Letter learning: feature detection & combination

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Summary

Letters are identified in two stages: feature detection and feature combination. At which stage does the learning of unfamiliar letters occur? To make this distinction, we designed three letter identification tasks. One challenges both detection and combination; a second challenges only detection; a third challenges only combination. The difficulty of detection is eliminated by presenting letters at a high contrast. The difficulty of combination is eliminated by presenting a single feature. We find that learning occurs at both the detection and combination stages. Plotting threshold contrast as a function of number of trials, learning feature detection is very slow (log-log slope of –0.03) and learning feature combination is very fast (log-log slope of –2).

1 Challenge detection and combination

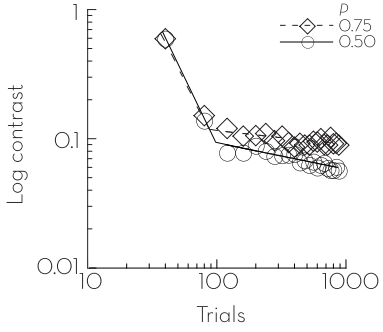

Figure 1 Task 1 challenges both detection and combination by presenting a gabor letter at threshold contrast. When asked to identify a letter from the unfamiliar alphabet, combination is challenged because the observer does not know the letter shape. As the observer's integration improves, fewer feature detections are needed for criterion performance (0.50 or 0.75). We adaptively adjust contrast to maintain criterion performance, providing only enough contrast for the observer to detect the required number of features. Since this contrast is not enough to allow the observer to consistently detect all four of the presented features, it challenges detection. Thus, Task **1** challenges both detection and combination.

2 Challenge detection only

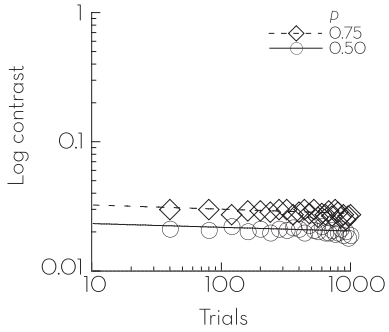

Figure 2 Task 2 challenges only detection by presenting a single gabor at threshold contrast. The task requires only that the observer report the orientation (horizontal or vertical) of the presented gabor, without needing to remember or combine the gabors across trials. Thus, Task **2** challenges detection, but not combination.

3 Challenge combination only

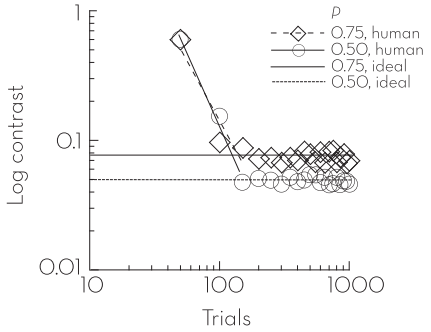

Figure 3 Task 3 challenges only combination by presenting a fraction of the letter's features, randomly sampled, but at high contrast. At high contrast, the probability of detecting a presented feature is practically 1, so all gabors presented are reliably detected. However, we limit the probability of each gabor being presented to achieve criterion performance, challenging combination. Thus, Task **3** challenges combination, but not detection.

Suchow, J.W., & Pelli, D.G. (2008). Letter learning: feature detection & combination. Vision Sciences Society, Naples, Florida. May 9-14, 2008.
>> http://psych.nyu.edu/pelli/posters.html

Conclusion

While previous studies have been unable to distinguish learning detection from learning combination, we successfully separate the learning at each stage. Learning new letters consists of an improvement in both feature detection and combination. Learning combination is seventy times faster than learning detection.

Figure 4 Gabor letters. Each letter consists of four gabors, each of which is a feature. Each gabor is horizontal or vertical.

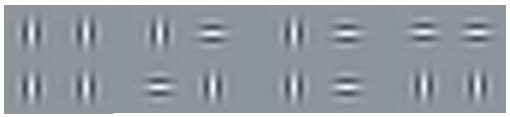

Table 1 Slope of learning across identification tasks. Plotting threshold contrast as a function of the number of trials, we fit parameter *b*, the log-log slope. The dividing line separates the familiar from the unfamiliar, and less complex stimuli from more complex stimuli. We assign a rank of 0 to tasks that used stimuli unfamiliar to the observer, and a rank of 1 to tasks that used familiar stimuli. We assign complexity rankings based upon a rough estimate of perimetric complexity.

b	Stimuli	Complexity	Familiarity	Source
–0.02	Familiar letters	2	1	Pelli et al., 2006
–0.03	IndyFour A-D gabors	1	1	Task **2**
–0.05	Gabors	1	1	Lu & Dosher, 2004
–0.05	2x3 checkers	2	1	Pelli et al., 2006
–0.14	Unfamiliar letters	2	0	Suchow & Pelli, 2005
–0.16	4x4 checkers	3	0	Pelli et al., 2006
–0.16	IndyFour A-D letters	2	0	Task **1**, second line
–0.21	Compound gratings	3	0	Fine & Jacobs, 2000
–0.26	Filtered noise textures	3	0	Gold et al., 1999
–0.40	Unfamiliar faces	4	0	Gold et al., 1999
–0.49	Compound filtered noise textures	4	0	Michel & Jacobs, 2008
–2.1	IndyFour A-D partial letters	2	0	Task **3**

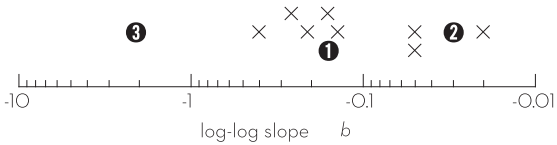

Figure 5 Slope of learning across identification tasks. Each symbol represents the average log-log slope *b* for a study in Table 1. ❶ is the second leg of our combination- and detection-challenging Task **1**, ❷ is our detection-challenging Task **2**, and ❸ is our combination-challenging Task **3**.