Adapting search based on hypothesis space sparsity

Doug Markant and Todd M. Gureckis
Department of Psychology, New York University

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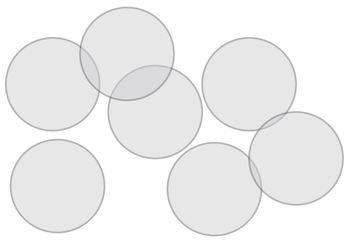
Do people take into account the structure of a hypothesis space when deciding what to learn about?

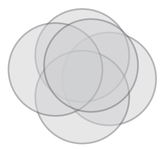
The positive test strategy (PTS) is a kind of confirmatory sampling in which a learner seeks out information that is predicted by one or more focal hypotheses. This behavior has long been considered an example of biased information sampling, in contrast to normative models of search (e.g., *information gain*).

However, whether confirmatory sampling is suboptimal depends on the structure of the hypothesis space. **For example, the PTS is consistent with an optimal search strategy when the hypothesis space is sparse** (Navarro and Perfors, 2011, *Psych Review*), but not when it is dense:



Sparse hypothesis space

- Average overlap (in terms of observable features) between hypotheses is LOW
- PTS performs similarly to optimal information-based sampling



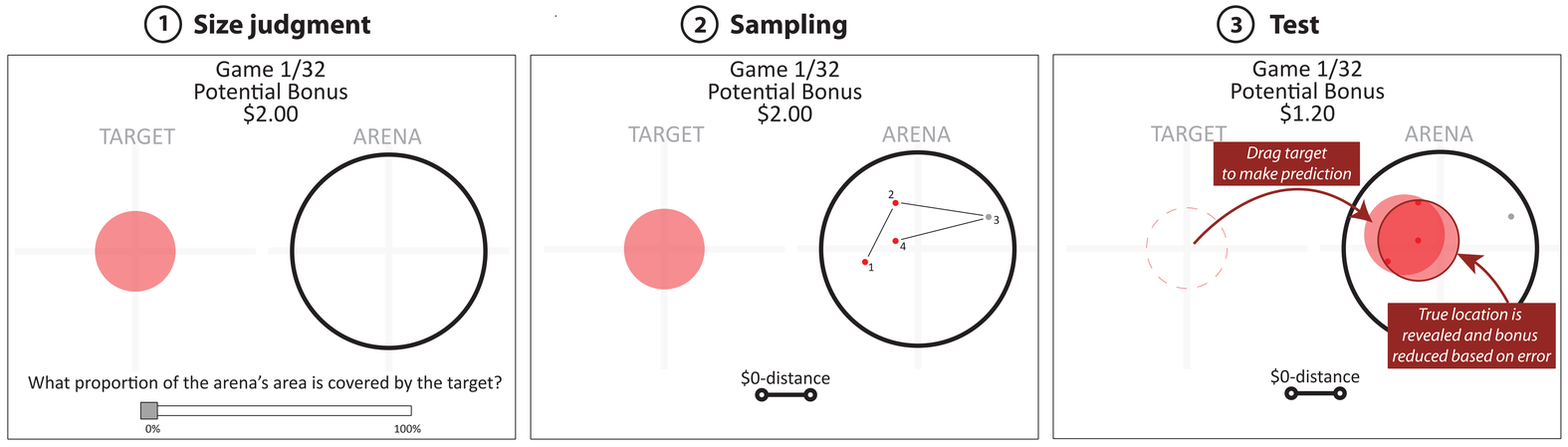
Dense hypothesis space

- Average overlap between hypotheses is HIGH
- PTS performs systematically worse than information-based sampling

Current study:

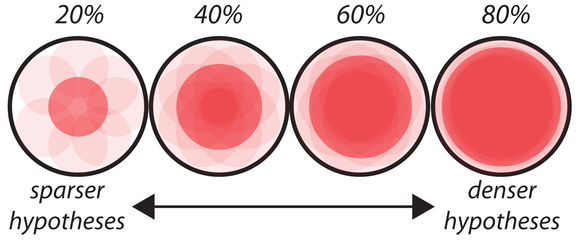
Do people adapt search decisions based on the sparsity of the hypothesis space?

Experiment



- In each game, a ***red target*** (left side of display) is hidden somewhere in an ***arena*** (right side). There were four possible arena sizes, and for each there were four relative target sizes (see at right).
- Goal is to learn the location of the target by sampling four locations within the arena, after which a predicted location is chosen.
- Reward is based on how far the predicted location is from the true location of the target (with the bonus dropping to $0 if the error is as large as the displayed *$0-distance*). As target size increased, the bonus decreased more quickly with distance to achieve similar level of difficulty across conditions.

