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Thematic Relations Affect Similarity Via Commonalities

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Abstract

Thematic relations are an important source of perceived similarity. For instance, the *rowing* theme of boats and oars increases their perceived similarity. The mechanism of this effect, however, has not been specified previously. We investigated whether thematic relations affect similarity by increasing commonalities or by decreasing differences. In Experiment 1, thematic relations affected similarity more than difference, thereby producing a non-inversion of similarity and difference. Experiment 2 revealed substantial individual variability in the preference for thematic relations and, consequently in the non-inversion of ratings. In sum, the experiments demonstrated a non-inversion of similarity and difference that was caused by thematic relations and exhibited primarily by a subgroup of participants. These results indicate that thematic relations affect perceived similarity by increasing the contribution of commonalities rather than by decreasing the contribution of differences.

KEYWORDS: difference; similarity; structural alignment; thematic integration; thematic relations.

Similarity is fundamental to cognition and to some extent has been implicated in nearly every cognitive process from perceptual classification to economic decision-making. For example, recall of an item set is influenced by both perceptual (Conrad, 1964) and semantic similarity (Deese, 1959) as well as by the similarity between conditions at encoding and conditions at retrieval (Godden & Baddeley, 1975); categorization depends on an item's similarity to a prototype (Rosch, 1973) or to a set of exemplars (Medin & Schaffer, 1978); the course of spreading activation in a semantic network reflects the similarity between nodes (Meyer & Schvanenveldt, 1971); the success of analogical transfer is influenced by the similarity between the source and target problem (Gick & Holyoak, 1980); and inductive reasoning is often guided by the similarity between possible solutions and instances stored in memory (Tversky & Kahneman, 1974). So, given its ubiquity, it is crucial to determine what factors influence the perception of similarity.

In general, perceived similarity is determined by direct comparison (Tversky, 1977). This is the case for just about any pair of stimuli, from simple concepts (Markman & Gentner, 1993) to complex scenes (Markman & Gentner, 1996). However, perceived similarity is also influenced by thematic relations, which arise when two stimuli participate in a common scenario. For example, *milk* is generally rated more similar to *cow* than to *horse* (Wisniewski & Bassok, 1999), presumably because of the thematic relation between *milk* and *cow*. Currently, the mechanism of this thematic influence remains unspecified. Similarity judgments are based on commonalties and differences. Do thematic relations influence similarity by increasing the contribution of commonalities, or by decreasing the contribution of differences? In this article we report two experiments that utilize difference ratings as a diagnostic tool for discriminating between these explanations.

Comparison and Similarity

Perceived similarity is largely based on the commonalities and differences between stimuli (Tversky, 1977). The structural alignment model (Gentner & Markman, 1994, 1997; Markman, 1996; Markman & Gentner, 1993) specifies how these commonalities and differences are determined, combined, and weighted during similarity judgments. The model assumes structured representations consisting of predicates that take one or more arguments. For example, assume that *rose* and *violet* are represented respectively as *and* [*scent* (SWEET), *petal color* (RED)] and *and* [*scent* (SWEET), *petal color* (BLUE)]. Aligning stimulus representations can yield three main types of output. A matching predicate and matching attribute (e.g., *scent*: SWEET) indicate a *commonality*, whereas a matching predicate and mismatching attribute (e.g., *petal color*: RED, BLUE) reveal an *alignable difference*. Finally, some predicates have no corresponding arguments in the comparison stimulus (e.g., roses have thorns, violets do not); these constitute a *nonalignable difference*. The model further assumes that alignable differences are conceptually linked to commonalities. Indeed, the number of commonalities is positively correlated with the number of alignable differences, but is negatively correlated with the number of nonalignable differences (Markman & Gentner, 1993). For example, although a rose has more commonalities with a violet than with a violin, roses also have more alignable differences with a violet than with a violin. Roses and violins, in contrast, have more nonalignable differences (Markman & Wisniewski, 1997). So as a consequence of structural alignment, commonalities and alignable differences tend to be more salient than nonalignable differences (Gentner & Markman, 1997; for exceptions see Estes & Hasson, 2004).

The predicate (argument) representational structure is flexible enough to represent not just attributes (e.g., SWEET, BLUE), but also the relationship between attributes. For instance, the relation between a flower's stem and its petals could be represented as *support* (STEM, PETALS). In fact such *structural relations*, which link two arguments together, are more salient than common attributes (Markman & Gentner, 2000). To illustrate, Medin, Goldstone, and Gentner (1990) presented base stimuli along with alternatives that matched the base in terms of either an attribute or a relation, and participants chose which alternative was more similar to the base. To provide a simplified example, participants judged base stimuli such as □-□ to be more similar to a relation match such as ○-○ than to an attribute match such as □-○. Apparently, the common structural relation (i.e., a repeated object) was more salient than the common attribute (i.e., a square). Thus, the structural alignment model favors higher-order relations and preferentially weights matches at the most abstract level (Markman & Gentner, 2000).

In summary, the structural alignment model specifies how the analogous predicates and arguments are put into correspondence, and which of these are relevant for perceived similarity. The model implicitly describes two stages of similarity judgment. An alignment stage reveals the commonalities and differences between stimuli, and subsequently an assessment stage weights these commonalities and differences to arrive at a perception of similarity. Moreover, much research on perceived similarity indicates that commonalities are weighted more heavily than differences, that structural relations are more salient than attributes, and that alignable differences are more salient than nonalignable differences (Gentner & Markman, 1994, 1997; Markman & Gentner, 1993, 2000).

Thematic Relations and Similarity

Thematic relations arise from the co-occurrence or interaction of stimuli via some common scenario (cf. Lin & Murphy, 2001, p. 3). To illustrate, boats are related to oars via a rowing theme, doctors are related to nurses via a hospital theme, and money is related to a receipt via a purchasing theme. Unlike structural relations, which occur between the attributes of a single stimulus, thematic relations occur between two different stimuli. Thematic relations are central to understanding actions and events because these are usually organized according to theme (Bower, Black, & Turner, 1979; Schank & Abelson, 1977). Consequently, thematic relations affect language comprehension (Estes & Jones, 2009), conceptual combination (Estes, 2003a; Estes & Jones, 2006; Gagne & Shoben, 1997; Wisniewski, 1997), and memory (Jones, Estes, & Marsh, 2008). Thematic relations also influence categorization, sorting, naming, and induction (Lin & Murphy, 2001; Murphy, 2001). For instance, in an elegant series of experiments, Lin and Murphy demonstrated that a base concept (e.g., dog) was frequently grouped with a thematic option (e.g., bone) rather than a taxonomic option (e.g., cat).

Thematic relations also affect perceived similarity. Using complex semantic stimuli, Bassok and Medin (1997) discovered that many participants justified their similarity judgments of sentence pairs by thematically relating them. For example, when justifying the similarity between "The carpenter fixed the chair" and "The carpenter sat on the chair", one participant wrote "Similar because he sat on the chair to see whether he fixed it well." Bassok and Medin (1997) argued that thematic integration predominates when comparison is not easy, as with nonalignable items. Because the above sentence stimuli lack a shared relational structure (i.e., they describe different events), comparison is difficult and this conflict triggers integration. By this account, comparison is the primary process for determining similarity, but integration is an important secondary process for certain types of items.

