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Replacing Language: Children Use Non-Linguistic Cues and Comparison in Category Formation

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Abstract

Language is a powerful instrument for extracting relational information from stimuli. In a label extension task common labels invite comparison processes that help children focus on the more subtle relational similarity and away from the readily available perceptual similarity of the stimuli. The current experiment aims to explore whether non-linguistic representations of category membership are sufficient to invite such abstractions of relational information. Preschool children were asked to extend a category to either a relational or an object match. When given the opportunity to compare two instances of the category, and provided with a non-linguistic cue children extended the category to the relational match. These results further extend the benefit of comparison in learning, and suggest that language labels are not the only cue children can use in category formation.

Keywords: categorization; cognitive development; relational processing; non-linguistic representations of relations.

Introduction

Analogical reasoning – the ability to see and use relational similarity between situations and events lies in the core of human cognition (Hofstadter, 2001). It is what makes humans so smart and it is potentially what distinguishes us from other species (Gentner, 2003; 2010). Analogy is central to many cognitive processes including learning, reasoning, decision-making, and categorization (Gentner, 1983; Gentner & Markman, 1997; Kokinov, 1998) and it promotes conceptual development in children (Christie & Gentner, 2010; Gentner & Namy, 1999; Graham, Namy, Gentner, & Meagher, 2010; Rattermann & Gentner, 1998). Thus, analogy is a key process of higher-order cognition that benefits learning (Gentner, 2010; Kokinov, 1998).

There is evidence that young children show analogical abilities, if they have knowledge of the relations involved (Gentner, 1983; 1988; Holyoak, Junn, & Billman, 1984). However, children tend to focus first on object similarities, before they start to notice common relational structure, independent of the objects involved. Gentner defines this phenomenon as the *relational shift hypothesis* (Gentner, 1988). She asked children to interpret different kinds of metaphors and say how they are alike. When children were asked to interpret the metaphor “A tire is a shoe”, 5-6-year-olds replied based on perceptual similarity (e.g. both are black), and 9-10-year-olds based their answer on the specific roles and functions of the two, thus giving a relational answer [e.g. you can go places with both (Gentner, 1988)]. When asked to perform a mapping task,

children first base their reasoning on the salience of object features (e.g. color, shape, etc.) thus failing to map the relations involved. To have a true relational ability, children must resist the temptation of the object features, and base their reasoning on the more subtle common relations involved (Gentner & Toupin, 1986).

Rattermann & Gentner (1998) provided further support for the relational shift hypothesis. They gave children a relational mapping task in which the experimenter and the child each had a set of three objects. The experimenter hid a sticker under one of her objects (e.g., the middle one). The child had to find his sticker in the same place (the middle of his objects). In some of the conditions, objects were cross-mapped, i.e. the middle object in the experimenter’s set was the same size as the leftmost object in the child’s set. In this condition, 3-year-old children had a difficulty resisting the perceptual similarity and instead of searching under the corresponding relational location, they searched under the identical object in their set. In contrast, 5-year-olds were better able to resist the object matches and give relational matches.

When searching for an interpretation of a given similarity, people (especially young children and novices) first focus on the object commonalities (Christie & Gentner, 2010; Kotovsky & Gentner, 1996). However, interpretations based on object attributes are not useful in deriving causal principles. Potential analogs are more difficult to notice because relations are more subtle and require a deeper analysis of the information. However, once found, the analogy is very useful in deriving key principles, since the structure holds true for both the base and the target (or the two situations), regardless of the objects involved in it. There are two factors that contribute to relational reasoning – relational comparison and relational language.

Relational Language and Learning

The first question is whether providing children with a noun label would help them learn a novel category. Evidence suggests that providing children with a count noun may bias them toward an object-centered interpretation of what kind of members are to be included into the category, since labels invite children to group things of *like kinds* together (Markman, 1989). Young children often base their reasoning on the more compelling perceptual similarity, and thus their intuition of likeness relies on object similarity. On the other hand, providing a common term could also serve

as an invitation to search for and find a common relation, thus promoting relational abstraction (Gentner, 2010).

