Supplemental Methods

Dichoptic Video Game Play

Establishing alignment, fusion, and luminance adjustment before gameplay. Achieving adequate fusion and alignment is critical for amblyopic individuals when playing a dichoptic game. To achieve alignment, participants were shown the two frames with a half cross in each, and were asked to adjust the stereoscope mirrors so that a full cross is perceived at the center (see Figure 2B). The left eye viewed the bottom vertical and left arms while the right eye viewed the top vertical and right arms. High-contrast surrounding frames and four squares were also presented to assist fusion (see Figure 2B). While the participant viewed through the stereoscope, we decreased the alpha filter level (affecting both luminance and contrast) of the image presented to the NAE until both frames were visible. Participants were then required to adjust the vertical and horizontal positions of the two frames separately (achieved by adjusting the stereoscope mirrors) until a full cross was perceived at the center of the image.

Second, images of objects that were taken from the UT videogame were presented, such that the AE and the NAE each viewed one half-image. These are complex, dynamic scenes, viewed in color, with objects that vary in both brightness and luminance. With these complex videogame scenes, luminance and contrast are not perfectly correlated across the entire scene. Since our aim was to balance the perceptual strength of the two eye's signals within the context of the game, participants were asked to adjust the alpha filter level of the NAE until the object was perceived as having equal luminance/contrast on both halves. The alpha filter controls a simple linear interpolation between a foreground and background pixel. When the foreground color is black (f=0), alpha blending reduces to a linear interpolation between the background. The alpha filter level affects both luminance and contrast; see http://www.stonesc.com/pubs/Contrast%20Metrics.htm for more details).

A method-of-adjustment procedure was used to adjust the alpha level of the NAE, so that the two eyes' images were reported as having equal perceived strength. Participants viewed a total of 63 images: 7 different scenes, each scene appeared 9 times with each repetition having different initial alpha value. The mean value of the alpha match points in these 63 'trials' was used as the starting level for the NAE for the game for each participant.

Alpha values were converted into luminance values by the following steps. At the beginning of the study, and at regular intervals, the monitor was gamma corrected by measuring luminance with a photometer (Minolta Chromameter, CS-100), at 10 different levels and in order to calibrate gamma. A table was then created that mapped the strength of 11 different game scenes under 27 different alpha levels (from 255 to 5 in steps of 10, as well as the value of alpha = 0) to luminance. We did so by averaging, for each alpha level, the luminance values obtained from the 11 different scenes. The measured luminance values were then plotted as a function of (input) alpha values, and the data were fit with a second order polynomial regression equation. This equation was subsequently used to convert the alpha to units of luminance, on a subject-by-subject basis. Using this table as a reference, we were able to match the alpha level of the NAE at the start of each session to luminance values.

For participants unable to achieve alignment or fusion, the alpha level of the NAE was set to zero, having patients effectively playing monocularly for the initial 3-4 hours until binocular game play was feasible (n = 12).

Alignment and fusion (as described above) was performed at the start of each training session. For each session, the initial alpha level of the NAE was set to be the same value used in the last session + 50 on a scale between 0-255 (or, for the first training session, the value obtained from the equalizer program described below). Participants were then asked to adjust the alpha filter value of the NAE so that both cross halves were perceived as having equal luminance/contrast. This value was used for that day's training session.

Progression of game difficulty during gameplay. The goal of the game is to slay as many bots (computer controlled players or opponent) as possible without getting killed, within a certain time limit. Difficulty level of the game was altered either by increasing the number of bots or by increasing the bots' skill level (such as novice, average, experienced, expert etc.). Participants began the study by playing at an easy introductory level game map(s) for a total of 3 hours. These tutorial level maps introduce participants to the basics of game play, including how to use game controls, how to navigate, jump or turn in a game environment (see Bayliss et al., 2013 for full details), and contained fewer features compared to the regular maps. The number of bots in these introductory maps was increased gradually over these 3 hours (with 1, 3, 6, 9 and 16 bots). The final introductory session and all the remaining sessions of the game training with a given map, were mostly played with 16 bots. During the remainder of the training sessions, participants completed between three and five 23-minute 'blocks' of game play. In order to maintain a high level of interest, we chose 3 different 'Death Match' game maps to train participants. These maps were chosen such that they were similar in terms of visual appeal and sizes. Participants played each map for ~12 hours before switching to the next map. Whenever the training maps were switched, bot numbers were lowered to 9 for the first one or two blocks, and once participants were familiar with the new map, the bot numbers were increased to 16. In each map, difficulty level (i.e. bot skill) was initially set to the easiest level, and was advanced to the next level if the ratio of kills to deaths was equal to or larger than 2:1 during the previous session.

Orientation discrimination PL task with Gabor target. An adaptive Gabor discrimination task, similar to the ones employed in perceptual learning studies, was presented to the AE during game play. A Gabor patch, presented only to the AE (with Gaussian SD = 1 deg, on a gray mean luminance patch with sides subtending 4 deg each), was tilted either to the right or the left (± 35deg from base angle 90°), and appeared, on average approximately every 7 seconds, for a duration of 4.5 seconds. Participants were instructed to shoot the patch if it was tilted to the right, and to ignore it (or hit 'E') if it was tilted to the left. If participants failed (either failed to hit right-tilted patches or incorrectly shot left-tilted patches), the Gabor patch turned into a very powerful enemy bot with the potential to kill the player in the game. Participants were instructed to prioritize the Gabor patches over other enemy bots. The Gabor target appeared approximately 315 times per hour of game play.

The initial spatial frequency of the Gabor patch for each session was set to be the average frequency of the carrier gratings of the last 5 trials from the previous session minus 1 cpd. For instance, if the average was 4 cpd, the next session began with a Gabor stimulus consisting of a 3 cpd carrier grating. The spatial frequency of the Gabor patch was adapted using a 3-up 1-down procedure (Levitt, 1971). The spatial frequency ranged from 0.2 to 9 cycles-per-degree (cpd), and the carrier grating frequency increased by 0.2 cpd after three consecutive correct responses. The upper limit of 9 cpd was chosen since normally-sighted participants who were piloted on the game reliably perceived only up to 9 cpd Gabor patches during gaming. This may be because resolution is decreased in a cluttered background with many competing objects of interest, as game play unfolds at the same time as the Gabor is presented (Levi, 2008). Only one subject reached the 9 cpd ceiling in the course of game play, which may have resulted in a slight underestimate of their final resolution limit.

Additional Suppression checks before and during gameplay. In order to minimize the chances of suppression during dichoptic game play, we implemented frequent suppression checks. At the beginning of each training session, we presented a green crosshair to one eye, and a red crosshair to the other. Participants were instructed to make sure both crosshairs were visible and aligned during gameplay. If they failed to perceive one of the crosshairs, small luminance/contrast adjustments to the NAE were made until both cross hairs were visible. In addition, during gameplay, if participant reported missing or misaligned cross hairs, game play was paused and minor adjustments were made to correct any discrepancies before resuming game play. This suppression check was in addition to those described earlier: (a) setting the alignment and luminance/contrast level of NAE at the beginning of every session and (b) the Gabor task: since the Gabor patches were presented only to AE, the patch would be perceived only if the AE was not suppressed during dichoptic game play.

REFERENCES

Levi, D. (2008). Crowding--an essential bottleneck for object recognition: a mini-review. Vision Res. *48*, 635–654.

Levitt, H. (1971). Transformed up-down methods in psychoacoustics. J. Acoust. Soc. Am. *49*, Suppl 2:467+.