Representation of Semantic Attributes vs Semantic Relations

Introduction

A commonly held assumption in the field is that similarity and difference can be treated as inverse properties such that, the more similar objects are, the less different they are, and vice versa. Structured around the question of this inverse nature of similarity and difference, a study by Medin, Goldstone, and Gentner (1990) revealed insights into the representation of attributional and relational features as distinct mental structures in the visual domain. By showing participants various visual stimuli and asking participants to engage in a forced choice of either the more similar or more different stimulus to the base, it was shown that there is an asymmetry in the decision making. They found that relations seemed to be a greater determining factor when assessing similarity, while attributes were attended to more in difference judgements. The fact that relative importance of attribute and relation matches as well as mismatches depended on whether similarity or dissimilarity judgments are engaged suggests that attributes and relations are psychologically distinct. While the Goldstone, Medin, and Getner study applied to the visual domain, there is a question as to whether their conclusions about visual properties apply to the semantic domain. If people were to make similarity and difference judgements in a way that seems to weight semantic attributes and relations differently when engaging with linguistic stimuli as they did with visual stimuli, this would give an indication to support that attributes and relations are represented differently in some way.

Attributes and Relations

Previous research has shown that people rely on two different kinds of information when they make similarity and difference judgments: relational or structural information, on one hand,

and attributional or surface-level information, on the other. In their 1991 paper, Goldstone, Medin, and Gentner proposed definitions for attributes and relations whereby attributes are understood as any constituent property of a stimulus, which can be colloquially understood as attributes of a particular entity. Relations, on the other hand, are descriptions of connections between two or more entities or attributes. Relational information includes overarching relationships among components or properties of an object, while attributional information includes properties of an object as a whole or of an object's individual components. However, the scenarios in which an individual more heavily relies on either relational or attributional information differ based on the type of judgment being made.

The Similarity Process

Similarity is a single value that integrates across many different sources of input and thus relies on feature aggregation. Similarity judgement between two word pairs integrates all the attributes and relations with there being two separate pools that are weighted differently according to whether one is making a similarity or difference judgement. When people judge how similar two objects are, they tend to heavily rely on structural information about those objects and their overarching relationship— attending more heavily to their relational similarity. For example, when people judge how similar apples are to oranges, they might consider more strongly the fact that they both consist of an outer layer of “skin” surrounding an internal area of “fruit,” as well as the fact that they contain seeds distributed in their internal area. On the other hand, when people judge how different two objects are, they tend to heavily rely on surface-level information about those objects such as their properties and components—their attributional similarity, or lack thereof. As such, semantic meaning and relations need to be contrasted against each other because we are proposing that what goes into the similarity or difference judgement are the two pools that are weighted differently based on whether it is a similarity judgement or a difference judgement.

The MAX Model

Goldstone, Medin, and Gentner (1991) advanced the claim that relations and attributes are psychologically distinct and formal measures of similarity should not treat all types of matching features equally. As such, they described by which this phenomenon could be explained, one of which was the MAX model which specifically differentiates attributes from relations, and weights the two types of similarity differently, depending on the other features present. MAX model provides a framework for understanding how attributes and relations are considered in similarity and difference judgements and potentially provides clarity as to the mechanism which results in the asymmetry of this consideration in similarity and difference decisions. If semantic attributes and relations are in fact represented distinctly as they are with the visual objects, then the MAX model can be applied within the semantic domain with regards to how representations of these attributes and relations are structured and engaged with.

Semantic Similarity Determinations

Bassok and Medin's 1997 study sought to understand how a similarity judgment is made with regards to semantic objects, specifically assessing the applicability of the Structural Alignment Hypothesis as an explanation for the similarity process, which necessitates the distinct representation of object attributes and relations. The procedure followed by Bassok and Medin involved comparing 5-word sets composed of nouns, which represented attributes, and verbs, serving the role of relations. In each trial, participants were exposed to three of these 5 word sets - the base set (which had the attributional and relational target) which was compared to a set that was attributionally similar to the base (the nouns matched but the verbs were different), and one of three relationally similar sets. The three types of relationally similar sets were a) relational and inferred relational similarity (the explicitly relationship indicated by the verb matched the base as well as an inferred relationship between the object and subject of the sentence), b) relationally similar (the verb of the sentence matches the base), and c) relational and attributional similarity (both the verb and the subject noun matched the base). In this study, the relational similarity between the base and the compared objects is determined by which object has the same verb as the base, and the attributionally similar object is likewise the one with the same noun. This aspect of the procedure confounds the results due to the matching grammatical categories as, relational similarity is confounded by matching verbs, and attributional similarity is confounded by matching subjects. As such, any conclusions drawn about the similarity process can potentially be explained by sentence components matching. In order to avoid this potential confound, in this study, we chose to utilize comparisons of word pairs and word sets rather than sentences so that similarity judgements were based solely on participants evaluations of the attributes and relations between the words themselves rather than relying on broader grammatical and linguistic capacities.

Methods

Following a similar procedure to the Medin, Goldstone, and Gentner study with semantic stimuli instead of visual, there was a Standard T word pair with a particular relation between the words in the pair as well as a semantic domain in which the words both fall. In addition to the standard, there were two alternative options presented to the participant, A and B. In the primary trials, one alternate pair was highly semantically similar to the standard and lowly relationally similar, while the other option was lowly semantically similar and highly relationally similar to the standard. Participants were called to make similarity or difference judgements to determine which of the word pair options were either more similar or more dissimilar. In order to avoid demand characteristics as well as loss of attentiveness, additional combinations of word pairs were intermixed throughout the trial: a) Primary Interest: Semantically Similar vs Relationally Similar, b) Attention Check 1: Semantically & Relationally Similar vs. Relationally Similar, c) Attention Check 2: Semantically & Relationally Similar vs. Semantically Similar. Additionally, the side on which each pair type was displayed was counterbalanced. The attention check provided the ability to assess if participants were correctly performing the test and ensured that participants were engaging with the stimuli, preventing biased behaviors. As such, it avoided the case where all trials are exactly the same - that is, without the attention check - resulting in participants employing a different cognitive faculty than the one of interest in this study. This structure also prevents the likelihood of demand characteristics as a result of participants inferring a pattern in the stimuli.

