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Re-representation Using Labels: Comparison or Replacement?

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Abstract

The practice of labeling seems to allow children to make difficult relational similarity matches. Two experiments explore the cognitive processes of comparison and replacement that have been implicated in the beneficial effects of linguistic labeling. Since linguistic labels may be implicated in a number of these processes, our experiments used traditional non-linguistic labels (post-its) to promote *either* the process of comparison or replacement. Results from two relational matching tasks suggest that comparison is more influential than replacement.

Keywords: relational reasoning, transfer, symbols, labels, comparison, re-representation.

Introduction

Any story about development and learning must address the shift from dependence on concrete and physical similarity to behavior based on more abstract and derived sorts of similarities (Piaget, 1952; Quine, 1960). There are many empirical demonstrations of a shift showing that children and novices use superficial object-based similarities while mature learners can respond according to more subtle relational similarities (see Gentner & Rattermann, 1991 for a review). The broad goal of the experiments reported here is to develop a greater understanding of how this relational shift occurs.

The acquisition of linguistic labels that refer to relations is consistently identified as playing a large role in augmenting cognitive abilities (Clark, 1997; Gentner, 2003). Contemporary discussions of how labels may promote relational reasoning involve several steps. First, labeling a relation (e.g., AA as "same" and BB as "same") may foster comparison, a process which has been shown to direct attention to higher order relational similarities (Goldstone, Medin, & Gentner, 1991; Loewenstein & Gentner, 2001). Comparison and the subsequent highlighting of relations also serve as an important gateway to re-representation, altering the description of a situation in terms of these newly salient relations (Gentner, 2003). This process of re-representation is not just a convenient byproduct of experience, but rather has even been proposed as a fundamental part of human development (Karmiloff-Smith, 1992).

This multi-step process has several components that may be separable. One of these is the "re-representation" process itself. Labels of all kinds, word forms as well as physical tokens, are themselves physical stimuli (and internally represented forms) that can be perceived (and mentally manipulated) to benefit cognitive processes. Labels could directly promote re-representation by acting as stand-ins for internal computation (Bruner, 1990; Clark, 1997). The argument for label replacement runs as follows: 1) objects are generally easier to process than relations, 2) if a relation is associated with an object-like label (words or other symbolic tokens), then processing relations becomes essentially equivalent to processing new objects. A compelling example of this concerns judgments of same/different relations by chimpanzees (Thompson, Oden, & Boysen, 1997). In these studies, the chimpanzees are taught to label a relation with an arbitrary physical token, such as a heart-token for same (e.g., ♥ → AA) and another token for different (e.g., # → AB). Having learned this, chimpanzees can make second-order matches, judging AA to be related to BB. Chimpanzees could potentially do this task, not by abstracting the relation of sameness across instances, but by knowing that AA → ♥ and BB → ♥. Then they can simply respond to the sameness of ♥ and ♥. That is, the second-order relation (that "same" and "same" are the same relation) might result from direct computations over the labels standing in for relations. Thompson and colleagues theorized that by mentally replacing AA with a heart-token and BB with a heart-token, these chimpanzees were able to re-represent this relational matching problem as an object-matching problem.

It seems likely, that linguistic labels work in both ways – through comparison processes that highlight relations and lead to more abstract representations and through replacement that leads more directly to easily manipulated representations. Nonetheless, in the experiments that follow, we attempt to disentangle these two hypotheses about the role of labeling in children's relational reasoning.

LABELING ⇓ COMPARISON ⇓ HIGHLIGHTS RELATIONS ⇓ RE-REPRESENTATION	LABELING ⇓ REPLACEMENT ⇓ RE-REPRESENTATION

Figure 1: Two hypotheses of how the practice of labeling with symbolic tags facilitates relational generalization.

