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Comparison and the development of knowledge☆, ☆☆

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Abstract

This paper considers the role of comparison in the development of knowledge. Results show that comparing similar objects makes them appear more similar. Comparing dissimilar objects, on the other hand does not make them appear more similar, and in some circumstances may make them appear less similar. The effect of comparison on similar items was especially striking since participants judged items to be more similar after comparison even if the comparison task was to list differences between the two items. Further, this effect appears specific to comparison and does not appear to be simply due to a "fleshing out" of object representations (listing properties of two objects without comparing the objects themselves served to increase the objects' similarity regardless of whether the objects were similar or dissimilar to start). This suggests that comparison may play a special role in partitioning bits of experience into categories, sharpening categorical boundaries, and otherwise helping us create conceptual structure above and beyond that offered by the world.

Are our mental representations of things in the world simply a reflection of the structure of the world, or do we create new structures and partitions in conceptual

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space? Further, are our representations static, or do they change over time in systematic ways as a result of the way we process and use our knowledge? This paper suggests that some common cognitive processes (in this case, comparison) can introduce systematic biases into our representations of the world. These biases may be beneficial for separating out bits of experience into categories, sharpening categorical boundaries, and otherwise helping us create conceptual structure above and beyond that offered by the world.

This paper focuses on object similarity. Similarity is a central construct in explanations of cognition. Explanations of categorization, induction, learning, and memory all rely on the construct of similarity. Things that are similar are likely to end up in the same categories, are likely to support inductive inferences for each other, will aid in the learning of other similar things, and serve as good reminders for one another in memory. But where do similarities come from? Are similarities between objects apprehended immediately and automatically, or do they develop as a function of directed processing and experience?

Previous research suggests that aspects of experience can play an important role in the development of similarity. For example, there is evidence that object representations can change as a result of category learning (with objects assigned to the same categories becoming more similar) (e.g., Freyd & Tversky, 1984; Gauthier, James, Curby, & Tarr, 2003; Goldstone, Lippa, & Shiffrin, 2001; Kurtz, 1998; Medin, Goldstone, & Gentner, 1993; Schyns, Goldstone, & Thibaut, 1998; Schyns & Murphy, 1994; Schyns & Rodet, 1997), and that the perceptual and conceptual similarity of objects can be affected by comparison processes (Hassin, 2001; Lin & Murphy, 2001; Medin et al., 1993; Tversky, 1977; Tversky & Gati, 1978). Further, previous research by Gentner and Namy (2000) suggests that providing children with an opportunity for comparison may help them in category learning by allowing them to discover deeper relational similarities between category members (see also Kurtz & Gentner, 1998).

This paper considers the role of comparison in the development of similarity. Results of four experiments suggest that comparison can play an important role in knowledge development. By making similar things appear more similar, and dissimilar things appear less similar comparison may help us partition bits of experience into categories and sharpen categorical boundaries.

Four experiments explore the effects of comparison on object representation. Experiments 1 and 2 examine the effects of comparison on the perceived similarity of similar and dissimilar objects. Experiment 3 contrasts the effects of comparison with those of simple "fleshing out" or elaboration of object representations. Experiment 4 extends the findings of Experiments 1and 2 to novel objects.

1. Experiment 1

1.1. Method

1.1.1. Participants

One hundred and thirty-two Stanford University undergraduates participated in the study in order to fulfill a course requirement.

1.1.2. Materials

Materials consisted of a one-page questionnaire. The top of the page contained line-drawings of four named familiar animals (a deer, a horse, a goat, and a donkey) as shown in Fig. 1A. The rest of the page contained three questions. For 73 participants, the first question asked them to describe three similarities between two of the animals (e.g., "Please describe 3 similarities between the goat and the donkey.") For the other 59 participants, the first question asked them to describe three differences between two of the animals (e.g., "Please describe 3 differences between the goat and the donkey.") Participants were given three blank lines for their responses. Which two animals were chosen for comparison was counterbalanced across participants such that each pair of adjacent shapes was the focus of comparison equally often. Which animal was named first in the comparison was also counterbalanced across participants. The last two questions asked participants to rate the similarity of the two animals they had just compared (e.g., "How similar are the goat and the donkey?"), and of the other two animals (e.g., "How similar are the deer and the horse?"). Half of the participants rated similarity for