When exploring children's understanding of categories, researchers use the word-extension task in which children are taught a new word and are given an example for it and then asked to extend the word to another example, thus showing an understanding of the category membership of the new item. Common labels invite deep reasoning and help children focus on like kinds. For example, in a series of experiments Gentner and Namy (1999) explored children's categorization abilities. The results show that children group items based on shape when they examine them in isolation (i.e. when they see only one standard). However, providing a label enhances the likelihood of children engaging in comparison, prompting children to compare the items bearing the same label.

Christie and Gentner (2010) extended these findings and showed that 3- and 4-year-old children successfully learned a novel label and extended category membership to the relational match. They explored how children base their hypotheses for category membership and showed the mutual benefit of comparison and relational label. When children had the opportunity to compare two examples of a given (novel) category, and heard a novel label, they extended the category to a relational match. This research shows the mutual bootstrapping between relational language and analogical abilities in preschool children (Christie & Gentner, 2010; Gentner, 2010).

Language and analogical comparison interact in the process of learning. This claim is supported by the language as a toolkit view, proposed by Gentner (2003; 2010). According to this view, acquiring a language provides new resources that support cognitive skills, while not replacing prelinguistic abilities. Specifically, this view assumes that structural alignment supports language learning, and that relational language supports structural alignment and reasoning. In addition, Gentner discusses four ways in which language interacts with analogical abilities to foster learning (Gentner, 2003; 2010). First, common labels invite comparison and abstractions, thus prompting children to compare two items that share the same label. Second, a linguistic label helps to preserve the abstraction derived from the comparison and makes it more accessible for future use, thus promoting reification. Next, naming promotes uniform relational encoding, which ensures the encoding of the relations in the same manner on different occasions. Last, the systematic structure of language can invite conceptual structure. Thus, language and analogical comparison interact with analogical abilities to foster learning and development (Gentner, 2010).

Relational Comparison and Learning

Analogical comparison promotes learning via a structural alignment process that is akin to relational mapping, thus highlighting the common relational structure and rendering it more salient (Gentner, 2010; Gentner & Markman, 1994; 1997). Similarity comparison process is one of alignment

and mapping of common relational structure, like the structure-mapping process of analogy. A result from carrying out a similarity comparison is that it highlights the relational structure and makes it more salient, thus enabling further abstractions and use. The alignment hypothesis assumes that the process of making a similarity comparison may lead to change in the representation. This change in turn will increase the uniformity of the two representations (Gentner, 1983; Gentner & Markman, 1997). Thus, alignment makes the relational commonalities more salient and the representations uniform. This typically increases the perceived similarity between the paired items. For example, Gentner and colleagues conducted a series of experiments that investigated the effects of comparison and common labels in children's categorization. The results show that when preschool children saw only one instance of a particular category, they extended the category to the perceptually similar match. In contrast, when children saw two examples simultaneously and were prompted to compare them, they were more likely to extend the category to a new, structurally similar item, than to a perceptually similar one (Christie & Gentner, 2010; Gentner & Namy, 1999; Graham, et al., 2010).

Gentner and Namy (1999) sought out to investigate how children form categories. They gave 4-year-olds a novel label (e.g. a *blicket*) for a pictured object (e.g. a bicycle) and asked children to find another *blicket* between two alternatives: a perceptually similar, but taxonomically different object (e.g. eyeglasses) or a perceptually different object from the same category (e.g. a skateboard). When children were presented with only one example of the category (e.g. a bicycle or a tricycle), they tended to choose the perceptual match. However, when they observed two examples (a bicycle *and* a tricycle), they were more likely to choose the relational match. Interestingly, the obtained results cannot be accounted to a traditional view in which comparison is considered a simple feature overlap. Rather, it seems that comparison selectively highlighted the relational commonalities (Gentner & Namy, 1999; Gentner, 2010).

Christie and Gentner (2010) followed this procedure and further extended the findings, showing the benefits of comparison in learning new relations. They presented 3- and 4-year-olds with animals in a novel spatial orientation and attached a novel label to it (e.g. a *dax*). When presented with only one example, or when two examples were provided but children were not prompted to compare them, they extended the category to the object match. However, children who compared the two examples of the category extended it to a relational match.

These results show that analogical comparison is useful in learning new principles, forming new categories, and retaining material better for transfer. One cannot help but see a tendency in all experiments discussed above – the mutual presentation of two (versus one) examples *and* providing a common label. It would be interesting to see if these two factors work mutually or if they could contribute

to category formation separately. This question is of particular interest in the present study.