Kotovsky and Gentner (1996) offer an interesting series of experiments that provide a useful basis for exploring the benefits of each of these processes in a relational match-to-sample task. They presented four-year-old children with a triad of cards, a standard and two answer choices consisting of a relational match and a non-relational foil. Children were introduced to two relations, symmetry and monotonic increase. The symmetry would be displayed, for example, on a card with three elements (small-big-small squares or light-dark-light colored squares). Monotonic increase would be on a card with three squares increasing in size or color. The elements in the answer choices were similar to each other (i.e. xXx and xxX) but differed from the standard (i.e. oOo) to ensure that only the relational answer shared similarities with the standard. When the standard and relational match instantiated the critical relation on the same dimension (i.e. size symmetry, oOo and xXx), they found that 4-year-olds succeeded in responding to relations such as symmetry. However when the relational dimension changed (i.e. oOo and light blue-dark blue-light blue) or the relational polarity changed (i.e. oOo and XxX), their performance went down to chance.

In order to help these children respond relationally particularly in the more difficult cross-dimensional and cross-polarity triads, Kotovsky and Gentner introduced linguistic labels (i.e. "even" to indicate symmetry) such that multiple training instances showed the same relation being labeled with the same name. As in previous research (e.g., Loewenstein & Gentner, 2001), this labeling facilitated relational responding at transfer. Why did the label work? One possibility is that labeling two instances with the same name may have caused children to compare them. Alternatively, children may – by associating the instances with the label – be able to recognize (and match) instances without any comparison or abstraction of the higher order relation. That is, labeling opportunities that may result in comparison may also promote re-representation by way of replacement. It is conceivable that children were able to recode the standard as "even" and the relational match as "even" and make an object level match through replacement and re-representation.

Rationale for the Present Study

The goal of the present experiments is to provide additional evidence on the role of labels in promoting comparison and/or redescription in children's relational learning. To do this, we did not use linguistic labels since they may implicate both comparison and replacement. Instead we sought a form of "label" that could be manipulated in ways to directly promote comparison versus redescription. In this effort, we invented symbols that are *iconically* related to the relation. For example, as illustrated in Figure 2, if the instance of the symmetry relation was a card with a cross, penguin, and cross, the associated "label" was a series of squares arranged symmetrically. In order to implement a condition that promoted comparison and one that promoted redescription, these squares were actually colored post-it notes that could be stuck onto the cards – either below the iconically corresponding figures on the card, thus (perhaps) promoting comparison, or directly on top of the figures (also shown in Figure 2), thus perceptually replacing the original instances and in this way promoting a more direct form of redescription. In this way, post-its act as a proxy for symbolic tokens providing a convenient means for re-representation. However, post-its, being objects themselves, can also be compared to other objects.

We used a modified form of Kotovsky and Gentner's (1996) match-to-sample paradigm for preschoolers as the test for noticing relations, but preceded it with two training conditions with physical labels designed to induce comparison or redescription of salient object information. Children were shown cards with objects such as animals, vehicles, and colored shapes on them. These objects are arrayed in an "even" relation like ABA (small-big-small; obj1-obj2-obj1) or a "leading" relation such as BAA (big-small-small; obj2-obj1-obj1). Four-year-olds are trained to label small objects with small post-its and large objects with large post-its (see Figure 2). In the comparison condition, children are trained to place the post-its below the object, which allows for side-by-side perceptual comparison. In the replacement condition, children are trained to place the post-its over the object. In this condition, the post-its play the redescriptive role of labels, providing new computational units that replace initially salient object information; and there is not as much opportunity for perceptual comparison because the original objects are no longer perceptually available. Notice, in addition, that another way to conceptualize the two conditions is whether learners see the instance and iconically related form simultaneously (comparison condition) or successively (replacement condition). A control condition did not receive any label training. These three groups were then asked to generalize their training to new examples of the learned relations.

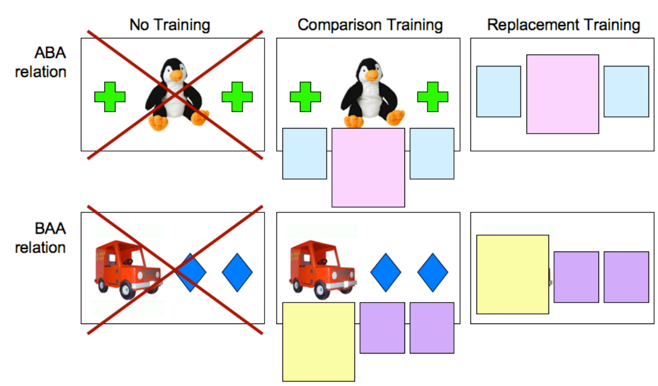

Figure 2: Training conditions for Experiments 1 and 2. The control condition did not see these training cards at all.

