Report

Current Biology

Perceptual Learning of Contrast Detection in the Human Lateral Geniculate Nucleus

Highlights

- Contrast learning shows specificity to the trained eye and visual hemifield
- Contrast learning boosts the activity of the M layers of the LGN
- Perceptual learning in human adults can occur as early as at the thalamic level

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In Brief

Yu et al. reveal that perceptual learning of contrast detection leads to an eye- and hemifield-specific neural response increase to low contrast in the M layers of the LGN and suggest that visual training can induce plasticity in subcortical nuclei.

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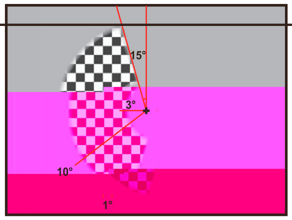
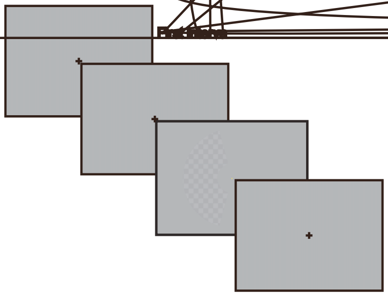
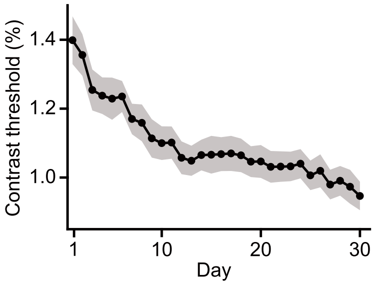
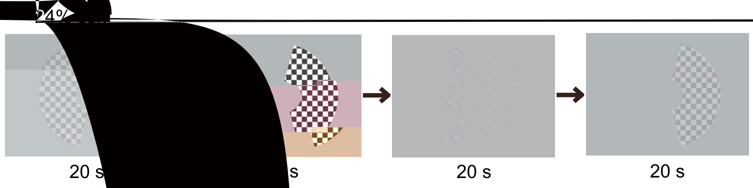




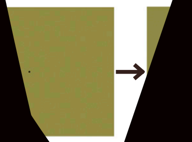


voxels was further constrained by the anatomical locations of the LGN based on high-resolution T1 images. On the T1 images in Figure 2A, which shows the LGN from a representative subject, the LGN appeared darker relative to surrounding brain tissues. The LGN is the thalamic component in the retinocortical projection and has been traditionally viewed as a passive relay station for retinal signals on their way to the primary visual cortex, or V1 [13]. This view has been challenged recently. There is growing evidence from human fMRI and monkey neurophysiology studies that neural responses in the LGN are influenced by perceptual and cognitive tasks (see [14] for a review).

Using the counterphase flickering checkerboard stimuli, we measured fMRI contrast response functions in the ROIs at three contrast levels (6%, 24%, and 96%). During scanning, subjects performed a demanding task to detect the color change of the fixation point (Figure 2B). Therefore, the peripheral checkerboard stimuli were task irrelevant. The fMRI contrast response functions are shown in Figure 2C. For each ROI and each test condition, blood-oxygen-level dependent (BOLD) amplitudes were submitted to a repeated measures ANOVA, with training (pre- and post-training) and contrast (6%, 24%, and 96%) as within-subject factors. The main effects of contrast were significant (LGN: all $Fs(2, 38) > 82.82$, $p < 0.001$; V1: all $Fs(2, 38) > 142.77$, $p < 0.001$; V2: all $Fs(2, 38) > 168.93$, $p < 0.001$; V3: all $Fs(2, 38) > 122.98$, $p < 0.001$, Bonferroni corrected). The BOLD responses increased with contrast. The main effects of training were not significant (LGN: all $Fs(2, 19) < 3.195$, $p > 0.36$; V1: all $Fs(2, 19) < 0.378$, $p = 1$; V2: all $Fs(2, 19) < 0.445$, $p = 1$; V3: all $Fs(2, 19) < 1.217$, $p = 1$). The interaction effect between training and contrast was only significant in the THTE condition in the LGN (THTE: $F(2, 38) = 6.839$, $p < 0.05$; UHTE: $F(2, 38) = 0.567$, $p = 1$; THUE: $F(2, 38) = 0.350$, $p = 1$; UHUE: $F(2, 38) = 1.408$, $p = 1$, Bonferroni corrected). Furthermore, post hoc t tests showed that the BOLD response after training was significantly



to differentially activate [illegible] (M stimulus) and P (P stimulus) neurons in 15 of the [illegible]bjects. The P stimulus was a high-spatial-frequency [illegible]minant red/green square wave pattern and was counte[illegible]e flickered at 1 Hz. The M stimulus was a low-spatia[illegible]uency sine wave pattern, with 30% luminance contras[illegible]d was counterphase flickered at 7.5 Hz (Figure 3A). The [illegible]ayers of the LGN were identified as voxels showing a gre[illegible] response to the M stimulus than to the P stimulus, and v[illegible] versa for the identification of the P layers. It should be no[illegible] that, due to the spatial resolution limit of fMRI, some voxel[illegible] the identified M or P layers might contain both M and P ne[illegible]ns (see [20], in which M layers and P layers are approximat[illegible] 2 and 4 mm thick, respectively). However, it is safe to cl[illegible]n that voxels identified as located



the glutamate receptor agonist to block visual responses in on-center retinal ganglion cells and found that the inactivation led to a rapid emergence of off-center responses from on-center neurons in the LGN. A significant stride we made in the present study is that, without such abnormal visual experience (i.e., eyelid closure or pharmacological inactivation), even regular practice could profoundly change local receptive field properties of the LGN neurons in human adults. Recently, it has been recognized that the LGN and other thalamic structures actively regulate information transmission to the cortex and between cortical areas using various mechanisms, thereby contributing to perception and cognition much more than we previously believed [14, 41]. Exploring the functional plasticity of the subcortical structures induced by training is an important research topic in the future, which is necessary for us to fully understand the adaptive nature of perceptual and cognitive information processing in the brain.

EXPERIMENTAL PROCEDURES

The procedures and protocols used in this study were approved by the human subject review committee of Peking University. Complete procedures can be found in the Supplemental Information.

SUPPLEMENTAL INFORMATION

Supplemental Information includes two figures and Supplemental Experimental Procedures and can be found with this article online at http://dx.doi.org/10.1016/j.cub.2016.09.034.

AUTHOR CONTRIBUTIONS

Q.Y. and F.F. designed the study. Q.Y. and J.Q. conducted the experiments. Q.Y., P.Z., and F.F. analyzed the data and wrote the manuscript.

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