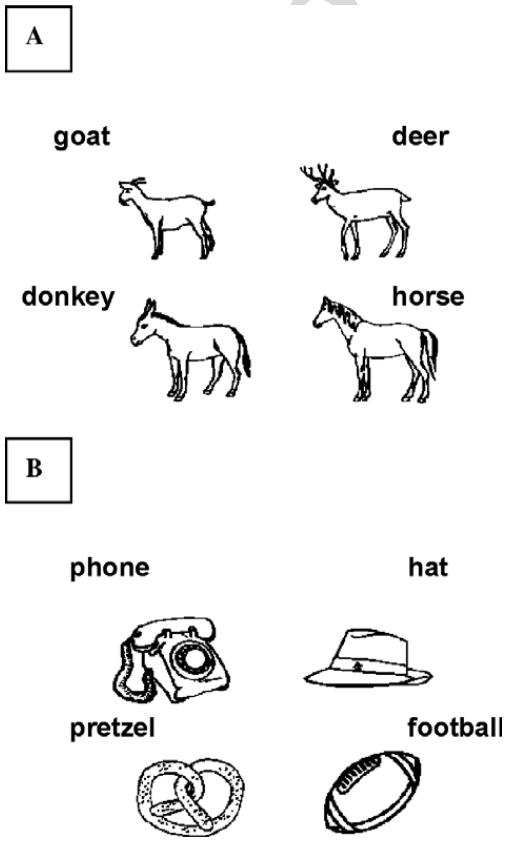

Fig. 1. Stimuli used in Experiments 1 and 2 [shown in (A) and (B), respectively]. Images were taken from Snodgrass and Vanderwart (1980).

the previously compared pair first, and the other half rated similarity for the other pair first. As before, which animal was named first in each comparison was counterbalanced across participants. Participants rated similarity on a 10-point scale (1 = not similar and 10 = very similar).

1.1.3. Procedures

The one-page questionnaire was embedded in a larger questionnaire packet which contained many other pages unrelated to this study. Participants completed the questionnaire at home on their own time.

1.2. Results

Comparing two similar items made people think of them as more similar. This was true regardless of whether the comparison involved naming similarities between the two items ($M = 6.49$ after naming similarities, $M = 5.89$ without naming similarities, $t = 2.66$, df = 3, $p < .05$) or naming their differences ($M = 6.71$ after naming differences, $M = 6.32$ without naming differences, $t = 2.93$, df = 3, $p < .05$). There was an overall effect of comparison ($F(1,6) = 14.3$, $p < .01$) and no interaction between the two comparison types ($F(1,6) = .64$, $p = .46$).

1.3. Discussion

Experiment 1 showed that comparing two things (even when looking for their differences) can cause people to discover similarities between the two things. But why should the similarity of two objects increase after they are compared, especially if one's task is to describe their differences? One possibility is that in the process of finding and articulating differences, people are also finding similarities. As shown by Gentner and Markman (1994), the most meaningful (and easiest to name) differences are those that are attached to the structural similarities. On this view, because the process of comparison involves an alignment between two representational structures (see Markman & Gentner, 1993a, 1993b, 1996), discovering meaningful differences involves first establishing the similarities. To take a particular example, if one wanted to mention that the goat has a shorter tail than the donkey (a difference), this makes salient the fact that both animals have tails (a similarity).

But there could also be a less interesting explanation for these results. What if similarity only increases after comparison because people create a new feature for the things they compare, something like "thing I compared before." If this is the case, similarity might be increasing simply because the two things previously compared now both have this extra feature in common. One way to test this possibility is to ask people to carry out comparisons between things that are so different, that no meaningful similarities are likely to be found. If comparison no longer serves to increase perceived similarity, then it is the ability to find meaningful similarities (and not just the creation of an extra feature) that is responsible for the findings of Experiment 1. In Experiment 2, the pictures of four similar animals used in Experiment 1 were

replaced with pictures of four quite dissimilar objects: a phone, a pretzel, a hat, and a football.