Experiment 1

If comparison is more important for directing attention to relevant relational information, we expect children who put post-its beneath the objects, having had a perceptual opportunity to compare instances, to generalize to novel exemplars of the learned relations. However, if re-representation really mediates such generalization, we would expect children who replaced the objects with the post-its to do equally well or outperform those in the comparison condition. Additionally, these learning opportunities should facilitate relational matching over no learning opportunities at all.

Method

Participants. Forty-four children, mean age of 56 months (51-68 months) participated from local daycares. One child did not complete the experiment and was excluded from the analysis.

Materials. Children were trained on two examples of two relations presented on laminated cards, each depicting an array of three objects. The ABA relation was presented with a triangle-bear-triangle card and a cross-penguin-cross card. The BAA relation was taught with a car-diamond-diamond card and a boat-rectangle-rectangle card. Large pink post-its and small blue ones were used for the ABA relation cards while large purple post-its and small yellow ones were used for the BAA relation cards.

Generalization tests were match-to-sample triads with a standard made out of post-its (i.e. large pink-blue-blue post-it array) and two answer choices which were novel instantiations of ABA and BAA (see Figure 3). The novel cards instantiated these relations in the dimensions of shape (e.g., circle-diamond-circle), color (e.g., purple-lavender-purple), or opposite size polarity (e.g., big-small-big). The standard was shown on a box and children placed their answer choice inside it.

Additional stimuli included task-training triads used to train children on the match-to-sample task. These triads had a novel standard (i.e., pentagon) and an exact match and an unmatching foil (i.e., pentagon versus circle). There were also easy filler triads made up of a novel standard (i.e., two orange triangles) and two easy answer choices (i.e., two orange triangles versus one yellow triangle). These triads were designed to help encourage children during the experiment while also serving as a measure of their engagement in the task.

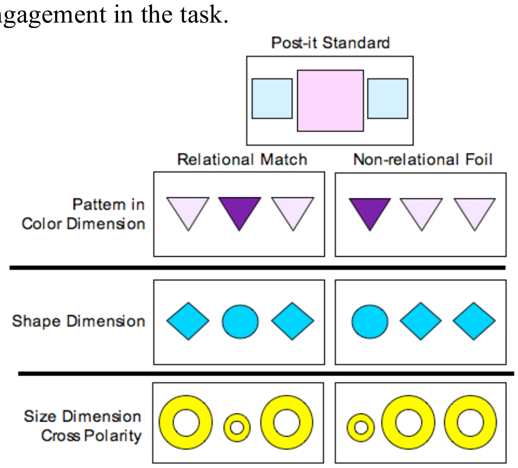

Figure 3: Test trials from Experiment 1

Procedure and Design. There were three between-subject conditions: Comparison, Replacement, and a no-training Control. Children in the control condition did not see the training cards nor did they have experience with post-its.

In the training phase, the experimenter showed the child how to place post-its appropriately onto a training card. Immediately afterward, the child was given an identical training card and their own set of post-its (e.g., large pink and 2 small blue ones) and instructed to do the same. This occurred four times, one for each training card. The training was always done in the same order (bear, penguin, car, boat) such that the children saw two ABA cards in a row and then BAA cards in a row. Children were given corrective feedback if they placed post-its incorrectly. Experimenters were instructed to provide children with opportunities to place post-its until they were able to do it correctly on their own. However, every child placed post-its correctly.

Next, children were trained to do the match-to-sample task with the two task-training triads. These easy triads were repeated until the child got both triads correct without feedback. This was followed by 6 match-to-sample triads, half with the ABA post-its as the standard and half with BAA. Each triad was repeated for a total of 12 test trials. The spatial location of the relational match alternated between trials. There were an additional four filler trials that were interspersed with the test trials. These 16 trials were presented in a semi-random order and children were given neutral feedback (e.g., "Okay! Thanks!").

