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A tale of two similarities: comparison and integration in conceptual combination

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Abstract

The perception of semantic similarity derives from distinct processes of comparison and integration. A dual process model of conceptual combination claims that attributive combination (e.g., UMBRELLA TREE) entails comparison, while relational combination (e.g., PANCAKE SPATULA) requires integration. The present research uses similarity as a test of this dual process model. Participants ($N = 168$) were presented attributive and relational conceptual combinations. Half of the participants interpreted the combinations before rating the similarity of their constituent concepts, while the other half provided similarity ratings without interpreting the concepts together. The experiment revealed that attributive combination decreased the perceived similarity of the constituent concepts, whereas relational combination increased the similarity of the constituents. This result indicates that attributive and relational combination occur via distinct processes. Results of a post-test ($N = 60$) suggested that these effects were specific to the particular concepts compared or integrated, and do not generalize to other concepts not compared or integrated. The present research thus supported a dual process model of conceptual combination by demonstrating differential effects of comparison and integration on the perception of semantic similarity.

1. Introduction

An exciting recent discovery in the cognitive sciences is that the perception of semantic similarity derives from (at least) two distinct processes, namely, comparison and integration (Bassok & Medin, 1997; Wisniewski & Bassok, 1999). Given the central role that similarity plays in cognitive science, this discovery may have important implications across a broad range of cognitive domains (e.g., analogy, categorization, memory, etc.). For instance, similarity is

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central to models of conceptual combination. It is no coincidence, then, that one current model of conceptual combination supposes that distinct processes of comparison and integration operate during comprehension. The present research uses similarity as a test of this model. Specifically, the comparison and integration processes are hypothesized to have opposite effects on perceived similarity. Therefore, if conceptual combination involves both types of processes, then those opposite effects on perceived similarity should both be observable in conceptual combination. Such a result would have critical implications for linguistic, computational and psychological models of conceptual combination. Prior to presentation of the empirical data, similarity and conceptual combination are considered separately below.

1.1. Similarity

One intuitively thinks of similarity as resulting from a comparison process. To determine the similarity of CATS and DOGS, for example, we compare their features and evaluate the degree of commonality relative to the degree of distinctiveness (Tversky, 1977). Although this simple intuition appears for the most part correct, the comparison process itself turns out to be rather complex. Comparison occurs by a process of structural alignment. That is, the representational structure of one concept is aligned with the representational structure of the other concept, such that the dimensions of one are put into correspondence with analogous dimensions in the other. For instance, the cat's tail is aligned with the dog's tail, revealing a commonality between CATS and DOGS. And the cat's meow is aligned with the dog's bark, thereby revealing a difference. Thus, comparison entails alignment, which leads to the detection of commonalities and differences (Gentner & Markman, 1997). These commonalities and differences are then used to compute the similarity of the concepts (cf. Tversky, 1977).

Recently, however, it has been shown that there is more to similarity than just comparison; an integration process also contributes to the perception of semantic similarity. By this process, thematic relations that integrate the concepts may be apprehended, and this integration may impact perceived similarity. For instance, MILK is judged more similar to COFFEE than to LEMONADE, presumably because milk and coffee have an extant thematic relation (i.e., one pours milk into coffee) while milk and lemonade do not. More generally, Wisniewski and Bassok (1999; see also Bassok & Medin, 1997) demonstrated that thematically related concepts are judged more similar than thematically unrelated concepts.

As evidence that comparison and integration are distinct sources of similarity, Gentner and Gunn (2001) showed that one process can be activated independent of the other. Participants initially either compared (i.e., listed a commonality of) or integrated (i.e., listed a thematic relation between) a set of concept pairs. Subsequently, in a speeded difference task, participants listed one difference for as many concept pairs as they could, but were not given sufficient time to list a difference for every concept pair. Importantly, half of the concept pairs were from the first phase of the experiment (i.e., "old"), whereas the other half of the concept pairs had not previously been compared or integrated (i.e., "new"). Gentner and Gunn found that, after comparison, differences were *more* likely to be listed for old pairs than for new pairs. But interestingly, after integration, differences were reliably *less* likely to be listed for old pairs than for new pairs. In other words, prior comparison of two concepts facilitated the listing of a difference between them, but prior integration inhibited the listing of differences.

