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An efficient-coding model of choice-behavioral context effects

Existing models of 'context effects' in choice behavior make strong claims about valuation or are finely tuned to a particular experimental paradigm. Here, we apply and extend a functional model of perceptual encoding to predict these and other choice-behavioral biases.

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Violations of 'rational' choice

'Independence of Irrelevant Alternatives' (IIA), a fundamental principle of rational choice, posits that an agent's preference for one option or another should not change if a non-preferred ('inferior') option is introduced into the choice set. However, there is substantial evidence that humans and non-human animals alike violate this principle, in a phenomenon called the 'decoy effect' (also called the 'asymmetric dominance effect') (Figure 1).

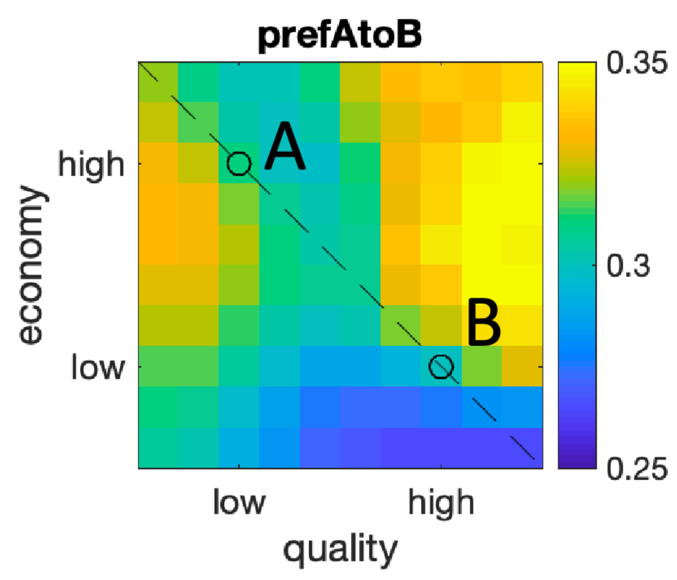

Figure 1. Behavioral data illustrating the decoy effect, from Dumbalska et al. (2020). Participants (n = 223) were asked to choose between houses described by two attributes: quality (estimated from each participant's subjective evaluation of a photo of the house) and economy (inverse of cost). Options A and B are equally preferred (i.e., lie on an isopreference curve, dashed) when they are the only two options. However, when a 'decoy' option D is introduced in a particular regime of attribute space (each square in the grid), participants' preferences for option A over option B (square color) change. When D is inferior to A and B (i.e., below the isopreference curve), any dependence of the preference for A over B on the value of D violates IIA.

Objective

To apply a quantitative, principle-driven, functional model of perceptual encoding to account for the decoy effect.

Efficient coding

The principle of efficient coding has been demonstrated to predict perceptual bias in other experimental paradigms related to vision (Zhaoping, 2014), and is therefore a reasonable candidate to explain biases in choice behavior. It stipulates that, for a given array of true values, $\boldsymbol{x}$ (e.g., the visual scene, or, in this case, values describing the option set), the agent encodes a noisy mental representation, $\boldsymbol{r}$. Importantly, the agent only has access to $\boldsymbol{r}$ (and not to $\boldsymbol{x}$) at later stages in cognitive processing, and so its behavior is ultimately guided only by $\boldsymbol{r}$.

For this reason, it is to the benefit of the agent to have as informative an $\boldsymbol{r}$ as possible; however, neural resources and precision are limited. So, as efficient coding posits, the agent is best served by an $\boldsymbol{r}$ that maximizes the *mutual information* between $\boldsymbol{r}$ and $\boldsymbol{x}$ (i.e., the degree to which knowing $\boldsymbol{r}$ decreases the uncertainty in $\boldsymbol{x}$, and vice versa), subject to some resource constraint on $\boldsymbol{r}$ (here, its dynamic range, or variance). The tradeoff between information and cost is expressed by the following loss function (to be minimized), with weighting parameter λ:

$$\mathcal{L}(r) = \mathrm{E}[r^2] - \lambda\, I(r; x) \tag{1}$$

Predictions for choice behavior

The agent's mental representation, $\boldsymbol{r}$, is computed as a noisy version of $\boldsymbol{x}$, after applying a linear filter, K:

$$\boldsymbol{r} = K(\boldsymbol{x} + \boldsymbol{\eta}_i) + \boldsymbol{\eta}_o \tag{2}$$

