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A THEORETICAL NOTE ON THE RELATIONCHIP BETWEEN SEARCH ASYMMETRY AND ASYMMETRY IN SIMILARITY JUDGMENTS

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Search Asymmetry or Asymmetry in Visual Search

A group of phenomena called 'search asymmetry' was identified by Treisman and colleagues (Treisman & Souther, 1985; Treisman & Gormican, 1988). Search asymmetry refers to the significant difference in people's performance between two visual search tasks that are related to each other symmetrically. In a visual search task, an experimenter asks a human subject to search for a predesignated target among nontargets or distractors presented together with the target in a display. The simplest example of such a search task may be to find a circle among squares. A task relationally symmetric to this task is to find a square among circles. The experimenter measures how fast subjects can search for the target in terms of reaction time. Though these specific tasks with circles and squares are constructed for the purpose of explanation, many experiments with pairs of stimuli have taken place and their results reported many of them revealing search asymmetry (Treisman & Souther, 1985; Treisman & Gormican, 1988).

The findings of search asymmetry comprise at least three classes. The first is that class in which a target is easier to search for among distractors when there is clearly a discriminative feature present in the target but not in the distractors. This compares to when the relation between the target item and

the distractor item is reversed. An example of this is the search for a circle with an intersecting line segment among simple circles. This search is easier than the search for a circle among circles which all have intersecting lines (Treisman & Souther, 1985). The second class is the case where targets with larger values are easier to search for than targets with smaller values. For example, a vertical line segment is easier to search for when it is longer than distractor line segments which are also vertical. This compares to when a shorter line segment is searched for as a target among longer line segments as distractors (Treisman & Gormican, 1988). The third class, which will become the focus of the following discussion, includes all examples in which it is easier to search for what may be considered a standard or prototype among those that are not. This compares to a search for what may be a nonstandard or nonprototypical (or deviating) target among standard or prototypical distractors. A simple example of this is that a vertical line is more difficult to search for among tilted lines than a tilted line among vertical lines. Another example is that a circle is more difficult to search for among ellipses than an ellipse among circles (Treisman & Gormican, 1988).

The third class, which may be called search asymmetry between a standard and a nonstandard (or between a prototype and a deviating item), is quite interesting in that it elicits the thought that there may be some analogy between search asymmetry and asymmetry in similarity judgments. The reason is that asymmetry found in similarity judgments is also asymmetry between prototypes and deviants; it has been found, with various stimuli or items, that a deviant member in a category is more similar to a prototypical member in the same category than the prototype is to the deviant (Rosch, 1975, 1978; Tversky, 1977). Thus, the asymmetry found in the study of early vision and the asymmetry found in the research on similarity in the domain of category seems to converge with respect to the relationship between proto-

types and deviations. However, Treisman and Gormican(1988) have denied this possibility by mentioning some difficulties for connecting asymmetries in these two areas consistently (See below).

In the following sections I describe the general nature of asymmetry in similarity judgments, outlining the difficulties mentioned by Treisman and Gormican (1988). I argue that these difficulties can be resolved.

Asymmetry in Similarity Judgments

The notion of similarity in commonsense usage is nondirectional or symmetric. In other words, the similarity between a and b is considered to be symmetric to or the same as the similarity between b and a.

However, it is possible to ask people to judge directional similarity as in the question,"How similar a is to b?" or"How similar b is to a?", according to directional judgment. In these directional questions the second item may be considered as a reference point in relation to which the first item is measured.

Rosch (1975) used linguistic hedges to examine directional similarities between prototypes and non-prototypes belonging to a category. Examples of linguistic hedges used were: "___ is essentially ___"; "___ is basically ___ ." It was supposed that how similar an item was to another item could be measured by counting how often one or the other was placed in the first or the second blank of the linguistic hedges when people were asked to place the two items in the blanks so that the resulting sentences would sound most natural to them. The major finding by Rosch(1975) was that prototypical items were placed more frequently in the second blank than in the first blank. This suggests that non-prototypical items are perceived as more similar to prototypical items than vice versa. This asymmetry between prototypes and non-prototypes is generally thought to constitute evidence for asymmetry in similarity

judgments.