Can language be replaced?

The main question we are asking here is whether language is unique in promoting analogical abstraction. Mutafchieva & Kokinov (2007) explored the hypothesis that a non-linguistic representation of specific relations would be beneficial in a relational mapping task. Following the procedure of Rattermann & Gentner (1998), they used labels (e.g. Daddy, Mummy, and Baby), a train analogy, or a physical representation of the relation *pulling* in the analogy (e.g. drawbars). The hypothesis was that the drawbars should be sufficient for the child to abstract the relation, and thus solve the mapping task. The results showed no difference between the various types of presentation (i.e. language labels, drawbars, or analogy). Interestingly, there was no evidence that providing labels further benefit performance on a mapping task. The drawbar condition seemed to be successful in promoting relational matches, similar to the labels, and the analogy condition.

Similarly, Gentner and colleagues conducted a series of experiments on the acquisition of relational categories that show that for 4-year-olds comparison alone without relational language is sufficient to invite relational responding (Gentner, Anggoro, & Klibanoff, 2011). In addition, Gentner, Namy and colleagues examined the role of comparison and shared names in categorization of novel objects. For example, Graham et al. (2010) gave 4-year-olds novel object sets that consisted of one, or two standards and two test objects to choose from, a texture match and a shape match. The results of the study are quite interesting. When children were presented with one standard, they extended the category based on shared shape, regardless of whether the objects were named. When children were presented with two standards that shared the same texture and the objects were named with the same noun, they extend category based on shared texture. Interestingly, the opportunity to compare in the *absence* of a shared label, led to an attenuation of the effect of shape, although not to a significant preference of texture. Interestingly, the authors found that adding a common label by itself did not change children's responding, however, it seems to augment the effect of comparison in shifting children toward the texture response (Graham et al., 2010).

One possible explanation of the obtained results is that in the No-word condition the authors provided children with a broad term (e.g. pointing to the standard(s): "This is one!"), thus limiting the possibility that the child could abstract a specific category cue. The term used is too general for children to elicit specific category representations and abstract common relational features between the two standards. On the other hand, the interesting fact that even without labels but with the opportunity to compare, children still could start to resist the perceptual match (e.g. shape), leaves a possibility that another type of non-linguistic representation of the category membership in addition to

comparison could benefit categorization among preschool children.

Continuing this line of research, the present experiment aims to explore the possibility that comparison is sufficient not only to promote abstraction of relational information, but also to aid category formation. The present study suggests that a non-linguistic cue in addition to comparison would successfully promote relational matches in a categorization task, thus showing that language labels are not unique in promoting relational categorization.

Experiment

The goal of this study is to explore the possibility that children can use non-linguistic cues when categorizing items. If language (a common label) is unique in promoting relational categorization, then it should be sufficient. Moreover, when deprived from the opportunity to benefit from a common label, children should fail to extend category membership based on relational similarity. However, if another mechanism (comparison) is present, and children rely on it during categorization, then it is possible that a non-linguistic cue will provide sufficient ground for children to extend the category based on relational similarity. Specifically, a non-linguistic cue that represents the category membership of two standards (e.g. a sticker) could provide enough ground for children to extend the category membership based on relational similarity. Bearing in mind that young children typically are tempted by the perceptual similarity and often fail to notice the relational similarity between two instances, it is important to investigate the various strategies children use to group the things they encounter into categories.

Following the idea that providing a means for category inclusion (whether the cue is linguistic or not) will further benefit children in their performance, here we test the roles of comparison and various types of cues. Comparison enables children to abstract the interconnected relational structure and focus on the commonalities between the two examples, especially shared relations. This helps children to disambiguate between two working hypothesis: object match vs. relational match. The specific cue provides further support and acts to focus their attention to the underlying common relations. Thus, the highlighted structure will become more salient and more available to new examples of the category.

The specific hypothesis of the study was that children in the Label and Sticker Condition would choose the relational match more often compared to the children in the NoWord Condition. In addition, children in the Label and Sticker Condition will do equally well. This logic follows from the language as a toolkit view discussed earlier (Gentner, 2003; 2010). Building upon this view, I posit that a non-linguistic cue will act in the same way as novel language labels do, prompting children to go beyond the readily available perceptual commonalities, and focus on the deeper relational commonalities.

