each have three syllables; the simpler term might have been easier for children to learn. In support of this point, the vast majority of the color labels children know at this age are monosyllabic (red, green, blue, etc.) or disyllabic (orange, purple), and almost none are trisyllabic. Additionally, color label was conflated with the color of the object; children might have been more willing to accept a new term for the red-purple color for some reason, rather than for yellow-green or gray-blue. Because children’s performance with “mauve” was different than with the other two colors, we should hesitate before generalizing the shape familiarity effect. However, for those children who learned “mauve,” shape familiarity did have a marked effect.

The main goal of this study was to explicate the nature of the interaction between lexical contrast and mutual exclusivity in a single word-learning situation. We found that these interact in a very specific way; contrary to our expectations, their effects are not additive. Children seem to use only one or these other of these sources of information when they assign a meaning to the new word, that is, their performance is not improved by having both cues available. Either they use the familiarity of the shape to block a shape interpretation for the word and apply a color meaning, or they use Child’s Own Contrast to reject their previous label for the object’s color and accept the new color label. It is possible that, once they have processed information from one of these sources and made their decision about how to interpret the new word, converging evidence from a second source does not help them further.

Another possibility for this lack of an additive effect is that children in all conditions believe that they already have a label for the object's color, and are thus unwilling to accept a second label. Those children who hear Child's Own Contrast have explicit information with helps them to overcome this unwillingness, and they do so to an equal extent regardless of shape familiarity. Those children who hear Random Contrast or No Contrast have no further information about how to interpret the new word, so they must then rely on shape familiarity to aid their interpretations. We discuss this possibility further in the General Discussion.

Experiment 1 painted a fuller picture of how children integrate multiple sources of information as they learn words. This study also showed in detail how children use mutual exclusivity to constrain their theorizing about the meaning of a new word. When they know the name of the shape they see, they tend to reject the hypothesis that the new word refers to the object's shape. When the shape they see is unknown, they tend to apply the new term to the shape. In this study, shapes were familiar in virtue of children's previous knowledge; children knew the names of these shapes before their participation. This is one possible way to block a shape interpretation for the new word. Another way to block a shape interpretation might be to learn the name of the shape over the course of the study. Since mutual exclusivity does not allow a child to accept two labels for a single aspect of an object, providing children with a name for the object's shape should make them less likely to interpret the new word as a shape term. We predict that children with access to this information will behave like the children in our Familiar Shape condition, interpreting the new label as a color term by using the shape label to block a shape interpretation for the new term.

In Experiment 2, we test this hypothesis by presenting children with a label for an unfamiliar shape concurrently with information about a color to see if children would treat a recently labeled shape as though it was familiar. We decided to use only Random Contrast in this study because children perform at ceiling when hearing their own labels in the contrast. Aside from changes to the teaching phrase, the rest of the design was the same as for Experiment 1.

Experiment 2

In this study, we taught children a new color word in two conditions: No Shape Name and With Shape Name. In both conditions, children saw an unfamiliar shape. From Experiment 1 we know that, in the absence of any other information, children would treat a label applied to this object as a shape term. This is what we expected to happen the No Shape Name condition of Experiment 2, which was an exact replication of the Unfamiliar Shape/Random Contrast condition of Experiment 1. In the With Shape Name condition, we presented a label for the object's shape concurrently with the contrast phrase that contained the new color term: "See this hexagon? This hexagon is mauve." We expected that children would be able to use the information in these sentences to understand that we were providing them with both the name of the object and a property term for the object. Children in this condition should therefore treat the shape as familiar and apply the property term to the object's color. We thus expected children's performance in this condition to parallel their performance in the Familiar Shape/Random Contrast condition from Experiment 1, where children successfully learned that the new word referred to the object's color.

This is something of a counterintuitive prediction, that hearing two novel words in succession will facilitate children's learning rather than hindering or confusing them. However, work by Markman and Wachtel (1988, Study 3) shows that children can benefit from hearing two novel words over the course of a very brief session. These researchers taught children new words in two conditions, Familiarization and Unfamiliar. In the Familiarization condition, they showed children a picture of an unfamiliar object, such as a lung, and briefly taught a label for the whole object. They then provided children with a second label referring to the same object, such as "trachea." These children tended to correctly interpret "trachea" as referring to a part of the lung, rather than to the whole object. In contrast, children in the Unfamiliar condition received no training on the word for the whole object, and they tended to interpret "trachea" as referring to the whole object. This indicates that children in the Familiarization condition used the object label they had just learned to block a whole-object interpretation for the new word. This study provides evidence that children can very rapidly integrate recently learned information to constrain their theorizing about a new word, which is exactly what we predict children will do in Experiment 2. However, Markman and Wachtel (1988) gave children more extended and more explicit training on the new word than we do, making our task more difficult than theirs.

