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Authors
Sims, Clare
Colunga, Eliana

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When Comparison Helps: The Role of Language, Prior Knowledge and Similarity in Categorizing Novel Objects

Clare E. Sims (clare.holtpatrick@colorado.edu)
Department of Psychology and Neuroscience, 345 UCB
Boulder, CO 80309 USA

Eliana Colunga (eliana.colunga@colorado.edu)
Department of Psychology and Neuroscience, 345 UCB
Boulder, CO 80309 USA

Abstract

Research suggests a developmental shift from forming categories based on perceptual features, to recognizing deeper characteristics and relationships. One process found to highlight deeper properties is comparison between items. The bulk of the research on comparison, however, has been done with familiar items or familiar relationships. An open question remains: under which conditions will comparison help children attend to the deeper properties of novel objects? In two experiments we explore the effect of comparison in a word learning task and its interaction with prior knowledge, language support, and the perceptual features of the compared items. Our results suggest that comparison only highlights deeper similarities when children are given some support to counteract or reduce the influence of surface level features. These results have implications for how to best teach children depending on the amount of prior knowledge that they bring to the task.

Keywords: word learning; comparison; superficial vs. relational similarity

Introduction

The ability to look beyond surface similarities and make deeper connections between items is an important achievement in cognitive development. Although perceptual feature similarities (e.g., shape, material) are often a useful basis for grouping objects together, some categories may be better characterized by more abstract qualities. In analogy-making tasks and in categorization tasks, children seem to shift from attending to surface properties to being able to attend to relational or conceptual similarity at around age 5 (Gentner & Namy, 1999; Loewenstein & Gentner, 2005). The evidence also suggests that even young children who would not spontaneously attend to deeper similarities will do so with enough support. In two studies we examine the circumstances in which comparison is helpful in highlighting deeper similarities for novel categories for which children have no preexisting knowledge, even when the objects share perceptual features as well.

Comparison and deep similarities

A large body of research suggests that comparison is a mechanism that works to highlight deeper features. The evidence suggests that although a child may seem to only attend to surface, perceptual features when presented with a single item, being presented instead with two or more items to compare has the effect of highlighting deeper, relational features shared by those items. Researchers have found this effect in tasks such as word extension and analogical mapping. In these analogy tasks, children are typically shown a standard card showing three items that share some relational property. For example, Figure 1 shows a target card and two possible matches. The card on the left matches the target in superficial properties (they are three squares), whereas the card on the right matches it in relational similarity (two same-color figures flanking a different-color figure). Research using this sort of task indicates that without extra support, 4-year-olds will attend to properties of the specific items, rather than to the relational structure. However, when allowed to view two examples of the relational structure (say a second card with two white triangles flanking a black triangle) and compare it with the original target, the similarity in relational structure will be highlighted, allowing the child to abstract away from unimportant details such as the shapes of the items (Gentner, Rattermann, Markman, & Kotovsky, 1995).

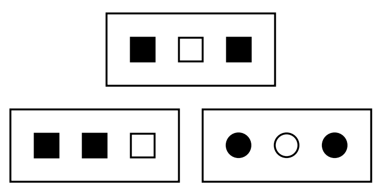

Figure 1: Example of an analogical mapping task.

A similar effect of comparison has been found in word learning tasks. Gentner and Namy (1999) taught 4-year-olds new names for known objects. For example, they showed children a picture of an apple and informed them that a toy dog had a special name for it: "blicket". Then children were offered a choice between a picture of a banana and a picture of a balloon and asked which of those would also be called a blicket. Surprisingly, four-year-olds chose the superficially similar balloon, rather than the taxonomic match, the banana, also a fruit. However, when allowed to see more than one standard (e.g., a pear and a bunch of grapes), children chose more taxonomic matches. More recently Gentner, Loewenstein, and Hung (2007) found that four-year-olds were similarly able to use comparison to learn novel names for specific parts of novel animal and object drawings. The process of comparison is thought to highlight deeper relations between items by promoting structural alignment (Gentner & Namy, 1999). Structural alignment refers to how considering two or more items together can focus attention on common relational structure that would not be readily apparent from only a single item. But how would comparison work if novel objects were used?