Using simpler stimuli, Wisniewski and Bassok (1999) demonstrated that thematically related concepts such as *milk* and *cow* are judged more similar than unrelated concepts like *milk* and *horse*. Wisniewski and Bassok also found that thematic relations influenced participants' justifications of their similarity judgments. While participants tended to compare alignable stimuli (e.g., "both are used to travel across water" for *ship / canoe*), they typically integrated stimuli that were thematically related (e.g., "a mechanic works on cars" for *car / mechanic*). Wisniewski and Bassok (1999) proposed that stimulus compatibility with comparison or thematic integration drives process selection. Because alignable concepts share features and structural relations they are readily comparable. Nonalignable concepts, which lack such commonalities, are more compatible with thematic integration. For instance, participants frequently cited implausible thematic relations between nonalignable concepts that were also unrelated (e.g., “an electrician doesn’t repair chairs” for *chair / electrician*). Thus, lack of shared conceptual structure can trigger integration even in the absence of a preexisting thematic relation. However, thematic relations also affected participants’ similarity ratings when the stimuli could be easily aligned and compared (e.g., *milk* / *coffee*). These stimulus factors interact with (but are not eliminated by) task factors, such as judging similarity versus thematic relatedness.

Finally, Estes (2003b) showed that the same concepts are judged more similar when they are integrated. For instance, *table* and *vase* were rated more similar by participants who first integrated the concepts as a *table vase* than by participants who simply rated their similarity without integrating them. Jones and Love (2007) also found that concepts were judged more similar when they were presented in the same thematic sentence than when presented in thematically unrelated sentences.

The influence of thematic integration on perceived similarity is now well documented, but the mechanism by which it does so is currently unknown. Because this uncertainty has potential consequences for any cognitive model pertaining to similarity, it is important to specify how thematic relations impinge upon similarity judgments. The above explanations concerning stimulus compatibility (Wisnkiewski & Bassok, 1999) and integration as a secondary process that occurs when the stimuli are incompatible with alignment (Bassok & Medin, 1997) both provide useful descriptive frameworks of the thematic effect. However, the present research goes a step further by considering possible mechanisms of this thematic effect on similarity. Because perceived similarity is computed across commonalities and differences, we will consider whether thematic relations influence perceived similarity via commonalities or via differences.

Let us first consider how thematic relations might influence commonalities. One possibility is that a thematic relation is expressed as a commonality during judgment. For example, when comparing sailors and ships, noticing the thematic relation between them (i.e., sailors sail ships) might lead one to induce a commonality – namely that both sailors and ships participate in SAILING. Construed in this way, the thematic relation would go on to influence similarity just like any other commonality. Thus, the thematic relation might increase the total number of commonalties between sailors and ships. And given that the addition of commonalities increases perceived similarity (Gati & Tversky, 1984), this would explain the thematic effect on similarity ratings. Another possibility is that thematic relations simply increase the weighting accorded commonalities. So rather than acting as a commonality itself, the "participates in SAILING" relation might emphasize other extant commonalities of sailors and ships, such as their common location. To be clear, the present experiments will not distinguish between these number-of-commonalities and weighting-of-commonalities explanations. The important point for present purposes is that by either account, thematic relations increase perceived similarity by increasing the contribution of commonalities. We refer to this explanation as the *commonality hypothesis*.

Alternatively, thematic relations could decrease either the number of differences that are detected during alignment or the weighting of differences during assessment (again, however, these explanations will not be distinguished empirically). For example, the "participates in SAILING" relation either could inhibit the detection of differences such as the differing material substances of sailors (i.e., flesh and bone) and ships (i.e., wood and metal), or it could more generally suppress the weighting of the differences that are detected. And because decreasing the difference between concepts increases their perceived similarity (even though commonalities receive more weight than differences during similarity judgments; Tversky, 1977), thematic integration would increase perceived similarity. Thus, thematic relations may increase similarity by decreasing the contribution of differences during judgment. We therefore refer to this as the *difference hypothesis*.

Some evidence already points to a thematic disruption of difference perception. Gentner and Gunn (2001) had participants list either thematic relations or commonalities between concept pairs such as *tree / child*, and subsequently asked those participants to list a difference between concept pairs. Critically, the difference listing task included both old pairs that had been integrated (relation listing) or compared (commonality listing) in the first stage and new pairs that were not previously seen. Gentner and Gunn found that participants who initially listed commonalities later identified more differences for old pairs, whereas participants who initially listed thematic relations later identified more differences for new pairs. The fact that participants in the thematic group actually showed poorer difference listing for old items than for new suggests an influence of thematic integration on difference perception; if thematic relations had no influence, then participants should have listed approximately the same number of differences for old and new items. Although this result offers some support for the difference hypothesis, it is important to note that exactly how impaired difference perception would influence similarity judgments depends on whether these differences were predominantly alignable or nonalignable, which is not reported.

In summary, the commonality hypothesis explains the thematic effect as an increase in similarity, whereas the difference hypothesis explains the thematic effect as a decrease in difference. Because both hypotheses predict that thematically related items will be judged more similar than unrelated items, distinguishing between these explanations will depend on understanding how thematic relations influence perceived difference.

Difference

Early models treated difference and similarity as complementary (Gregson, 1975, p. 8). In fact, spatial models of similarity (e.g., multidimensional scaling) were often based on discriminability measures, which are inherently difference based. As early as Hollingworth (1913, cited in Gregson, 1975), however, there was evidence that difference is not the mirror image of similarity. Most famously, Tversky (1977) demonstrated an inconsistency between similarity and difference using pairs of countries that were either well known (e.g., USA and USSR) or less well known (e.g., Ceylon and Nepal) by the experimental participants. The familiar countries had more features in common and were consequently judged to be more similar to one another than the unfamiliar countries. However, the familiar countries also had more distinctive features and therefore were also judged to be more different than the unfamiliar countries. Tversky concluded that common features are accorded more weight in perceived similarity, whereas distinctive features are accorded more weight in perceived difference. This difference in the relative importance of common and distinctive features can lead to a *non-inversion* between similarity and difference judgments. The result is that more similar concepts are not always correspondingly less different.