Methods

Participants

Twenty-four four-year-olds (mean age 4;6, range 4;0 to 4;11) participated in this study. Half were female. All children attended the same university-affiliated preschool as the participants in the first study, but no child participated in both studies.

Stimulus Materials and Procedure

The materials were the same as those used for Experiment 1. We taught the same three novel labels, "mauve," "celadon," and "infantry," using the two unfamiliar shapes from Experiment 1, hexagons and trapezoids.

There were two conditions in this study, With Shape Name and No Shape. There were twelve children in each condition, approximately counterbalanced for age and gender. The warm-up and testing procedures were exactly the same for this study as for Experiment 1. The only difference between the two studies was in the teaching phrases.

In the With Shape Name condition, children were presented with the name of their shape concurrently with the contrast phrase, for example: "See this hexagon? This hexagon is mauve. It's not green; this hexagon is mauve. Can you say 'mauve'? Very good. See, it's not green; this hexagon in mauve."

In the No Shape Name condition, a replication of the Unfamiliar Shape/Random Contrast condition from Experiment 1, children heard only the contrast phrase without any information about the shape's name: "See this? This is mauve. It's not green, it's mauve. Can you say 'mauve'? Very good. See, it's not green, it's mauve."

As in Experiment 1, each child learned only one new word. The sessions were videotaped, and each lasted for about five to 10 minutes.

Results

Color Interpretations

In this study, we taught children a new color word in two conditions. We predicted that children in the With Shape Name condition would successfully interpret the new word as a color term by using the presentation of the shape name to block a shape interpretation for the new word, as did children in the Familiar Shape/Random Contrast condition of Experiment 1. We predicted that children in the No Shape Name condition would fail to interpret the new word as a color term, interpreting it instead as a shape term, following the results of the Unfamiliar Shape/Random Contrast condition of Experiment 1.

We scored children's performance in the same way as in Experiment 1. Each participant received a score from 0 (no color interpretations) to 5 (color interpretations on all five tests). See Table 3 and Figure 2 for the average score per child for each condition.

We found no effects of gender, as revealed by a 2 x 2 (gender x condition) ANOVA, $F(1, 20) = 1.84$, $p > 0.10$. There were also no effects of age. To determine this, we split the data into a younger group (age 4;0 to 4;5, n=12, mean age = 4;3) and an older group (age 4;6 to 4;11, n=12, mean age = 4;9), and ran a 2 x 2 (age x condition) ANOVA. This test revealed no main effect of age, $F(1, 20) = 1.88$, $p > 0.10$.

We found that children in the With Shape Name condition gave significantly more color interpretations ($M=1.67$, $SD=2.19$) than children in the No Shape Name condition

($M=0.25$, $SD=0.87$), $t(22) = 2.08$, $p < 0.05$. This indicates that, as predicted, children were able to make use of the shape label information in the teaching phrase to successfully interpret the new word as referring to the object's color.

However, there was a large variance for children's scores in the With Shape Name condition. This indicates that children were not consistently giving color responses, and that they may have been confused in their interpretations of the new word. To determine this, we examined children's consistency in this task in the same way as in Experiment 1: children giving 4 or 5 color responses were scored as consistent in their color interpretation, and children giving 0 to 3 color responses were inconsistent (see Table 4). This analysis showed that only three children were consistent in their color responses. All of these children were in the With Shape Name condition; no child in the No Shape Name condition gave consistent color responses. The remaining nine children in the With Shape Name condition and all 12 children in the No Shape Name condition were inconsistent in their responses in this task. A chi-squared analysis of these scores revealed a marginally significant difference between children's consistency by condition, $\chi^2(1) = 3.43$, $p < 0.10$.