Comparison of Novel Objects

A first step in investigating whether comparison of novel objects can help children see beyond surface properties to deep features is to determine what these terms mean in the context of novel stimuli. A definition of surface properties can be transferred fairly straightforwardly from previous comparison research involving familiar items. That is, surface properties consist of perceptual features such as the shape, material, texture, and color of an object. Defining deep characteristics of novel objects is more complicated, for exactly the reason that such objects were chosen for this research: there is no prior knowledge or history associated with them. For example, in some previous work the deep features that are highlighted in comparison are defined as conceptual representations (Gentner & Namy, 2006). However, in other contexts, particularly analogical mapping studies, deep characteristics consist of the higher order relations or structures shared across items (Gentner et al., 1995). Gentner and Rattermann (1991) refer to this deeper level of similarity as analogy, and define it as "similarity in relational structure, independently of the objects in which those relations are embedded" (p. 226). For example, Figure 1 shows a sample analogical mapping involving a structure of two identical darker figures flanking a lighter figure. Understanding this structure at the analogy level means understanding that such a relation can encompass a flanking structure in various dimensions, such as darkness or size, and despite dissimilarities in other features like shape or texture (Gentner et al., 1995).

Drawing from this research on analogy, in the current experiments deep characteristics of novel objects are defined as the structure of the objects. Specifically, we designed the novel objects in these experiments such that the connections and relations betweens parts of individual objects conform to a generalizable structure. Figure 2 shows an example set of the novel object stimuli created for these experiments. The structure shared by the exemplars and structure choice test item in this set is one of three identical shapes, arranged vertically, and decreasing in size from bottom to top. While there is variation in surface level features, such as shape, color, material, and texture, the underlying structure is maintained. In this way, the novel objects created for the current experiments were carefully manipulated to have certain surface properties and deep features, in particular relational structure.

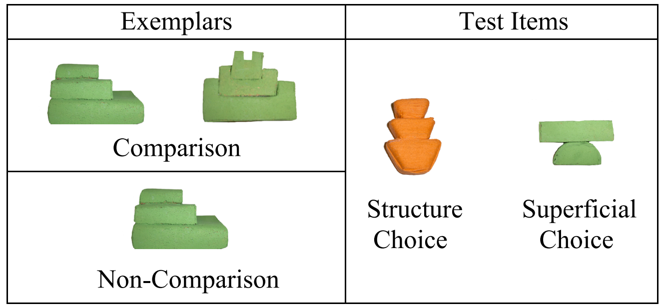

Figure 2: Sample item set from Experiment 1. Materials used include green foam and orange yarn.

Prior Knowledge Another key issue to consider in relation to the comparison of novel objects is the role of prior knowledge about the items that are compared. Much of the research cited so far supports the hypothesis that the development from categorization based on surface similarities to categorization based on higher order relations is driven by increases in domain knowledge. For example, understanding of higher order analogical relations has been found to develop between the ages of 4 and 8 years, but 4-year-olds can learn to appreciate and correctly use such relations through explicit teaching or over the course of targeted training (Kotovsky & Gentner, 1996). Experiments with novel objects offer a new way to test, and possibly further support, this hypothesis by controlling the amount of domain knowledge that participants have available. As will be shown in the first experiment, our novel object stimuli allowed us to directly explore the question of the role of prior knowledge in comparison. Using novel objects ensured that participants were not familiar with the stimuli, and we also manipulated the labels used (novel vs. known) to further control the amount of prior knowledge brought into the task. The label manipulation relates to the next issue as well.

Language Use Another guiding question of our design of the current experiments has to do with the role of language. Specifically, in the first experiment we explore an intriguing finding on the role of language in analogical mapping. Previous research shows that children as young as three years old can map familiar relational labels, like "top," "middle," and "bottom" onto spatial relations between presented items, and use those mappings to make correct relational choices, even in the face of tempting perceptual choices (Loewenstein & Gentner, 2005). We wondered whether the use of familiar structure related labels could have a similar influence on children's comparison processes with novel objects. Such labels would offer children some support in linking familiar structural representations with the novel objects to be learned; the first experiment tests whether they can effectively use this support to aid task performance.