Structural alignment provides a more specific account of difference judgments. As described earlier, structural alignment emphasizes structural relations and alignable differences. The model predicts that structural relations are more heavily weighted in similarity judgments, whereas alignable differences are more heavily weighted in difference judgments (Markman, 1996). Therefore, stimuli with structural relations in common and with salient alignable differences should be judged high in both similarity and difference. For example, Medin et al. (1990) found that a base stimulus (e.g., □-□) was judged both more similar to *and* more different from a relation match (e.g., ○-○) than an attribute match (e.g., □-○). Markman (1996) argued that the relation match was chosen as more similar because it shared a structural relation with the base (i.e., repeated shape), and was chosen as more different because it had more alignable differences from the base (i.e., two circles rather than one circle). Thus, structural alignment contends that the outputs of the comparison process (e.g., structural relations, alignable differences) are weighted differently across judgments. Estes and Hasson (2004) replicated this non-inversion with other geometric stimuli, and Bassok and Medin (1997) obtained the effect with sentential stimuli. In all three of those studies, the non-inversion was caused by a differential influence of structural relations on perceived similarity and difference.[1]

In addition to structural relations, thematic relations also affect difference judgments. As described previously, Gentner and Gunn (2001) found that listing a thematic relation between concepts decreased the likelihood that participants subsequently would list a difference between those concepts. Moreover, we have demonstrated elsewhere (Simmons and Estes, 2008) that thematic relations can induce a non-inversion of similarity and difference. We showed that a base concept (e.g., dog) was often judged both more similar to and more different from a thematic alternative (e.g., bone) than a taxonomic alternative (e.g., cat). In fact, the commonality hypothesis and the difference hypothesis both predict that thematic relations will induce a non-inversion between similarity and difference. Critically, though, the hypotheses make opposing predictions regarding the direction of this presumed non-inversion. Consider the thematically related concept pair *coffee* / *milk* and the thematically unrelated pair *coffee* / *lemonade*. *Coffee* should be judged more similar to *milk* than to *lemonade* because the thematic relation between *milk* and *coffee* either increases their commonalities (commonality hypothesis) or decreases their differences (difference hypothesis). So let’s assume that the similarity ratings, on an increasing scale from 1 to 7, are 5 for *coffee* / *milk* and 4 for *coffee* / *lemonade*. More informative are the difference judgments of these stimuli. The commonality hypothesis predicts that thematic relations will have a *smaller* influence on difference judgments, because commonalities receive less weight in difference than in similarity (Markman, 1996; Tversky, 1977). Their difference ratings, again on an increasing scale from 1 to 7, might both be 4. That is, the thematic relation between *milk* and *coffee* should increase their similarity but should have little or no effect on their difference. In contrast, the difference hypothesis predicts that thematic relations will have a *larger* influence on difference judgments, because differences receive more weight in difference judgments than in similarity judgments (Markman, 1996; Tversky, 1977). Given similarity ratings of 5 and 4 for *coffee* / *milk* and *coffee* / *lemonade*, their difference ratings should be more like 2 and 4. That is, the thematic relation between *milk* and *coffee* should increase their similarity slightly, but should decrease their difference more dramatically.

To recap, the commonality hypothesis predicts that thematic relations will have a *smaller* influence on difference judgments. That is, the thematic relation between *milk* and *coffee* should increase their similarity but should have little or no effect on their difference. In contrast, the difference hypothesis predicts that thematic relations will have a *larger* influence on difference judgments. That is, the thematic relation between *milk* and *coffee* should increase their similarity slightly, but should decrease their difference more dramatically. Thus, the non-inversion of similarity and difference can be used as a diagnostic tool to discriminate between the commonality hypothesis and the difference hypothesis. The present experiments therefore investigated the role of thematic relations in similarity and difference.

Experiment 1

In Experiment 1 participants rated either the similarity or the difference of stimulus pairs for which alignability and thematic relatedness were orthogonally crossed. That is, following Wisniewski and Bassok (1999), the stimuli were alignable and thematically related (A+T+; *milk & coffee*), alignable and unrelated (A+T-; *milk & lemonade*), nonalignable and related (A-T+; *milk & cow*), or nonalignable and unrelated (A-T-; *milk & horse*). Alignability was included as a factor both to make our design more comparable to Wisniewski and Bassok's (1999) and to increase the generality of our results. The experiment thus had a 2 (Alignability) × 2 (Thematic Relatedness) × 2 (Judgment) mixed design, with judgment (similarity, difference) manipulated between-participants. If thematic relations differentially affect perceived similarity and perceived difference, then Thematic Relatedness should interact with Judgment. More specifically, a larger effect of Thematic Relatedness in similarity judgments than in difference judgments would support the commonality hypothesis. The opposite pattern, a smaller thematic effect in perceived similarity than in perceived difference, would instead support the difference hypothesis.

Method

Participants. Participants in both of the experiments reported below were undergraduates at the University of Georgia, all were native English speakers, and all received partial course credit for participation. Sixty undergraduates participated in Experiment 1.

Materials. Stimuli were sampled from Wisniewski and Bassok (1999). Each of twelve base concepts was paired with one target concept in each cell of the 2 (Alignability) x 2 (Thematic Relatedness) factorial, thus yielding 48 stimulus pairs. All alignable pairs were members of the same taxonomic category. Category membership is a good proxy for alignability because category co-members tend to share many alignable differences, which indicates structural similarity (Markman & Wisniewski, 1997). All thematic pairs shared a functional relationship. For example, the base concept "milk" was paired with "coffee" (A+T+), "lemonade" (A+T-), "cow" (A-T+), and "horse" (A+T-). For a complete list of stimuli, see Table 1.

Procedure. Participants were randomly assigned to either a Similarity condition or a Difference condition. In both conditions, all 48 stimulus pairs appeared in a pseudo-random order with the restriction that pairs containing the same base did not appear consecutively. Each trial began with a stimulus pair presented in the center of the display. After 1800 ms, participants in the Similarity condition were asked “On a scale of 1 (not at all similar) to 7 (extremely similar) how similar are [base] and [target]?” This prompt appeared beneath the stimulus pair and remained onscreen until a response was entered by key press. The Difference condition was procedurally identical, except that all instances of the word “similar” were replaced with “different”.

Data analysis. In both of the experiments reported below, data were analyzed according to the same statistical procedures. In order to facilitate comparison with the similarity ratings, the difference ratings were reverse scored in all analyses, figures, and tables. To control for incidental differences between the similarity and difference scales, ratings were transformed to standard (z) scores separately for similarity and difference judgments prior to analysis; raw scores are reported in the figures and tables to maximize interpretability. Data were analyzed via separate ANOVAs, one with participants random (F_p) and another with items random (F_i). Alignability and Relatedness were analyzed within-participants and between-items, whereas Judgment was between-participants and within-items. Across experiments, all effects or interactions not reported were not significant by both participant and item analyses.

Results

To summarize, a non-inversion was obtained, with a larger thematic effect in similarity than difference. This effect was more pronounced with alignable items. Thus, thematic integration caused a non-inversion that was moderated by alignability. Means and standard errors are reported in Table 2. A 2 (Alignability) x 2 (Thematic Relatedness) x 2 (Judgment) ANOVA indicated significant main effects of both alignability [F_p (1, 58) = 183.36, $p < .001$; F_i (1, 44) = 135.75, $p < .001$] and thematic relatedness [F_p (1, 58) = 48.33, p

< .001; F_i (1, 44) = 25.25, p < .001]. Alignable items were judged to be more similar and less different than nonalignable items, and thematically related items were judged more similar and less different than unrelated items. Alignability accounted for the majority of the variance in similarity (η_p^2 = .70) and difference (η_p^2 = .81). Importantly, thematic relations accounted for more variance in similarity (η_p^2 = .54) than in difference (η_p^2 = .34). These effects were qualified by two significant interactions, which are illustrated in Figure 1.