In summary, the perception of semantic similarity appears to involve distinct processes of comparison and integration. Moreover, these distinct processes appear to have opposite effects: comparison facilitates the detection of differences, whereas integration inhibits the detection of differences. As we will see, this finding has important implications for conceptual combination.

1.2. Conceptual combination

Many linguists have analyzed the conceptual combinations that occur in natural language (e.g., Warren, 1978), and the consensus is that comprehension requires a relational inference (see Ryder, 1994 for a review). That is, in order to comprehend two concepts together, one must infer some relation between them. The combination DOG COLLAR, for instance, is understood by inferring that it is a collar *worn by* a dog. Thus, one commonality of the various linguistic models is the supposition of a process strikingly akin to the integration process described above. Essentially, the integration process may be considered a psychological instantiation of the relational inference posited by the linguists (see Gagné & Shoben, 1997).

In contrast to these early linguistic models of conceptual combination, which largely emphasized integration, one current psychological model posits two distinct mechanisms of comprehension. According to Wisniewski's (1997) dual process model, relational combination occurs when a relation is inferred to exist between the constituent concepts. A CACTUS GARDEN, for instance, is ordinarily interpreted as a garden in which cacti are grown. This interpretation requires inferring a *locative* relation, just as the linguists suggested. But additionally, there is a process of attributive combination that occurs when one concept attributes a property to the other concept. For example, a CACTUS CARPET is often interpreted as a prickly carpet. Here, a property (i.e., prickly) is attributed from one concept (i.e., CACTUS) to the other (i.e., CARPET). Importantly, dual process theory claims that these different interpretations arise from distinct processes. Namely, relational combination results from integration, while attributive combination results from comparison. Thus, like similarity, conceptual combination may involve dual processes of comparison and integration.

Although linguistic models have emphasized relational combination, many of them have also recognized the occurrence of attributive combination (e.g., Warren, 1978). They further recognize that attributive combination appears to result from comparison rather than integration *per se*. Nevertheless, those models invariably relegate comparison to secondary status (Wisniewski & Love, 1998), asserting that attributive combination does not occur frequently enough to warrant the supposition of a distinct processing mechanism, or that attribution can more parsimoniously be accounted for by the same relational mechanism that accounts for all other combinations. Following the linguistic models, for example, Gagné (2000) raised the possibility that attributive combinations may be interpreted via a *resemblance* relation: a CACTUS CARPET is simply a carpet that *resembles* a cactus in some important respect (cf. Warren, 1978). In this way, the comparison process is obviated, and a single-process integration model could account for all combinations. Costello and Keane's C^3 (*C*onstraint-guided *C*onceptual *C*ombination) algorithmic model similarly includes both attributive and relational comprehension, but rejects the claim that they result from distinct processes: "the constraint theory does not assume that the different interpretation types are 'special cases' requiring specific independent explanations" (2000, p. 333).

Wisniewski and Love (1998) attempted to demonstrate that comparison and integration are in fact distinct processes in conceptual combination. They examined the interpretation of ambiguous combinations, which could be interpreted either attributively or relationally. For example, a DINOSAUR SCIENTIST can be interpreted attributively as "an old scientist" or relationally as "a scientist who studies dinosaurs." Wisniewski and Love preceded these ambiguous target combinations with a series of either attributive (e.g., BULLET SPRINTER) or relational (e.g., KIDNEY SURGEON) prime combinations, and they found that the different prime-types differentially affected interpretation of the ambiguous targets. The targets were more likely to be interpreted attributively after the attributive primes, and were more likely to be interpreted relationally following the relational primes. Wisniewski and Love's finding that one process could be primed independent of the other suggests that comparison and integration are in fact distinct processes in conceptual combination. Unfortunately, however, Gagné (2000) used the same stimuli and procedure, but failed to replicate their result. Thus, it remains equivocal whether distinct comparison and integration processes do occur in conceptual combination, as predicted by dual process theory (Wisniewski, 1997).

