Linear Separability and Concept Learning: Eyetracking Individual Differences

Aaron B. Hoffman (aaron.hoffman@nyu.edu)
Bob Rehder (bob.rehder@nyu.edu)
Department of Psychology, New York University
6 Washington Pl., New York, NY 10003 USA

Asking people whether a tomato is fruit, or whether chess is a sport, reveals differences between individuals' concepts. How can the same perceptual information result in different representations? Perhaps people's initial attention to particular category information determines what representations they will form. When first learning about chess, for example, attention to its competitive aspect may cause one to classify it as a sport, whereas attention to its non-athletic nature will cause one to classify it as a game.

Early research focused not on individual differences but rather on questions such as whether people can learn nonlinearly separable (NLS) categories, (as predicted by exemplar memorization), or whether they favor linearly separable (LS) categories (as predicted by prototype abstraction). Indeed, it is generally believed that this question was laid to rest by Medin and Schwanenflugel (1981), who found that NLS can be learned as easily as LS categories. However, Blair and Homa (2001) in fact found individual differences, with some subjects favoring LS, others NLS categories, and others neither.

The present study investigates why individuals might prefer LS over NLS categories, or vice versa. We do this in a novel and direct way, by using categories with independently predictive dimensions that provide an LS solution, and additional, configurally predictive dimensions that provide an NLS solution.

Forty-five Ss learned 2 categories of eight 'ceremonial symbols'—stimuli with five, spatially-separated, binary dimensions, as shown in Fig. 1. The categories were, loosely speaking, both LS *and* NLS; a subset of three dimensions composed a linear decision rule and the remaining two a nonlinear decision rule. Providing this choice between LS and NLS category solutions was a direct test of preference for linear separability. We assessed LS-NLS preference by collecting typicality ratings for 32 test items, after learning.
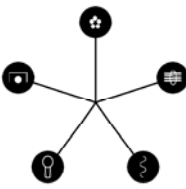

Figure 1

There were 18 learners completing two errorless blocks, 22 nonlearners, and 5 drop-outs. We measured dimension use in two ways. First, we regressed Ss' individual typicality ratings for the test items on all five dimensions, and all 2nd- through 5th-order interactions (32 predictors). We next created for each S a single LS weight and a single NLS weight by averaging any regression weights that included just the LS or the NLS dimensions, respectively. Comparing these two values, we observed three clusters of individual learners: 5 Ss mostly utilized the LS, 5 Ss mostly utilized the NLS and 8 Ss utilized a combination of both types of dimensions.

We also measured dimension use more directly, by recording eye movements during learning and at test. Extending our previous work (Rehder & Hoffman, 2005), Fig. 2 plots the relationship between regression weight and proportional fixation time (for the 32 test items) on the LS dimensions for learners. The graph reveals a strong linear relationship between fixations and dimension use ($r = .9$).
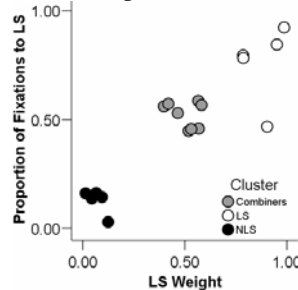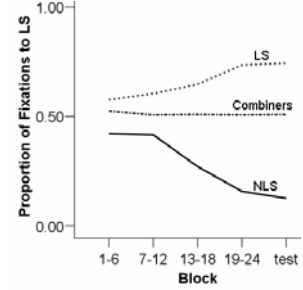

Figure 2

Figure 3

The clustering based on LS weight is also illustrated in the figure. As expected, LS learners spent the majority of time fixating the LS dimensions, NLS spent almost no time on LS dimensions, and the combiners fixated both.

Finally, Fig 3. shows fixations to the LS dimensions as a function of cluster and block. In contrast to Rehder & Hoffman's finding that eye movements were restricted only after errors were eliminated, the figure shows that by the sixth block, while subjects are still committing classification errors, eye gaze reflects the cluster to which Ss will eventually belong. Thus, individual differences in LS preference arise, in part, from whether the person spends more time attending LS or NLS information early in learning. More generally then, the particular information the learner attends early in learning is a large influence on their ultimate category representation.

References

Blair, M., & Homa, D. (2001). Expanding the search for a linear separability constraint on category learning. *Memory & Cognition, 29*, 1163-1164.

Medin, D. L., & Schwanenflugel, P. J. (1981). Linear separability in classification learning. *Journal of Experimental Psychology: Human Learning & Memory*, *7*, 355-368.

Rehder, B., & Hoffman, A. B. (2005). Eyetracking and selective attention in category learning, C*ognitive Psychology 51*, 1-41.