Figure 1 shows the magnitude of the thematic effect – that is, the difference in ratings for thematically related items minus thematically unrelated items. Higher values indicate a larger effect of thematic relatedness. Two main results are apparent. First, alignability and thematic relatedness interacted [F_p (1, 58) = 81.62, p < .001; F_i (1, 44) = 9.94, p < .01], indicating that the influence of thematic relations was larger for nonalignable items than for alignable items (see Figure 1). More importantly, thematic relatedness also interacted with judgment [F_p (1, 58) = 5.05, p < .05; F_i (1, 44) = 26.74, p < .001]. As shown in the figure, thematic relations affected similarity ratings (white bars) more than difference ratings (gray bars). We subsequently conducted 2 (Thematic Relatedness) x 2 (Judgment) ANOVAs for the alignable conditions (A+T+, A+T-) and for the nonalignable conditions (A-T+, A-T-) separately.

Alignable Conditions. For alignable items (e.g., *milk & coffee*; *milk & lemonade*), thematic relations increased perceived similarity but did not decrease perceived difference, thereby causing a non-inversion. The main effect of judgment was reliable by items [F_i (1, 22) = 5.53, p <.05] but not by participants [F_p (1, 58) = .65, p = .46]. This was qualified by an interaction between judgment and thematic relatedness [F_p (1, 58) = 6.89, p < .01; F_i (1, 22) = 11.53, p <.01]. Paired comparisons confirmed that thematic relations significantly increased similarity [F_p (1, 29) = 13.66, p < .01; F_i (1, 22) = 4.47, p < .05] but exerted no effect on difference (both p > .75). This non-inversion between similarity and difference is apparent in left half of Figure 1. While the difference in ratings for related and unrelated items is substantial for similarity judgments (white bar), it is almost non-existent for difference (gray bar). That is, *milk* was judged more similar to *coffee* than to *lemonade,* but *milk* was not judged any less different from *coffee* than from *lemonade*. Perhaps the simplest illustration of this non-inversion is the discrepant effect sizes for similarity and difference. While thematic relations accounted for nearly a third of the variance in similarity judgments ($\eta_p^2 = .32$), they accounted for almost no variance in difference judgments ($\eta_p^2 < .01$).

Nonalignable Conditions. For nonalignable items (e.g., *milk & cow; milk & horse*), thematic relations increased similarity and decreased difference. However, the effect of thematic relatedness was larger for similarity than for difference. Once again, the main effect of judgment was reliable by items [F_i (1, 22) = 8.43, $p <.01$] but not by participants [F_p (1, 58) = .52, $p = .47$]. The main effect of thematic relatedness was significant in both analyses [F_p (1, 58) = 75.06, $p < .001$; F_i (1, 22) = 38.88, $p <.001$]. The interaction was marginally significant [F_p (1, 58) = 2.85, $p = .09$; F_i (1, 22) = 16.19, $p < .01$], but paired comparison indicated that thematic relations both increased similarity [F_p (1, 29) = 44.09, $p < .001$; F_i (1, 22) = 37.00, $p < .001$] and decreased difference [F_p (1, 29) = 31.00, $p < .001$; F_i (1, 22) = 37.00, $p < .001$]. The right half of Figure 1 illustrates that the effect of thematic relations was substantial for both similarity (white bar) and difference (gray bar). So unlike the alignable condition, here, thematic relations influenced both similarity and difference ratings. However, like the alignable condition, the thematic influence on nonalignable items was larger in similarity ($\eta^2 = .60$) than in difference ($\eta^2= .52$).

Discussion

The results of Experiment 1 support the commonality hypothesis. Thematic relations did induce a non-inversion of similarity and difference, and this effect was larger for similarity than for difference. For instance, *milk* was rated more similar to *coffee* than to *lemonade*. This thematic effect in similarity could be due to thematic relations either inhibiting differences (i.e., the difference hypothesis) or increasing commonalities (i.e., the commonality hypothesis). If it were due to difference inhibition, then that thematic relation should decrease difference even *more* than it increases similarity, since differences are weighted more heavily in difference judgments than in similarity judgments (Markman, 1996; Tversky, 1977). Alternatively, if it were due to increasing commonalities, then that thematic relation should decrease difference *less* than it increases similarity, since commonalities are weighted more heavily in similarity judgments than in difference judgments. In actuality, *milk* was rated equally different from *coffee* and *lemonade*. Thus, because thematic relations influenced similarity more than difference, the results supported the commonality hypothesis.

A secondary result was that thematic relations had a larger influence on judgments of nonalignable stimuli than of alignable stimuli. This replicates Wisniewski and Bassok's (1999) finding that alignable stimuli induce comparison whereas nonalignable stimuli induce integration. That is, thematic relations have a larger effect on nonalignable stimuli, since those items are more compatible with integration.

Experiment 2

Some evidence points to substantial variation among individuals in the size of the thematic effect on similarity and difference (Simmons & Estes, 2008). In a previous project we presented base concepts (e.g. *dog*) with a taxonomically related option (e.g. *cat*) and a thematically related option (e.g. *bone*), and instructed participants to choose the option that is more similar to the base. We found that some participants clearly preferred taxonomic options, while others clearly preferred thematic options (see also Gentner & Brem, 1999; Lin & Murphy, 2000; Murphy, 2001; Waxman & Namy, 1997). Such individual variability in participants' use of thematic information was also present in the current Experiment 1. For instance nearly a third of participants (30%) typically assigned A-T+ items (e.g., *milk / cow*) a rating less than two, whereas nearly a fourth (23%) typically assigned these items a rating greater than five.

These results suggest that the commonality hypothesis may explain the behavior of some participants but not others. If this is the case, then the non-inversion between similarity and difference observed in Experiment 1 would be found in the ratings of a subset of participants, only. The triad task just described provides a useful way to identify how strongly participants' judgments are influenced by thematic relations. In Experiment 2 we tested the generality of the commonality hypothesis, by administering the triad task prior to the similarity / difference rating task. Firstly, we examined whether participants' choices on the triad task predicted their performance on the subsequent rating task. Secondly, we examined whether non-inversion in the ratings task is exhibited by most participants, or whether the effect is limited to participants with a strong thematic preference (as evidenced by the triad task). Participants who almost always select the thematic option as more similar to the base in the triad task should show a large effect of thematic relatedness in the ratings task and a non-inversion between similarity and difference. Participants who almost never select the thematic option in the triad task should show little or no effect of thematic relatedness in the ratings task and complementary similarity and difference judgments.

Method

One hundred thirty-two undergraduates participated. As in Experiment 1, participants rated the similarity / difference of the 48 items originally used in Wisniewski & Bassok (1999). This main experiment was preceded by a triad task, using thirty triads sampled from Lin & Murphy (2001). Each triad consisted of a centrally presented target word above two response options. One option was thematically related to the target and the other was taxonomically related. For example, the target word "pencil" had "pen" (taxonomic match) and “eraser” (thematic match) as response options. See Table 3 for a complete list of triad stimuli. Participants were instructed to choose the option “that is most similar to the target word” by pressing “1” or “2” on the number pad (Simmons & Estes, 2008). On half the trials “1” corresponded to a thematic match and on the other half “1” corresponded to an attribute match. The triads were presented in random order. Following the triad task, all participants completed either the similarity or the difference rating task described in Experiment 1.

