Structural and Thematic Alignments in Similarity Judgments

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Abstract

We examined similarity judgments between simple Noun-Verb-Noun statements that were matched either in their verbs or nouns (separate matches) and made either analogous or non-analogous assertions (combined matches). An analysis of written justifications that accompanied subjects' similarity judgments revealed that matching verbs and matching nouns lead to two qualitatively different types of alignments. Matching verbs (e.g., "The carpenter *fixed* the chair" and "The plumber *fixed* the radio") led subjects to construct structural alignments and evaluate the quality of the resulting analogies (e.g., "Not analogous because plumbers don't fix radios as part of their job"). By contrast, and contrary to any traditional account of similarity as a process of comparison, matching nouns (e.g., "The *carpenter* fixed the *chair*" and "The *carpenter* sat on the *chair*") led subjects to construct thematic alignments and evaluate similarity based on the plausibility of the resulting causal or temporal scenarios (e.g., "He sat on the chair to see whether he fixed it well").

Introduction

How do people establish similarities between objects, situations, or events? The answer to this question is crucial given that similarity serves as a central explanatory construct in theoretical accounts of other cognitive processes (e.g., categorization, inference, transfer of learning). Medin, Goldstone, and Gentner (1993) propose that similarity is an outcome of an active and constructive process of comparison in which people align the representations of the compared stimuli. In particular, they establish matches between two qualitatively distinct types of aspects: 1. Attributes, one-place predicates that take objects as arguments (e.g., BIG(house); RED(apple)), and 2. Relations, predicates that take two or more attributes, objects, or other relations as arguments (e.g., BIGGER-THAN(house, tent); SAME-COLOR(apple, book)). The motivation behind this distinction is that our representations of stimuli are structured such that objects and their attributes are interrelated (e.g., books are *made of* paper; carpenters *fix* chairs). Hence, people align the structured representations of the compared stimuli.

Evidence in support of the structural alignment hypothesis comes from studies that contrast the relative impact of relational and attributional matches on similarity judgments (e.g., Goldstone, Medin, & Gentner, 1991; Markman & Gentner, 1993; Medin, Goldstone, & Gentner, 1990). For example, Goldstone *et al.* (1991) found that people process relational and attributional matches in separate pools. They asked subjects to choose which of two targets was more similar to a given base. Presented with a base such as OXO, subjects were more likely to choose Δ*Δ (one relational match, i.e., symmetry) than Δ*O (one attributional match, i.e., circle). However, presented with a pair of targets with an additional attributional match (X), subjects were less likely to choose ΔXΔ (one relational and one attributional match, i.e., symmetry and X) than ΔXO (two attributional matches, i.e., XO). That is, the existence of an additional attributional match in the second pair of targets changed the relative weight given to the relational (symmetry) and attributional (O) matches. Such differential weighting of relational and attributional matches has been captured by the MAX model, which posits that these two types of matches are processed in separate pools, and that people assign higher weights to matches in the bigger pool.

Note that in order to contrast the impact of relational and attributional matches on similarity these studies used stimuli in which relations and attributes were separable and independent. For example, the symmetry of OXO and Δ*Δ (relation) is independent of whether the symmetric shapes in the two figures happen to be circles or triangles (attributes), or that a star is between two triangles (Δ*Δ) rather than vice versa (*Δ*). However, when people assess similarities between actual objects, situations, and events, relational predicates and the objects that serve as arguments in these predicates are not independent. For example, carpenters *fix* chairs as part of their profession whereas plumbers do not, cutting grass is a different type of cutting than cutting hair, and the difference in the costs of mozzarella cheese and cottage cheese is of a different magnitude than the difference between the costs of mozzarella cheese and a house. People are aware of such dependencies and spontaneously draw inferences based on their knowledge about the way in which various objects tend to be interrelated (e.g., Anderson & Ortony, 1975; Gentner & France, 1988; Ortony, 1979). Given such inferences, it is unclear whether the conclusion that people process separately relational and attributional matches can be generalized to stimuli in which these two types of aspects are interdependent.