2. Experiment 2

2.1. Method

2.1.1. Participants

One hundred and forty-nine Stanford University undergraduates participated in the study in order to fulfill a course requirement.

2.1.2. Materials

Just as in Experiment 1, materials consisted of a one-page questionnaire. The top of the page contained pictures of 4 dissimilar objects as shown in Fig. 1B. The rest of the page was constructed just as described for Experiment 1. The comparison task for 61 of the participants was to name differences between two items, and for 88 of the participants to name similarities.

2.1.3. Procedures

The procedures were the same as in Experiment 1.

2.2. Results

First, the stimuli in this experiment were indeed perceived to be much less similar to each other ($M = 2.60$) than those used in Experiment 1 ($M = 6.50$), $F(1,118) = 278.9$, $p < .001$. This was necessary as a manipulation check.

It turned out that comparing two dissimilar objects did not increase their similarity and in fact, may have slightly decreased it ($M = 2.75$ after comparison, $M = 2.87$ without comparison, $t = -2.04$, $\mathrm{df} = 3$, $p = .07$). Naming differences between two dissimilar objects actually made participants think of the objects as less similar ($M = 2.37$), than if they had not compared them before ($M = 2.75$), $t = -2.54$, $\mathrm{df} = 3$, $p < .05$. Naming similarities did not produce a significant effect of comparison ($M = 3.12$ after naming similarities, $M = 2.98$ without naming similarities, $t = .72$, $\mathrm{df} = 3$, $p = .26$). This pattern was significantly different from that observed in Experiment 1 as confirmed in an interaction in a 2×2 repeated measures ANOVA (2 (compared or not) $\times$ 2 (stimuli similar or dissimilar)), $F(1,6) = 12.1$, $p = .01$.

2.3. Discussion

Comparison appears to have different effects on similar and dissimilar objects. Comparing things that are similar can lead one to discover new (or highlight old) similarities, thereby increasing the perceived similarity of the two objects. Comparing things that are dissimilar on the other hand, is less likely to lead one to discover

similarities (since there are fewer similarities there to be discovered). Hence, comparing two dissimilar things may serve to make the items less similar (see footnote[1]).

To further explore these results, the actual differences listed by participants in Experiments 1 and 2 were analyzed. Structural alignment researchers distinguish between two kinds of differences: alignable and non-alignable (e.g., Gentner & Markman, 1994). A difference is counted as alignable if it mentions corresponding aspects of two items (e.g., "the horse is larger than the goat" or "the horse is large, the goat is small"). Any other kinds of differences that do not mention corresponding aspects are counted as non-alignable, including statements that describe the property of one item and simply negate it for the other (e.g., "the pretzel has salt on it, the phone does not"). On the structural alignment view, an increase in similarity after comparison would result from finding alignable differences between two items (because alignable differences are tied to deeper structural commonalities). In contrast, finding non-alignable differences between two items should not increase similarity since no common structure was discovered in the process of comparison. This predicts that more alignable differences should have been listed for items in Experiment 1 (which became more similar after comparison), than for items in Experiment 2 (which became less similar). This was indeed the case. Participants listed more alignable differences for items in Experiment 1 (80.8%) than for items in Experiment 2 (61.5%), $\chi^2 = 8.35$, $df = 1$, $p < .05$. This finding is again consistent with the structural alignment view of comparison.

The results of Experiment 2 suggest that the increase in similarity following comparison in Experiment 1 was not simply due to participants creating an extra feature (something akin to "thing I compared before") for items they were asked to compare. A co-history of comparison does not automatically result in higher similarity. Rather, it seems that only when meaningful similarities are to be found as a result of comparison, does comparison increase similarity.

A further question is whether comparison is special in having this polarizing effect on similarity, or whether any cognitive processing that helps to flesh out the representations might have the same effect. To investigate this question, instead of asking participants to perform comparisons between items, Experiment 3 asked participants to list properties of the items separately (without comparing the items). This property-listing task was designed to flesh out the representations without invoking the extra step of comparison. One group of participants performed this task with the similar items used in Experiment 1, and another group of participants performed the task with the dissimilar items used in Experiment 2.

