A cycling lane for brain rewiring

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Supplemental Experimental Procedures

Subjects

20 volunteers (7 males, mean age 22±3 years) participated in the study. All subjects but one were naïve to the experiment and had normal or corrected-to normal visual acuity and stereo acuity.

Ethics Statement

The experimental protocol was approved by the Tuscany regional ethics committee of the Azienda Ospedaliero-Universitaria Meyer and was performed in accordance with the Declaration of Helsinki. All of the participants gave written informed consent and received a financial compensation of 100 Euros.

Apparatus and Stimuli

The experiment took place in a dark and quiet room. Visual stimuli were generated by the ViSaGe stimulus generator (CRS, Cambridge Research Systems), housed in a PC (Dell) controlled by Matlab programs. Visual stimuli were two Gaussian-vignetted sinusoidal gratings (Gabor Patches), oriented either 45° clockwise or counterclockwise (size: $2\sigma = 2°$, spatial frequency: 2 cpd, contrast: 50%), presented on a uniform background (luminance: 37.4 cd/m^2, C.I.E: 0.442 0.537) in central vision with a central black fixation point and a

common squared frame to facilitate dichoptic fusion. Visual stimuli were displayed on a 20-inch Clinton Monoray (Richardson Electronics Ltd., LaFox, IL) monochrome monitor, driven at a resolution of 1024x600 pixels, with a refresh rate of 120 Hz. Observers viewed the display at a distance of 57 cm through CRS Ferro-Magnetic shutter goggles that occluded alternately one of the two eyes each frame. Responses were recorded through the computer keyboard. Monocular deprivation was performed using eyepatching. The eye-patch was made of a translucent plastic material that allowed light to reach the retina (attenuation 15%) but completely prevented pattern vision, as assessed by the Fourier transform of a natural world image seen through the eye-patch.

Task and Procedure

The effect of short-term monocular deprivation on the dynamics of binocular rivalry was tested for each participant in two separate conditions in a randomized order: an inactive control condition and a physical activity condition. Each individual patching session was separated at least by 24 hours. We also measured baseline conditions for each observer before patching, yielding eight separate measurements. After patch removal, we measured binocular rivalry continuously for 18 minutes in four separate 180sec-blocks, giving a short break every two minutes. Three-minute blocks of rivalry were tested again 30, 45, 60 90 and 120 minutes after restoration of normal binocular sight. Before monocular deprivation, two three-minute blocks of binocular rivalry were measured for each participant; the second block was used as baseline. Eye dominance was assessed operationally from binocular rivalry baseline recordings, with the dominant eye being the one that prevailed. Monocular deprivation was achieved by having subjects wear a translucent eye-patch over the dominant eye for 120 minutes. In the inactive control condition, during the monocular deprivation period subjects watched a movie while comfortably sitting in front of a TV screen at a viewing

distance of 80 cm, in a fully dedicated room. In the physical activity condition, a stationary bicycle was placed in front of the TV screen and, during the deprivation period, subjects watched a movie and were required to cycle intermittently (10 minutes of activity - 10 min of rest on a chair). During the cycling period the viewing distance from the TV screen was the same as in the inactive control condition (80 cm), however, because of the height of the stationary bicycle, during the 10 minutes of physical activity the visual angle was slightly different. Heart rate was monitored by a sensor on the bicycle handlebars. During physical activity the experimenter was present in the room and controlled that subjects kept a heart rate of about 120 beats per minute.

Immediately after the eye-patch removal, subjects returned to the testing room and sat in front of the monitor wearing the shuttering goggles and the first experimental session began. After an acoustic signal (beep), the binocular rivalry stimuli appeared. Subjects reported their perception (clockwise, counterclockwise or mixed) by continuously pressing with the right hand one of three keys (left, right and down arrows) of the computer keyboard. At each experimental block, the orientation associated to each eye was randomly varied so that neither subject nor experimenter knew which stimulus was associated with which eye until the end of the session, when it was verified visually.

Analyses

The perceptual reports recorded through the computer keyboard were analyzed using Matlab, and the resulting phase durations were compared with a repeated measures ANOVA. The three-minute blocks acquired after monocular deprivation were binned as follows: 0-8 min, 10-18 min, 30-48 min, 60-93 min, and 120-123 min.