The impact of inferences based on dependencies between relations and attributes has been recently documented in studies on analogical transfer (Bassok & Olseth, 1995; Bassok, Wu, & Olseth, 1995). Existing models of analogical transfer are based on the assumption that

attributional matches either support or compete with relational matches (Falkenhainer, Forbus, & Gentner, 1989; Holyoak, & Thagard, 1989). However, transfer performance was found to be affected by dependencies between these two types of aspects. For example, Bassok & Olseth (1995) found that after learning to solve physics problems involving constant change in speed, 71% of subjects spontaneously applied the learned solution to analogous non-physics problems involving continuous constant change (e.g., constant change in the rate of population growth in people/year), but only 27% of subjects applied the physics solution to analogous problems involving discrete constant change (e.g., constant change in the rate at which people attend an annual conference in people/year). Such differential transfer occurred even though the manner of change was never mentioned during training. Thus, it appears that people spontaneously interpreted "constant change in speed" to mean "continuous constant change." Matches and mismatches between the interpreted meaning of constant change in the learned and novel problems (i.e., continuous vs. discrete), rather than separate matches in relational terms ("constant change") or attributional terms ("people," "years") determined the scope of analogical transfer.

The present study was designed to examine whether the conclusion that people process separately relational and attributional matches can be generalized to stimuli in which these two types of aspects are interdependent. We asked subjects to rate similarities between simple Noun-Verb-Noun statements, letting verbs stand for relations between objects and nouns stand for objects and their attributes. The statements were matched either in their verbs or in their nouns. For example, subjects were presented with a base statement "The carpenter fixed the chair" and were asked to assess the degree to which this statement was similar to a "relational target" with matching verb ("The electrician *fixed* the radio") and to an "attributional target" with matching nouns ("The *carpenter* sat on the *chair*"). Subjects were also asked to justify in writing their similarity ratings. Because nouns and verbs are semantically interdependent, we expected people to construct "combined representations" for the Noun-Verb-Noun statements based on such semantic dependencies. For example, the above base statement could have been represented as "A professional doing his job."

If people treat combined representations as conceptual entities, they might base their similarity judgments on combined matches between base and target statements and ignore the distinction between separate matches in relations (verbs) and attributes (nouns). However, even non-arbitrary conceptual combinations of relations and attributes have to be aligned for comparison. Hence, in order to constrain the comparison process people might exploit the distinction between relational and attributional matches even when these two types of aspects are interdependent.

In order to examine the relative impact of combined and separate matches we created permutations of matching nouns and verbs that resulted in either analogous (i.e., combined match) or non-analogous (i.e., combined mismatch) relational targets. Specifically, we examined similarity judgments for three types of relational targets: Good Analogies (e.g., "The electrician *fixed* the radio"), Poor Analogies (e.g., "The plumber *fixed* the radio"), and Poor Analogies with matching subject (e.g., "The carpenter *fixed* the radio"). Each of these relational targets was paired with the same attributional target (e.g., "The *carpenter* sat on the *chair*") which, having a different verb, was obviously non-analogous to the base statement.

To foreshadow our results, we found that combined matches dominated separate matches, and that the distinction between relational and attributional matches did not result in differential weighting of these two types of matches. Nonetheless, separate matches in nouns and verbs played a crucial role in similarity judgments -- they determined the way in which subjects arrived at their similarity judgments. Matching verbs led subjects to construct structural alignments, i.e., to compare the combined meaning of the paired statements and evaluate whether the statements were analogous (e.g., "Not analogous because plumbers don't fix radios as part of their job"). By contrast, and contrary to any traditional account of similarity as a process of comparison, matching nouns led subjects to construct thematic alignments, i.e., to integrate the statements into causal or temporal scenarios and evaluate whether the resulting scenarios were plausible (e.g., "Quite similar because he sat on the chair to see whether he fixed it well").

Method

Materials

Eight action statements (e.g., "The carpenter fixed the chair") and four comparison statements (e.g., "Cottage cheese is cheaper than mozzarella cheese") served as base statements. For each of these 12 base statements we constructed four targets: one attributional (matching nouns) and three relational (matching verbs). Using these 12 sets of base and target statements we created three types of triplets, each consisting of a base, its attributional target, and one of its three relational targets. Below is one set of statements from which we constructed the three types of triplets (123, 124, and 125):

Base: 1. The engineer designed a car.