A closer look at the total scores reveals that only a single child gave any color responses at all in the No Shape Name condition. The other 11 children in the No Shape Name condition gave no color responses whatsoever. In the With Shape Name condition, by contrast, six children gave at least one color response, and the other six gave no color responses. (See Table 5) We performed a chi-squared analysis on these scores, revealing a significant difference by condition: $\chi^2(1) = 5.04$, $p < 0.05$. This is a further indication that the shape label information was helpful to children in interpreting the new word as a color term, and that children who did not hear the shape were extremely unlikely to interpret the new word as a color term.

As in Experiment 1, we found a significant interaction between color label and condition, as revealed by a 3 x 2 (color label x condition) ANOVA, $F(2, 18) = 4.68$, $p < 0.05$. This suggests that children learning certain colors were more likely to interpret their new word as a color term. In this study, only children learning “mauve” and “celadon” correctly gave color responses in the With Shape Name condition, and only children learning “infantry” incorrectly gave color responses in the No Shape Name condition. We do not have a ready explanation for why children’s responses seem to be affected by which color they learn or why their differential performance with these colors might vary by study.

In sum, these results verified our prediction that children in the With Shape Name condition would be more successful at learning the new color word than children in the No Shape Name condition. Children in the With Shape Name condition heard a novel shape term and a novel property term concurrently, and they were able to use the novel shape name to block a shape-name interpretation for the property term. These children correctly interpreted the new property term as a color term. Children in the No Shape Name condition, who did not hear such shape-label information, almost never interpreted the new word as a color term.

Shape Interpretations

We expected children to interpret the new word as a shape term in the No Shape Name condition, but not in the With Shape Name condition. To determine whether this was the case, we coded the data to reflect children's shape interpretations, as in Experiment 1.

We found no effect of gender ($F(1, 20) = 0.19$, $p > 0.10$) or age ($F(1, 20) = 0.22$, $p > 0.10$) on children's shape responses.

We found no significant differences between children's shape responses in the two conditions, $t(22) = -1.0$, $p > 0.10$. This indicates that, contrary to our prediction, children were equally likely to interpret the new word as a shape term regardless of condition. That is, many children in the With Shape Name condition did not use the provided shape-label information to help them interpret the new word as a color term. This finding emphasizes how difficult this task was, verifying that children in the With Shape Name condition may have been confused about how to interpret the new word.

Cross-study comparisons

We expected children's performance in the With Shape Name condition to mirror children's performance in the Familiar Shape/Random Contrast condition of Experiment 1. We predicted that providing a shape label would lead children to treat their target shape as familiar. Looking at the average scores shows that children's performance in Experiment 2 seems to be worse than their performance in the comparable Experiment 1 condition. The average number of color responses per child in Experiment 2 was 1.67, compared to an average of 2.42 in Experiment 1. However, a t-test on these scores revealed no significant difference between children's performance in these two conditions, $t(22) = -0.78$, $p > 0.10$. This indicates that a recently presented shape label is just as helpful to children as an already-known label in learning a color term. These two conditions were also not significantly different in terms of shape interpretations, $t(22) = -0.89$, $p > 0.10$. Children in the With Shape Name condition gave an average of 1.58 shape interpretations, compared to 1.67 in the Familiar Shape/Random Contrast condition.

We also expected children's performance in the No Shape Name condition to replicate our findings with the Unfamiliar Shape/Random Contrast condition of Experiment 1, because these two conditions were identical. As predicted, performance in these two conditions was not significantly different, $t(22) = -0.53$, $p > 0.10$. Children in Experiment 2 gave an average of 0.25 color interpretations, compared to 0.42 color interpretations in Experiment 1. Children's shape interpretations were also very similar in these two conditions, with 2.50 shape interpretations on average in the No Shape Name condition and 3.25 in the Unfamiliar Shape/Random Contrast condition. This difference was not significant, $t(22) = -0.97$, $p > 0.10$.

Discussion

This study examined the effect of providing children with a shape label concurrently with a property term. We expected that children who heard the shape label would treat their shape as familiar and successfully interpret the new word as a color term, following the results of the Familiar Shape/Random Contrast condition in Experiment 1. This is indeed what we found; children gave significantly more color responses in the With Shape Name condition than in the No Shape Name condition. Children in the No Shape Name condition tended to interpret the new word as a shape term, replicating the findings of Experiment 1's Unfamiliar Shape/Random Contrast condition. It is particularly telling that only a single child in the No Shape Name condition gave any color responses at all, confirming our prediction that only children in the With Shape Name condition would attach a color interpretation to the new word. These data confirm our counterintuitive hypothesis that children hearing two novel words could learn one of these words more successfully than those children who hear only a single new word could.