1.3. Similarity and conceptual combination

As apparent from the preceding sections, research on similarity and conceptual combination has evolved in an analogous manner. Moreover, similarity is thought to play an important role in conceptual combination: The alignability of a pair of concepts predicts whether those concepts are combined via comparison or integration. Specifically, highly alignable concepts tend to be compared, while concepts low in alignability tend to be integrated (Wisniewski, 1997). And because similar concepts tend to be more alignable than dissimilar concepts (Gentner & Markman, 1997), similarity should be positively correlated with comparison and negatively correlated with integration. In support of this prediction, Wisniewski (1996; see also Wilkenfeld & Ward, 2001) found that combinations with highly similar constituent concepts were more likely to be interpreted attributively (i.e., via comparison), while combinations low in constituent similarity were more likely to be interpreted relationally (i.e., via integration; but see Estes & Glucksberg, 2000).

Although some research (described above) has examined the effect of similarity on conceptual combination, virtually nothing is currently known about the effect of conceptual combination on similarity. In the experiment reported below, I used the comparison and integration processes to conduct such an investigation. If comparison and integration have opposite effects on similarity (cf. Gentner & Gunn, 2001), and if conceptual combination involves both comparison and integration (Wisniewski, 1997), then comparative (i.e., attributive) combinations and integrative (i.e., relational) combinations should produce opposite effects on perceived similarity.

2. Experiment

Participants were presented attributive and relational conceptual combinations. Half of the participants were asked to interpret the combinations before rating the similarity of their constituent concepts (i.e., the experimental condition), while the other half provided similarity ratings without interpreting the concepts together (i.e., the control condition). In the experimental condition, the attributive combinations should induce comparison, while the relational combinations should induce integration (Wisniewski, 1997).

Differences are critical in attributive combination. It is the detection of a difference between concepts that allows the attribution of a property from one concept to another (Wisniewski, 1997). For, if the two concepts are *not* different in some relevant respect, then the combination is redundant; that is, the attributed property would not add new information to the combination, hence violating communicative norms (cf. Costello & Keane, 2000). So assuming that differences are indeed critical in attributive combination (Wisniewski, 1997), and given that comparison facilitates the noticing of differences (Gentner & Gunn, 2001), then the comparison induced by attributive combination should decrease perceived similarity.

The integration induced by relational combination, on the contrary, should increase perceived similarity. This prediction follows from the findings that thematically related concepts are judged more similar than thematically unrelated concepts (Wisniewski & Bassok, 1999), and that integration inhibits the detection of differences (Gentner & Gunn, 2001). Thus, if comparison and integration both occur in conceptual combination, then attributive and relational combinations should produce differential effects on the perceived similarity of the constituent concepts. Dual process theory, therefore, predicts an interaction of Condition and Combination-type. Alternatively, if attributive and relational combinations are both comprehended by one and the same process (Costello & Keane, 2000; Gagné, 2000; Warren, 1978), then the two combination-types should have the same effect on perceived similarity.

2.1. Method

Fourteen attributive (e.g., UMBRELLA TREE) and 14 relational (e.g., PANCAKE SPATULA) combinations were selected from previous investigations of concept combination (e.g., Estes, 2003; Estes & Glucksberg, 2000). Stimuli are presented in Table 1. The design was a 2 (Condition: control, experimental) × 2 (Combination-type: attributive, relational), with Condition manipulated between-participants and Combination-type within-participants. The 28 stimuli were presented in random order, with Combination-type intermixed. Participants in the control condition simply rated the similarity of the two concepts. Each pair of concepts was presented as follows: "In general, how similar are Xs and Ys?" where X and Y were the concepts. Below each question was a scale ranging from 1 ("not at all similar") to 7 ("extremely similar"). The experimental condition was identical, except that participants were instructed to define the combination XY before rating the similarity of Xs and Ys. The prompt was presented as follows: "An XY is a . . . ." This prompt for a definition appeared directly above the similarity question for each item. Participants were instructed to provide a brief definition of the word pairs before rating the similarity of the constituent concepts. One hundred sixty-eight undergraduates at the University of Georgia participated for course credit.

