# Generalizing from Simple Instances:
# An Uncomplicated Lesson from Kids Learning Object Categories

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## Abstract

Abstraction is the process of stripping away irrelevant information so that learners can generalize on relevant similarities. Can we shortcut this process by directly teaching abstractions in the form of simplified instances? We tested this prediction in the domain of shape-based generalization and found that young children were able to generalize better when taught with simplified shapes rather than complex detailed ones. Simplicity during training allowed shape novices to generalize like shape experts.

**Keywords:** category generalization, shape, word learning.

## Introduction

Applying past learning to new circumstances requires the recognition of similarities between those past experiences and the present. The relevant similarities are often embedded with many task-irrelevant similarities and differences. Thus, processes of abstraction – of finding the right similarities – are crucial to theories of generalization (see Harnad, 2005 for a defense of this assumption). Abstraction and generalization are also crucial to understanding the differences between immature and mature learners and between novices and experts, as mature learners generally, and experts more specifically (e.g., Chi, Bassok, Lewis, Reimann & Glaser, 1989; Gick & Holyoak, 1983), seem able to abstract the right similarities over which to generalize past experiences. Such abstracted understandings may be responsible for experts' ability to transfer their learning to highly dissimilar situations (Holyoak, 1984).

The experiments reported here explore the relationship between abstraction and generalization. If the key to generalization is the formation of a sufficiently minimal description of the relevant properties, then one should be able to directly teach that abstraction and, as a consequence, get broad and appropriate transfer. Some studies with adults learning difficult domains such as chicken sexing (Biederman & Shiffrar, 1987) or scientific principles (Goldstone & Sakamoto, 2003; Sloutsky, Kaminski & Heckler, 2005) have shown generalization benefits when information is presented with more perceptually abstract forms that leave out irrelevant details. In this paper, we ask whether training with abstractions increases transfer in a specific domain: the development of 3-dimensional object recognition in toddlers. Around 2 years of age, when young children become experts in generalizing names for things to new instances, is this an expertise based on abstraction?

## Development of Shape-based Noun Categories

Early word learning is defined by proper generalization. Children comprehend that certain nouns go with particular categories of objects at about 9 months of age (Huttenlocher, 1974). Paul Bloom (2000) summarizes how extremely early words are learned and extended to new instances slowly but soon the pace of both learning and generalization accelerates such that shortly after 24 months, children add words to their vocabulary at a staggering rate and also generalize a newly learned name broadly and correctly to category members after experiencing just *one* instance (Markman, 1989). These young word learners do not need to experience a whole variety of elephants or staplers to know the range of things that are elephants or staplers. One example will do; apparently these children know the right similarity to generalize over.

The relevant similarity, at least for concrete noun categories, often involves shape (e.g., Clark, 1973; Imai, Gentner & Uchida, 1994). The key experimental results documenting the importance of shape to children's noun generalizations derive from a task in which children are taught a name with a *single* never-before-seen exemplar then asked to generalize that name to new also never-before-seen instances. In these tasks, 18 month olds show a limited bias to extend object names by shape whereas 30 month olds systematically extend the category name to new instances by shape, ignoring a variety of other properties including color, size, material, and fine-grained details.

At the same time children also become able to recognize common object categories from highly minimalist representations of their 3-dimensional shapes. Figure 1 shows an example of a minimalist shape which leaves out finer grained details, coloring, and texture information in contrast to the richly detailed and lifelike versions presented to 18 to 24 month olds in an experiment by Smith (2003). Although to adults these objects seem very similar, younger children with more limited word knowledge did not recognize the simplified forms but did recognize (nearly perfectly) the richly detailed versions when asked, "Where is the ice cream?" In contrast, slightly older children with more advanced word knowledge recognized the simplified shapes just as well as they recognized the richly detailed shapes. Smith proposes that the process of category learning *was* abstracting shape descriptions.

