Decoupling location specificity from perceptual learning of orientation discrimination

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Perceptual learning of orientation discrimination is reported to be precisely specific to the trained retinal location. This specificity is often taken as evidence for localizing the site of orientation learning to retinotopic cortical areas V1/V2. However, the extant physiological evidence for training improved orientation turning in V1/V2 neurons is controversial and weak. Here we demonstrate substantial transfer of orientation learning across retinal locations, either from the fovea to the periphery or amongst peripheral

periphery (5° retinal eccentricity on the horizontal meridian, left visual hemifield) before foveal training. However, the new training procedure with new stimuli produced similar data to those with the Gabor stimuli (Fig. 2B–E). First foveal orientation thresholds floored after 5–6 sessions of training, suggesting that significantly more sessions of training was redundant. Second, peripheral orientation discrimination was about equally improved (peripheral MPI = 47.9 ± 2.3%, $p < 0.001$ vs. foveal MPI = 50.0 ± 4.2%, $p < 0.001$, approximately a factor of 2 decrease in threshold), similar to the results with Gabor stimuli. Third and most importantly, like our previous data, successive peripheral training did not improve orientation discrimination further (MPI = −4.4 ± 13.8%, $p = 0.34$), suggesting again optimized peripheral orientation discrimination after foveal training.

So what made the results between the Schoups et al. and the present study so different after the differences of stimuli and training durations were excluded? The only remaining difference between two studies was that before foveal training, we briefly pretested peripheral thresholds (six staircases, or approximately 200 trials) as a baseline to gauge the fovea-to-periphery transfer of learning. Did this brief pretest enable the optimization of peripheral orientation discrimination? To test this we repeated the above experiment without the pretest in six new observers, and this time the results replicate those of Schoups et al. (Fig. 3B). That is, after foveal training (F_ori1) which reduced orientation thresholds in all observers (MPI = 46.7 ± 4.6%, $p < 0.001$; Fig. 3C), additional peripheral training at 5° retinal eccentricity on the horizontal meridian of the left visual hemifield continued to improve orientation performance at this peripheral location in five out of six observers (MPI = 33.3 ± 10.9%, $p = 0.014$, (Fig. 3D). The sixth observer had lower peripheral threshold after foveal training, which did not benefit from further peripheral training (the far left data point near the diagonal line, Fig. 3D). So this observer's data were similar to those in the previous experiment with pretesting (Fig. 2).

In summary, the above experiments (Figs. 1–3) allowed us to decouple location specificity from orientation learning by showing that location specificity in Schoups et al.'s classical study can be abolished with a brief pretest. In Section 4 we will show that this brief pretest alone enabled complete transfer of foveal learning to accomplish the optimization of peripheral performance.

3.2. Transfer of orientation learning among peripheral locations

A more common and straightforward way to study location

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tent with neurons in non-visual high brain areas not being orientation selective (e.g., Mohler, Goldberg, & Wurtz, 1973).

Perceptual learning at central brain sites would easily explain why receptive field tuning changes in visual areas up to V4 can only account for a very small part of behavioral learning data (“at least an order of magnitude smaller than the behavioral changes”, Raiguel et al., 2006). We suggest that perceptual learning may reflect training induced improvements in decision making which is modeled by Dosher and Lu (1999), but this process has to occur in non-retinotopic high brain areas, which coincides with recent neurophysiological evidence that perceptual learning is correlated to neuronal changes not in sensory cortical areas, but in higher areas associated with decision making (Law & Gold, 2008). Further experimental and computational evidence is necessary to spell out the possible central mechanisms underlying perceptual learning.

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