Perceptual Features Our final guiding question about the role of perceptual features influenced our overall task design and is the focus of the second experiment. To address this question we drew on research from the word learning literature. Our task has many parallels to the novel noun generalization (NNG) paradigm, in which a child is presented with a novel object that is labeled with a novel name, and is subsequently asked whether he or she would apply that label to various other novel objects that vary from the original in specific dimensions such as shape, size, color, or texture, while matching in other dimensions. Research using the NNG task has provided many interesting findings about the kinds of object properties that children use to guide their learning and labeling of different kinds of items. For example, from a young age children consistently and preferentially use the shape of an object, as opposed to other features like size, color, or material, to guide their labeling and categorization of artifact-like items (Jones, Smith, & Landau, 1991). On the other hand, the material of an item is treated as more important than other features in guiding children's novel noun generalization of non-solid substances (Soja, Carey, & Spelke, 1991). Because the novel objects created for the current experiments are artifact-like, we were concerned that having a shape match between exemplars and test items would strongly influence our results. To avoid the possible confound of a shape match, we minimized the degree of shape matching and manipulated other features known to be less influential in artifact-like object naming, particularly material and color. The second experiment in particular explores how the manipulation of these perceptual features influences comparison.

In two experiments we explored the effect of comparison on preschooler's learning about novel objects. We used previous work on comparison as well as word learning to guide our experimental task design. The current experiments explore the roles of prior knowledge, of language, and of perceptual features in children's comparisons of novel objects. The first experiment explores the role of prior knowledge and language, and the second experiment focuses on the role of perceptual features.

Experiment 1

The first goal of Experiment 1 was to create and test an experimental task that paralleled those used in the comparison literature but that involved only novel objects. To this end, we modeled our task after one designed by Gentner and Namy (1999, Experiment 2) in which children were presented with either one or two standard items (non-comparison and comparison conditions) and then decided which one of two test items best matched the standard, a perceptual choice or a taxonomic choice. The authors used drawings of familiar items, and carefully chose the stimuli such that each standard item was more strongly perceptually similar to the perceptual choice than the taxonomic choice. The design of our stimuli aimed to capture similar relations between the perceptual and structural characteristics of novel objects. We manipulated the surface level features of material, color, and shape to create exemplar objects that strongly matched the superficial choice test object. We manipulated the relationships between the parts of these objects to create structural similarities between the exemplar objects and the structural choice test object, which was perceptually dissimilar to the exemplars (see Figure 2). In this way we believe our experimental task is an accurate translation of the Gentner and Namy (1999) task from familiar item drawings to novel physical objects.

The other goal of Experiment 1 was to test two of our guiding questions: what is the role of prior knowledge and what is the role of language in novel object comparison? We included two labeling conditions: a novel label condition and a known label condition consisting of structurally related familiar words. The combination of novel objects and novel labels ensured that children in that condition had no prior knowledge of the task items. In the known label condition, we used familiar words that related to structure to see whether children could effectively use language support to make connections to known structural relationships.

If children treat novel objects similarly to how they treat familiar items, then we should see similar results in our novel label condition as those of Gentner and Namy (1999); that is, children will make more perceptual choices when there is non-comparison between exemplars, and will make more structural choices when there is comparison. In other words, comparison of novel objects will function as it does with familiar items, highlighting the deeper relations present between them. On the other hand, because children have no prior knowledge of novel objects given novel labels, comparison might not function in the same way, perhaps instead highlighting surface rather than deep features. Additionally, we expected the use of known labels to be effective in highlighting object structure in both the comparison and non-comparison conditions, and thus act to increase children's structural choices in both comparison conditions.

Method

Participants. Fifty-two 4-year-olds (*M* = 4;6) were assigned to the comparison or non-comparison condition, and to the novel label or known label condition in a 2 x 2 design.

