Supplemental Information for:

Monocular deprivation boosts long-term visual plasticity

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Supplemental Data

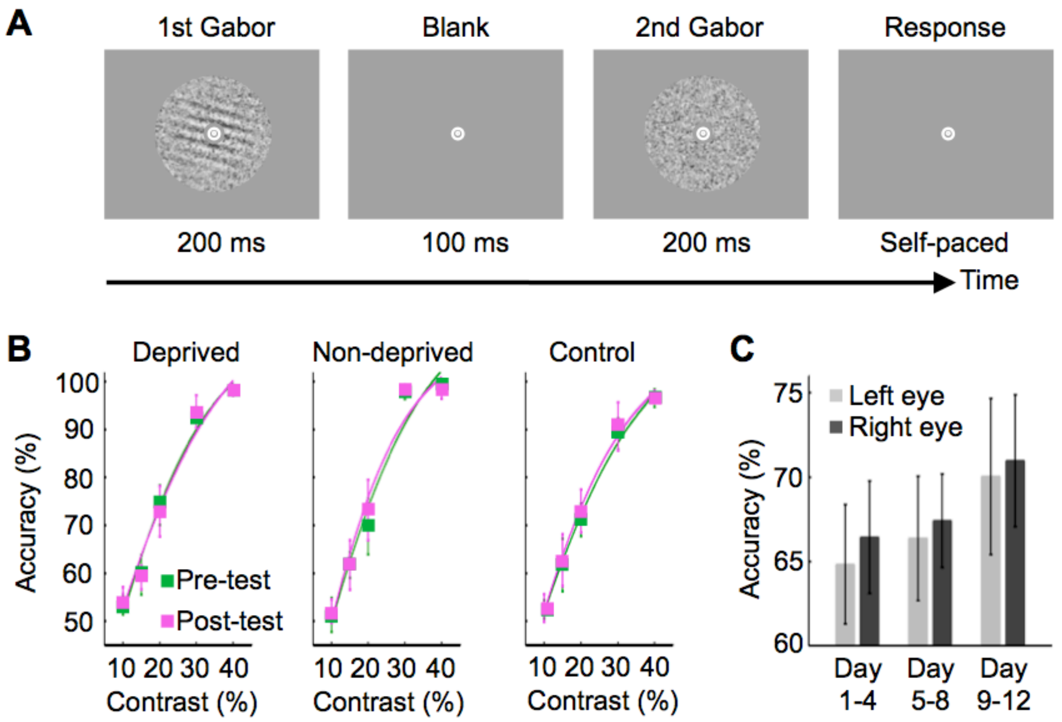

Figure S1. Procedures and supplemental results of the main and control experiments.

(A) An example of a stimulus sequence in a contrast detection task. (B) No significant difference in the performance between the pre- and post-tests in the main (left and middle panels) and the control experiments (right panel). In the pre- and post-MD test stages of the main experiment, we measured subjects' performance on a two interval forced choice (2IFC) contrast detection task for each eye. Eye of presentation was counterbalanced across trials, and stimuli were presented at five contrast steps (10, 15, 20, 30, 40%). Results of three-way ANOVA (test stage x eye x contrast) with repeated measures indicated significant main effect of contrast ($P < 10^{-3}$); we found no significant effect of test stage (P = 0.641), eye (P = 0.923), or any interactions between the factors (P >

0.229). As in the main experiment, we measured subjects' performance on a 2IFC contrast detection task for each eye at five contrast steps in the pre- and post-test stages of the control experiment. Since no MD was conducted in the control experiment, data from the two eyes of the same subject were averaged. Results of two-way ANOVA (test stage x contrast) with repeated measures indicated a significant main effect of contrast ($P < 10^{-3}$); we found no significant effect of test stage ($P = 0.614$) or interaction between contrast and test stage ($P = 0.624$). (C) Mean (±SEM) performance in the early (Day 1-4), middle (Day 5-8), and late (Day 9-12) periods for the left and right eyes in the training stage of the control experiment.

Supplemental Experimental Procedures

Experimental schedule

The main experiment consisted of: pre-monocular deprivation (MD) test stage, MD stage, post-MD test stage, and training stage (Figure 1A). The control experiment consisted of the pre- and post test stages, without the MD stage between them, and subsequent training stage. This study was approved by the Institutional Review Board of Advanced Telecommunications Research Institute International (ATR).

Subjects

All subjects gave written informed consents. A total of 8 adult subjects (20 to 35 years old; 5 males and 3 females) with normal or corrected-to-normal vision participated in the study. The subjects were familiar with psychophysical experiments in general but naïve to the purpose of this study. Subjects were randomly assigned to the MD experiment or the control experiment in which no MD was involved.

Apparatus

Visual stimuli were presented on a LCD display (CV722X, Totoku; 1024 × 768 resolution, 60 Hz refresh rate) using Matlab and Psychtoolbox 3 [1] on Mac OS X. All sessions were conducted in a dim room. Brightness of the display was linearized with a gamma correction.

Visual stimuli

Oriented Gabor patches (orientation determined by condition, see below; spatial frequency = 1 cycle/deg; sigma of its Gaussian filter = 2.5 deg; random spatial phase) were presented within an annulus subtending a radius from 1 to 5 deg from the center of a gray screen (Figure S1A). The Gabor patch was spatially masked by noise at 30% signal to noise (S/N) ratio [2, 3]. That is, 70% of the pixels in the Gabor patch were randomly replaced by the noise. The noise was generated from a sinusoidal luminance distribution, and the amplitude of this distribution was matched to that of the Gabor patch. In this way, the statistics of the luminance distribution were preserved between the Gabor patch and noise, so that there were no texture elements that could distinguish the Gabor patch from the noise field when the contrast of the Gabor was brought to 0%. Perceptual learning with this stimulus has been reported in previous studies [2, 3].