2.2. Results

Mean similarity ratings were submitted to two separate 2 (Condition: control, experimental) × 2 (Combination-type: attributive, relational) repeated measures analyses of variance.

Table 1
Stimuli

Attributive	Relational
Cactus carpet	Battle theory
Feather luggage	Defeat frown
Junkyard desk	Doctor library
Lemon paint	Frog egg
Mirror lake	Glass rose
Rock bread	Honey soup
Sandpaper skin	Motorcycle documentary
Shark politician	Mountain snake
Skunk cigar	Pancake spatula
Thunder voice	Patio cigarette
Umbrella tree	Stereo headphones
Vampire insect	Table vase
Warehouse brain	Wire collar
Zebra clam	Wood stove

In the participant analysis (F_p and t_p), Condition was a between-participants factor, while Combination-type was within-participants. In the item analysis (F_i and t_i), Condition was a within-items factor, whereas Combination-type was between-items.

Mean similarity ratings are presented in Fig. 1. As predicted by dual process theory, attributive interpretation tended to decrease the perceived similarity of the constituent concepts, whereas relational interpretation tended to increase the similarity of the concepts. This Combination-type × Condition interaction was significant [$F_p(1, 166) = 17.88$, $p < .001$ and $F_i(1, 26) = 10.20$, $p < .01$]. The main effect of Condition did not approach significance in either analysis [both $F < 0.12$]. The main effect of Combination-type was

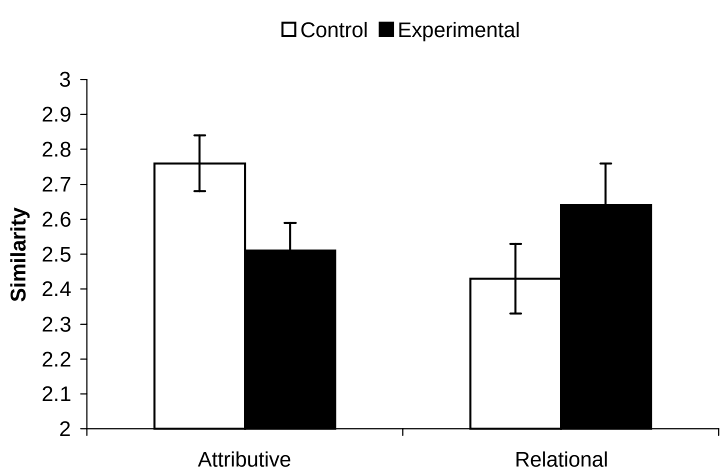

Fig. 1. Mean similarity ratings of attributive and relational combinations by condition. *Note*. Error bars represent one standard error of the mean.

nonsignificant in the item analysis [$F_i(1, 26) = 0.11$] but was marginal in the participant analysis [$F_p(1, 166) = 3.67$, $p = .06$]. The reliable interaction was examined more closely via planned comparisons.

Planned comparisons revealed that similarity ratings of attributive combinations were significantly lower in the experimental condition ($M = 2.51$, $SE = 0.08$) than in the control condition ($M = 2.76$, $SE = 0.08$), $t_p(166) = 2.20$, $p = .03$ and $t_i(13) = 2.27$, $p = .04$. Attributing a property of one concept to another concept actually decreased the perceived similarity of those concepts. This result is predicted by dual process theory. According to the theory, attributive interpretation involves a comparison process, the result of which is the noticing of differences between the concepts. When these differences are made salient by the comparison process, perceived similarity thus decreases.