Comparisons between this study and Experiment 1 show that children's performance in the With Shape Name condition did not differ from their performance in the parallel condition from Experiment 1, the Familiar Shape/Random Contrast condition. This is further proof of the utility of hearing a shape label concurrently with a color term, showing that a recently introduced shape label is enough to make the object as familiar as the previously known shapes in Experiment 1 were.

Despite children's success at learning color in the With Shape Name condition, we found no difference between children's shape responses in the two conditions; children in both conditions were equally likely to interpret the new word as a shape term. This indicates that, although some children were able to make use of the shape label information to interpret the new word as a color term, not every child could. Additionally, children's color interpretations were inconsistent, with only three children giving consistent color responses to the tests.

These findings indicate that giving color interpretations in the With Shape Name was difficult for children. They needed to sort out form class information to determine which of the two new words referred to the object and which referred to a property of the object. Once they had done so, they needed to attach a meaning to the property term. As we have seen, some children successfully interpreted the word as a color term, while others thought it referred to the object's shape. Although interpreting the word as a color term was the correct answer, applying a shape name interpretation is certainly plausible in this situation. Children may have thought that our teaching phrase, "this hexagon is mauve," was providing them with an object label and a term for the object's shape, as does the phrase, "this circle is round." Since this is a valid way to interpret our teaching phrase, children had no way to determine whether the new adjective referred to shape or to color. This explains why some children thought the new word was a color term and others thought it was a shape term.

General Discussion

In these two studies, we examined children's use of mutual exclusivity and lexical contrast in word learning, and how children integrate these two cues in a single word-learning situation. This study completes a series of responses to Carey and Bartlett (1978), which claimed that children could use lexical contrast to learn a new color word. Later studies (Heibeck and Markman, 1987; Au and Markman, 1987; Au and Laframboise, 1990) showed that children's use of contrast is far more complex than Carey and Bartlett suggested. Taken together, these studies show that children's theorizing about a new word depends on what kind of contrast they hear and what kind of object they see. Children tend to interpret a new word in a way that is consistent with mutual exclusivity or the principle of contrast, preferring to apply the new term to an unnamed property of an object rather than accepting a second label for a single property

(Heibeck and Markman, 1987; Au and Markman, 1987). Children can use contrast to learn a color term only when they hear their own mistaken color label in the contrast phrase, treating color labels as mutual exclusive unless they hear explicit information to the contrary (Au and Laframboise, 1990). The present studies integrate and extend these previous results to show the effect of combining these two cues in a single situation.

Replicating the findings of Au and Laframboise (1990), we found that children could use only corrective contrast, not semantic contrast, to help them interpret the new word as a color term. Children from Experiment 1 who heard their own color label in the contrast phrase learned that the new word referred to color more successfully than did children who heard a random label in the contrast phrase or no contrast at all. In these two latter conditions, the Random and No Contrast conditions, contrast was unhelpful to children in interpreting the new word. Those children who heard these two types of contrast tended to interpret the new word such that it did not overlap with any previous labels for the object, consistent with predictions from mutual exclusivity. Child's Own Contrast provided the children with explicit information that the new word referred to color, allowing them to accept the word as a color term although they already had a label for the object's color.

Au and Laframboise (1990) suggested that Child's Own Contrast is more helpful to children than Random Contrast because it is more pragmatically felicitous. It makes sense to contrast a color word that the child just applied to the object, while bringing in a previously unmentioned word from the color domain could be more confusing. Additionally, the color words used in the Random Contrast phrase were very different from the target colors. Because a child would probably not mistakenly label a mauve object as being green, using such random labels in the contrast phrase is not pragmatically sensible. On this argument, the child does not need to explicitly provide the word used in the contrast phrase in order to benefit from Child's Own Contrast. The pragmatics account predicts that a color word that is easily confusable with the target color, or a color word that other children tend to apply to this color, would help the child equally well as that particular child's own label. To test this, we could eliminate the warm-up portion of our task, in which we elicit the child's label for the object's color, and simply provide them with a contrast phrase using a plausible overextended label.