Results

Triad Choice Task

As a measure of performance in the triad task, we calculated for each participant the proportion of trials on which the thematic option was chosen (henceforth “thematic proportion”). Across all participants, the thematic proportion ranged from 0.00 to 1.00. The mean was .64 (SD = .40) and the median was .87, thus indicating that participants tended to choose the thematic alternative as more similar to the target. Moreover, the distribution was extremely polarized; most participants exhibited a clear preference either for taxonomic matches or for thematic matches (see also Lin & Murphy, 2001; Murphy, 2001). For example, while 32% of participants selected the thematic match on 30% or less of trials, 58% selected the thematic match on 70% or more of trials. Only 10% of participants exhibited no clear preference for taxonomic or thematic choices. Thus, striking individual differences in similarity judgment were observed (see also Simmons & Estes, 2008). We used these individual differences to predict the non-inversion in the subsequent rating task.

Regression Analyses

First we examined the relationship between thematic proportion and non-inversion across all participants via regression analysis. As a general measure of the effect of thematic relatedness, we took the difference in ratings between the related and unrelated conditions (henceforth “relatedness effect”). That is, for each participant, the mean of the unrelated conditions (A+T- and A-T-) was subtracted from the mean of the related conditions (A+T+ and A-T+). Next, we tested whether participants' thematic proportion (from the triad task) predicted their relatedness effect (from the rating task). Indeed, thematic proportion significantly predicted the relatedness effect in both similarity ratings [$R^2 = .39$, $F(1, 65) = 40.87$, $p < .001$] and difference ratings [$R^2 = .10$, $F(1, 63) = 7.15$, $p = .01$]. Finally, to test whether thematic proportion predicted the relatedness effect significantly better in the similarity ratings than in the difference ratings, we used participants' thematic proportion to predict the interaction between the relatedness effect and judgment type via linear regression. The model fit was reliable [$F(1, 130) = 31.70$, $p < .001$; $R^2 = .20$, $\beta = .44$], thus indicating that thematic proportion better predicted the relatedness effect in similarity than in difference. Participants who tended to choose the thematic alternative in the triad task also tended to exhibit a relatively large influence of thematic relations in the similarity rating task. But performance on the triad task was less predictive of the effect of relatedness in the difference rating task.

Group-wise Analyses

We also examined the relationship between thematic proportion and non-inversion via analyses of variance. In this analysis we treated thematic proportion as a categorical variable, thereby creating one group of participants who exhibited a strong preference for the taxonomic alternative (i.e., the “attribute group”) and another group who strongly preferred the thematic alternative (i.e., the “relation group”). Of all participants in the similarity rating condition, the 20 who exhibited the lowest thematic proportion were selected for the attribute group, and the 20 who exhibited the highest thematic proportion were selected for the relation group. The same process was used to select attribute participants and relation participants from the difference rating condition. The mean thematic proportion was .08 (SE = .01) for the attribute group and was .98 (SE = .01) for the relation group. An initial 2 (Group: attribute, relation) x 2 (Alignability) x 2 (Thematic Relatedness) x 2 (Judgment) ANOVA revealed that the Group factor exhibited several significant three-way and two-way interactions with other factors. Overall, the results replicated the findings of Experiment 1. There was a main effect of Alignability [F_p (1, 76) = 413.21, p < .001; F_i (1, 44) = 227.58, p < .001] and of Thematic Relatedness [F_p (1, 76) = 76.87, p < .001; F_i (1, 44) = 30.73, p < .001] as well as a significant interaction between these factors [F_p (1, 76) = 92.98, p < .001; F_i (1, 44) = 11.75, p < .001]. The Thematic Relatedness by Group interaction was marginal in the participant analysis and significant by items [F_p (1, 76) = 3.52, p = .07; F_i (1, 44) = 15.27, p < .001], indicating a trend towards greater influence of thematic relations on similarity than on difference. Most importantly, the three-way interaction between Group, Thematic Relatedness, and Judgment was significant [F_p (1, 76) = 5.75, p < .05; F_i (1, 44) = 35.86, p < .001]. Thus, for simplicity, the attribute and relation groups are considered in separate analyses below (see Table 2).

Attribute group. Participants who tended to select the attribute match in the triad task showed little effect of thematic relatedness on similarity ratings (see Figure 2A). In the Judgment x Alignability x Thematic Relatedness analysis, the main effect of alignability was significant [F_p (1, 38) = 349.67, p < .001; F_i (1, 44) = 381.11, p < .001], accounting for most of the variance in similarity (η_p^2 = .95) and difference (η_p^2 = .85). Contrary to the results of the previous experiment, thematic relations accounted for relatively little variance in either similarity (η_p^2 = .11) or difference (η_p^2 = .20). This main effect of thematic relatedness was only significant by participants [F_p (1, 38) = 6.96, p < .05; F_i (1, 44) = 2.74, p = .11]. However, thematic relatedness and alignability significantly interacted [F_p (1, 38) = 42.37, p < .001; F_i (1, 44) = 6.24, p = .02]. We therefore analyzed the alignable and the nonalignable items separately.

For the alignable items, thematic relations had no influence on similarity or difference. Neither main effect was significant, nor was their interaction. This is apparent in the left half of Figure 2A, where the thematic effect is negative and close to zero. That is, if anything, these participants gave slightly higher similarity ratings to A+T- items than to A+T+ items. For the nonalignable items, only the main effect of thematic relatedness was significant in both analyses [F_p (1, 38) = 19.07, $p < .001$; F_i (1, 22) = 30.17, $p < .001$]. The lack of interaction indicates that thematic relations affected similarity ($\eta_p^2 = .27$) and difference ($\eta_p^2 = .39$) approximately equally. Thus, for these participants, thematic relations only affected similarity and difference for nonalignable stimuli.

Relation group. Participants who preferred the thematic option in the triad task showed a markedly different pattern of results (see Figure 2B). Although alignability still accounted for a large proportion of the variance in similarity ($\eta_p^2 = .55$) and difference ($\eta_p^2 = .83$), thematic relations accounted for a comparable proportion of rating variance in similarity ($\eta_p^2 = .77$). Consistent with Experiment 1, thematic relations accounted for less variance in difference judgments ($\eta_p^2 = .51$). Thematic participants clearly exhibited a non-inversion in the alignable conditions. In the Judgment x Alignability x Thematic Relatedness analysis, each of the two-way interactions was significant (all $p < .05$). Thus, the alignable and the nonalignable items are examined separately below.