Attributional target:
(AA) 2. The engineer drove a car.

Relational targets:
(RC) 3. The choreographer designed a dance.
(R) 4. The lawyer designed a dance.
(RA) 5. The engineer designed a dance.

The separate and combined matches between the base (1) and each of its targets (2 through 5) appear in parentheses: A denotes an attributional match (noun), R a relational match (verb), and C a combined match (good analogy). Note that the base and relational Target 3 (Good Analogy) made assertions that were compatible with people's default semantic expectations (e.g., professionals doing their job). By contrast, relational Targets 4 and 5 (Poor Analogies)

made assertions that violated such default expectations (e.g., neither lawyers nor engineers design dances as part of their job, although they could do it as individuals).

Each triplet was typed on a separate page, with the base centered above the two targets. The left and right positions of the relational and attributional targets were randomized. A 7-point rating scale appeared below each of the two targets. The scale assessed either similarity or difference[1]. Accordingly, the lowest rating (1) was labeled either "not at all similar" or "not at all different" and the highest rating (7) was labeled either "very similar" or "very different." We constructed 12-page booklets by randomly selecting a triplet type (123, 124, or 125) for each of the 12 base statements and collating the selected pages in randomized order.

Procedure

Subjects were 80 undergraduates from University of Chicago and from Northwestern University. They were tested individually or in small groups. Subjects were asked to rate either how similar (N=39) or how different (N= 41) each of the two bottom statements was to the top statement and to justify their ratings in the space provided below the rating scales. The task lasted between 15-30 min.

Results and Discussion

In what follows we first describe the distribution of similarity ratings and then present an analysis of the justifications that accompanied these ratings.

Similarity Ratings

We transformed the difference ratings into similarity ratings (8-rd=rs), and in the present paper we do not distinguish between these two types of judgments (see again Note 1). Table 1 presents the average ratings for the three types of relational targets and their corresponding attributional targets. Standard deviations appear in parentheses.

Because each of the three relational targets was paired with the same attributional target (1-2 ratings in the right column of Table 1), it is of little surprise that the average similarity ratings for the attributional targets did not differ across the three triplet types (F<1). The comparisons of interest are between the three relational targets in the left column of Table 1.

The first comparison of interest is between the Good Analogy (Target 3) and Poor Analogy (Target 4) relational targets. These targets were equated in their separate matches to the base (i.e., matching verb and mismatching nouns). However, Good Analogies (i.e., combined match) were rated more highly than Poor Analogies (4.63 vs., 3.13, respectively, $F(1,78)=79.12$, $Mse=2.29$, $p<.001$). The second comparison of interest is between the two Poor Analogy relational targets in the 124 and 125 triplets. Both targets mismatched the base in their combined meaning, but Target 5 had an additional attributional match (+ Subject) relative to Target 4. This additional match resulted in higher similarity ratings (3.92 vs. 3.13 for Targets 5 and 4 respectively, $F(1,78) = 33.56$, $Mse=1.53$, $p<.001$).

This pattern of similarity ratings shows that when the compared stimuli consist of semantically interdependent relations and attributes, matches in the inferred combined meaning of the statements override separate matches. Thus, overall, Good analogies were rated more highly than Poor analogies even when Poor analogies had an additional attributional match (Target 3 > Target 5 > Target 4). However, when the compared stimuli differ in their combined meaning similarity increases with the number of separate matches.