The probability of the agent choosing each option in a fixed choice set can be derived according to the statistics of $\boldsymbol{r}$ for a given $\boldsymbol{x}$. The choice patterns reported by Dumbalksa et al. (2020), shown in Figure 1, are predicted for a range of parameters describing the statistics of the stimuli in the experiment (Figure 2, left). Interestingly, different experimental conditions are predicted to yield qualitatively different decoy effects (Figure 2, right), which is consistent with the heterogeneity in quantitative characterizations of the decoy effect in the literature.

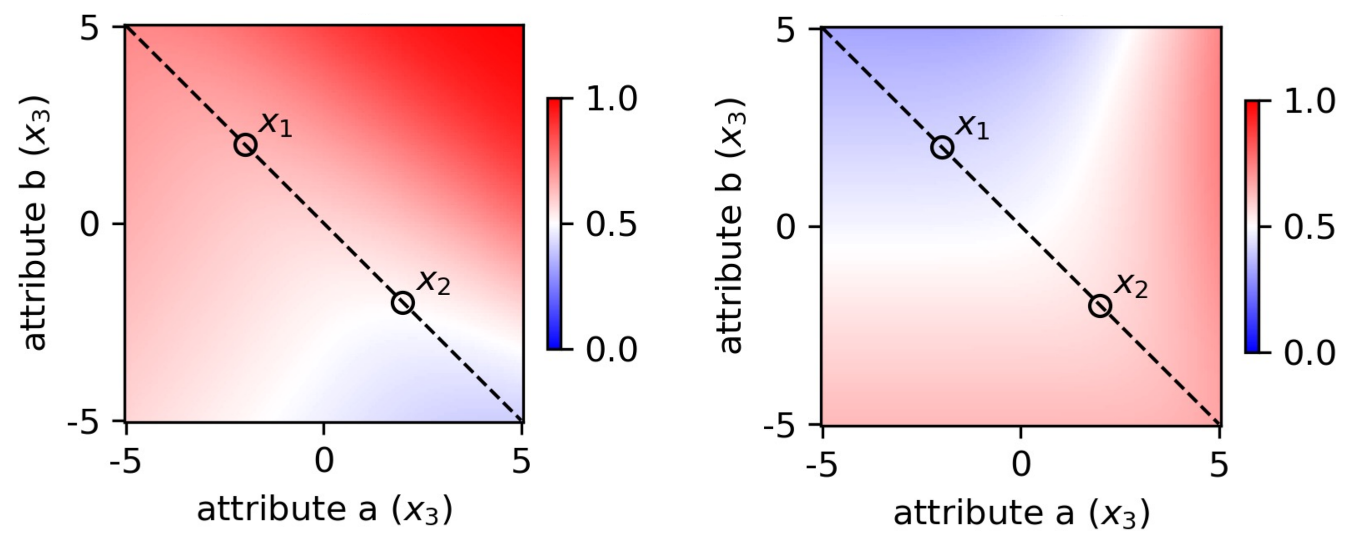

Figure 2. Predictions for choice depend on the statistics (variance, covariance) of the attributes of each option. ***(Both panels)*** *Preference for option 1 over option 2 (equally valued: $a_1 + b_1 = a_2 + b_2$) as a function of the attribute values of option 3.* ***(Left)*** *For a certain range of attribute statistics, the model predicts a decoy effect resembling that reported by Dumbalska et al. (2020) (Figure 1).* ***(Right)*** *For different attribute statistics, the model makes qualitatively different predictions for choice bias.*

Conclusions and future directions

Efficient coding offers a parsimonious and conceptually intuitive account of the decoy effect; it suggests that choice biases in the presence of a decoy may derive from perceptual bias rather than changes in subjective valuation. Moreover, the model predicts a variety of profiles of decoy effect according to the experimental conditions used, and it also predicts choice bias for a choice set of two options and of more than three options (not shown). In further work, we hope to be able to extend the model to offer novel accounts for other known choice-behavioral anomalies (e.g., risk seeking and risk aversion in risky gambles) and to apply the model to design experiments that test its predictions for choice bias in participant cohorts who may have processing differences.

References

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