According to our account, the important aspect of the Child's Own Contrast condition is that the contrast information preempts the child's label for the color, allowing them accept a label for an already-labeled color. It does not matter to this account exactly how the child's own color label is preempted, nor does it matter that the child explicitly produced a label for the color. Experiment 1 accomplished the preemption by eliciting and using the child's own label, but an easily-confusable label for this color, one which the child did not necessarily produce, would most likely work just as well.

We found that children use mutual exclusivity to constrain their hypotheses about the meaning of the new word. We saw this behavior in children in the Familiar Shape conditions of Experiment 1 and in the With Shape Name condition of Experiment 2. These children already knew the name of the shape they saw, either because they had learned this name previously or because they were presented with it during the study. In both cases, children rejected a shape-name interpretation of their target word, unwilling to accept a second label for the object's shape. These children correctly interpreted the new term as referring to the object's color. Conversely, children who saw unfamiliar shapes interpreted the new term as a name for the object's shape in both studies. When the shapes were unnamed, mutual exclusivity did not prevent children from accepting a label for this shape.

In addition to this lack of interference from mutual exclusivity, children may have been encouraged to find a label for this unfamiliar shape by the whole object assumption or the shape bias. The *whole-object assumption* states that children who hear a word applied to a novel object assume that it refers to the entire object and not to a part or a property of the object (see Woodward and Markman, 1998, for a summary). Other research (e.g., Landau, Smith, and Jones, 1988) suggests that children have a *shape bias*, prompting them to pay closer attention to an object's shape than to its other properties when learning a new word. According to the shape bias account, children should want to apply a name to an object's shape before naming any of its properties, because shape is such a salient dimension. Both of these constraints assume that, when children see an unnamed object, they tend to think that any label applied to this object refers to the object itself. According to these accounts of word-learning, children in our studies may have been more likely to interpret the new word as a shape term when seeing an unfamiliar shape, because the dimension of shape was a more salient candidate for accepting a label.

The main goal of this study was to show how children use the interactions between lexical contrast and mutual exclusivity to infer the meaning of the new word. We predicted that the cues would have an additive effect. In the Familiar Shape/Child's Own

Contrast condition, the two cues converged on a color interpretation for the new word, so we expected children to be most successful at learning the color word in this condition. In conditions where children had only a single cue, the Unfamiliar Shape/Child's Own Contrast, the Familiar Shape/Random Contrast, and the Familiar Shape/No Contrast conditions, we expected that children would still succeed, although not quite at the level of those children who had access to two cues. Children should have the fewest color responses in conditions where no cues would lead them to a color interpretation, the Unfamiliar Shape/Random Contrast condition and Unfamiliar Shape/No Contrast condition.

Our predictions about the Unfamiliar Shape/Random Contrast and Unfamiliar Shape/No Contrast conditions were correct, since children in these two conditions failed to learn that the new word is a color term. Although this result was expected, given the findings of previous studies, it is still striking that children cannot use random contrast at all as a clue that color is the relevant domain. They perform in the same way in the Random Contrast conditions as in the No Contrast conditions, behaving in both cases as if they have no cues at all leading them to interpret the word as a color term.

Contrary to our expectations, however, the two cues did not have an additive effect. Children performed at the same level when they heard Child's Own Contrast, regardless of shape familiarity, and their performance did not vary by contrast type when they saw a familiar shape. This means that children are using only one of the two possible cues to succeed at learning a color word. Either they use explicit contrastive information to override their color label, or they use information from mutual exclusivity that the new word does not refer to a shape.

Our explanation for the lack of additive effect is that children are using mutual exclusivity as the underlying mechanism for their use of contrast. Children in this study believe that they already have a label for their object's color, so they are unwilling to accept a second label for this color, regardless of condition. They must therefore posit a different aspect of the object to which to apply a new label. For those children who see unfamiliar shapes, the object's shape is the natural hypothesis for the meaning of the new word. However, those children who see a familiar shape are unwilling to accept a new label for their target's shape as well as for its color. Thus, before hearing any type of contrast phrase, children who see a familiar shape have no readily available hypothesis for the meaning of the new word, and children who see an unfamiliar shape think that a new word is most likely a shape term.

