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The eye gets stronger after seeing the world in chaos

Resembling the fact that some people are left-handed while some are right-handed, our two eyes are not functioning equally. Usually, our brain has a preference to the input signals from one of the two eyes, which is referred to as ocular dominance. Recent studies on adult humans have demonstrated that covering one eye (monocular patching) for a short period of time could strongly strengthen the patched eye. For example, in a binocular rivalry task, the patterns displayed to the patched eye are more often perceived than the conflict ones displayed to the non-patched eye after 3 hours patching.

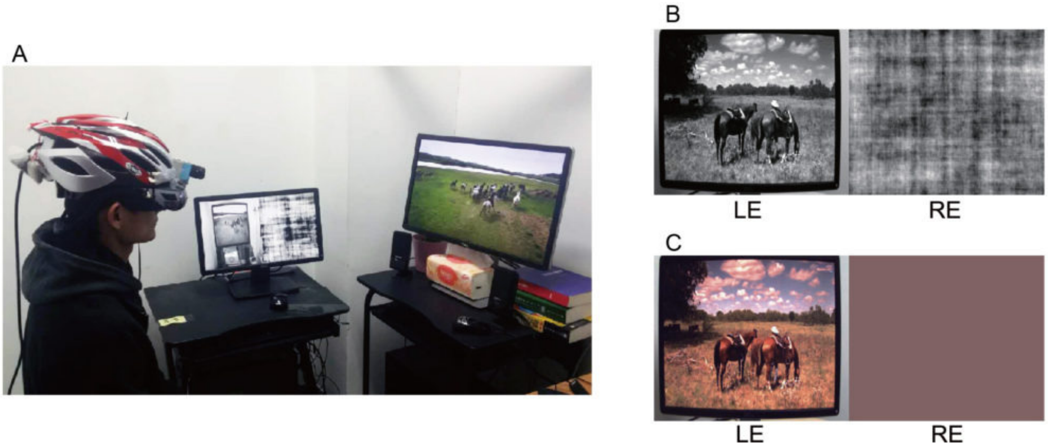

Fig. 1 (A).The alter reality system and an example of the experimental scene. The system comprised of a camera connected to a computer that fed into the HMD. This computer processed the images taken by the camera in real-time, and then presented the images to the HMD. The original image was presented to one eye, while the altered image to the other eye. Participants wore the HMD during adaptation when they could view the world freely or watch movies as shown in the figure. The small LCD monitor was also connected to the computer, which worked in a clone mode with the HMD. This enabled the experimenters to see what the subject viewed. (B) and (C) show the images presented to left eye (LE) and right eye (RE) in the phase deprivation and simulated patching experiments, respectively.

It is widely accepted that the early visual neurons could be considered as "Fourier filters", analyzing the amplitude and phase of the input images. Since no pattern information is transmitted for the patched eye during patching, it is thought that the patched eye is deprived of both the Fourier amplitude and phase information. This raises a question what is the consequence of depriving the Fourier phase information alone?

To answer this question, we developed an ''altered reality" system (Fig. 1A). This system comprised of a camera (The Imaging Source) connected to a computer that feeds into a head-mounted display (HMD). With this system, subjects could interact with the natural world that had been changed through real-time image process. For 3 h, one eye's inputs were replaced with spatially correlated (or ''pink") noises (Fig. 1B). This method realizes the Fourier phase scrambling in real-time, and guarantees identical amplitude spectra in both eyes by strictly preserving the complex conjugations of the Fourier transforms throughout adaptation. To simulate the method of monocular patching, in a separate session subjects received the original camera video in one eye and the mean color of the camera video image in the other eye during the 3-h deprivation (Fig. 1C).

We used two different tasks to measure the sensory eye dominance. In the binocular rivalry task, two gratings with orthogonal orientations were presented dichoptically on the center of the screen; subjects kept tracking the orientation of perceived grating during each 1-min trial. In most cases, only the stimulus from one of the two eyes could be perceived at a time. The perception alternated between the stimuli in the two eyes time to time, and the stimulus in the preferred eye would be perceived more often. In the interocular phase combination task, the dichoptical stimuli were two horizontal gratings whose phase shifted in the opposite direction by 22.5°, subjects adjusted a reference line to the center of their perceived grating. The grating in the dominant eye contribute more when judging the perceived phase.

It turns out that monocular deprivation of Fourier phase regularity shifted the eye dominance to the deprived eye when the eye dominance was measured with a binocular rivalry task. Partial deprivation of Fourier phase regularity still induced a shift of eye dominance in the same direction as the full deprivation, but the effect size was smaller. Removing of monocular phase regularity produced no detectable effects when measured with the interocular phase combination task. However, the simulated eye patching produced similar changes of eye dominance when tested with both tasks.

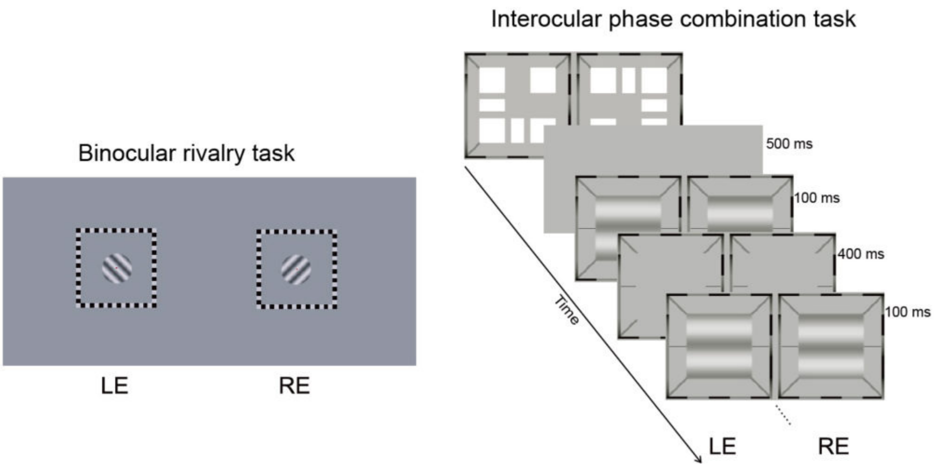

Fig. 2. Stimuli for binocular rivalry task and a typical trial of the interocular phase combination task.

Our results demonstrate that depriving Fourier phase information alone is sufficient to alter the eye dominance. The findings thus reveal the unique role of phase in monocular deprivation, suggesting the similar importance of phase in human vision and computer vision. Besides, the results indicate that the measurements of binocular rivalry task and interocular phase combination task are likely supported by different mechanisms, and ocular dominance plasticity occurs at different stages of visual processing.

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Publication

Monocular deprivation of Fourier phase information boosts the deprived eye's dominance during interocular competition but not interocular phase combination.
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