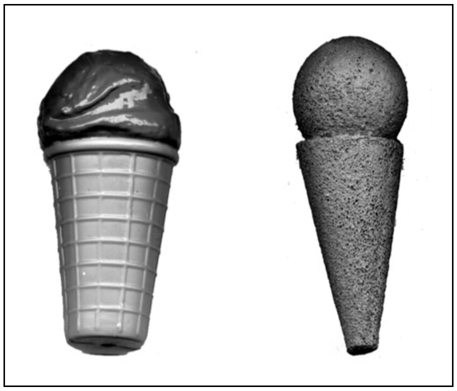

Figure 1: Realistic detailed stimuli and its corresponding minimalist shape of a familiar object used in Smith (2003).

Are simple representations responsible for shape-based generalization? Then these very young children, who do not recognize simple shapes nor generalize by shape, may benefit from explicit training with simple instances rather than complex detailed ones. In particular, simple training should result in shape-based generalization. Our experiments use two types of training: novel names linked to simple objects or complex ones. But there is one driving question: Is there greater generalization from training with the simplified or detailed shape? The results of the two experiments provide insights into the development of object recognition and also into broader issues of learning.

## Experiment 1

Children are presented with a single novel exemplar and taught its name and then asked to generalize the name to other objects. Children participated in one of two conditions. In the complex condition, names were paired with richly detailed exemplars. The generalization targets were the very same detailed shape as the exemplar – only differing in color. In the simple condition, the names were paired with simple shape abstractions and the generalization targets were the same shapes in a different color. These simple stimuli provide shape information unencumbered by frills and details. In contrast, the stimuli in the complex condition present lots of extraneous (and potentially useable) features. If minimalist representations of shape promote generalization, and rich ones hamper it, then these young children should show more appropriate patterns of generalization in the simple than in the complex condition.

### Method

**Participants.** Thirty-one children participated (15 male, 16 female). The mean age was 17 months (range 15 to 20 months).

**Materials.** Two corresponding sets of novel objects, complex and simple, were created for this task. Fantasy vehicle toys were purchased for the complex objects. They had detailed parts that were intricately painted using three different colors to enhance the finer details. The simple objects were constructed from 2 to 4 geometric components. They had no details and were painted a uniform color. There were 12 unique objects painted in 12 unique colors, that were arranged into 3 stimulus sets of four objects each. Each set contained (1) a target exemplar trained with a name, (2) an unnamed training distractor, (3) a transfer target with the same exact shape as the exemplar but different in color, and (4) a transfer distractor with the same exact shape as the training distractor but different in color. Figure 2 shows a training exemplar and transfer target pair for the complex condition and for the simple condition. Unique names were paired with each of the three training exemplars: *zupp*, *wazzle*, and *peema*.

**Procedure and Design.** There were two between-subject conditions, Complex and Simple. Children in the complex condition only saw complex objects and those in the simple only saw simple objects.

The task was based on one used previously by Woodward and Hoyne (1999). In the familiarization phase, the child was taught the name of the target (e.g., “This is a zupp.”) and also acquainted with a second object, the distractor, that was not named (e.g., “Look at this.”). Objects were presented one at a time. This familiarization sequence was repeated twice. The second phase, test, occurred after a 3 sec delay. This phase began with a memory test. The original target and distracter were placed on the table and the child was asked to get the target by name (e.g., “Where is the zupp?”). The memory test was immediately followed by a generalization test, two new objects, the transfer target and transfer distractor, were placed on the table, one matching the training target in exact shape, the other matching the training distractor. Both of these generalization objects differed in color from the familiarization exemplar and distracter. The child was asked for the target by name. The memory and generalization tests were then repeated for this same set. The spatial location of the correct choice alternated between test trials. This whole procedure was repeated for each of the 3 unique stimulus sets, yielding a total of 6 memory tests (2 per unique stimulus set) and 6 generalization tests (2 per unique stimulus set).