Materials. The stimuli consisted of 16 novel objects created in the lab (8 exemplars and 8 test items). There were four sets of test items consisting of a structure choice and a superficial choice. For each set of test items there were two exemplars (see Figure 2 for a sample set). All exemplars were structural matches with the structure choice for their group, and also matched in material and color with the superficial choice. Due to the extent of surface similarity between the pairs of exemplars, this set is referred to as "high similarity" throughout this paper.

Both of the exemplars were used for the comparison condition, and the exemplar that matched the superficial choice somewhat on shape was used for the non-comparison condition.

Two types of labels were also used in two labeling conditions: novel and known. For the novel labeling condition four pseudoword labels were created, one for each set of objects. For the known labeling condition, four real, structurally related words were selected to go with each set of objects. The words selected were intended to be familiar to four-year-olds; for example, the items in Figure 2 were given the familiar label "stairs." The other known labels were "see-saw," "bumps," and "spiral."

Procedure. Participants sat at a table across from the experimenter. Participants were randomly assigned to one of four conditions: novel label comparison, novel label non-comparison, known label comparison, and known label non-comparison.

In the comparison conditions, the experimenter showed the participant two exemplar objects and labeled each with either the same novel label or with the same known label. For example, in the novel label comparison condition, the experimenter would say, "This is a tink. This is also a tink. See how they are both tinks?" The participant was able to examine the objects before the experimenter put them out of sight. Then the experimenter brought out two test items on a tray and asked the participant to "Get the tink." The experimenter then recorded whether the participant chose the structure match or superficial match. The non-comparison condition proceeded in a similar manner but with only one exemplar shown and labeled, for example "This is a tink. See how it is a tink?" In all conditions participants completed four trials with the order of trials counterbalanced across participants. In the novel label conditions the novel nouns used to label the four stimuli sets were also counterbalanced.

Results

The dependent variable was the average number of structure match choices that participants made across all test trials. Average numbers of structure choices were submitted to a 2 (comparison or non-comparison) x 2 (label type: novel or known) between-subjects analysis of variance (ANOVA). There was a main effect of label type such that children made more structure choices when objects in the task were given familiar, relational labels, $F(1, 48) = 12.43$, $p < .001$. There was also a significant interaction between comparison condition and label type, $F(1, 48) = 4.72$, $p = 0.03$ (see Figure 3). In the novel label condition, children made fewer structure choices after comparing two exemplars compared to viewing only one exemplar. This relationship was reversed in the known label condition, with more structure choices made in the comparison condition than the non-comparison condition.

Post hoc t-tests were conducted to further explore this interaction. Within the novel label condition, structure choices were marginally lower in the comparison than non-comparison condition, $t(24) = -1.77$, $p = 0.089$. This difference did not reach significance in the known label condition ($p = 0.17$), however looking across labeling conditions, structure choices following comparison were significantly higher with known compared to novel labels, $t(29) = 4.46$, $p < .001$.

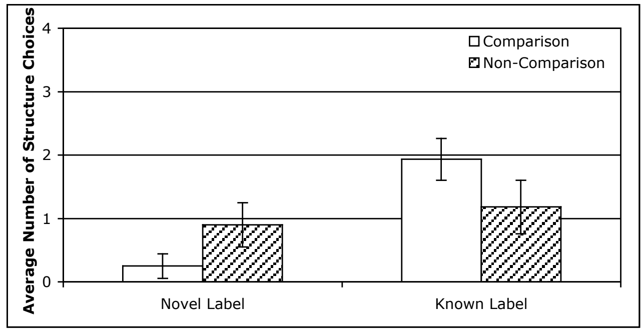

Figure 3: Experiment 1 results; all stimuli were high similarity.

Discussion

Overall the results of Experiment 1 show that the availability of prior knowledge in a task influences how comparison functions. Comparing the novel label condition to the Gentner and Namy (1999) experiment on which it was modeled, we found the opposite pattern of results. Rather than highlighting deeper relations between items, comparison in the novel label condition seemed to very strongly cue children's attention to the perceptual similarities between novel objects. The results of the novel label condition add support to the hypothesis that the capacity of comparison to highlight deeper features depends on the amount of relevant domain knowledge that participants have. In the novel label condition participants had no prior knowledge of the objects to help them identify the deeper structural similarities, and instead focused on surface level features to guide responses. Overall, the novel label condition of Experiment 1 shows that comparison of objects about which children have no prior knowledge functions differently than comparison of familiar items.