[1] It is too early to conclude that all types of comparison will make dissimilar items less similar. The important finding is that similar and dissimilar items are affected differently under the same conditions, with similar items more likely to become more similar.

3. Experiment 3

3.1 Method

3.1.1. Participants

Two hundred and thirty-four Stanford University undergraduates participated in the study in order to fulfill a course requirement. Of these, 119 completed the task with similar items from Experiment 1 and 115 completed the task with dissimilar items from Experiment 2.

3.1.2. Materials

Just as in Experiments 1 and 2, materials consisted of a one-page questionnaire. The top of the page contained either pictures of the 4 similar animals shown in Fig. 1A or the four dissimilar objects shown in Fig. 1B. Instead of being asked to name similarities or differences between two of the items, participants were asked to name properties of two of the items separately (e.g., "Please describe 3 properties of the phone" followed by three blank lines for participants to fill in and further followed by "Please describe 3 properties of the pretzel" again followed by 3 blank lines). All of the counterbalancing and the rest of the page was done just as described for Experiment 1.

3.1.3. Procedures

The procedures were the same as Experiment 1.

3.2. Results

Participants judged items to be more similar if they had previously been asked to name their properties than if they had not. This was true for both the similar items from Experiment 1 ($M = 6.34$ after naming properties, and $M = 5.92$ without naming properties, $t = 1.90$, $p < .05$) and the dissimilar items from Experiment 2 ($M = 3.37$ after naming properties, and $M = 2.97$ without naming properties, $t = 2.14$, $p < .02$). This pattern for the dissimilar items was significantly different from that observed in Experiment 2 as confirmed in an interaction in a 2×2 repeated measures ANOVA (2 (items were focused or not) $\times$ 2 (comparison or property-listing)), $F(1, 174) = 6.817$, $p = .01$.

3.3. Discussion

Unlike comparison, listing properties of individual items did not have a different effect on similar and dissimilar items. Whereas comparison served to increase the similarity only for similar items, property-listing increased similarity for both similar and dissimilar items (see footnote[2]). The process of comparison appears to have the special effect of selectively increasing the similarity of similar items (and possibly

[2] There are several possible reasons why property-listing might serve to increase similarity, though further work would be necessary to establish a more certain answer. The important finding is that comparison discriminates between similar and dissimilar items, whereas property-listing does not.

decreasing the similarity of dissimilar items). Simply fleshing out the representations (by listing properties) was not sufficient to have this effect.

It appears that the process of comparison could play a crucial role in the development of knowledge. However, the studies so far have only tested the effects of comparison on familiar items, things that people already have representations for. Can comparison play a similar role even when people are just learning about something new? To investigate this, novel shapes were used in Experiment 4.

4. Experiment 4

4.1. Method

4.1.1. Participants

One hundred and eighty-eight Stanford University undergraduates participated in the study in order to fulfill a course requirement.

4.1.2. Materials

Just as in Experiment 1, materials consisted of a one-page questionnaire. The top of the page contained color pictures of 4 named novel shapes. One set of questionnaires used the four similar objects shown in Fig. 2A, and the other used the dissimilar objects shown in Fig. 2B. The rest of the page was constructed just as in Experiment 1, with the following two differences: (1) all of the participants were asked to focus on differences (none named similarities) between the shapes, and (2) before being asked to verbally describe the differences, participants were asked to circle three differences between two of the novel shapes on the pictures themselves (e.g., "Please circle 3 differences between Chico and Harpo.") The rest of the page was constructed and counterbalanced just as for Experiment 1.

4.1.3. Procedures

The procedures were the same as Experiment 1.

4.2. Results and discussion

First, a manipulation check: participants indeed judged the "similar" items in Fig. 2A to be more similar ($M = 3.84$) than the "dissimilar" items in Fig. 2B ($M = 2.37$), $F(1, 186) = 36.6$, $p < .001$.