Similarity ratings of relational combinations exhibited the opposite pattern of results, as illustrated in Fig. 1. For these combinations, similarity ratings were higher in the experimental condition ($M = 2.64$, $SE = 0.12$) than in the control condition ($M = 2.43$, $SE = 0.10$). This difference was reliable in the item analysis ($t_i(13) = 2.28$, $p = .04$), though not in the participant analysis ($t_p(166) = 1.41$, $p = .16$). This result was in the direction expected on the basis of previous research (e.g., Bassok & Medin, 1997; Wisniewski & Bassok, 1999), and is consistent with the dual process theory.[1]

2.3. Post-test

One may wonder whether the Combination-type × Condition interaction was attributable to comparison/integration of the specific concepts for which similarity was judged, or to the comparison/integration process more generally (cf. Wisniewski & Love, 1998). That is, would interpreting one conceptual combination (e.g., A snow shovel is . . .) affect the similarity of a different pair of concepts that also elicit that same process of comparison or integration (e.g., How similar are pancakes and spatulas?)? In the present experiment, the finding that interpreting a conceptual combination affected the similarity of its constituents may be attributable to either of two explanations: (1) interpreting a combination of two concepts affects the similarity of those two concepts in particular, or (2) interpreting a combination of two concepts affects the similarity of any two concepts in general.

In order to differentiate between these two explanations, a post-test was conducted. The materials from the control condition of the experiment proper were preceded by one of two priming manipulations. In the Attributive Prime condition, participants interpreted 10 attributive combinations (e.g., BULLET TRAIN) before completing the similarity rating task. In the Relational Prime condition, participants interpreted 10 relational combinations (e.g., SNOW SHOVEL) before the similarity task. Importantly, the prime combinations contained none of the concepts appearing in the similarity task. Recall that the similarity task included 28 target word pairs, half attributive and half relational, intermixed. The post-test therefore had a 2 (Prime-type: attributive, relational; between-participants) × 2 (Target-type: attributive, relational, within-participants) mixed design. If interpreting *any* attributive combination (or *any* relational combination) affects the similarity of subsequent attributive (or relational) combinations, then the different prime conditions should yield differential similarity ratings. Alternatively, if the effect of conceptual combination on similarity is specific to the particular concepts being combined, then there should be no difference between conditions, because the prime combinations do not contain the same concepts as the target word pairs. Sixty undergraduates at the University of Georgia participated in the post-test (30 in each condition). The results were very clear: there was no hint of a reliable difference amongst the four condition means (all of which were between 2.89 and 2.92). This remarkably null result suggests that the comparison and integration processes specifically affect the similarity of the particular concepts that are compared or integrated, and do not affect the similarity of unrelated pairs of concepts.

3. General discussion

The above results have implications for conceptual combination and similarity. These implications are discussed separately below.

3.1. Conceptual combination

Attributive and relational combination produced opposite effects on perceived similarity: attributive combination decreased similarity, whereas relational combination increased similarity. The result follows from the distinction between comparison and integration as independent sources of similarity. Comparison facilitates the noticing of differences, while integration inhibits the noticing of differences (Gentner & Gunn, 2001). Thus, if attributive combination entails comparison, then it should decrease similarity by facilitating difference. And if relational combination involves integration, then it should increase similarity by inhibiting difference. Exactly this pattern of results obtained. Thus, conceptual combination appears to involve dual processes of comparison and integration (Wisniewski, 1997). Single-process linguistic (e.g., Warren, 1978), algorithmic (Costello & Keane, 2000) and psychological (Gagné, 2000) models fail to predict this result, and would require additional assumptions in order to account for it.

Although Gagné (2000) suggested that relational combination is attempted serially prior to attributive combination, I have shown elsewhere (Estes, 2003) that the attributive and relational processes do not occur serially. But this left two possible models of conceptual combination: either (1) attributive and relational combinations are interpreted via the exact same mechanism, or (2) they require distinct mechanisms that may be attempted in parallel. The present result supports the latter model. Wisniewski's (1997) dual process model is one instantiation of this.

Wilkenfeld and Ward (2001) offer another intriguing possibility. They point out that even if attributive and relational processes are distinct, they need not operate entirely independently. Indeed, the similarities and differences detected during comparison might well facilitate the integration process. As an example, consider PANCAKES and SPATULAS. Comparison might reveal that pancakes and spatulas are both flat. This commonality is functionally important because the typical fragility of pancakes requires a flat cooking instrument, while spatulas are typically used to cook flat foods. Thus, comparison suggests that PANCAKE and SPATULA can be sensibly integrated as PANCAKE SPATULA. And conversely, integration may indicate which features are relevant for comparison. Integrating PANCAKE and SPATULA suggests that shape and rigidity are critical for the combination of those concepts, and therefore their shape and rigidity may be compared to determine their functional compatibility. Thus, although the attributive and relational processes are distinct in conceptual combination, there is reason to speculate that they may nevertheless be interdependent processes.