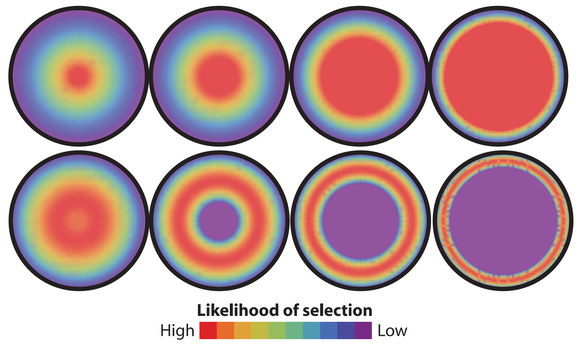
4 relative size conditions



Predictions

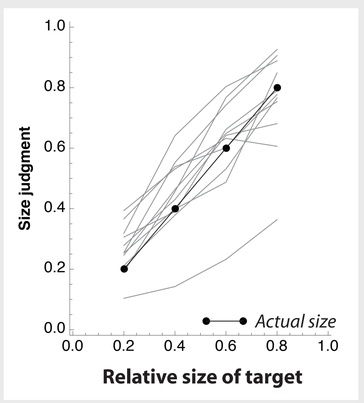
- If people account for the sparsity of the hypothesis space, they should adapt their sampling based on the relative target size.
- With increasing density of hypotheses (larger targets relative to the arena), samples should be directed farther from the center of the arena to maximize the information gained

Where should people sample?



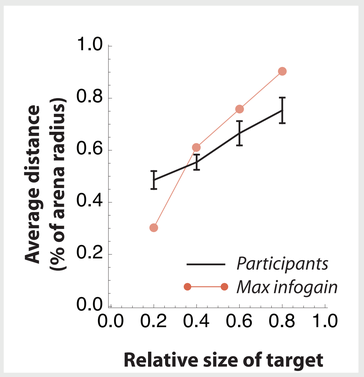
Results

Size judgments



- Participants were relatively accurate in judging the relative size of the target as compared to the arena (across all 4 arena sizes)

Distance of first sample from center



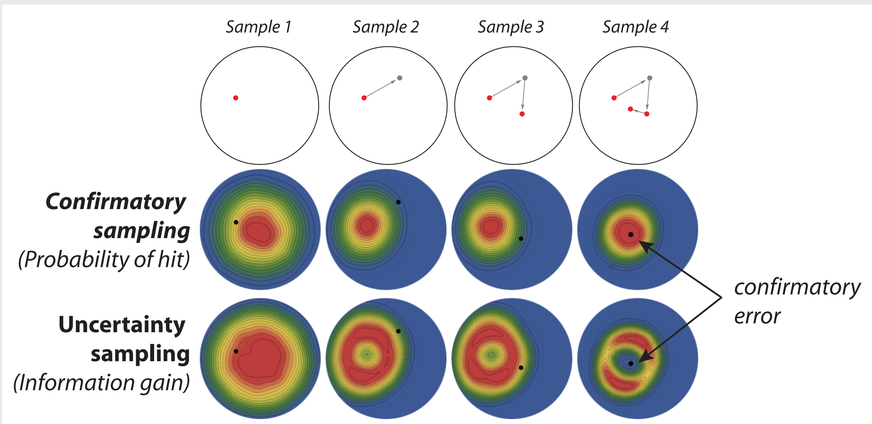
- For 9 of 11 participants, there was a significant effect of target size on the distance of the first sample from the center (all p's < .05).
- For 7 participants, relative size judgments were a better predictor of the first sample distance than the true size of the target

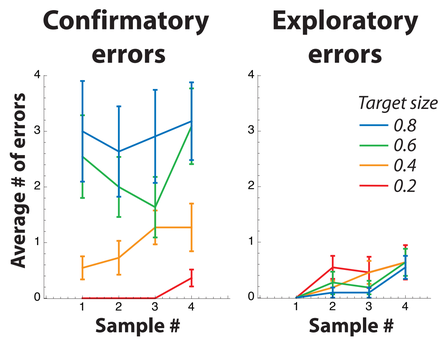
Sampling models and errors

- Used an ideal observer model to measure two types of sampling errors:

Confirmatory error *Locations known to belong to target (p(HIT)=1)*

Exploratory error *Locations that cannot belong to target (p(HIT) = 0)*

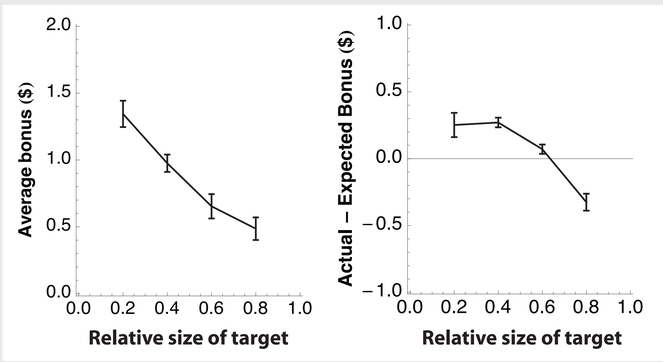




- People made few exploratory errors across all relative size conditions
- High rate of confirmatory errors, including the first sample of the game
- Due to high rate of confirmatory errors, 10 of 11 people best-fit by confirmatory sampling model

Test performance

- Earned bonuses declined with increasing relative target size
- Compared to expected bonus based on ideal observer model, people outperformed the model when the target was small, but performed worse than expected for the largest target size.



Conclusions

- Most participants adjusted their search behavior in response to changes in sparsity
- However, there was still evidence of confirmatory sampling in dense hypothesis spaces, as shown by the high rate of confirmatory errors

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