Humans Perform Semi-Supervised Classification Too

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Abstract
This work explores the connections between machine learning and human learning. Under a specific setting, human behavior conforms well to a generative model (Gaussian Mixture Models) for semi-supervised learning. We seem to learn semi-supervisedly.

The semi-supervised learning task
Two-class classification. Two labeled examples. Decision boundary in the middle.

Procedure
Two groups: L-subjects and R-subjects. Each subject sees 6 blocks of stimuli. Order within each block is randomized. Only block 1 is labeled.

- [labeled] 10 (x=1,y=1), 10 (x=1,y=−1)
- [test-1] x=−1, 0, 0.9, …, 0.9, 1
- [unlabeled-1] 230 sampled from two Gaussian (left or right shifted). 21 “range stimuli” evenly in [-2.5, 2.5].
- [unlabeled-2] same as block 3
- [unlabeled-3] same as block 3
- [test-2] x=1, −0.9, …, 0.9, 1

Behavioral experiment results
Observation 1: Unlabeled data changes the decision boundary. [test-1] (0.11); L-subjects [test-2] (-0.1); R-subjects [test-2] (0.48)
The shift represents the effect of unlabeled data on subjects, and fits the expectation of semi-supervised classification.

Observation 2: Reaction time reflects decision boundary shift.
- The harder the stimuli, the longer the reaction time
- Peaks shift to follow new decision boundary

Observation 3: GMMs predict the decision boundary shift.

Observation 4: Unlabeled example weight λ controls the amount of decision boundary shift. Unlabeled data seems to be worth less than labeled data. Best fit: λ=0.06.

Observation 5: GMMs also explain reaction time \( t=aH(x)+b \), where \( H(x) \) is the entropy of class prediction for \( x \).

Conclusions
- Humans and machines both perform semi-supervised learning.
- Flatness of classification curves on [test-2] not well explained.
- Other forms of semi-supervised machine learning (e.g., manifold regularization, S3VMs, co-training) in humans should be explored.
- Further study may lead to new learning algorithms.