Given these two situations as a baseline, let us examine what happens when the child encounters a contrast phrase. Those children in the Child's Own Contrast conditions hear an unambiguous correction of their color terms. From the contrast phrase, they have explicit information that their color term is incorrect or overextended. They are thus willing to accept a label for the object's color, a label which otherwise would have been blocked by mutual exclusivity. This formulation of children's performance explains why there is no difference between the Familiar Shape/Child's Own Contrast condition and the Unfamiliar Shape/Child's Own Contrast condition. Mutual exclusivity blocks a color-interpretation for the new word equally in both of these conditions. When children hear the contrast phrase, this eliminates the block on a color interpretation, allowing children to correctly interpret the new word as a color term.

Without such explicit information from contrast, as in the Random and No Contrast conditions, children have no helpful information about how to interpret the new word. They are left to rely on aspects of the object itself to apply a meaning to this word. Children in the Unfamiliar Shape conditions can easily interpret the word as a shape term, since a shape-interpretation for the new word is not blocked by mutual exclusivity. However, children in the Familiar Shape conditions encounter a puzzle. They believe that they already have a name for both the object's shape and its color, and mutual exclusivity discourages them from accepting a second label for either of these properties. To which aspect of this object could the new word refer? A small percentage of children in these conditions applied the new word to the object's material, for want of a better hypothesis about the new word's meaning. The majority of the children in these conditions interpreted the new word as a color term, although some children did think that the new word was a shape term. This is further evidence that these children are unclear about the new word's meaning, explaining our inconsistent pattern of results for children in the Familiar Shape/Random Contrast and Familiar Shape/No Contrast conditions. Children in these two conditions cannot readily interpret the new word as either a color term or a shape term, so most choose to violate mutual exclusivity by interpreting it as a color term, while others choose the equally logical route of violating mutual exclusivity by interpreting it as a shape term.

In these two conditions, children have no a priori reason for applying a color interpretation or a shape interpretation to the new word; both are equally likely since both are blocked by mutual exclusivity. However, most children chose to correctly interpret the new word as a color term. On what basis did they make this decision? Perhaps children are simply more likely to accept a new word for a color rather than for a shape. This is possible because there are many terms for non-focal colors, and children at this age might understand the role of such non-focal colors. They may have reasoned (correctly) that this new word described such a color, and accepted it on these grounds.

Experiment 2 extended the shape familiarity effect from Experiment 1, examining the limits of children's use of mutual exclusivity. Children in the With Shape Name condition of Experiment 2 heard two new words, one of which referred to their unfamiliar target shape, the other of which referred to a property of this shape. As predicted, children were able to use information about the shape's label to reject a shape interpretation for the new word, and to correctly interpret the new word as a color term. The shape label information was not helpful to all children, however, since many children still interpreted the new word as a shape term. This interpretation is consistent with mutual exclusivity; children might have thought we were providing them with a shape term for a labeled object, as in, "this circle is round." These findings from Experiment 2, together with the Familiar Shape conditions of Experiment 1, indicate that children benefit from knowing a term for the whole object when learning property terms, even if they are familiarized only briefly with the whole object's label.

Although some children in the With Shape Name condition of Experiment 2 incorrectly interpreted the new word as a shape term, children were as successful in this condition as they were in the comparable Experiment 1 condition in learning a color term. This provides evidence that hearing a shape label helps at least some children to correctly interpret the new word as a color term. We believe that the With Shape Name condition reflects the situation children are in when learning words in context. As they learn new words, children may quite often hear sentences containing multiple unfamiliar words, and they need to sort out the meanings of these new words using form class information, context clues, and word-learning constraints. The With Shape Name condition examined children's "first pass" hypotheses about the meaning of a new word, studying children's interpretations of the new property term after a single context of exposure. Children learning words in a naturalistic setting will encounter the same word many times in many different situations, which will help them to further refine the meaning of that word. Children's incorrect interpretations of the new word as a shape term simply shows that children need these multiple exposures to correctly fix a new word's referent, since some children are mistaken in their first interpretations of this new word. However, those children who were successful at learning a color word in this task show that, at least in some cases, a single exposure context is enough to correctly interpret a new word. These successes highlight children's remarkable abilities to rapidly integrate information from multiple sources in their interpretations of a new word.