Contrast detection task

Throughout the task, subjects were asked to fixate on a white bull's-eye on a gray disc (1 deg radius) at the center of the display. In each trial (Figure S1A), the subjects performed a two interval forced choice (2IFC) contrast detection task, in which one interval contained a noisy Gabor patch while the other interval contained a pure noise pattern which was randomly generated from a sinusoidal luminance distribution. Each trial started with a 500-ms fixation period. After the presentations of two 200-ms stimulus displays separated by a 100-ms blank period, the subjects were asked to report which interval contained the Gabor patch by pressing one of two buttons on the keyboard. After the button press, a 500-ms inter-trial interval was inserted. The time interval during which the Gabor patch was presented was counterbalanced across trials.

Pre-MD test stage

The subjects performed a 2IFC contrast detection task for 320 trials. The contrast of the Gabor patch was varied in a random order from trial to trial in five steps (10, 15, 20, 30, 40%). In the first half of trials, Gabor patches with one preselected orientation were presented only to one eye. In the second half of trials, Gabor patches with the other orientation were presented only to the other eye. During the test for one eye, the other eye was occluded with a black concave eye-patch (CVS/Pharmacy), and the subjects replaced the eye-patch by themselves according to the instruction presented on a screen. The order of tested eyes in relation to the deprivation during MD was counterbalanced across subjects. The two orientations were randomly selected from 10, 70, and 130 degree for each subject. A 10-sec break period was provided after every 32 trials. Between the first and second halves of trials subjects were asked to take a 5-min break outside of the experiment room. The entire pre-MD test stage took about at least 40 min. The procedure for the pre-test stage with the control group was the identical to that for the pre-MD test stage in the main experiment.

MD stage

MD started immediately after the conclusion of the pre-MD test stage in the main experiment. During the MD stage, one eye was continuously covered by an occlusive eye dressing (Pro-Opta Junior Maxi, Lohmann & Rauscher) and a black concave eye-patch, which was used during the pre-test stage, to prevent any visual input. Subjects were asked not to take off the eye-patch unless any health issue occurs due to wearing the eye-patch.

The left eye was dominant for 2 subjects, and the right eye was dominant for the other 2 subjects. To prevent a possible interaction between the deprivation and eye dominancy, the deprived eye and dominant eye were counterbalanced across the subjects. Thus, 2 dominant eyes (2 subjects) and 2 non-dominant eyes (2 subjects) were deprived during the MD stage. Subjects 1 and 2 (see Fig. 1B) were deprived of light with their dominant eyes and Subjects 3 and 4 (see Fig. 1B) with their non-dominant eyes.

Subjects spent their daily lives (24 hours a day) with one eye occluded in this manner and came back to participate in the rest of the experiment 72 hours later. In each day of the MD stage, we contacted the subjects at a scheduled time and confirmed that they had not remove the eye-patch. No health issue was reported in this experiment.

In the control experiment, in which no MD stage was conducted, subjects spent 72 hours without the eye-patch and then returned to participate in the rest of the experiment.

Post-MD test stage

The post-MD test stage started 60 min after the conclusion of the MD stage. The procedure was identical to that of the pre-MD test stage. The entire post-MD test stage took about at least 40 min. The procedure of the post-test stage in the control group was the identical to that of the post-MD test stage in the main experiment.

Training stage

The training stage started 80-120 min after the conclusion of the post-MD test stage and lasted for 12 days. On each day, subjects were trained on the 2IFC contrast detection task for 960 trials. Stimulus presentation was monocular and counterbalanced between the eyes across trials. After every 32 trials a 10-sec break period was provided. After every 160 trials the tested eyes were switched and a 30-sec break period was provided. The order of training eye in relation to the deprived eye was counterbalanced across subjects. Namely, 2 subjects started training with the deprived eye, while the other 2 subjects with the non-deprived eye. After 480 trials, the subjects were asked to take a 5-min break outside of the experiment room. During training with one eye, the other eye was occluded with a black concave eye-patch, and the subjects replaced the eye-patch by themselves according to the instruction presented on a screen. Orientations used in the training stage were the same as the orientations used in the pre-MD and post-MD test stages for each subject. Contrast of the Gabor patch was determined for each subject based on his/her pre-MD test performance, so that the initial “correct” performance was approximately 65%. The contrast used in the training stage ranged from 14% to 18% across the subjects. The procedure of the training stage for the main and control groups was identical.

One may wonder whether eye dominancy and/or eye-patch adaptation, rather than the boosting effect by 3-day MD, could account for the results found in the present study. First, eye dominancy should not account for the results because the deprivations of the dominant and non-dominant eyes were counterbalanced across the subjects. The order of training of the deprived and non-deprived eyes in the subsequent perceptual learning task was also counterbalanced. Second, it is also unlikely that eye-patch adaptation (impaired performance of a visual task due to wearing an eye-patch), accounts for the results found in the main experiment. Since only the non-deprived eye was used to seeing scenes during the MD stage, performance with the non-deprived eye should show the least eye-patch effect at the post-MD stage (before training). However, the performance with the non-deprived eye at the post-MD stage does not show any significant difference either from that at the pre-MD stage, or from the performance with the deprived eye at the post-MD stage (Figure S1B). These results indicate that the eye-patch adaptation was negligible in the present experiment.

Supplemental References

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