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Relational Processing in Conceptual Combination and Analogy

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Abstract: We evaluate whether evidence from conceptual combination supports the relational priming model of analogy. Representing relations implicitly as patterns of activation distributed across the semantic network provides a natural and parsimonious explanation of several key phenomena observed in conceptual combination. Although an additional mechanism for role resolution may be required, relational priming offers a promising approach to analogy.

Leech et al. propose that analogies are understood by relational priming. For instance, PUPPY:DOG::KITTEN:??? is completed by applying the relation between the base concepts (a PUPPY is the *offspring* of a DOG) to the target concepts (a KITTEN is the *offspring* of a CAT). In addition to its occurrence in analogy, relational priming also occurs regularly in common language use. Indeed, object concepts are combined frequently in language (e.g., BIRD NEST), and like analogies, such conceptual combinations are understood by retrieving or inferring some relation (e.g., *habitation*) between the given concepts. In conceptual combination, relational priming occurs when one phrase (e.g., BIRD NEST) facilitates comprehension of a subsequent phrase (e.g., FISH POND) that instantiates the same relation (Estes 2003; Estes & Jones 2006; Gagné 2001; Spellman et al. 2001). Given this fundamental similarity between analogy and conceptual combination, then, research on conceptual combination may serve as a useful tool for evaluating models of analogy.

Leech et al. posit that relations are represented as transformations between activation states. More specifically, a relation is represented as the pattern of activation required to transform an input object (e.g., APPLE) into an output object (e.g., CUT APPLE). In terms of conceptual combination, this corresponds to a simple concept (e.g., NEST) being transformed into a compound concept (e.g., BIRD NEST). Because such transformations are carried out within the hidden layer of the model, a relation is represented implicitly as a pattern of activation within the semantic network.

This transformational model of relational representation naturally explains several of the key observations in research on conceptual combination. First, familiar combinations (e.g., BIRD NEST) and novel combinations (e.g., TURTLE CAGE) are understood via the same processes. Intuitively, it seems that familiar combinations would be understood by simply retrieving the compound concept from memory, whereas novel combinations necessitate a relational inference. However, the evidence suggests that familiar and novel combinations undergo the same computations (e.g., Gagné & Spalding 2004). The transformational model provides a straightforward explanation for this otherwise counterintuitive observation: The relational inference entails a transformation from simple concepts to a compound concept, regardless of the familiarity of the compound. Although the relational transformation may proceed more quickly for familiar compounds than for novel compounds, it nevertheless must occur in both cases.

Second, relational representations are independent of the concepts that instantiate them. If relational representations were concept bound, then relational priming should only occur when the base and target exhibit lexical repetition (e.g., BIRD CAGE → BIRD NEST; Gagne 2001). In actuality, however, relational priming also occurs in the absence of lexical repetition (Estes 2003; Estes & Jones 2006; Raffray et al. 2007; Spellman et al. 2001). For example, FISH POND facilitates the comprehension of BIRD NEST because both combinations utilize the same relational representation. Because the transformational model posits that relations are represented as unique patterns of activation that may be triggered by multiple input objects, the model clearly predicts relational priming without lexical repetition (otherwise, it couldn't possibly explain analogy). The independence of relational representations is further evidenced by the facilitative effect of relational labels on analogy completion. Although a relational label does not add new information to the network, it effectively cues the relational transformation, regardless of the concepts that instantiate it.

Finally, relational representations are somewhat specific. To illustrate, BIRD NEST, TURTLE CAGE, and COOKIE JAR all nominally instantiate a general *location* relation. So if relational representations were this general, then TURTLE CAGE and

COOKIE JAR should both facilitate comprehension of BIRD NEST. But in actuality, TURTLE CAGE facilitates comprehension of BIRD NEST, but COOKIE JAR does not. This selectivity of relational priming indicates that relational representations are specific, more like *habitation* (i.e., TURTLE CAGE and BIRD NEST) and *containment* (i.e., COOKIE JAR). The transformational model explains this selectivity of priming as a consequence of relational similarity. That is, the pattern of activation required to transform NEST into BIRD NEST is highly similar to that required to transform CAGE into TURTLE CAGE but is relatively dissimilar to the transformation from JAR to COOKIE JAR. Without sufficient relational similarity, relational priming cannot occur (Estes & Jones 2006).

An important issue that may pose a challenge for the transformational model is role resolution. That is, once a relation between concepts is inferred, those concepts must also be assigned to appropriate roles in that relation. Otherwise, the relational inference would lead to frequent errors in interpretation (Hummel & Holyoak 2003). Consider the causal relation, for which it is crucial to distinguish cause from effect (see Fenker et al. 2005). WIND EROSION and GROWTH HORMONE both instantiate the causal relation, but note that the ordering of cause and effect is reversed in the two combinations. Because the transformational model has only implicit relational representations, with no explicit provision for role resolution, it is unclear how the model will account for such differences. To demonstrate the issue with analogy, consider WIND:EROSION::SMOKE:???. Once the base pair activates the causal transformation, the target pair will tend to undergo the same transformation. But on what basis will the model correctly produce an effect of SMOKE (e.g., COUGH) rather than a cause (e.g., FIRE)? A simple solution is to stipulate that each relation has two distinct transformations, one for each possible ordering of role assignments (e.g., cause → effect and effect ← cause). However, the cost of this relational proliferation may essentially offset the benefit of representing relations implicitly. Thus, we view role resolution as an important issue requiring explicit elaboration in the model.

In summary, the transformational model parsimoniously explains several key phenomena of conceptual combination. Although important issues remain to be addressed, we believe that Leech et al. have provided a promising framework for modeling analogy and other relational processes, such as conceptual combination.

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