In some conditions of these two experiments, children saw shapes that were familiar, either because they already had names for the shapes or because we provided them with a shape label during the study. In addition to these two methods, there are other ways to preempt a shape interpretation for the new word. One possibility might be to use objects that are not as readily named as shapes, such as amorphous blobs of color. In such a condition, children may be unlikely to interpret the word as a name for this object's shape, since it does not have a definable, nameable shape. It is possible that children would be more likely to interpret the new word as a color term if they saw this type of object, just as they were when the object's shape was familiar.[1]

This proposed extension of our results raises an important question about their generalizability. We taught only color words in this study, following the methods of the studies to which we were responding. However, it is possible that we would obtain different results if we taught shape terms or material terms. It is reasonable to think that children might treat color terms differently than terms in other domains, because the domain of color differs from other domains in two main ways. First, it is a gradient that can be cut up into ever-finer divisions, each of which represents a different color that can accept a label. There is no analogous gradient for shapes, for example, since shapes do not vary along a continuum, each step of which could be another nameable shape. Other dimensions, including temperature and size, do have such gradients. However, these dimensions differ from color in that they range from one extreme to another: hot to cold, big to small. Color does not represent a range between polar opposites in the same way. These two properties make color a unique dimension, and this uniqueness makes it plausible that children treat color differently than other domains.

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[1] We thank Michael Ramscar for bringing this possibility to our attention.

To test this, we could replicate our results using shapes, reversing the roles that shape and color played in the current study. For example, we could show children a “non-focal” shape, such as an oval, painted either a familiar or an unfamiliar color. We could use contrast in the same way, either eliciting the child’s own label for the shape and using this in the contrast phrase (“This isn’t a circle, it’s an oval”), or using a random shape label in the contrast (“This isn’t a square, it’s an oval”). We could also replicate our study using material terms. It is possible that we would obtain different results about the interactions between contrast and mutual exclusivity if we studied a domain other than color words.

We believe that this is unlikely to happen. Heibeck and Markman’s (1987) study showed that children performed in analogous ways when presented with colors, shapes, and materials. Following these results and our account of the current study’s findings, children should use contrast and mutual exclusivity in the same way regardless of domain. We have no reason to believe that these cues apply differently to shapes and materials, or even to whole objects or object categories. Furthermore, the two aspects of the color domain that make it unique most likely have no bearing on children’s use of lexical contrast or mutual exclusivity. The fact that color is a gradient but one that does not vary between two polar opposites might have made children more willing to accept to a new color label for the non-focal color targets they saw. But it would be equally possible to construct “non-focal” shapes or materials and provide names for these in an analogous version of this study. Color served merely as the test case for a theory of the interaction between mutual exclusivity and contrast in word learning, meaning that the unique aspects of this domain should not limit the theory behind our findings.

Our results in these two experiments explored children's access to the word-learning cues lexical contrast and mutual exclusivity, and the ways these cues interact as children form hypotheses about the meaning of a new word. Our examination of these cues provides evidence that children rapidly and accurately integrate both explicit and implicit information in a word-learning situation to correctly infer the meaning of a new word. This research examined important aspects of children's theorizing about new words, offering a fuller picture of how children learn words in context.

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Appendix

We used Liquitex professional high-viscosity acrylic paints for all stimuli. The mauve color was Deep Magenta; celadon was Brilliant Yellow Green; infantry was Twilight mixed with Black and White to create a more grayish hue.

There were four target shapes in the study, a triangle, a square, a hexagon, and a trapezoid. The triangle was 2.25 inches on each side; the square was 2 inches on each side, and the hexagon was 1.25 inches on each side. The base of the trapezoid was 3 inches long, its top was 1.25 inches, and it was 1.5 inches high.

In addition to the targets, there was a series of objects used in the warm-up task to determine whether the child knew the name of the target color, shape, and material. For the warm-up shape question, we cut the four target shapes out of the same artboard material, but these were unpainted white. The warm-up color question involved three 1-inch radius artboard circles painted in the three target colors. The warm-up material question used a piece of the artboard, unpainted, cut into a jagged pattern that did not resemble any named shape.

We made eight shape-associates for the testing arrays to see how children would extend the new word. There were two shape-associates for each of the target shapes, made so that the only thing they had in common with the targets was shape. These were the same shape as the targets, but cut out of plastic overhead projector sheets and painted in primary colors (Acra Red, Bismuth Yellow Light, Phthalocyanine Blue, and Emerald Green). The triangles were red and yellow; the squares were green and blue; the hexagons were yellow and green; the trapezoids were blue and red.

There were also 12 color-associates, painted the same color and using the same shapes as the targets but on plastic overhead sheets. Each child saw only color-associates that did not match their target shape, so that all of the color associates actually used in a test were of a different shape and material from the child's target.