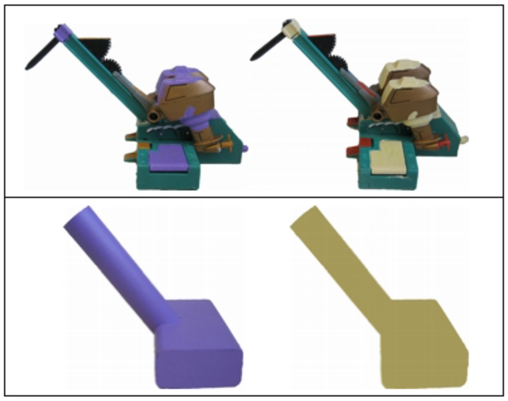

Figure 2: Exemplar/transfer target pairs for complex (top) and simple (bottom) conditions in Experiment 1.

## Results and Discussion

Performance on both memorization and generalization trials are shown in Figure 3. Children in both the simple and complex conditions exhibited similar performance on the memory trials, scoring 67% correct, *t*(29) = -.231. Clearly they can link a name to a specific object, simple or complex, and remember it. In contrast, performance on the generalization tests showed a strong effect of stimulus type. Children correctly generalized the name of the simple exemplars more than complex ones, *t*(29) = -2.495, *p*<.05. Children in the simple condition generalized to the same shaped transfer target on average 68% of the time (*SD* = .21) whereas the children in the complex condition did so only 44% of the time (*SD* = .31), consistent with performance at chance.

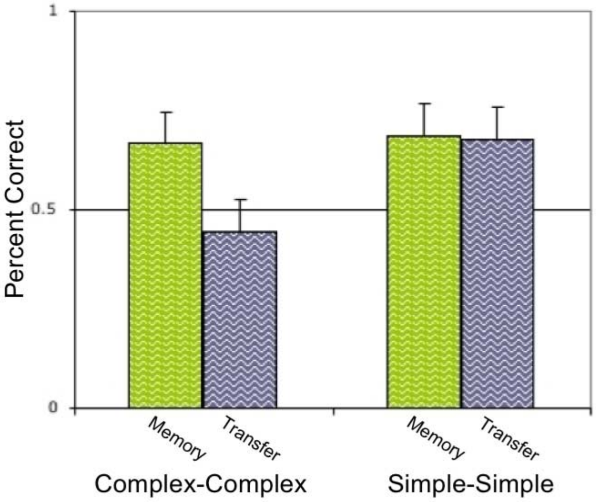

Figure 3: Results of Experiment 1.

However, the effect of simplicity in Experiment 1 could be attributed a general difficulty of learning about complex things so for each child, we determined the likelihood of correct generalization following only successful memorization trials and averaged over all memorization-generalization pairs (6 total). There was a significant difference in the conditional probabilities of shape generalization given memorization between the simple and complex groups, *t*(29) = -3.412, *p*<.01. When participants in the complex condition correctly memorized the target object, the conditional probability of generalization was only 0.48. However, the conditional probability for the simple object group was 0.83. Even when the children were able to remember and identify the initial complex object, they were unlikely to generalize to a same-shape different-color object.

In brief, children who learned a name for an object presenting only simple geometric information about overall shape readily extended the category label to a new object of the same simple shape regardless of the color difference. Children who learned a name for a complex object did not generalize that name to a new complex object with exactly the same complex shape (including fine details) but differently colored.

This pattern is predicted if simplified shapes provide children with the right amount and type of information for forming shape-based object categories, whereas richly detailed objects provide too much information (at least for very young children who cannot abstract global shape from such a complex whole). However, the results are also puzzling. After all, the many details on the complex forms (excluding color) were potentially relevant in that they were shared by the training and transfer target. Indeed, Tversky (1977) found that adults judge a complex object as more similar to itself than a simple object is to itself. Presumably this is because of the increase in number of overlapping features. In the present experiment, the complex training and transfer targets have more overlapping features than do the simple ones and thus should be more similar, and as a consequence should yield better transfer. But they do not. This analysis of feature overlap, however, assumes that the learner registers all the features for the complex objects. This may be beyond the attentional ability of young children who may sample different featural details for the two differently colored complex things. The objects stripped of details in the simple shape condition avoid this problem of too much information by limiting the information available.