The ratios between mean phase durations of the deprived and non deprived eye, plotted as a function of time from eye-patch removal, were fitted by a power function of the form:

$$y = 1 + \left(\frac{a}{\log(t+1)}\right)^b$$

(eq. 1)

Where *y* is the magnitude of the effect, *t* is time expressed as a logarithm and *a* and *b* are free parameters determining respectively amplitude and decay time.

Phase duration distributions were fitted by a two-parameter (r, λ) *gamma distribution* of the form:

$$g(x) = \frac{\lambda^r x^{r-1}}{\Gamma(r)} e(-\lambda x)$$

(eq. 2)

where Γ is the *gamma function*, r is the shape parameter and λ is the scale parameter.

For both the power decay and gamma distribution fits, a 10000 repetitions of bootstrapping were performed, re-fitting for each repetition the randomly re-sampled data. The parameters of the fit (see Table S1) were obtained by averaging the 10000 parameters obtained by the bootstrap procedure. The parameters were then statistically compared by performing a two-tailed bootstrap sign-test.

Supplemental Figure

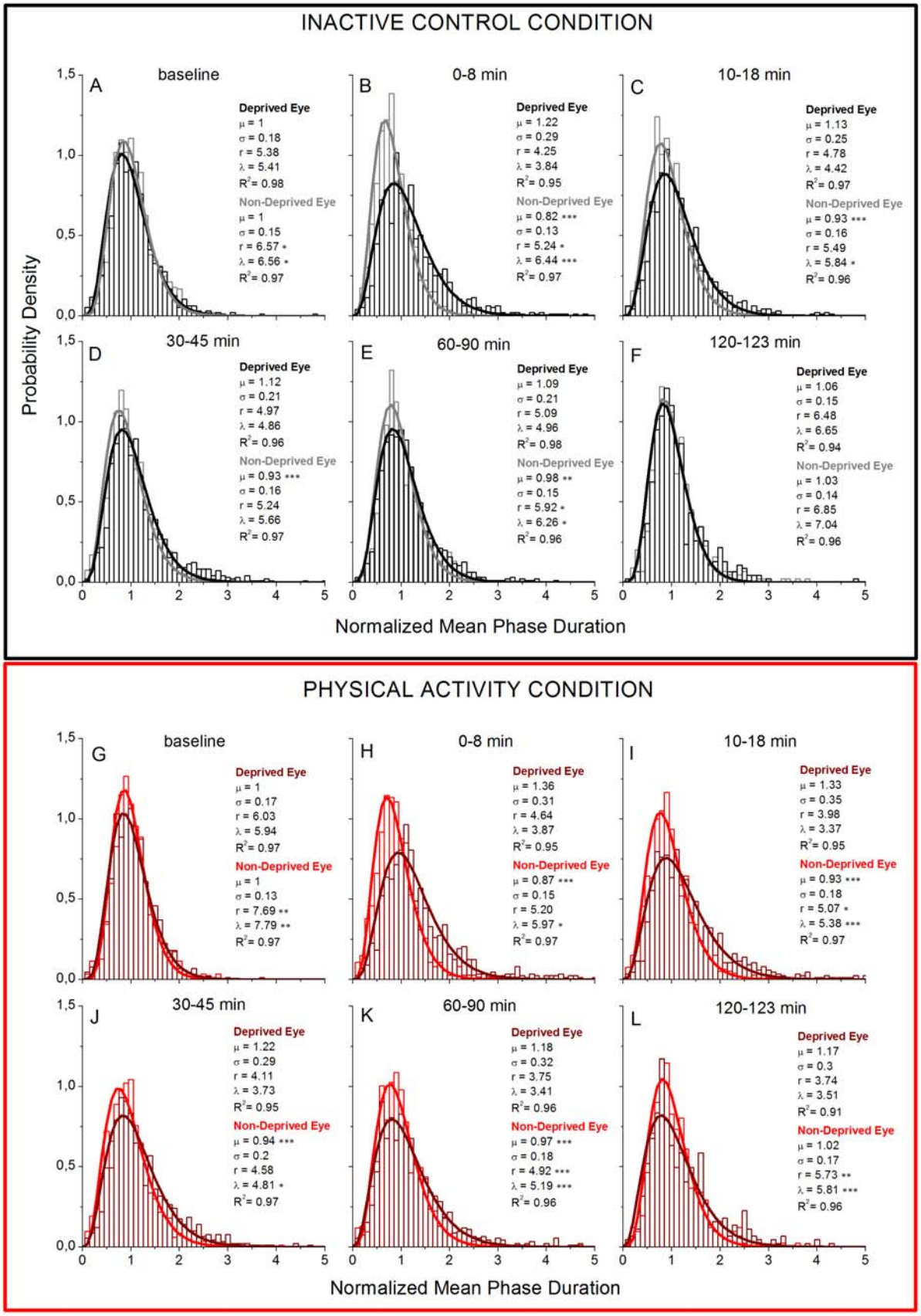

Figure S1. Mean phase-duration distributions.