We also made two material-associates, which had only their material in common with the targets. These were cut out of the same artboard as the targets, but were circles 1 inch in radius and painted purple and brown.

For the co-hyponym task, we used two wooden circles, also 1 inch in radius and about 0.25 inch thick. These were painted orange and black.

For the color-identification task, we made three corduroy pentagons, which were 1.25 inches on each side. Each of these was painted in one of the three target colors.

Tables

Table 1

Color responses by condition for Experiment 1

Condition	Total color responses (max = 60)	Average color responses (max = 5)
Familiar Shape/Child's Own Contrast	34	2.83
Familiar Shape/Random Contrast	29	2.42
Familiar Shape/No Contrast	17	1.42
Unfamiliar Shape/Child's Own Contrast	41	3.42
Unfamiliar Shape/Random Contrast	5	0.42
Unfamiliar Shape/No Contrast	1	0.08

Table 2

Number of children giving consistent and inconsistent color responses, by condition, for Experiment 1

Child's Own Contrast

	Familiar Shape	Unfamiliar Shape
Consistent	6	6
Inconsistent	6	6

Random Contrast

	Familiar Shape	Unfamiliar Shape
Consistent	6	0
Inconsistent	6	12

No Contrast

	Familiar Shape	Unfamiliar Shape
Consistent	3	0
Inconsistent	9	12

Tables, continued

Table 3

Color responses by condition for Experiment 2

Condition	Total color responses (max = 60)	Average color responses (max = 5)
With Shape Name	20	1.67
No Shape Name	3	0.25

Table 4

Number of children giving consistent and inconsistent color responses, by condition, for Experiment 2

	With Shape Name	No Shape Name
Consistent	3	0
Inconsistent	9	12

Table 5

Number of children giving any color responses, by condition, for Experiment 2

	With Shape Name	No Shape Name
Any Color Responses	6	1
No Color Responses	6	11

Figures

Figure 1

Average color responses per child by condition for Experiment 1 (±1 standard error)

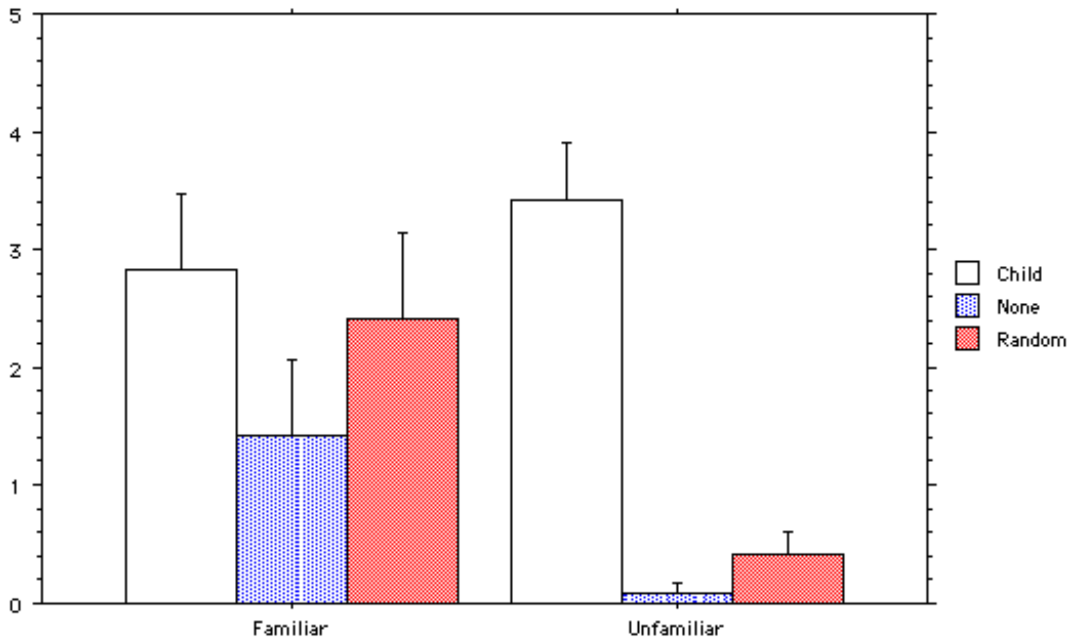

Figure 2

Average color responses per child by condition for Experiment 2 (±1 standard error)