Sampling at the Margins to Learn Perceptual Categories

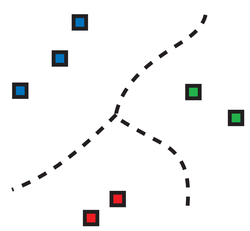
Doug Markant and Todd M. Gureckis
Department of Psychology, New York University

CogSci 2011 | Boston, MA

How do people use uncertainty to guide information search during learning?

In both human and machine learning, concepts can be acquired more quickly when the learner is able to choose information that they learn about (Settles, 2009; Castro, 2008; Markant and Gureckis, 2010).

In a category learning task, for example, there may be some items that the learner can confidently classify, while there are other items about which they are less certain. **By using judgments of uncertainty to sample items that are the most informative, the category may be learned more quickly** than is possible through passive observation or random sampling.

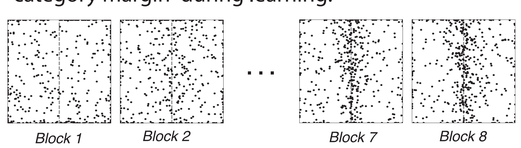


If the above items from three different categories have been observed, where should the learner sample next?

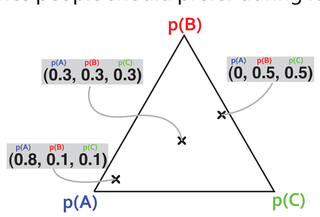
How is classification uncertainty converted to information value?

The aim of this project is to capture information collection using one or more "sampling norms"--i.e., functions that define how informative a future observation will be given the learner's current uncertainty.

We propose that learners may rely on simple judgments of classification uncertainty to choose samples. In a previous study of binary classification learning (Markant and Gureckis, 2010), we showed that self-directed learners directed their samples toward the "category margin" during learning:



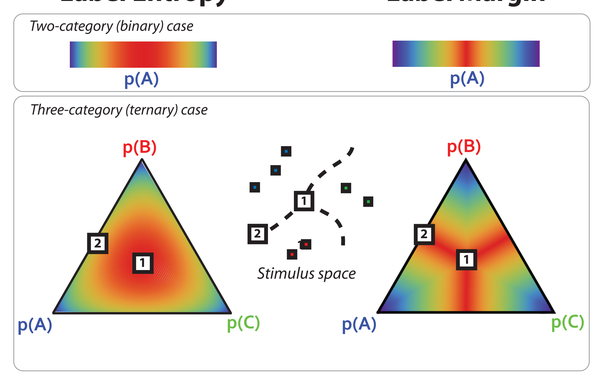
However, in binary classification, different sampling norms make the same predictions about potential observations (see top right). In the current study, we extended self-directed classification learning to a three-category case where sampling norms make distinct predictions about the samples people should prefer during learning.



When there are three possible category labels, the uncertainty in the label of any item can be visualized within the same plot. Sampling norms based on label uncertainty are evaluated over the same space of probability judgments (Settles, 2009).

Label Entropy

Label Margin

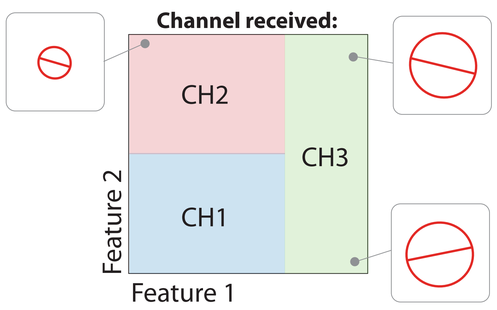


Label Entropy: Sample items that are likely to belong to all three categories (using predictions about all possible labelings).