This first experiment examined children's ability to make *near* transfer of an object name to an *exact* shape match and found that simple training exemplars led to more generalization by shape than did complex ones. By hypothesis, however, the contribution of directly teaching abstractions is that doing so also enables appropriate *far* transfer. We test this hypothesis in Experiment 2.

# Experiment 2

To extend the findings of Experiment 1, we changed the generalization targets from *near* exact shape matches to *far* structural shape matches. There are two conditions in this experiment. In the Simple-to-Complex condition, children were presented with a simple idealized shape as the exemplar, taught its name, and then tested to determine whether they would extend that name to a richly detailed realistic object of the same global shape. In the Complex-to-Simple condition, children were presented with a complex realistic object, taught its name, and then tested to determine whether they would extend that name to a simplified shape idealization of that object. If similarity is symmetric, then generalization from the exemplar to transfer target in the two conditions should be identical. However, if an internally represented abstraction directs attention to the right properties at transfer, then we should find greater generalization in the simple-to-complex condition than in the complex-to-simple condition.

## Method

**Participants.** Thirty-seven children (16 males, 21 females) participated. Mean age was 20.5 months (range 16.9 to 27.0).

Figure 4: Realistic detailed stimuli and corresponding simple shape of an unfamiliar object category used in Experiment 2.

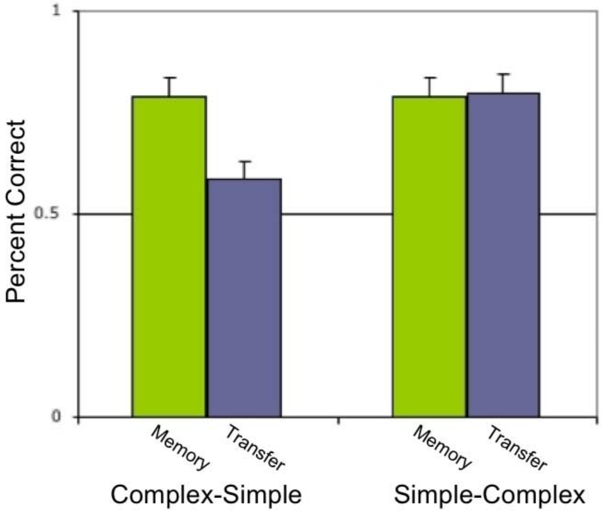

Figure 5: Results of Experiment 2.

**Materials.** The stimuli used in this experiment were selected to be from real categories likely to be unfamiliar to young children: artichoke, manatee, doily, reamer, masher, jellyfish, watering can, sand castle (see Fenson et al, 1994, for a normative list of nouns typically known by 30 months). They were named with their real world labels. There were two versions of each object, one a richly detailed and colorful real or toy version and the other a simplified shape. The simple stimuli were composed from 2-4 geometric components and painted gray. Figure 4 shows the realistic artichoke and its corresponding idealized shape.

**Procedure and Design.** The procedure was identical to that of Experiment 1 with two phases: familiarization and test. For the children in the complex-to-simple condition, the familiarization stimuli – training target and distractor – were the richly detailed complex versions. The test stimuli – transfer target and distractor – were the simplified shapes of the complex objects. For children in the simple-to-complex condition, the familiarization stimuli were the simple shape idealizations and the test stimuli were the complex realistic versions of the idealizations. Each child was tested on four unique stimulus sets created by forming four target-distractor pairs from the 8 object categories. Since each memory and generalization test for each of the four unique stimulus sets was repeated twice, there was a total of 8 memory tests (2 per each set) and 8 transfer tests (2 per each set). Order of stimulus sets and designation of target/distractor within sets were counterbalanced across children. The spatial side of choice on test trials alternated across trials.