On the other hand, the results of the known label condition show that if there is some conceptual support, such as familiar labels that highlight the structure of objects, comparison seems to work in a way similar to that seen in studies using familiar items. This result is also consistent with previous work showing that young children can use language to guide performance in analogical mapping tasks (Loewenstein & Gentner, 2005). The role of language in this context seems to be to situate the novel objects in terms of familiar representations, allowing for recognition and use of structural properties in the task.

In the next experiment we explore the role of perceptual similarity in novel object comparison.

Experiment 2

The goal of Experiment 2 was to test the role of perceptual features in comparison of novel objects. This experiment also allowed for further exploration of how comparison operates in a context of low prior knowledge, that is, our task involving novel objects with novel labels. The first experiment showed that the process of comparison was only conducive to making structural choices when supported by familiar structure-related labels. In the second experiment we set out to investigate another way in which comparison of novel objects would highlight their deeper shared structure. To this end we used the same general procedure as in the novel label condition of Experiment 1, but varied the perceptual features of the novel objects. In Experiment 2, the stimuli were designed such that there was a lower degree of surface feature similarity between the exemplars in relation to each other as well as in relation to the test items (see Figure 4). With this manipulation, the results of the task using the low surface similarity novel object set can be directly compared to the results of the Experiment 1 novel label condition, which used a high surface similarity object set.

We predicted that the number of structure choice responses would increase overall when the task involved low surface similarity novel objects as compared to the high similarity objects of Experiment 1. Comparison of the high similarity objects seemed to more strongly highlight the perceptual feature overlap than the common structure of the objects. Therefore we reasoned that reducing the degree of that overlap should reduce the amount that comparison highlights surface features, and allow children to see the deeper relational match of the structure choice.

Method

Participants. Twenty-four additional four-year-olds (M = 4;4) were recruited for the second experiment, and were randomly assigned to the comparison and non-comparison conditions.

Materials. The stimuli consisted of 16 novel objects created in the lab (8 low similarity exemplars and the 8 test items from Experiment 1). As in the first experiment, there were four sets of test items consisting of a structure choice and a distractor choice, and four corresponding pairs of exemplars. All exemplars were structural matches with the structure choice for their group. For the low similarity exemplars, one object matched the distractor choice somewhat in shape only, and the other object did not match the distractor choice in shape, material, or color. For each pair of exemplars, both objects were used for the comparison condition, and the exemplar that matched the distractor choice somewhat on shape was used for the non-comparison condition.

Procedure. The procedure was the same as that used for the novel label condition of Experiment 1. Participants were randomly assigned to one of two conditions: comparison or non-comparison. As in the first experiment, each participant completed four trials; trial presentation order as well as the novel nouns used to label the four stimuli sets were counterbalanced.

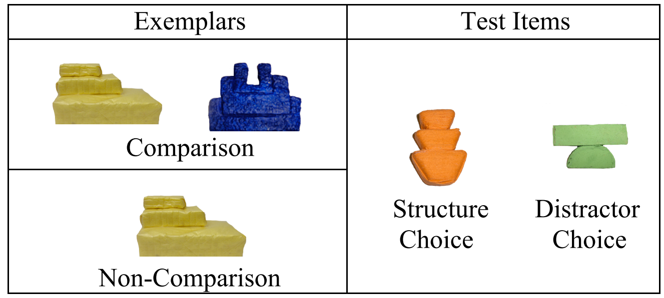

Figure 4: Sample item set from Experiment 2. Materials used include yellow cellophane, blue clay, orange yarn, and green foam.