In order to avoid other confounding factors, the experiment was structured so as to pair up sufficiently contrasted semantic domains and relation types. Each trial consisted of sets of contrasted domain pairs and relation types in order to prevent confounding effects of participants inferring categories significantly different from those intended by experimental design. Within each trial, the combinations of relation type and semantic domain were counterbalanced as well as which relation type and semantic domain constituted the base pair. As such, each relation type and semantic domain occupied the base pair position and the foil position, and each combination of relation type and semantic domain was utilized.

Materials

We have constructed our stimuli in sets, with each set consisting of a base pair relation (B), and two choice stimuli (A and B) for the participants to choose between. For each set, we created stimuli that were relationally similar (R), semantically similar (S), and both relationally and semantically similar (RS) to the base pair. The relationally similar stimuli share only the base pair's relation (but belong to a different semantic domain), the semantically similar stimuli share the base pair domain (but comprise a different relation), and the relationally and semantically similar option share both the domain and relation of the base pair.

To ensure the validity of the semantic and relational similarity between our stimuli and the base pairs, we computed semantic similarity by calculating the cosine distance between Word2Vec word embeddings representing each word pair (Mikolov, 2013). This helped us certify that the degree of semantic similarity for the semantically similar stimuli and the base pair was much more significant than the degree of semantic similarity for the relational stimuli and the base pair. Similarly, to ensure that the degree of relational similarity for the relationally similar stimuli and the base pair was much more significant than the degree of relational similarity for the semantic stimuli and the base pair, we computed relational similarity by calculating the cosine distance between relation vectors generated by the BART model (Lu, Wu, & Holyoak, 2019).

When creating our stimuli, we chose words that would be easily understood by the average adult. To avoid confounding factors, we did not use any duplicates of any of the words used in the stimuli. With regards to the semantic and relational categories of our stimuli, we deliberately chose subject domains and relations that would be accessible and understandable. The 4 subject domains for the base pairs were: *animals, tools, modes of transport, food, plants, and furniture*. The 6 relations for the base pairs were: *exemplar:category, part-whole/object:component, item:location, and exemplar:exemplar.* Each base pair domain was matched with a relation, leading to a total of 24 stimuli sets. Out of these 24 stimuli sets, 16 focused on our study's main manipulation (R vs S), while 8 were used as manipulation checks.

Although the distinction we are exploring is between the subjects' choice of relationally or semantically similar stimuli, we have introduced RS vs R and RS vs S stimuli options as manipulation checks to ensure that our subjects do not pick at random and actually consider both relational similarity and semantic similarity in their comparisons. For the RS vs R attention check, we expect the subjects to pick the RS option if asked to choose which item is more similar to the target, and the R option if asked to choose which item is more different than the target. For the RS vs S attention check, we again expect the subjects to pick the RS option if asked to choose which item is more similar to the target, and the S option if asked to choose which item is more different than the target. These manipulation checks will comprise 4 stimuli sets each for a total of 8 manipulation checks, meaning that 1 out of every 3 stimuli sets will be an manipulation check.

Procedure

Participants, who selectively enrolled in the study through the UCLA SONA subject pool, accessed the experiment virtually. After reading a set of instructions describing how to complete the task, participants had to make decisions between the choices in each of the 24 stimuli sets. The experiment (which was constructed through PsychoPy), terminated upon the subjects' completion of the 24 trials.

Discussion

To dissect our results, we recorded and analyzed all of the participants' choices for each stimuli set. In general, we expected to see an asymmetry in the subjects' choices of similar and different stimuli. Namely, we believed that when presented with the same stimulus, participants would choose the relational option depending on whether they were asked to pick the item more similar or more different from the target. Thus, there should be significant similarity between the subjects' selections for the stimuli sets in the similarity and the difference conditions, as well as an overall tendency in selection for the relationally similar option.

For future exploration, one potential extension of this study could be to instruct participants to make their judgments as quickly as possible, thus adding a time component to the study. Due to prior research that suggests that judgments of relational similarity require more cognitive effort than judgments of relational similarity, it would be possible that subjects will overwhelmingly select the semantically similar option during the trials. Other experiments could employ a within-subjects design, in which participants are alternatively asked to make both similarity and difference judgments. This would show whether the non-inverse effect holds true even if the same individual makes similarity and difference judgments. Finally, an interesting manipulation for future experiments could be to adjust the phrasing of the instructions; for instance, instead of asking subjects to judge between similarity and difference, asking them to judge which items are most similar and most *dissimilar*. This could lead subjects to always reason about the stimuli in the context of similarity rather than similarity and difference, potentially leading to responses where dissimilarity judgments are indeed inverses of difference judgments.

The average person makes hundreds of judgments a day, and these judgments vary widely based on context, stimuli being judged, and numerous other factors. Although we are only exploring one dimension of similarity and difference judgments, we believe that the results of our experiment would contribute to the existing literature by demonstrating the use of relational and attributional reasoning in different contexts. Moreover, by exploring the differences in similarity and difference judgments, we set a foundation to better understand the cognitive processes that underlie them.

References

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