Label Margin: Sample items for which the 2 most likely categories have similar probabilities (ignoring information about the 3rd, least likely category)

Experiment

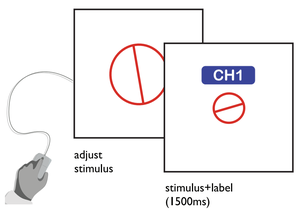
- Participants learn to classify "TV antennas" that vary along 2 continuous dimensions (size and orientation) into one of three categories by sampling new items to learn.
- The channel received by each antenna is determined by a conjunctive rule:



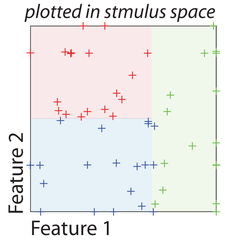
- On half of the trials, we elicited judgments of the probability that the item queried by the learner belongs to each of the three categories
- After each block of 6 sampling trials, classification accuracy was measured using a set of 8 items randomly chosen from a uniform grid
- The experiment concluded when the learner successfully classified 20 stimuli in a row

Sampling

On every trial, the learner "designs" a new antenna that they want to learn about. The feature values for each stimulus queried are recorded, as shown below for one subject:

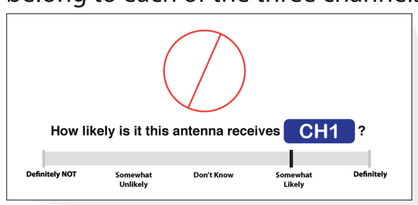


Example subject's samples plotted in stmulus space

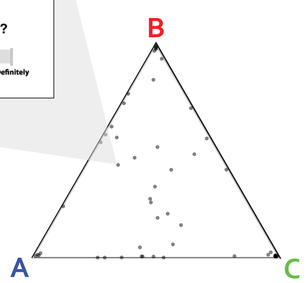


Probability Judgments

On half of the trials, before the category label is presented, the participant judges the likelihood that the antenna they have just designed will belong to each of the three channels:

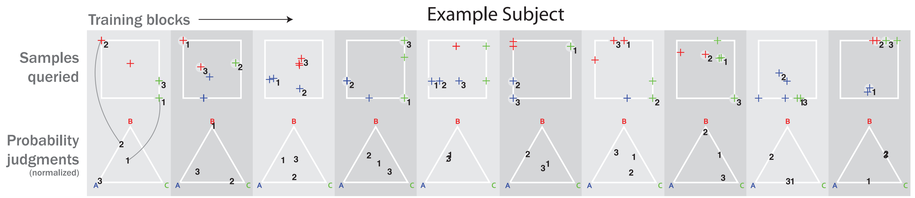


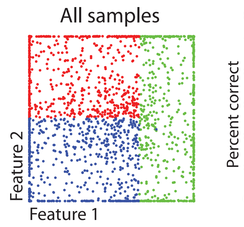
Each set of probabilty judgments (one judgment for each category) is normalized and plotted as shown to right for one subject:

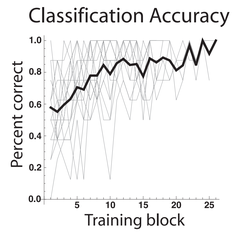


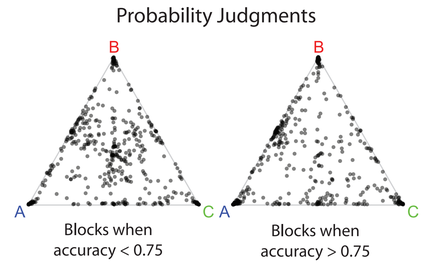
Results

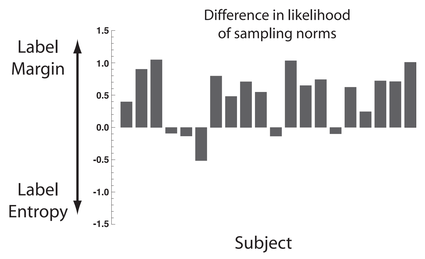
- Sampled stimuli and probability judgments were collected for 20 subjects who reached the learning criterion (6 additional subjects were excluded from analysis for not reaching criterion)
- Probability judgments were scored according to both Label Entropy and Label Margin, and the likelihood of each participants' samples was calculated using a probabilistic ("softmax") choice rule











- For 15/20 participants, sampling choices were better fit by Label Margin than Label Entropy
- Sampling along the category margins is less efficient than sampling by label entropy, but may reflect people's limited resources for updating their representation of the category boundaries
- Neither sampling norm predicted observed "confirmatory" sampling (choosing items that can already be confidently classified), behavior that may support maintenance of the category structure in memory during learning