## Results and Discussion

Figure 5 shows children's performance on the memory and generalization trials in the two conditions. An analysis of variance yielded a significant interaction between presentation order and test type, $F(1,35) = 8.844$, $p<.005$. Children identified the labeled target on the memory trials equally in the two conditions, $t(35) = .026$, and did so with considerable accuracy: 78% ($SD$=.15). However, children in the complex-to-simple condition were much less likely to generalize that learning to the same-shape targets than children in the simple-to-complex condition, $t(35) = -4.551$, $p<.001$. Children who learned labels with the complex object transferred that name to the simple object 59% ($SD$=.15) of the time while children who had the simple learning exemplar transferred the name to the complex object with 80% ($SD$=.12) shape-based responses. Children who learned names of simple objects can generalize to complex instances despite the addition of shape details and colors. However, children learning with complex objects could not generalize to the simplified shapes striped of their details.

Again, as in Experiment 1, training with simplified exemplars promoted transfer, and in this case, far transfer to an object of the same global shape but not the same exact shape. This is a critical skill in the development of object recognition and noun categories. Instances of a basic level category, while roughly similar in shape, are not the exact same shape. Varieties of chairs, varieties of cups, and variety of trucks are the "same shape" only under some highly abstract and minimalist description of shape. The present results indicate that directly teaching children such an abstraction enhances generalization. By giving the child the abstraction we provide what children normally build slowly through repeated experience with a variety of instances, a minimalist and thus category-encompassing description of shape.

# General Discussion

The children who participated in the present experiments are not yet full-blown experts in learning object names. Nonetheless, we were able to make them look more advanced by providing them with exemplars that were simpler versions of the detailed shapes of real things in the world. Presumably, one limitation on young children's extension of a newly learned object name to novel category members is the need to extract a minimal description of the shape from the more complex and idiosyncratic learning instance. When we provide this abstraction for young children, they systematically extend a newly learned name by shape. These results contribute specifically to understanding the development of shape abstractions for object recognition but also to understanding how learning and transfer happens generally.

## Abstractions for Learning to Recognize Objects

The results reported here indicate a particular importance of simplicity during *training*, in directing attention to a subset of information while learning object categories. This is crucial particularly for young learners who have difficulty appreciating the relevant similarity, in this domain global shape information, They fail to generalize past learning because they attend too much to easily separable features and parts to recognize things (e.g., Rakison & Cohen, 1999). Colunga (2003) showed that 18-month-olds looked at and used features such as eyes and face when recognizing pictured animals, and wheels and headlights when recognizing vehicles. Twenty-four-month-olds, in contrast, looked broadly at different parts of the pictures, and used overall shape in deciding what the entities were.

An over-emphasis on features rather than global shape may be a general property of nonexpertise in visual object recognition, which may be relevant to the results of Experiment 1. In that experiment, the children failed to extend the name of an object to exact shape replica that differed only in color when those shapes were complex with detailed featural information. These complex shapes, more than the simple ones, offer many opportunities for generalization because of their very complexity and many features. For example, if a child had noticed only the fancy exhaust on an exemplar vehicle, that child should have been able to extend the name to the target simply by finding that same exhaust. However, the children were apparently unable to do this. The problem with trying to recognize objects by their features – and perhaps the reason children abandon this in the early course of development – is that there are too many densely packed features that are, at this scale, similar to each other.