For the alignable items, thematic relations increased perceived similarity but not perceived difference (see the left half of Figure 2B). This interaction was significant [F_p (1, 38) = 11.43, $p < .01$; F_i (1, 22) = 14.32, $p < .01$]. Paired comparisons confirmed that thematic relatedness affected similarity [F_p (1, 19) = 26.68, $p < .001$; F_i (1, 22) = 14.31, $p < .01$] but not difference (both $p > .05$). The left half of Figure 2B clearly illustrates this differential influence of thematic relations on similarity ($\eta_p^2 = .58$) and difference ($\eta_p^2 = .18$); the white bar, indicating the thematic effect on similarity, is clearly higher than the gray bar, indicating the thematic effect on difference. For the nonalignable stimuli, the main effect of thematic relatedness was significant [F_p (1, 38) = 84.70, $p < .001$; F_i (1, 22) = 58.57, $p < .001$], and there was mixed evidence for an interaction between thematic relatedness and judgment [F_p (1, 38) = 2.42, p = .13; F_i (1, 22) = 21.78, p < .001]. Thus, thematic relations clearly influenced similarity and difference, though this influence was larger for similarity (white bars, $\eta_p^2 = .80$) than for difference (gray bars, $\eta_p^2 = .55$). Consequently the non-inversion was observed.

Discussion

Prior to the similarity/difference rating task, participants were presented a series of base concepts (e.g., dog) and were asked to choose whether a taxonomic option (e.g., cat) or a thematic option (e.g., bone) was more similar to that base. A regression analysis indicated that participants' choices on the triad task reliably predicted their performance on the subsequent rating task. More interestingly, however, participants' triad choices better predicted their similarity ratings than their difference ratings. We also examined the generality of the commonality hypothesis by comparing one group of participants who rarely chose the thematic option against another group who almost always chose the thematic option in the triad task. The extent of the thematic effect and, consequently, of non-inversion was much greater in the relation group than the attribute group. The discrepancy between these groups was most pronounced with alignable stimuli, where the attribute group exhibited no thematic effect and no non-inversion, whereas the relation group exhibited a strong thematic effect on similarity and a large non-inversion. This individual variability means that the commonality hypothesis advanced in Experiment 1 explains the behavior of the large subset of participants for whom thematic relations are salient, but does not characterize the responses of participants who ignore thematic relations in similarity and difference.

It is possible that another mechanism is responsible for the small thematic effect found in the attribute participants' judgments of nonalignable items. Preliminary support for this idea comes from Simmons and Estes (2008), who found that thematic preference in the triad task was independently predicted by two factors – an explicit belief that thematic relations are relevant to similarity and low need for cognition (Caccioppo & Petty, 1982). Thus, the commonality hypothesis might apply only to participants who believe that thematic relations are a legitimate source of similarity, while another mechanism might underlie the judgments of low NFC thematic participants. Although additional research is needed to clarify this issue, collectively, these results provide the strongest evidence to date that thematic relations cause a non-inversion of similarity and difference.

General Discussion

The experiments reported here were motivated by two converging lines of research. Some studies have demonstrated an effect of thematic integration on perceived similarity (Bassok & Medin, 1997; Estes, 2003b; Jones & Love, 2007; Wisniewski & Bassok, 1999), and others have indicated that certain types of information are weighted differently across similarity and difference judgments (Estes & Hasson, 2004; Medin et al., 1990; Simmons & Estes, 2008; Tversky, 1977). We utilized this non-inversion to elucidate the mechanism through which thematic relations influence similarity and difference judgments. In sum, the experiments demonstrated a non-inversion of similarity and difference that was caused by thematic relations and exhibited primarily by a subgroup of participants. Results suggest that thematic relations affect perceived similarity via commonalities, the relative influence of which varied not only across stimuli and tasks (see also Wisniewski & Bassok, 1999), but also across individuals (see also Simmons & Estes, 2008). We first review the empirical results in greater detail, and then we consider their theoretical implications for models of similarity and difference.

Empirical Review

Alignability. The largest and most consistent effect in these experiments was a main effect of Alignability. Stimuli that could be aligned easily (e.g., *milk & coffee*) were rated significantly more similar and less different than nonalignable stimuli (e.g., *milk & cow*).

Thematic Relatedness. Both experiments also exhibited effects of Thematic Relatedness. Thematically related stimuli (e.g., *milk & coffee*) were rated reliably more similar and less different than unrelated stimuli (e.g., *milk & lemonade*).

Judgment x Thematic Relatedness. The interaction between Judgment and Thematic Relatedness indicates a non-inversion of similarity and difference. To illustrate, in Experiment 1 *milk* was judged more similar to *coffee* than to *lemonade*. Furthermore, this effect was larger in similarity than in difference. In Experiment 2, the non-inversion was more pronounced among participants for whom thematic relations are particularly salient.

Alignability x Thematic Relatedness. The interaction between Alignability and Thematic Relatedness, which was obtained in both experiments, indicates that thematic integration exerted a larger effect on nonalignable stimuli than on alignable stimuli. Nonalignable stimuli share few structural relations and have few alignable differences, and therefore participants' judgments were largely affected by thematic relations. But because alignable stimuli are easily compared, the thematic influence is tempered (Wisniewski & Bassok, 1999). We also observed differential effects of stimulus alignability on the non-inversion of similarity and difference; the non-inversion occurred primarily with alignable stimuli.

Individual Variability. Some participants showed a greater effect of thematic relations on their ratings than other participants (cf. Lin & Murphy, 2001; Murphy, 2001; Simmons & Estes, 2008). Interestingly, one's overall preference for thematic choices in a triad task strongly predicted one's similarity ratings, but only weakly predicted one's difference ratings. Furthermore, participants who tended to choose the thematic option in the triad task also tended to exhibit a large non-inversion of similarity and difference. Other participants, who tended to choose the taxonomic option in the triad task, exhibited no non-inversion for alignable items and an attenuated non-inversion for nonalignable items.

Theoretical Implications

The present experiments tested two potential mechanisms of this thematic influence. According to the difference hypothesis, thematic relations indirectly influence perceived similarity by decreasing difference (either by decreasing the number of differences detected or by decreasing the weighting of those differences). According to the commonality hypothesis, thematic relations influence similarity by increasing perceived commonalities. If thematic relations act via differences, then relations should have a larger effect on perceived difference than on perceived similarity, because differences are more important to difference than to similarity (Markman, 1996; Tversky, 1977). Or if thematic relations act via commonalities, then relations should have a larger effect on perceived similarity, because commonalities are more important to similarity than to difference. Results supported the commonality hypothesis: In Experiment 1 and a subset of Experiment 2 the effect of thematic relations was larger in similarity than in difference (Figures 1, 2B). In no case did thematic relations exert a significantly larger effect on perceived difference than on perceived similarity.

Thematic relations contributed substantially to the perception of similarity in both experiments. Perhaps the strongest effect of thematic relations was observed in the Relation Group of Experiment 2 (Figure 2B). For those participants, thematic relatedness ($\eta_p^2 = .77$) was more important than alignability ($\eta_p^2 = .55$) for the perception of similarity. In fact, when alignability and thematic relatedness were pitted against one another, the thematically related stimuli (A-T+) were judged more similar than the alignable stimuli (A+T-). For example, those participants judged *milk* to be more similar to *cow* than to *lemonade*. Thus, the thematic effect was quite striking for some participants. At the same time, the Attribute Group exhibited virtually no thematic effect on either similarity or difference (Figure 2A).