Methods

Participants Forty-three 4-year-olds were recruited from kindergartens in Sofia area (28 females, $M_{age} = 52$ months; 15 in Label Condition, 14 in Sticker Condition, and 14 in NoWord Condition). Permission to participate was obtained from their parents prior to the study. Children received a small gift for their participation.

Materials The study uses the materials from the original study¹. The instructions were translated into Bulgarian. Children were given a word extension task on a triad of pictures that depicted animals. The two standards were labelled with a novel noun, and children were asked to extend the label to one of two alternatives: a relational match (new animals in the same configuration) or an object match (same animal[s] in different configuration).

The stimuli consisted of eight sets of animal pictures, with two standards, an object match and a relational match. Each picture depicted two or three animals configured in a novel spatial relation (e.g., two identical pigs facing each other). The second standard within a given set showed different animals in the same spatial configuration (e.g., two identical fish facing each other). The object match contained an exact animal match from each standard but in a different relational pattern (e.g., a pig and a fish turned back on each other). The relational match was composed of new animals in the same relational configuration as the two standards (e.g., two identical turtles facing each other; Figure 1).

In addition, two training sets depicting shapes were included that aimed to help children become more familiar with the procedure. Children did not receive feedback during the training session and the results from it were not counted in the analyses.

Procedure Children were randomly assigned to one of three between-subjects conditions: Label, Sticker, or NoWord. Materials were presented on laminated paper cards. Children were seated across from an experimenter.

In the Label condition, the experimenter laid the two standards and labeled them with a novel count noun (e.g. pointing to the first card, “*This is a blicket.*” Then, pointing to the second card, “*And this is a blicket, too.*”). Next, the child had to compare the two standards: “*Do you see why these two are both blickets?*” The experimenter then placed the two alternatives side by side below the standards and asked the child, “*Which one of these is also a blicket?*” After the child made a choice, the experimenter continued with new standards from a new set. Eight unique novel labels were used, one for each relational pattern.

The NoWord condition began the same way. The experimenter laid the two standards, but instead of labelling them with a novel word, she used the same generic term for all sets: (e.g. “*This is one. And this is one, too.*”). Then, the child was prompted to compare the standards, “*Do you see why these two are the same kind of thing?*” Last, the two

alternatives were presented, and the child was asked: “*Which one of these is the same kind of thing?*” This procedure continued for all eight sets of pictures.

In the Sticker condition, the experimenter laid the two standards and placed a sticker (a small circle) in the top middle of each standard. Then, the child had to compare the standards: “*Do you see why these two have stickers?*” Then, the two alternatives were presented and the child was asked: “*On which one of these should we also put a sticker?*” After the child made a choice, the experimenter continued with the next set. Eight different stickers were used for each of the sets.

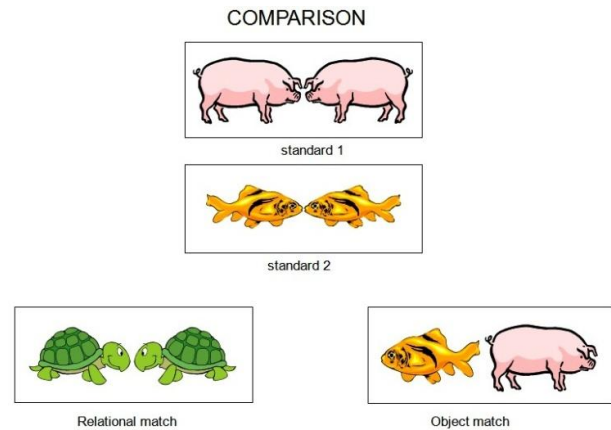


Figure 1: A sample of the sets in the categorization task

Results and Discussion

Mean proportion of relational matches in the category task were measured. Two different analyses were used to measure performance. First, a one-way ANOVA was used to calculate differences between the conditions. The analysis revealed a significant effect of condition, $F(2,40) = 4,867$, $p = .013$. Bonferroni post-hoc tests showed that children in the Sticker condition ($M_{relational} = 0.6$, $SD = 0.35$) made significantly more relational matches compared to the Label ($M_{relational} = 0.23$, $SD = 0.36$) and the NoWord ($M_{relational} = 0.28$, $SD = 0.34$) conditions. The Label Condition was not different from the NoWord condition, $p = 1.00$.