The effects of comparison were exactly as predicted by Experiments 1 and 2. Naming differences between two similar shapes (Fig. 2A), again made people think of the two shapes as more similar ($M = 4.09$ after naming differences, and $M = 3.58$ without naming differences, $t = 2.83$, $p < .01$). Naming differences between two dissimilar shapes (Fig. 2B), on the other hand made people think of the two shapes as somewhat less similar ($M = 2.31$ after naming differences, and $M = 2.43$ without naming differences, $t = -.61$, $p = .27$). The patterns for similar and dissimilar items were significantly different from each other as confirmed in an interaction in a 2×2 repeated

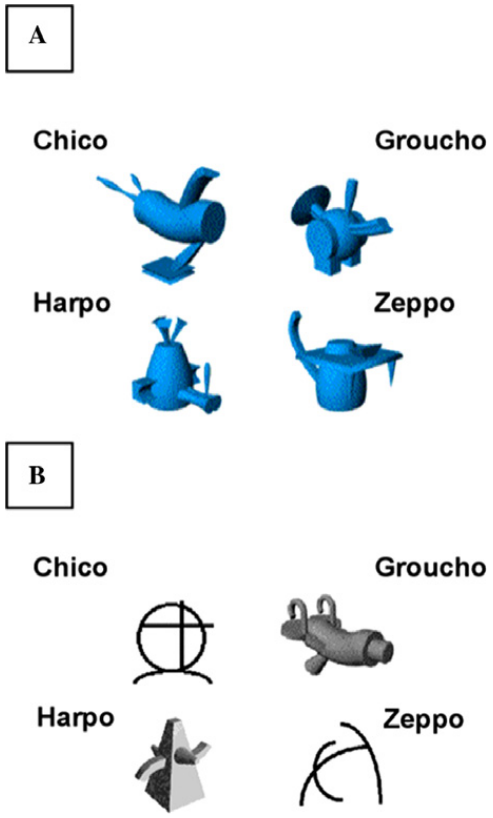

Fig. 2. Stimuli used in Experiment 4. More similar items are shown in (A) and less similar items are shown in (B). Images provided by Michael J. Tarr (Brown University) and Pepper Williams (University of Massachusetts).

measures ANOVA (2 (named differences or not) × 2 (stimuli similar or dissimilar)), $F(1,186) = 4.43$, $p < .05$.

It appears that the process of comparison had the same effect on novel items as it did on familiar items in Experiments 1 and 2. Comparing two similar novel items made them appear more similar, while comparing dissimilar novel items made them appear less similar.

5. General Discussion

The studies described in this paper examined the effects of comparison on perceptions of similarity. It appears that comparison can alter people's representations of objects by leading them to discover (or take note of) new similarities and differences. In future studies, it would be interesting to see how long effects of comparison last, and if these effects also extend to categorization. Previous research by Gentner and Namy (2000) suggests that this may indeed be the case. Further studies looking directly at the effects of comparison on categorization would be an interesting extension of this research.

Also worthy of further investigation are the interactions between similarity, structural alignability, and the process of comparison. In the studies reported in this paper, comparison was found to have different effects on similar versus dissimilar items (making similar items more similar, and dissimilar items less similar). However, the similar items used in these experiments were similar in several different ways: for example, both in terms of surface features and in deeper structural ways. Since several kinds of similarity were confounded, it is not clear which of these aspects contributed to the effect. In future studies it would be interesting to investigate the separate contributions of structural and surface similarity as they interact with the comparison process. These further studies should also shed more light on why comparison has the effect it does.

6. Conclusions

Four studies showed that comparing similar objects makes them appear more similar, while comparing dissimilar objects makes them appear less similar. This was true for both novel and familiar objects. The effect of comparison on similar items was especially striking since participants judged items to be more similar after comparison even if the comparison task was to list differences between the two items. Further, this effect appears specific to comparison and does not appear to be simply due to a "fleshing out" of object representations. When participants were only asked to list properties of objects without comparing the objects themselves, the perceived similarity of the objects increased regardless of whether the items were similar or dissimilar to start. By making similar things appear more similar, and dissimilar things appear less similar, comparison may play a special role in category development. Further, it appears that even incidental conceptual experience (e.g., happening onto one comparison versus another) can play an important role in knowledge development.

These results suggest that common cognitive processes like comparison can introduce systematic biases into our representations of objects and their similarities. These biases may be beneficial for separating out bits of experience into categories, sharpening categorical boundaries, and otherwise helping us create conceptual structure above and beyond that offered by the world.

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