Neuron, volume *70*

Supplemental Information

Cortical Map Plasticity Improves Learning but Is Not Necessary for Improved Performance

Amanda Reed, Jonathan Riley, Ryan Carraway, Andres Carrasco, Claudia Perez, Vikram Jakkamsetti, and Michael P. Kilgard

Supplemental Results

A. Table S1, related to Figure 2

Additional Analysis of Variance for Experiment 1

We used repeated measures ANOVA to determine whether the three groups showed differences in learning after NBS-tone pairing (Figure 2, main text). There were three group levels (Low, High, or Passive) and three independent variables that were measured (0.5, 1.0 and 2.4 octaves). As reported in the main text, there were significant differences in behavioral performance between the three groups ($F(2,14) = 4.94$, $p = 0.028$). As expected, there were also significant differences in the discrimination performance on each distracter stimulus ($F(2) = 35.85$, $p < 10^{-4}$). There was also a significant interaction effect between group and distracter stimulus ($F(4,24) = 2.83$, $p = 0.047$), because the improved discrimination performance by the Low Group was most pronounced for the easiest stimuli (2.4 octaves).

Source	df	F-value	p-value
Group	2,14	4.94	0.0272
Frequencies	2	35.85	$p<10^{-4}$
Group x Frequencies	4,24	2.83	0.0467

Table S1. Results of a repeated measures ANOVA comparing discrimination performance for the three groups in Experiment 1 on discrimination of all three distracters (0.5, 1 and 2.4 octaves above the target). df, degrees of freedom.

B. Table S2, related to Figure 3

Additional Analysis of Variance for Experiment 2

A repeated measures ANOVA was also used to determine changes in behavioral performance for the Pretrained Groups. There were again three group levels (Pretrained Low, Pretrained High, and Pretrained Passive), but there were 5 independent variables which were measured (all distracters from 0.38 to 1.0 octaves). As reported in the main text, behavioral performance was significantly different between the three groups

$F(2,16) = 3.65$, $p = 0.049$). Again, there was a significant difference in discrimination performance to each distracter stimulus ($F(4) = 77.08$, $p < 10^{-4}$). There was not a significant interaction effect between group and distracter stimulus ($F(8,64) = 1.70$, $p = 0.12$), indicating the worsening of discrimination performance for the Pretrained High group occurred equally across all distracter stimuli.

Source	df	F-value	p-value
Group	2,14	3.6454	0.0496
Frequencies	4	77.0807	$p<10^{-4}$
Group x Frequencies	8,64	1.6989	0.1158

Table S2. Results of a repeated measures ANOVA comparing discrimination performance for the three groups in Experiment 2 (Pretrained groups) on discrimination of all distracters with values more than 0.38 octaves above the target frequency. df, degrees of freedom.

C. Figure S1, related to Figures 4 & 5

Changes in map organization and receptive field size after NBS-tone pairing and behavioral training

Three groups of trained animals – Behavior Alone, High Group and Control Group – showed task-specific map plasticity in A1. In all of these groups, a larger percentage of neurons in A1 responded to low-frequency tones versus high-frequency tones (Figures 4A and 5A, Main Text). This shift was caused by two types of receptive field plasticity in A1 neurons. First, A1 sites in these three groups shifted their receptive fields so that a larger percentage of A1 sites had CF's tuned to low-frequency tones than in Naïve controls (Figure S1A). Second, the sites that were responsive to the target stimulus developed narrower bandwidths (Tone In, sites that respond to a 2 kHz tone at 50 dB SPL, Figure S1C). However, the bandwidth of sites that did not respond to the target stimulus were unaltered (Tone Out sites, Figure S1D). Similar patterns of plasticity after behavioral training have been observed in previous studies (Polley et al., 2006; Recanzone et al., 1993), and receptive field narrowing also occurs even when

there are no shifts in the central tuning (ie, preferred frequency or preferred orientation) of sites after behavioral training (Ghose et al., 2002; Ohl and Scheich, 2005).

The net effect of the shift in tuning towards low frequencies and the decrease in bandwidth of low-frequency tuned sites was that the percentage of A1 neurons that responded to low-frequency tones did not change (Figure S1E), but the percentage of A1 neurons which responded to high-frequency tones was significantly decreased (Figure S1F). This resulted in a significant increase in the relative area of A1 which responded to low versus high frequency tones (Figures 4A and 5A, Main Text).