On each test trial, the experimenter would attach the post-it standards onto a box with a slot cut out on top. The experimenter would then place two answer choices in front of the child and ask, "Which card is like this one (pointing to standard)? Pick the card like this one (pointing to standard)! Put that one in the box!"

Results and Discussion

Children in all three conditions did not differ on their performance on the easy filler trials, $F(2, 43) = 1.678$. Only 6 children made errors at all on these trials. Their ceiling performance (M=.95, SD=.12) suggests that they were engaged in the task. However, an ANOVA revealed that correct test trial performance was significantly different between the groups, $F(2, 43) = 6.043$, p<.01 (see Figure 4).

Children who had comparison training made significantly more relational matches to the post-it standards than children in *both* the control condition, $t(28) = 12.629$, p<.01, and replacement training conditions, $t(30) = 4.615$, p<.05. Replacement condition performance did not significantly differ from control responses, $t(27) = .236$. However, it was not the case that replacement training made no impact at all. While control children chose relational matches .57 of the time (SD=.18) a rate consistent with performance at chance, $t(12) = 1.391$, children in the replacement condition did not made relational matches at random. Average replacement performance was .67 correct relational matches (SD=.23), significantly different from chance, $t(14) = 2.815$, p<.05. Predictably, comparison performance (M=.84, SD=.21) was also significantly different from chance, $t(15) = 6.264$, $p<.001$.

Although replacement training may have had some effect on children's ability to make relational matches, it seems that comparison provided a more powerful opportunity to learn about relations in a way that generalized beyond the four training cards. Theories about comparison often include re-representation as part of the process (e.g., Gentner, 2003) so it may be that comparison not only shifted attention to relevant relational information but also gave children the time and opportunity to reinterpret the crosses and penguins in more general terms. Covering up the objects did not allow children to do this on their own.

This first experiment examined children's ability to make *near* transfer of trained post-its to new relationally similar instances. But comparison in past literature is proposed to affect behavior in *far* transfer. Multiple instances viewed simultaneously afford a side-by-side comparison where similarities can be highlighted (Namy, Smith, & Gershkoff-Stowe, 1997). Since the post-its and penguins/crosses do not have many properties in common besides their relational similarities, these similarities may have been attentionally boosted during comparison training. If so, this perceptual experience can potentially help children find the relational similarities in match-to-sample triads *even* without the presence of mediating post-its. The generalization test in Experiment 2 is more like Kotovsky and Gentner's (1996) original study where the standards are no longer the familiar post-its but are themselves novel cards.

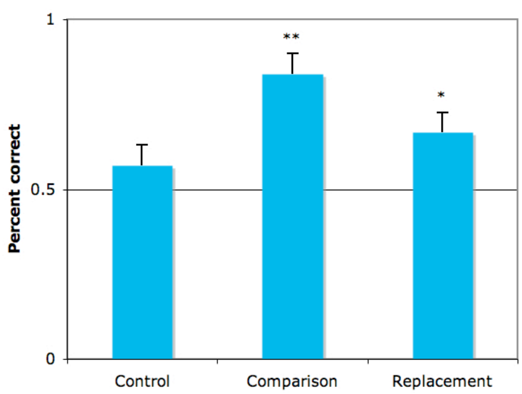

Figure 4: Results of Experiment 1.

Experiment 2

In Experiment 1, comparison training was found to have a significant benefit on relational generalization. Replacement training also showed limited benefits when the test trials included post-its to mediate their relational generalization. In Experiment 2, we will test whether these training programs can result in relational matches between novel answer cards and novel standards. Children are presented with the same two forms of post-it training (or no training if they are in the control condition), only the tests of generalization have changed. If comparison directs attention to relational information, we should still see benefits of comparison training. Additionally, if re-representation uses post-its as the new representations, the absence of post-its should also reduce the number of correct relational responses made by children in the replacement condition.

Method

Participants. Thirty-eight children, average age 53.8 months (range 45 to 62), participated in this experiment. Five children were taken out of the analysis (three who did not finish the experiment and two who only chose cards presented on their right side).