In the second analysis, the means of each group was compared to chance (50%). The comparisons revealed that children in the Label and NoWord condition chose object matches significantly more than chance, $t(14) = -2.981$, $p = .01$ and $t(13) = -2.48$, $p = 0.028$, respectively. However, the Sticker Condition was not significantly different from chance, $t(13) = 1.076$, $p = .301$.

As predicted, children who received a generic label performed worse than children who received a non-linguistic cue during category formation. Further, they showed a strong preference toward the object match, selecting it significantly more than chance. However, contrary to prediction, children who heard a novel label also performed worse than the children who received a non-linguistic cue, choosing the object match more often and significantly above chance level. Importantly, children in

¹ The materials were kindly provided by Stella Christie.

the Sticker condition chose the relational match more often, though not significantly above chance level. The obtained results provide further insights into the strategies that are available for children to use during category formation tasks.

General Discussion

Children improve dramatically in their analogical abilities over the preschool and early school years. Various factors contribute to the development of analogical abilities in young children. General experience (Rattermann & Gentner, 1998), maturation of executive functions (Richland, Morrison, & Holyoak, 2006; Thibaut, French, & Vezneva, 2010), and processing capacity (Halford, Wilson, & Phillips, 1998) all contribute to the development of analogical abilities. However, other mechanisms are also crucial to relational ability and learning in general – relational language and comparison (Gentner, 2003; 2010; Alfieri, Nokes-Malach, & Schunn, 2013).

Comparison is a general learning mechanism that provides efficient means for learning. In particular, in relational learning, comparisons provide children with the opportunity to engage in a process that is akin to relational mapping. This means that children are able to notice and abstract the underlying relational structure between the two standards and thus it becomes more salient and more available for new examples. Children acquire relational terms that support relational representation and reasoning (Christie & Gentner, 2010; Gentner, 2003; 2010; Gentner et al, 2011). Previous research shows that providing two examples with a common label prompts children to focus their attention to the more subtle structural commonalities (Christie & Gentner, 2010; Gentner & Namy, 1999; Namy & Gentner, 2002).

In this experiment, we sought to replicate data from the Christie and Gentner study (2010) and to further the findings with new conditions. We asked 4-year-olds to compare two examples of a given category and to extend the category to either an object match or a relational match. The results obtained in this study show that when children received a non-linguistic cue (e.g. a sticker) that represented category membership, they extended the category to a relational match. However, when they received either a specific novel label (e.g. *a blicket*) or a generic word (e.g. *one*), they extended the category to an object match.

Concerning the linguistic cues, there are two possible explanations for the obtained results. First, it is possible that providing children with a count noun as a category label focused them to pay more attention to the objects involved (Markman, 1989). As mentioned above, children understand that labels refer to like kinds, but their naïve intuition is to assume that the likeness refers to the objects and not to other commonalities. Children often encounter relational nouns (nouns whose meaning is defined by their relation to other entities) in everyday speech when interacting with adults. However, there is some ambiguity between object construal and relational construal. For example, when children hear a

relational noun (e.g. X is an uncle), they typically focus on perceptual features (e.g. old man) than relational features [(e.g. brother of mother); Gentner, 2003; Christie & Gentner, 2010].

A second possibility is that children in the Label condition had a difficulty to encode the specific labels used. It is possible that the labels we used are phonologically very different from the majority of words in Bulgarian. If children focused on trying to understand the meaning of an awkward word, their capacity to process the relational information for the two standards was limited. In addition, children in both the Label condition and the NoWord condition heard a word representing the category membership, whereas children in the Sticker condition were able to see the sticker at all times during the categorization task. It is possible that when children hear a word it is more difficult to encode and update the cue, but when a cue is always present and readily available there is no need to store it in working memory and thus encoding it is easier. Although such an assumption seems rather unsupported, having in mind the data from previous research on language labels and comparison among preschool children, it is worth investigating further why our experiment failed to replicate the Label condition in the original study.

Following the main idea of the present study – to explore the various strategies children use during relational categorization, further work is needed to see how comparison supports relational abstraction in preschool children independent from language. It is worth mentioning that the experiment presented here is part of a larger ongoing study. We are currently collecting more data that will provide further insights into the specific roles of different types of presentation and cues in category formation in preschool children.

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