Models of object recognition reflect adult behavior in that, as varied as they might be, there is a strong preference to use shape information over other dimensions of variation. Object-based models, such as the recognition-by-components account (Hummel & Beiderman, 1992), emphasize shape by depending on minimal shape descriptions. View-based approaches, by strengthening commonalities across view-specific instances, result in representations that capture shape (Palmieri & Gauthier, 2004; Edelman & Intrator, 2000). Note that both object and view-based accounts posit psychological descriptions of shape that emphasize some aspects of shape over others and are thus *simplifications* of the more numerous, more varied, more detailed, and more specific shapes of real experience. Smith's (2003, also Jones & Smith, 2005) finding that young children cannot recognize well known objects from their idealized shapes indicates that simplified representations have to be developed as object categories are learned. The present results add that one can foster the development of these abstractions by explicitly showing them to young children. This finding has particular relevance in the context of understanding and remedying atypical developmental trajectories. Recent work (Jones & Smith, 2005) suggests that late-talking children do not generalize object names by shape and also that they do not recognize common objects from simple shape caricatures of 2-4 geometric components. Training these children to abstract global shape and to generalize names by shape may well help them over a significant developmental hurdle.

## Abstractions for Learning in General

The present experiments are with children learning and generalizing over the appropriate similarities relevant to visual object recognition. However, it is possible that this is a specific example of a more pervasive principle about learning and generalization. A primary goal of education and learning is to promote generalization across appropriately similar situations; the benefit of teaching with simplified instances shown a range of domains such as mathematics (Sloutsky, Kaminski, & Heckler, 2005), physics (Bassok & Holyoak, 1989), and complex adaptive systems (Goldstone & Sakamoto, 2003) predict our results in shape-based transfer. Spanning across children and adult learners, there are advantages to learning with perceptually sparse representations.

Goldstone and Sakamoto's participants (2003) learned the principles of competitive specialization of ants distributing themselves over food resources with abstracted ants (pictured as dots) versus rich ants (pictured as ants). Students in the abstract condition exhibited better transfer performance to a contextually dissimilar but isomorphic problem than those in the rich concrete condition. Even though the transfer situation was the same for both conditions, prior experience with simple dots facilitated abstract understanding of the underlying principles. Increased concreteness may have actually distracted learners from a more abstract construal of the ant situation. This is consistent with our results stressing that simplicity *during learning* allows relevant information to be abstracted. Specific features that come with increased complexity may have distracted young participants in our experiments from attending to global shape. A chorus of researchers (Uttal, Liu, & DeLoache, 1999; Goldstone, Medin, & Gentner, 1991) have described a competition for attentional resources between abstract and concrete construals of a situation. Particularly in tasks where concrete features compete against abstract structural construals for attentional resources, these studies show that removing potentially distracting features might be a good teaching strategy.

Some of the difficulties facing novices is that potentially useful and potentially distracting features may not be psychologically separable. Schyns and Rodet (1997) taught adult learners about two different kinds of "Martian cells," cell type A or cell type AB. Transfer tests showed that subjects who first learn about cell type A subsequently learned about cell type AB as composed of two separate features, A and B. Subjects who learned about AB cells simply learned that the two cell types, A and AB, differed. In their terms, learning A set up the perceptual vocabulary through which a componential AB was perceived. The present results are strongly consistent with this pattern. Learning the simple shape first may have enabled our young learners to see the complex object as containing the simple shape along with other features. Learning the complex shape first does not provide a decomposed perceptual vocabulary and thus the learner sees the first complex object as simply different from the shapes, simple or complex, that follow.

## Conclusions

Our results intersect with research regarding in generalization in varying domains, from object recognition to more general forms of learning and categorization. Real object category learning during development may well draw on domain-general learning mechanisms. The influence of simplicity seen in this particular domain may be found wherever these mechanisms are involved because learning is about abstracting the right information. Experts may not perceive *all* available aspects of a situation but they clearly appreciate the *relevant* ones. In fact, part of being an expert is the ability to ignore irrelevant information that may be misleading. Simplicity during learning allows novices to simulate expert perception because only the relevant similarities are available.

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