This research also provides the first demonstration of an effect of thematic relations on difference judgments, and contributes to the evidence for non-inversion that is caused by thematic relations (see also Simmons & Estes, 2008). In some respects, the thematic influence on difference was analogous to the thematic effect on similarity; thematically related items were generally judged to be less different than unrelated items. However, this effect was smaller in difference than in similarity, and it was particularly evident in ratings of alignable items. As with similarity judgments, the strength of the thematic effect varied between individuals. For example, for the attribute group in Experiment 2, thematic relations accounted for very little variance in difference ratings ($\eta_p^2 = .04$)), but for the relation group, thematic relations accounted for over half of the variance in difference ratings ($\eta_p^2 = .58$).

The existence of such striking individual differences raises the important question of how prevalent the thematic effect is for similarity and difference. Stated alternatively, if thematic relations were shown to exert only a small effect on only a small minority of participants, then it might be more parsimonious to exclude them from models of similarity and difference. There are at least three reasons to reject this suggestion. First, both the absolute magnitude of the thematic effect and the proportion of variance explained by thematic relatedness were relatively large. Second, a large percentage of the participants in Experiment 2 exhibited a preference for thematic similarity choices. Indeed, we have found in other studies that this preference for thematic similarity choices is not only prevalent, but also highly robust (Simmons & Estes, 2008). Finally, even participants who strongly preferred taxonomic similarity choices (i.e., the Attribute Group of Experiment 2) nonetheless exhibited an effect of thematic relations with nonalignable stimuli. These findings collectively suggest that similarity and difference judgments are best predicted by taking thematic relations into account. Models of cognition pertaining to similarity may also benefit from considering the contribution of thematic relations. For example, categorization models that use only feature-based similarity may underestimate the probability of assigning thematically related concepts to the same category, and models of semantic priming fail to anticipate lexical priming from thematic integration (Estes & Jones, 2009).

Like structural relations and attributes, thematic relations enrich one's knowledge about the relationship between concepts. For example, in comparing *ship / tugboat*, recognizing that tugboats tow ships permits further inferences about tugboats, in general (e.g. although they are smaller than ships, tugboats must have powerful engines to perform their job). Because thematic relations provide specific knowledge about a particular scenario, they allow one to "plan future activities and understand current events" (Lin & Murphy, 2001 p 23). Thus, people for whom thematic information is salient might make more or qualitatively different types of inferences than people who ignore thematic relations. This knowledge can then influence interactions with objects or aid in problem solving (e.g. if tugboats can tow ships they can be used to tow a variety of things). Given the consequences of a thematic effect on similarity, the present research endeavored to specify the mechanism underlying this influence.

In summary, our results offer several insights into the mechanism and characteristics of the thematic effect on perceived similarity. First, thematic relations influence perceived similarity and difference by increasing the contribution of perceived commonalities between concepts. Secondly, like structural relations and attributes, thematic relations are more salient for similarity than for difference. Thirdly, thematic relations have less influence when there are many structural relations and attributes than when there are few such commonalities. Finally, the salience of thematic relations varies across participants (see also Simmons & Estes, 2008). Thus, the present results demonstrate that capturing similarity and difference judgments requires a quite flexible model; it must accommodate rather dramatic variability in the weighting of thematic relations across stimuli (alignable v. nonalignable), across judgments (similarity v. difference), and across participants (taxonomic v. thematic preferences).

References

Bassok, M., & Medin, D. L. (1997). Birds of a feather flock together: Similarity judgments with semantically rich stimuli. *Journal of Memory and Language, 36*, 311–336.

Bower, G. H., Black, J. B., & Turner, T. F. (1979). Scripts in memory for text. *Cognitive Psychology*, 11**,** 177–210.

Cacioppo, J. T., & Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology, 42,* 116-131.

Conrad, R. (1964). Acoustic confusion in immediate memory. *British Journal of Psychology, 92*, 149-154.

Davidoff, J. & Roberson, D. (2004). Preserved thematic and impaired taxonomic categorization: A case study. *Language and Cognitive Processes*, *19,* 137-174.

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology, 58*, 17-22.

Estes, Z. (2003a). Attributive and relational processes in nominal combination. *Journal of Memory and Language*, *48,* 304-319.

Estes. Z. (2003b). A tale of two similarities: Comparison and integration in conceptual combination. *Cognitive Science 27,* 911–921.

Estes, Z. & Hasson, U. (2004). The importance of being nonalignable: A critical test of the structural alignment theory of similarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30,* 1082-1092.

Estes, Z., & Jones, L. L. (2006). Priming via relational similarity: A COPPER HORSE is faster when seen through a GLASS EYE. *Journal of Memory and Language, 55,* 89-101.

Estes, Z. & Jones, L. L. (2009). Integrative priming occurs rapidly and uncontrollably during lexical processing. *Journal of Experimental Psychology: General, 138,* 112-130.

Gagné, C. L., & Shoben, E. (1997). The influence of thematic relations on the comprehension of modifier-noun combinations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23,* 71-87.

Gati, I. & Tversky, A. (1984). Weighting common and distinctive features in conceptual and perceptual judgments. *Cognitive Psychology, 16*, 341-370.

Gentner, D. & Brem, S. K. (1999). Is snow really similar to a shovel? Distinguishing similarity from thematic relatedness. Proceedings of the 21st Annual Conference of the Cognitive Science Society. Hillsdale, NJ: Earlbaum.

Gentner, D. & Gunn, V. (2001). Structural alignment facilitates the noticing of differences. *Memory and Cognition, 9*, 565-577.

Gentner, D. & Markman, A. B. (1994). Structural alignment in comparison: No difference without similarity. *Psychological Science, 5,* 152-158.

Gentner, D. & Markman, A. B. (1997). Structure mapping in analogy and similarity. *American Psychologist*, *52,* 45–56.

Gick, M. L. & Holyoak, K. J. (1980). Analogical problem solving. *Cognitive Psychology*, *12*, 306-355.

Godden, D. R. & Baddeley, A. D. (1975). Context dependent memory in two natural environments: On land and underwater. *British Journal of Psychology, 66,* 325-331.

Jones, L. L., Estes, Z., & Marsh, R. L. (2008). An asymmetric effect of relational integration on recognition memory. *The Quarterly Journal of Experimental Psychology, 61*, 1169-1176.

Jones, M. & Love, B. C. (2007). Beyond common features: The role of roles in determining similarity. *Cognitive Psychology, 55,* 196-231.

Lin, E. L. & Murphy, G. L. (2001). Thematic relations in adults' concepts. *Journal of Experimental Psychology: General, 130,* 3-28.

Markman, A. B. (1996). Structural alignment in similarity and difference judgments. *Psychonomic Bulletin and Review, 2*, 227-230.

Markman, A. B. & Gentner, D. (1993). Splitting the difference: A structural alignment view of similarity. *Journal of Memory and Language, 32,* 517-535.

Markman, A. B. & Gentner, D. (1996). Commonalities and differences in similarity comparisons. *Memory and Cognition, 24,* 235-249.