Phase-duration distributions of the deprived and non-deprived eyes, plotted separately for different time intervals measured after monocular deprivation and for the two experimental conditions (data acquired in the inactive control conditions are reported in panels A-F, black symbols represent the deprived eye, grey symbols the non deprived; data from the physical activity conditions are reported in panels G-L, dark-red symbols represent the deprived eye, bright-red symbols the non deprived). Phase-durations were normalized to the mean baseline phase-duration for each subject, because of the great inter-individual variability in mean phase duration (from 2 to 6 seconds). Phase durations distributions are well fitted by a two-parameter (λ, r) gamma distribution of the form given in eq.2 in the methods section. For each time interval and each condition the mean of the distribution and the gamma distributions parameters were compared for the deprived and non-deprived eye using a 10000 repetitions two tailed bootstrap signtest: * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Supplemental Tables

	amplitude	decay
inactive control condition	0.55±0.07	1.1±0.17
physical activity condition	0.72±0.09	0.92±0.12
two-tailed sign test	p=0.12	p=0.37

Table S1. Parameters of the power decay fit for the inactive control and physical activity condition.

The *a* and *b* parameters (amplitude and decay respectively) of the power decay function given in Eq. 1 used to fit the ratio between the deprived and non-deprived eye mean phase duration plotted as a function of time from eye-patch removal (Figure 2A main text), are reported for the inactive control condition and the physical activity condition. The parameter means and their s.e.m. were estimated by performing a 10000 bootstrap repetitions. Even though a trend for increased amplitude (expressed by the free *parameter a*) and decreased decay rate (expressed by the free *parameter b*) in the exercised group was present, there was no statistical difference (10000 repetitions of a bootstrap two-tailed sign test) between the two conditions, indicating similar time-courses of the effect of deprivation.

	baseline	0-8 min	10-18 min	30-48 min	60-93 min	120-123 min
deprived eye - inactive control condition	3.93±0.27	5.05±0.42	4.57±0.36	4.7±0.45	4.63±0.47	4.33±0.35
non-deprived eye - inactive control condition	3.51±0.23	3.02±0.27	3.34±0.24	3.39±0.27	3.59±0.26	3.84±0.34
deprived eye - physical activity	3.87±0.24	5.77±0.47	4.83±0.37	4.83±0.37	4.79±0.43	4.91±0.59
non-deprived eye - physical activity	3.47±0.23	2.94±0.2	3.21±0.22	3.26±0.21	3.51±0.28	3.62±0.25

Table S2. Mean phase durations.

Mean phase durations of the deprived and non-deprived eye ±1 s.e.m. acquired in the two experimental conditions tested are reported for the baseline measurements and for the different time intervals tested after monocular deprivation. A (2x2x6) repeated measures ANOVA revealed a main effect of the factor EYE ($F(1,19)=51.6$, $p<0.001$), a main effect of the factor TIME ($F(5,95)=3.39$, $p=0.007$), a significant interaction between the factors EYE and TIME ($F(5,95)=30.16$, $p<0.0001$) and a significant interaction between the factors EYE and CONDITION ($F(1,19)=6.68$, $p=0.018$). We additionally divided the sample in two groups according to the order in which the two experimental conditions were performed and added the between-subjects factor ORDER to the repeated measure ANOVA. We found no main effect of the factor ORDER ($F(1,18)=0.0001$, $p=0.998$) and no significant interactions between the factor ORDER and the other factors (EYE*ORDER: $F(1,18)=0.95$, $p=0.34$; CONDITION*ORDER: $F(1,18)=0.95$, $p=0.34$; TIME*ORDER: $F(1,18)=0.18$, $p=0.969$; EYE*CONDITION*ORDER: $F(1,18)=0.06$, $p=0.8$; EYE*TIME*ORDER: $F(1,18)=0.6$, $p=0.69$; CONDITION*TIME*ORDER: $F(1,18)=0.11$, $p=0.98$; EYE* CONDITION*TIME*ORDER: $F(1,18)=0.67$, $p=0.64$).