Results

Our goal is to determine the binding mechanism that best fit the human predicate-filler rating data. Using the human single item ratings (see below) we determined predicted predicate-filler similarities for all word pairs in the experiment. As noted above, the similarity between two tensor product bindings (TP) is equal to the product of the similarity of the roles to the similarity of the filler, or:

where *rf* is the tensor product of *r* and *f*. Similarly, for asynchrony-based binding (AB), the similarity between two role filler bindings is equal to the weighted average of the similarity of the roles and the similarity of the fillers, or:

where, *A*(*r*,*f*) is the binding of *r* to *f* via systematic asynchrony, and *n* is a weighting parameter, here set to 0.5 to get an unbiased average.

Modeling the result of synchrony-based binding is not so straightforward, as the results of the binding process vary greatly when *r* and *f* are coded on independent or non-independent dimensions. See supplemental materials for more discussion of this issue and illustration by simulation.

After calculating the predicted similarities of predicate-filler bindings using both TP and AB, we used both to model the human similarity ratings. We built two hierarchical models with TP and AB predicting human ratings, with participants as a random variable (intercept only; modeling participants with independent slopes produced similar results). The results are presented in Table 1.

Table 1. Summary of results of quality of models using tensor product (TP) and asynchrony-based binding (AB) to predict human ratings of similarities of role-filler pairs.

|  |  |  |  |
| --- | --- | --- | --- |
| **Model** | **AIC** | **BIC** | **estR2** |
| Rating~TP | 261721 | 261754 | .58 |
| Rating~AB | 258088 | 258121 | .63 |

In short, human ratings followed the predictions of AB rather than TP. Moreover, the relative closeness of the estimated R2 was in large part a product of the similar predictions made by both AB and TP for a subset of the similarities of predicate-filler pairs (e.g., both models predict maximal similarity when both roles and fillers are identical). In line with this observation, adding the TP predictions to a model with AB increased estimated R2 by 0.002.