Markman, A. B. & Gentner, D. (2000). Structure mapping in the comparison process. *American Journal of Psychology, 118,* 501-538.

Markman, A. B. & Wisniewski, E. J. (1997). Similar and different: The differentiation of basic level categories. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*, 54-70.

Medin, D. L., Goldstone, R. L., & Gentner, D. (1990). Similarity involving attributes and relations: Judgments of similarity and difference are not inverses. *Psychological Science, 1*, 64-69.

Medin, D. L., & Schaffer, M. M., (1978). Context theory of classification learning. *Psychological Review, 85*, 207-238.

Meyer, D. E. & Schvanenveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology, 90*, 227-234.

Murphy, G. L. (2001). Causes of taxonomic sorting by adults: A test of the thematic-to-taxonomic shift. *Psychological Bulletin and Review, 8*, 834-839.

Rosch, E. H. (1973). On the internal structure of perceptual and semantic categories. In T. E. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 111-144). New York: Academic Press.

Schank, R. C., & Abelson, R. (1977). *Scripts, plans, goals, and understanding.* Hillsdale, NJ:

Erlbaum.

Simmons, S. & Estes, Z. (2008). Individual differences in similarity and difference. *Cognition, 108,* 781-795.

Tversky, A. (1977). Features of similarity. *Psychological Review*, *84*, 327–352.

Tversky, A. & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185*, 1124-1131.

Waxman, S. R. & Namy, L. L. (1997). Challenging the notion of thematic preference in young children. *Developmental Psychology, 33,* 555-567.

Wisniewski, E. J. (1997). When concepts combine. *Psychonomic Bulletin & Review, 4*, 167-183.

Wisniewski, E. J. & Bassok, M. (1999). What makes a man similar to a tie? Stimulus compatibility with comparison and integration. *Cognitive Psychology, 39,* 208-238.

Footnotes

1. Obtaining a different result for similarity and difference judgments, in itself, would be unremarkable. After all, different questions and scales have unique response characteristics. But the structural alignment model predicts a differential influence of a specific type of information across judgments that, when present, can induce a non-inversion. This is very different (and more interesting) than predicting an absolute non-inversion, where similarity and difference judgments always differ. This latter non-inversion simply could reflect scaling incompatibility rather than a deeper conceptual difference between judgments. For this reason, we will focus exclusively on non-inversion that arises because a type of information is more important to one judgment than to another.

Table 1. Stimuli used in the rating tasks for experiments 1 and 2.

	Match Type			
Base	A+T+	A+T-	A-T+	A-T-
milk	coffee	lemonade	cow	horse
ship	lifeboat	canoe	sailor	soldier
car	tow truck	pickup truck	mechanic	plumber
chair	table	bed	carpenter	electrician
telephone	ans. machine	tape recorder	receptionist	waitress
tie	suit	dress	man	woman
chisel	hammer	screwdriver	sculpture	painting
cat	mouse	hamster	veterinarian	pediatrician
cup	kettle	pan	tea	wine
fly	spider	beetle	screen	curtain
peanut butter	jelly	cream cheese	knife	fork
apple pie	ice cream	jello	baker	tailor

Source: Wisniewski & Bassok (1999)

Table 2. Similarity and reverse-scored difference ratings (*M* and *SE*) across experiments.

Experiment	Judgment	Stimuli			
		A+T+	A+T-	A-T+	A-T-
1	Similarity	4.69 (.15)	4.08 (.19)	3.41 (.33)	1.71 (.14)
	Difference	3.78 (.17)	3.74 (.19)	2.31 (.23)	1.31 (.07)
2 – Attribute	Similarity	4.07 (.18)	4.25 (.18)	1.71 (.23)	1.27 (.10)
	Difference	4.18 (.07)	4.34 (.08)	2.00 (.19)	1.27 (.06)
2 – Relation	Similarity	4.57 (.19)	3.34 (.19)	4.22 (.32)	1.69 (.10)
	Difference	4.72 (.19)	4.46 (.19)	3.01 (.33)	1.40 (.11)

Table 3. Stimuli used in the triad task, Experiment 2.

	Match Type	
Base	Taxonomic	Thematic
cat	lion	litter box
spider	wasp	spider web
French fries	baked potato	ketchup
panda bear	grizzly bear	bamboo
chalk	marker	blackboard
king	president	crown jewels
organ	accordion	church
Tortilla chips	potato chips	salsa
pepperoni	pork chops	pizza
bees	flies	honey
camel	antelope	desert
crib	water bed	baby
police car	sedan	police officer
pencil	pen	eraser
Hollywood	Chicago	movie stars
monastery	synagogue	monk
can opener	bottle opener	can
diamond ring	bracelet	engagement
robbery	treason	bank
beer	juice	party
airplane	car	pilot
swimming	golf	swimming suit
Hawaii	Missouri	beach
milk	soda	calcium
saxophone	harp	jazz
turkey	swan	Thanksgiving
waitress	stewardess	restaurant
igloo	cabin	Eskimo
hot dog	steak	mustard

Source: Lin & Murphy (2001)

Figure 1. The thematic effect ($M_{\text{related}} - M_{\text{unrelated}}$) as a function of Judgment (Similarity, Reverse-scored Difference) and Alignability, Experiment 1.

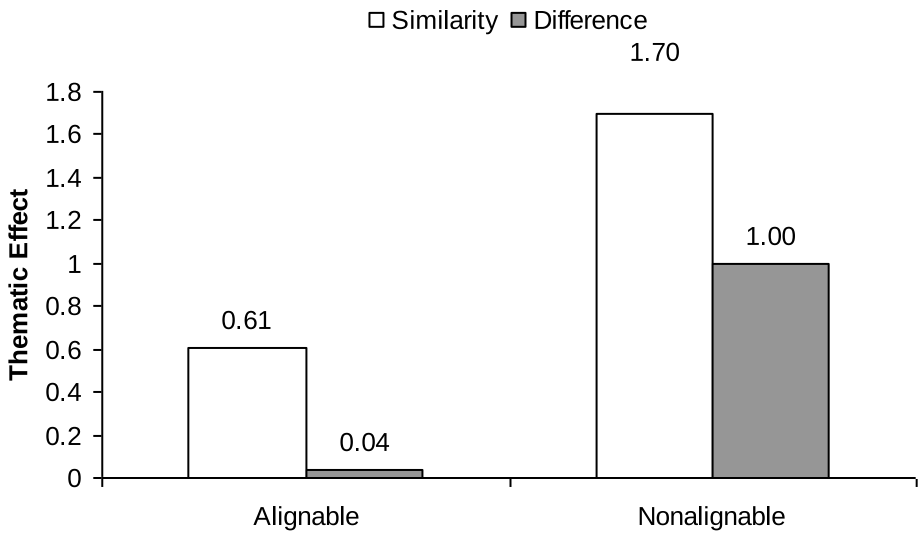

Figure 2. The thematic effect ($M_{\text{related}} - M_{\text{unrelated}}$) as a function of Judgment (Similarity, Reverse-scored Difference) and Alignability, presented separately for the *Attribute Group* (panel **A**) and the *Relation Group* (panel **B**), Experiment 2.