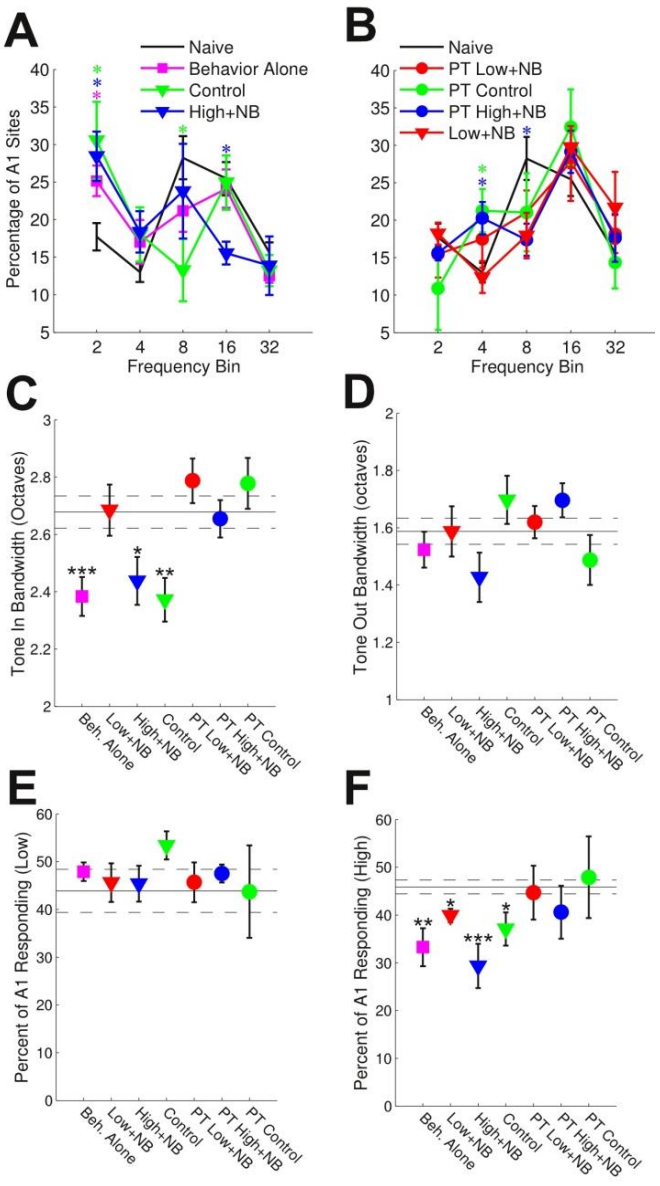

Figure S1. Changes in characteristic frequency and receptive field size of low-frequency neurons account for low-frequency map plasticity. A&B. Histograms of the percentage of A1 sites tuned within ½ octave of each frequency bin (mean ± s.e.m.). The black line in each panel indicates histograms for naive controls. A. Histograms for all groups that showed significant map plasticity for low-frequency tones (Figures 4A and 5A, Main Text). B. Histograms for all groups that did not show significant map plasticity (Figures 4A and 5A, Main Text). C&D. Mean ± s.e.m. bandwidth (BW30, see Methods) for all experimental groups. C. Bandwidth of all A1 sites that contained the target stimulus within their receptive field (Tone In), and were therefore responsive to the target stimulus (1.78 kHz @ 60 dB SPL). D. Bandwidth of all A1 sites that did not respond to the target stimulus (Tone Out). Sites that did not respond to the target stimulus were generally tuned to high frequencies and therefore had smaller bandwidths in all control and

experimental groups. E& F. Mean ± s.e.m. percentage of A1 cortex responding to low or high tones for all experimental groups. E. The percentage area of A1 that responds to the low tone used to calculate the response ratio in Figure 3D (2 kHz, 60 dB SPL tone). F. The percentage area of A1 that responds to the high tone used to calculate the response ratio in Figure 3D (19 KHz, 60 dB SPL tone). The solid and dashed lines in the background of plots (C-F) show mean ± s.e.m. values for naïve controls. Stars in all panels indicate the result of a t-test comparing each experimental group to naïve controls. *, $p<0.05$; **, $p<0.01$; ***, $p<0.001$. All error bars indicate standard error of the mean.

Supplemental References

Ghose, G.M., Yang, T., and Maunsell, J.H. (2002). Physiological correlates of perceptual learning in monkey V1 and V2. J Neurophysiol *87*, 1867-1888.

Ohl, F.W., and Scheich, H. (2005). Learning-induced plasticity in animal and human auditory cortex. Curr Opin Neurobiol *15*, 470-477.