Table 1:
Average similarity ratings
for relational and attributional targets

	Relational targets	Attributional targets
Good Analogy (123 triplets)	4.63 (1.21)	3.86 (1.48)
Poor Analogy (124 triplets)	3.13 (1.26)	4.11 (1.37)
Poor Analogy + Subject (125 triplets)	3.92 (1.41)	4.00 (1.34)

The finding that Good Analogies were rated more highly than Poor Analogies is consistent with Gentenr's (1983) systematicity principle, because combined matches can be considered as matches in inferred higher-order relations (e.g., the engineer *designed* a car *because* it is his job, and the choreographer *designed* a dance *because* it is her job). The systematicity principle predicts that higher-order relational matches would constrain separate matches, both relational and attributional. However, our findings do not support the claim that people process relational and attributional matches in separate pools and give higher weights to matches in the bigger pool (e.g., Goldstone *et al.*, 1991). In the independent case, two attributional matches (OXO-ΔXO) were found to be rated more highly than one relational match and one attributional match (OXO–ΔXΔ). By contrast, in the dependent case, there was no difference in the ratings of the attributional and relational targets in the 125 triplet (bottom row of Table 1) even though Target 2 had two matching nouns whereas Target 5 had one matching noun and one matching verb.

The present pattern of similarity ratings suggests that models of structural alignment (e.g., Gentner & Markman, 1994; Goldstone, 1994; Markman & Gentner, 1993) might need to be modified to accommodate the difference between the dependent and the independent case. In particular, it appears that in the dependent case people distinguish between combined (Target 3) and separate matches (Targets

[1] Similarities and differences are not always inverses (Medin, et al., 1990). However, because this variable did not interact with the results reported in this paper, we combined the results obtained for these two types of judgments.

2, 4, 5), but do not distinguish between separate relational and attributional matches (e.g., the relational and attributional targets in triplet 125). However, analysis of the justifications that accompanied subjects' similarity ratings revealed that existing models of similarity cannot be adjusted to accommodate the present results. All traditional models of similarity are based on the assumption that similarity is a process of comparison that is mediated by matches and mismatches between various aspects of the compared stimuli. By contrast, we found that in some cases similarity judgments are not mediated by a process of comparison. Rather, as we describe in the next section, similarity judgments can be mediated by a process of thematic alignment in which people integrate the base and target statements into causal or temporal scenarios.

Similarity justifications

Subjects generated between one to five justifications per target, resulting in a total of 1183 justifications for the relational targets (1.23 per target) and 1223 justifications for the attributional targets (1.27 per target). We classified these justifications into three general types: Syntactic, Separate, and Combined.

Syntactic. Justifications were coded as syntactic when they involved syntactic labels (e.g., "different verbs"); reference to words (e.g., "only the words are the same"); or reference to the structure of the sentence (e.g., "both have the same structure"). Syntactic justifications were infrequent (2% - 4% per target type) and were distributed uniformly across the relational and attributional targets.

Separate. Justifications were coded as separate when they referred to matches and mismatches between the specific nouns or verbs, either direct (e.g., "both about a chair," "both fix") or indirect (e.g., "both race and piano competition involve victory," "cutting is actively doing something as opposed to thinking about something"). Subjects were very likely to mention separate matches and mismatches in their justifications (61% 71% per target type), but the distribution of these justifications simply mirrored the distribution of noun and verb matches in our stimuli (i.e., more verb matches for relational targets and more noun matches for attributional targets). Thus, neither separate nor syntactic justifications can account for the significant differences in subjects' similarity ratings of analogous (1-3) and non-analogous (1-4) targets.

Combined. Differences in similarity ratings of the relational and attributional targets are adequately captured by the distribution of justifications that referred to the combined meaning of the compared statements (27% 35% per target type). In particular, we identified two qualitatively different types of combined justifications: (1) Analogies that aligned the structures of the compared statements, and (2) causal or temporal Scenarios that integrated the statements by forming thematic alignments. Below we first define these two types of combined justifications and then present their distribution in the relational and attributional targets.

Analogies: Combined justifications were coded as analogies when they involved explicit references to analogy (e.g., "the analogy is too farfetched," "barber:hair :: teen: lawn"), or described in what sense the statements were good or poor analogies (e.g., "the child and the woman both enjoyed something," "comparison of two sounds by two comparable sources"). Two prevalent types of combined justifications that were coded as analogies compared role appropriateness of the noun-verb-noun combinations (e.g., "a lawyer would never design a dance," "most children do not enjoy jobs") or the overall truth and validity of the compared statements (e.g., "does not say anything we don't already know like the other two," "the first sentence is a fact, whereas the second is an opinion").