Asymmetry in similarity judgments has been characterized as robust and has elicited theoretical explanations. Rosch and Mervis(1975; Rosch, 1978) cited the notion of family resemblance proposed by Wittgenstein (1953). According to Rosch and Wittgenstein, a natural category does not have criterial features shared equally and to a full extent by all members of the category (Note 1). Instead, a member of the category may share some feature with another member of the category, and this member may share some other feature with still other member of the category. In this way, the members of the category are related to each other not by means of criterial features but rather by means of a collection of local relations made by various features everywhere within the category. Such relations in a category are called family resemblance. Rosch and Mervis suggested that prototypical members of a category share more features with other members of the category and fewer features with members in contrast categories. This means the prototypes have large family resemblance within the category and least family resemblance to the contrast categories. In other words, prototypes have more cue valid features and fewer cue invalid features than non-prototypes. (The notion of cue validity becomes a key concept later in this paper. See Note 2.) This internal structure of a category — the relationship between being prototypical and family resemblance or cue valid features — was considered to make a prototype appear more likely to be a reference point and placed in the second blank in the linguistic hedge questions.

Tversky's (1977) explanation of asymmetry in similarity judgments is similar to the explanation by Rosch(1978; Rosch & Mervis, 1975), except that Tversky based his explanation on a general mathematical model for similarity judgments (Note 3). In Tversky's model, when a quantitative measure of the features belonging to an item is larger than a measure of the features belong-

ing to another item, the second item is judged to be more similar to the first item(Note 4). According to Tversky, it is the salience of a given item that makes the measure of the item larger. Prototypes are, generally speaking, more salient than others. That is why non-prototypical items are perceived to be more similar to prototypical items than vice versa.

Treisman and Gormican's (1988) argument that asymmetry in visual search and asymmetry in similarity judgments cannot be related consistently

Treisman and Gormican's(1988) argument contains at least two points. The first point is concerned with the number of features or attributes a prototype possesses. They argue that, while in visual search asymmetry adding a feature to a stimulus item is not a movement to prototypicality but to deviation, in asymmetric similarity prototypes have more features than others. Thus, in visual search, adding the feature of tilt to the feature of being vertical makes a slightly tilted line, a deviation from the vertical line as a prototype. This certainly contrasts with studies on asymmetry in similarity judgments that suggest that prototypes have more features than others.

The second argument by Treisman and Gormican(1988) diverges from Tversky's theory of asymmetric similarity judgments in which a prototypical item is supposed to be more salient in comparison to deviating items. The research on visual search has confirmed experimentally that it is a deviating item that perceptually pops out of prototypical distractors. Therefore the term 'salient' fits a deviating stimulus item much better than a prototype; a tilted line pops out among vertical lines, but a vertical line does not among tilted lines.

The consistent relation between asymmetry in visual search and asymmetry in similarity judgments

I propose that the asymmetries in the two domains can be related in a consistent way in spite of the difficulties suggested by Treisman and Gormican (1988). My argument contains two parts that correspond respectively to the two difficulties presented by Treisman and Gormican.

First, I examine the relationship between the number of features belonging to an item and prototypicality. The problem is that in the study on similarity prototypes have been considered to possess more features than others. However, in the study on visual search a deviating stimulus item is considered to have more features than a prototypical item. Two examples of the latter case are a tilted line in comparison with a vertical line, and an ellipse in comparison with a circle. A tilted line has two features, being almost vertical and being tilted, but a vertical line has only one feature, being vertical. Similarly, an ellipse has two features, circularity and elongation, but a circle has only one feature, circularity.

This difficulty pointed out by Treisman and Gormican (1988) cannot be resolved if we restrict our concern to the number of features belonging to an item without paying attention to the nature of the features. However, by examining the relationship between the number of features of an item and prototypicality proposed by Rosch and Mervis (1975), we notice that features are classified into two classes: cue valid features and cue invalid features. It is important to make clear that what Rosch and Mervis(1975) really meant with respect to the number of features was that prototypes have more cue valid features and fewer cue invalid features than non-prototypes. In the domain of visual search Treisman and Gormican (1988) did not make this distinction in counting the number of features. In comparing a vertical line with a tilted line

it should be noted that being vertical is a cue valid feature that makes an item with the feature more likely to be categorized as a member of the coarse category of the vertical. On the other hand, the feature of being tilted is a cue invalid feature that makes an item with the feature less likely to be categorized as a member of the same category of the vertical. The same could be said with circularity and elongation. Circularity is a cue valid feature for identifying an item with it as a member of the category of things that are circular. Elongation is a cue invalid feature for the same identification.

Adding a cue invalid feature to an item does not increase the number of the cue valid features of the item; therefore, it does not help to make the item more prototypical. Instead, it should be realized that the fact that a vertical line has fewer, actually no, cue invalid features than a tilted line, makes the vertical line more prototypical in the sense of Rosch and Mervis (1975). On the other hand, a tilted line should be considered as a deviating item in the same sense because of the possession of the cue invalid feature of being tilted. Exactly the same argument will apply to a circle and an ellipse, and circularity and elongation. In this way the problem of the relation between the number of features of an item and being prototypical can be solved.