Materials. Training materials were identical to those used in Experiment 1. Generalization tests were match-to-sample triads with a novel size standard (e.g., an array of three crosses, big-small-small) and two answer choices which were novel instantiations of ABA and BAA (see Figure 5). The novel standards were all size relations while answer choices differed on shape (e.g., star-square-square), color (e.g., purple-lavender-lavender), or opposite size polarity (e.g., small-big-big).

Procedure and Design. The procedure and design was almost identical to that of Experiment 1. Children in the comparison and replacement conditions got post-it training first. Then children in all three conditions were given task-training trials before moving onto the test and easy filler trials. Pilot testing on the novel standard triads revealed that this test was considerably difficult and easily frustrating for children so the number of unique match-to-sample triads was reduced to 4, half with the ABA pattern as the standard and half with BAA. Each triad was repeated for a total of 8 trials. The spatial location of the relational match alternated between trials. There were 4 additional easy filler triads.

Results and Discussion

An analysis of the easy filler trials revealed no difference among the three conditions, $F(2, 37) = .052$. Average performance was .89 correct (SD=.18). However, 12 children faltered on these filler trials, almost twice as many as in Experiment 1. This is reasonable considering that this task was considerably harder for children.

Initial summary statistics revealed that children's performance on the test trials were overall poor in this experiment. Even the best performance, shown by children in the comparison condition, was only an average of .61 relational matches (SD=.22). Replacement performance was .57 (SD=.23) and control performance averaged at .51 (SD=.16). These averages are all statistically equivalent to chance. According to an ANOVA, there was no difference in the novel standard test performance between groups, $F(2, 37) = .085$.

Because this task was difficult, more children seemed to lose interest partway through the experiment. To account for children who may have stopped paying attention or given up during the test, we analyzed the performance of children who got all four easy filler trials correct (see Figure 5). The only group who achieved above chance performance on this test was the comparison group (*M* = .68, *SD* = .17), $t(6) = 2.705$, $p<.05$. Even for children who presumably paid attention through the testing, replacement training did not allow performance to be better than chance (*M*=.54, *SD*=.17), $t(11) = .670$. As expected, even alert control participants were unable to exceed chance performance (*M*=.57, *.SD*=14), $t(6) = 1.333$.

As in Experiment 1, providing a perceptual experience that allowed for comparison promoted some relational generalization where as replacement training and no training did not. Although these results are more muted, partly due to task difficulty, the slight advantage of comparison even at this stringent level of difficulty indicates that it is indeed a powerful experience. Relational tasks require that children attend to less salient information than object properties and comparison seems to help direct them to this subtle regularity.

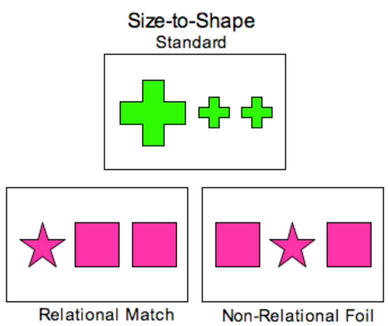

Figure 5: An example of a test trial with a novel standard card. There were size-to-shape, size-to-color, and size-to-opposite-polarity triads.

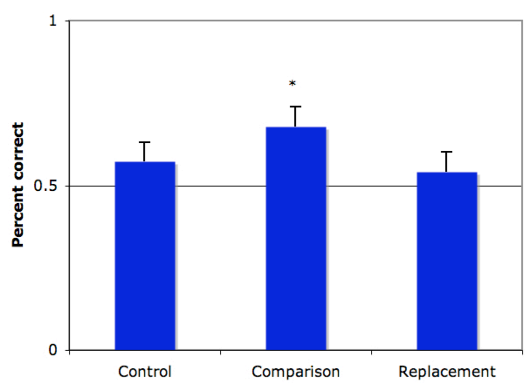

Figure 6: Novel standard test performance of children who completed all four filler trials correctly.

General Discussion

The preschool aged children in our experiment find it difficult to make relational matches across sets of objects. Our experiments provided children with a short training sequence, putting post-its on only four cards, but this experience helps them find subtle relational similarities and ignore salient object differences. One of the most surprising aspects of the results is the impact on children's learning made by a slight difference in training between the comparison and replacement conditions. The same cards and same post-its were used with the same generalization tests. However, the resulting experience from juxtaposing or covering with the labels is very different. It seems likely that these two different "labeling" conditions initiated different cascades of processes resulting in different perceptions of similarity and patterns of relational generalization.