Results

As in Experiment 1 the dependent variable was the average number of structure match choices that participants made across all test trials. Average numbers of structure choices from both Experiment 2 (low similarity) as well as the novel label condition of Experiment 1 (high similarity) were submitted to a 2 (surface similarity: high or low) x 2 (condition: comparison or non-comparison) ANOVA. There was a main effect of surface similarity such that number of structure match choices was higher when surface similarity was low, $F(1, 46) = 26.36$, $p < 0.001$. There was also a significant interaction between surface similarity and comparison condition, $F(1, 46) = 6.07$, $p = 0.02$ (see Figure 5). As shown in the results of Experiment 1, in the high surface similarity condition (novel label condition of Experiment 1) children made fewer structure choices after comparing two exemplars compared to initially viewing only one exemplar. The interaction here shows that this relationship reversed for the low surface similarity objects used in Experiment 2: children made more structure choices in the comparison condition than the non-comparison condition.

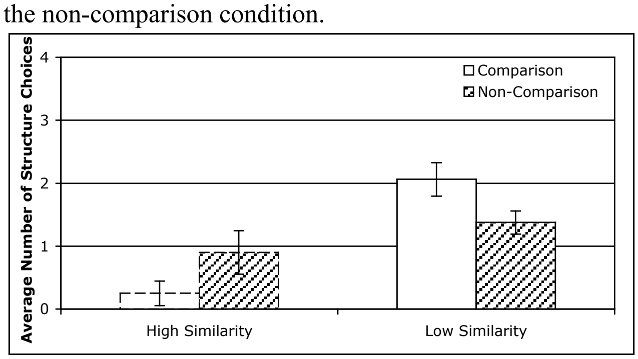

Figure 5: Experiment 2 results; all labels were novel. Note high similarity data is from the novel label condition of Experiment 1.

Post hoc *t*-tests were conducted to further explore this interaction. Participants were able to make significantly more structure match choices in the comparison condition when the exemplars had low surface similarity rather than high surface similarity, $t(30) = 5.51$, $p < 0.001$. Additionally, there was not a significant difference in number of structure choices in the non-comparison condition between high and low surface similarity, $p = 0.28$.

Discussion

The results of Experiment 2 help to shed some light on the role of perceptual feature similarities in comparison processes involving novel objects. In this experiment we varied the extent to which the exemplar objects shared surface feature similarities with the distractor choice test item. As shown in Experiment 1, when the exemplars were highly similar to the superficial choice in several dimensions, specifically material, color, and shape, comparison actually seemed to highlight surface similarities especially strongly. However when children performed the same task but with the low surface similarity exemplar objects of Experiment 2, comparison seemed to better highlight the deeper, structural relations between the exemplars and the structure choice test item. While this increase in number of structure choices in the comparison condition for low similarity as compared to high similarity objects was predicted, what is surprising is the magnitude of the increase. Specifically, administering this task with low surface similarity novel objects increased performance, in terms of number of structure choices, to the same extent as labeling objects with familiar structure related words.

General Discussion

In the current experiments we set out to explore the role of prior knowledge, language, and perceptual features in making comparisons of novel objects. We wondered whether the act of comparison highlights deeper relations rather than surface similarities, as has been found with studies using familiar items. In Experiment 1 we found that, in line with previous research in analogy making, prior knowledge of the items being compared does indeed matter: comparison *hindered* performance when novel objects and novel labels were used, that is, when prior knowledge of items was low. In the first experiment we also found that the use of known, structure-related labels led to increased identification of structural matches between novel objects. This indicates that language plays a role of supporting the integration of prior knowledge with new category information. In Experiment 2 we found that perceptual features also impact the comparison of novel objects. Reducing the degree of surface similarity between exemplar and test objects improved performance to the same extent as using familiar labels. Together these experiments show that in order for comparison to be beneficial, support has to be provided through links to prior knowledge. In the absence of prior knowledge that can be brought to bear, it is important to ensure that the possibility of mistakenly highlighting surface is minimized by comparing items of low similarity.

These results have implications for educational practices related to teaching new categories and concepts. Linking newly introduced items to familiar concepts, particularly with language, helps children make deeper connections between new items, and perhaps aids them in creating rich representations of new categories. Additionally, introducing new objects by presenting items that are more variable in surface features (i.e., share less surface similarity) further helps children by reducing the tendency to attend only to the superficial, especially when those feature similarities run counter to the deeper relationships.

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