# A Model Incorporating Relative Prominence for Asymmetric Similarity

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The aim here is to present and discuss a geometrically based model augmented with the notion of relative prominence for describing and predicting asymmetric proximity data.

The concept of similarity is fundamental to cognitive science in that it serves as an organising principle for concept formation and generalisation. A common way to perform theoretical analysis on, and to model, similarity is to use geometric models. However, in his well-known paper "*Features of Similarity*", Tversky (1977) presents empirical results from a wide range of domains suggesting that proximity data sometimes reveal significant and systematic asymmetries. Such asymmetries contradict distance based (geometric) models in that these need to satisfy the basic symmetry axiom. The magnitude and the direction of asymmetries appear be to determined by the relative *prominence* of the stimuli and the general pattern observed is that less prominent objects often are experienced as being more similar to more prominent objects than the reverse. Prominence is related to salience, intensity, frequency, familiarity, goodness in form and informational content.

Inspired by Tversky's findings, *the relative prominence model* (RPM) was developed (Johannesson,1997). In RPM, the proximity from stimulus $i$ to stimulus $j$, $p(i, j)$, is given by $p(i, j) = s(i, j) \cdot (j_p / i_p)$ where $s(i, j)$ is a symmetric similarity function, and $j_p$ and $i_p$ are prominences of $j$ and $i$.

RPM was originally proposed to describe and predict the subset of similarity/dissimilarity data collected in direct rating experiments. Such data are less likely to differ in terms of self-similarities compared to e.g. confusability data. Differences in self-similarity are something that the model clearly cannot handle in its present form.

RPM is essentially a special case of *the additive similarity and bias model* reviewed and discussed by Nosofsky (1991). The additive similarity and bias model is a descriptive model of proximity, able to cope with asymmetry by incorporating stimulus bias (which may be interpreted as interchangeable with prominence). In this model $p(i, j)$ is given by $p(i, j) = F[s(i, j) + r(i) + c(j)]$ where $F$ is an increasing function and $r$ (row) and $c$ (column) are bias functions on the individual objects.

RPM has here been evaluated by comparing its descriptive power with two other special cases of the additive similarity and bias model, the case when $F$ is the identity function (referred to as ASM) and the multiplicative variant $p(i, j) = r(i) \cdot c(j) \cdot s(i, j)$ (AMM). The parameters of the models were estimated using an iterative estimation procedure that operate directly upon proximities rather than on distances in a spatial representation, meaning that no specific assumptions regarding the relationship similarity-distance needed to be made. Evaluation using seven off-diagonal asymmetric data sets, both direct rated data and confusion data, showed that RPM tended to describe proximity data slightly better than ASM and AMM. It is difficult to judge if this result is completely general since it is based upon the use of estimation procedures that may lead to suboptimal rather than optimal results, it is, however, clear that RPM has a descriptive power at least comparable to ASM and AMM. An at least equally important property of RPM is that it incorporates one bias parameter (prominence) per object and therefore is simpler than ASM and AMM which incorporates two (row- and column - bias). An advantage of using a simple model like RPM is that the vague concept of prominence (or differential bias) could be studied explicitly and possibly be more well understood. Knowledge of factors behind prominence could be obtained, e.g. by searching for relations between relative prominences and properties of the objects under consideration. In the long run, knowledge of prominence and factors underlying it may have implications for e.g. concept formation. An example justifying such an hypothesis is that Johannesson (1997) found that the relative prominences for a set of colours seemed not to be determined by their respective focality.

Finally then, the similarity relation plays a fundamental role in cognitive science, and it is often asymmetric. Therefore, systematic studies of factors underlying asymmetric similarity could be a valuable source for increasing our knowledge about cognition.

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