3.2. Similarity

While the present result most obviously demonstrates that comparison and integration both occur in conceptual combination, a more subtle but no less notable contribution of the present research is the demonstration that integration actually increases similarity. It had previously been shown that thematically related concepts tend to be judged more similar than thematically unrelated concepts (Wisniewski & Bassok, 1999). So for instance, MILK is judged more similar to COFFEE than to LEMONADE. But the present result goes beyond that. In the present experiment, the *exact same concepts* were judged more similar after integration than when not integrated. For instance, PANCAKES and SPATULAS were judged more similar after being interpreted as a conceptual combination than when not interpreted as a combination. This novel result extends previous findings.

Analogously, the present experiment demonstrated that comparison may actually decrease the similarity of two concepts. UMBRELLAS and TREES, for instance, were judged less similar after they were interpreted together than when not interpreted as a conceptual combination. Note, however, that comparison may not always decrease similarity. Rather, this result may be unique to conceptual combination: because differences are critical in attributive combination (Wisniewski, 1997), and because comparison facilitates the detection of differences (Gentner & Gunn, 2001), the comparison induced by attributive combination decreases perceived similarity.

The growing body of evidence that comparison and integration are distinct sources of similarity seems to suggest a dual process model of similarity (Bassok & Medin, 1997; Wisniewski & Bassok, 1999). However, Gentner and Gunn (2001) alternatively propose that we reserve the term "similarity" for that which results from the comparison process alone. They argue that the process of integration merely intrudes on, or is confused as, true (comparison) "similarity." The relative merits and implications of this approach to similarity remain an interesting topic for future consideration.

3.3. Conceptual combination and similarity

Prior research had shown that the similarity of two concepts may predict whether those concepts will be combined via comparison or integration (Wilkenfeld & Ward, 2001; Wisniewski, 1996). The present research shows that, conversely, whether two concepts are combined via comparison or integration predicts whether the similarity of those concepts will increase or decrease. In particular, comparison decreased similarity, whereas integration increased similarity. The present research thus supported a dual process model of conceptual combination by demonstrating differential effects of comparison and integration on the perception of semantic similarity.

Note

1. Because the attributive combinations were more similar than the relational combinations in the control condition (i.e., the white bars in Fig. 1; $t_p(84) = 4.90$, $p < .001$ and $t_i(26) = 0.99$, $p = .33$), the data in the experimental condition may be explained by regression to the mean. Perhaps conceptual combination induces an elaboration of the representations of the concepts, and perhaps this elaboration makes similarities *and* differences salient. This might produce a decrease in similarity for attributive combinations, and an increase in similarity for relational combinations, such that there is no reliable difference between attributive and relational combinations in the experimental condition (i.e., the black bars in Fig. 1; both $t < 1.50$). But notice that if the similarity of attributive and relational combinations had been matched in the control condition, regression to the mean could not explain any difference in the experimental condition. Therefore, to rule out this alternative explanation, the two *most* similar attributive concept pairs and the two *least* similar relational concept pairs were removed, and the data were re-analyzed. Removing those four items had the effect of equating the similarity ratings of the attributive ($M = 2.53$, $SE = 0.08$) and relational ($M = 2.58$, $SE = 0.10$) concept pairs in the control condition. When the similarity was matched in this way, the identical pattern of results obtained: the Combination-type × Condition interaction was again significant [$F_p(1, 166) = 10.39$, $p < .01$ and $F_i(1, 22) = 5.41$, $p = .03$]. Critically, because the similarity of attributive and relational combinations was matched in the control condition, this interaction appears to be due to a difference between attributive ($M = 2.34$, $SE = 0.08$) and relational ($M = 2.76$, $SE = 0.12$) combinations in the experimental condition. Thus, regression to the mean cannot explain the reliable interaction.

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