The second difficulty in relating the study on search asymmetry and asymmetry in similarity judgments was concerned with the salience of an item. Tversky (1977) suggested that it was the salience of a prototype that caused asymmetry in similarity judgments. In Tversky's mathematical model it was impossible to predict asymmetric similarities without supposing the salience of a prototype. On the other hand, in the visual search experiments by Treisman and Gormican (1988) it was always an deviating item that was perceptually more salient than a prototype; a deviating item was easier to search for among prototypical items than a prototype was among deviating items.

This apparent contradiction can be resolved by interpreting Tversky's no-

tion of salience as a theoretical concept to be applied to his mathematical model in a functional way and not as something identical to the perceptual salience (or popout) in the visual search experiments. The salience of a prototype may also be recognized in the context of our subjective experience in everyday life. However, the subjective impression of salience need not correspond to the experimental findings (Note 5) nor to the theoretical concept. Tversky's notion of salience may coincide with the subjective impression of salience. The experimental findings by Treisman and Gormican (1988) may not coincide with the subjective impression of salience. However, by simply distinguishing the various usages of the term 'salience' we find that the second difficulty associated with saliency can be resolved.

Conclusion and proposal

In the preceding discussion I have tried to resolve the difficulties in relating the study on asymmetry in visual search and asymmetry in similarity judgments. I have suggested that the difficulty associated with the relationship between being prototypical and the number of features possessed by an item can be resolved by distinguishing cue valid features and cue invalid features. I have indicated that the difficulty associated with the notion of salience might be resolved by discriminating the various usages of the term 'salience'.

Resolving these difficulties does not necessarily provide a positive correlation or parallelism between asymmetries in the two domains. In conclusion, therefore, I propose a possible parallelism between these two asymmetries. The problem is basically how the fact that a deviating item is judged to be more similar to a prototype than the prototype is to the deviating item can be related consistently to the fact that a deviating item is easier to search for among prototypical items than a prototype is among deviating items in visual

search.

There seems to be two ways of thinking about this problem, one of which leads to inconsistency and the other to consistency. One can think of two directional similarities in visual search as factors affecting people's performance. One is how similar a target is to distractors, and the other is how similar the distractors are to the target (Note 6). The first directional similarity cannot be related to asymmetry in similarity judgments very well; a deviating item is more similar to a prototype while a deviating item as a target is easier to search for among prototypical items. The second directional similarity can be related to asymmetry in similarity judgments quite well; when distractors are more similar to a target, that is, when the distractors are deviating items and the target is a prototype, that would predict the relative difficulty of the search for the target, a prototype. On the other hand, when distractors are less similar to a target, that is, when the distractors are prototypical items and the target is a deviating item, that would predict the relative ease of the search for the target, a deviating item (Note 7).

My proposal is essentially that an effective determinant in asymmetric visual search is how similar distractors are to a target and not how similar a target is to distractors. This proposal being correct, search asymmetry can be nicely connected to asymmetric similarity in the domain of categorization (Note 8).

NOTES

Note 1. A more recent study by Malt and Johnson (1992) makes a similar point that artifact concepts do not have core or criterial features.

Note 2. A cue valid feature is a feature that makes a member of a category which has the feature more likely to be perceived as included in the

category. A cue invalid feature makes a member of a category more likely to be perceived as included in a contrast category.

Note 3. Tversky's(1977) model of similarity is basically a linear combination of quantitative measures of distinctive and common features of two items.

Note 4. The mechanism underlying this result is given in terms of Tversky's mathematical model.

Note 5. Another example of search asymmetry was found by Kawazu and Yokosawa (1992) between the search for a symmetric pattern among asymmetric patterns and the search for an asymmetric pattern among symmetric patterns. They report that in certain conditions it can be significantly easier to search for an asymmetric target than for a symmetric target. This finding makes a contrast with our subjective impression that symmetry is more salient than asymmetry.

Note 6. Duncan and Humphreys (1989, 1992) proposed a general model for visual search based on similarity relations between a target and distractors and between distractors themselves. Their notion of similarity was symmetric and was not directional.

Note 7. My proposal fits the model theoretic explanation of search asymmetry by Treisman and Gormican (1988). It may also be related to Duncan and Humphreys' (1989, 1992) theoretical work to some extent, especially in relation to their notion of spreading suppression. See also Treisman(1992).

Note 8. The theoretical analysis and the proposal made in this article is not meant to incorporate a new type of search asymmetry in visual search experiments with heterogeneous distractors (Treisman, 1991). In the experiments by Treisman and Gormican (1988) distractors were always homogeneous.

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