Comparison that Entails Re-representation

The results reported here indicate a particular importance of comparison during *training*, in directing attention to critical relational information. Experiments 1 and 2 showed consistent advantages of comparison in highlighting learned relations. Placing the iconically related labels in view and in one-to-one correspondence with the objects in the relational display gives children an opportunity to compare their locally matched label-object pairs to highlight a more global pattern of similarity. Once attentionally highlighted, most theories of comparison include re-representation and although our results do not directly address this question, it might seem tempting to interpret our positive comparison results to mean re-representation is not necessary.

However, this may be premature because we should consider a case where there is comparison that does not lead to re-representation: children are given training cards and labels that look identical to the objects (see Figure 7). Although there is a side-by-side opportunity for comparison, and the original crosses and penguins are perceptually available for reinterpretation, there is no impetus for such cognitive work. We have preliminary data suggesting that such an instance of comparison *without opportunity for redescription* is not sufficient to produce transfer.

So, how do comparison opportunities foster redescription? (1) Comparison allows local similarity and differences to suggest a recoding in terms of global structure (Markman & Gentner, 1993) or (2) comparison allows children to ignore specific information for a more abstracted/simplified recoding. We are currently running a version of our experiment testing these types of comparison.

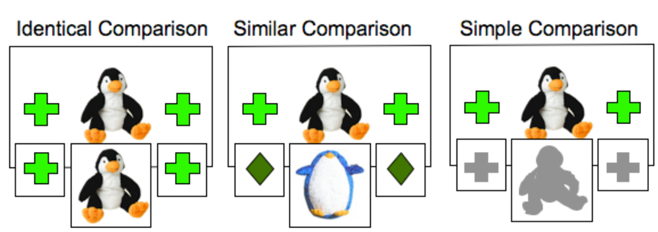

Figure 7: Training stimuli from currently running experiment in this series.

Similarity and Simplicity in Redescription

The provision of labels could support relational encoding on two levels: by fostering comparison among instances or by simplifying learning instances. Effectively utilizing simpler alignments to bring about higher-level reorganization echoes the purpose of re-representation (Karmiloff-Smith, 1992) and more specifically progressive alignment (Kotovsky & Gentner, 1996; Markman & Gentner, 1993).

According to progressive alignment (and its larger framework, Structure Mapping Theory, Gentner, 1983), local matches make global relations more salient. This has been shown in several relational domains including number (Mix, 2002) and map use (Loewenstein & Gentner, 2001).

However, labeling also provides simpler, less contextualized representations of embedded situation-specific information. These simpler representations are the labels themselves. Simpler representations such as symbols can encapsulate a wide variety of instances. The advantages of simplicity for the purposes of generalization has been widely documented from young children's symbol use (Uttal, Liu, & DeLoache, 1991) and object categorization (Son, Smith, & Goldstone, under review) to adult transfer in mathematics (Sloutsky, Kaminski, & Heckler, 2005) and physics (Bassok & Holyoak, 1989). Additionally, concrete details can potentially compete for attentional resources, distracting young children (Rattermann & Gentner, 1998) and novices (Goldstone & Sakamoto, 2003) from *relational* redescriptions, and creating object-inclusive descriptions instead. In sum, labels that draw on the combined forces of similarity and simplicity may be most beneficial for relational redescription.

Conclusions

What does is take for learners to generalize to dissimilar new situations? How do we foster abstract descriptions? How do we get problem solvers to attend to newly relevant information? These questions are important for educators and theorists alike. The processes of comparison, replacement, and redescription have been implicated in theories of higher cognition such as language, abstraction, similarity, and categorization. Systematic understanding of these simple processes may shed light on how they foster such sophisticated changes in thinking. Labeling in and of itself may not be a particularly special activity – but because it works together with comparison and redescription, it exerts great influence. Although labeling has been linked with high-level abstract descriptions and generalizations that characterize human cognition, these benefits may really be a product of the ongoing interaction of simpler processes.

Acknowledgements

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