Scenarios: Combined justifications were coded as scenarios whenever they related the compared statements by causal or temporal relations. Examples of causal scenarios are: "A teacher may have listened to the lecture to prepare" (for the base "The teacher prepared a lecture" and the target "The teacher listened to the lecture"); "Something the child might do if he/she enjoyed the toy, out of selfishness" (for the base "The child enjoyed the toy" and the target "The child hid the toy"); or "A logical step: since equations are more accurate they are more difficult to use" (for the base "Equations are more accurate than words" and the target "Equations are more difficult than words"). Examples of temporal scenarios are: "Very similar since he is now with the product he has just fixed," "A child might hide the toy while playing with it," "The barber would probably think about the hair before he cut it," or "Examining a case is something the lawyer would do when taking it."

Table 2 presents the proportion of analogies and scenarios generated for the relational and attributional targets.

Table 2
Proportion of Analogies and Scenarios in relational and attributional targets

	Analogies	Scenarios
Relational targets		
123 (N= 106)	100	0
124 (N= 132)	97	3
125 (N= 117)	87	13
Attributional targets		
123 (N= 116)	41	59
124 (N= 130)	36	64
125 (N= 107)	41	59

As can be seen by comparing the top and bottom panels of Table 2, analogies were virtually the only type of combined justifications generated for the relational targets (matching verbs), whereas more than half of the combined

justifications generated for the attributional targets (matching nouns) were scenarios. Thus, 94% of the 355 combined justifications generated for the relational targets were analogies and only 6% were scenarios. By contrast, only 39% of the 353 combined justifications generated for the attributional targets were analogies and 61% were scenarios. This overwhelming difference in the distribution of analogies and scenarios for the relational and attributional targets demonstrates that, when the base and target share a relational match, subjects construct structural alignments, but when the base and target share attributional matches, they construct thematic alignments .

The high proportion of scenarios generated by our subjects is especially striking given that "thematic justifications" are believed to characterize similarity judgments of young children or people from non-western cultures who "fail to appreciate" the value of relational similarities (Markman, 1989). Yet, extremely bright undergraduates who participated in this study generated a total of 234 thematic justifications, and 214 of these justifications were written next to high quality analogical arguments justifying similarity of relational targets in the corresponding triplets. This surprising finding could be understood in terms of the pragmatic role of similarity. We often use similarity to draw inferences (if y is like x in these ways, it may be like it in other ways). Scenario thinking can be seen as another way of drawing inferences where the two terms together suggest a context where understanding can be applied.

Conclusion

Medin *et al.* (1993) pointed out that relational and attributional matches constrain the "respects" that people select as relevant to their similarity judgments. In the present study we found that matches in these two types of aspects also affect the way in which people align the compared stimuli. Using semantically interdependent Noun-Verb-Noun combinations we found that matching verbs lead to structural alignments and matching nouns to thematic alignments. Although our results support the psychological validity of the distinction between relational and attributional matches, we found that when subjects assess similarities between sentences with matching nouns they do not always compare these sentences or their interpretations. Rather, contrary to any traditional view of similarity, they integrate them into common scenarios and base their similarity judgments on the plausibility of such scenarios. Note that thematic alignments could not have been discovered with stimuli consisting of separable and independent relations and attributes (i.e., it is unlikely that people would construct a scenario relating OXΔ and O*Δ), and that it might be impossible to generalize processing assumptions across different types of stimuli.

Clearly, comparison between various aspects of the paired stimuli is not the only process that underlies similarity judgments. In fact, our results suggest that thematic alignments will mediate transfer even without attributional matches. For example, it is likely that participation in a common scene or in a functional or causal relation will increase similarity between participants that do not share common attributes (e.g., snow and shovel vs. snow and rake; flowers and pot vs. flowers and pan). An important challenge for future research is to identify the conditions that support structural and thematic alignments. To the extent that similarity alerts people to potential contexts in which they could apply their knowledge, such conditions are likely to be found in studies that use semantically rich stimuli and ecologically valid tasks.

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