Current Biology, Volume *22*

Supplemental Information

Perceived Direction of Motion Determined by Adaptation to Static Binocular Images

Keith A. May, Li Zhaoping, and Paul B. Hibbard

Supplemental Experimental Procedures

Further Details of Test Stimuli

The test stimulus was presented for 250 ms within a square window subtending 4° × 4° visual angle, with a black border 2 arcmin wide. An opaque fixation stimulus (black '+' with bar thickness 4 arcmin and length 20 arcmin on a white circle, diameter 20 arcmin) was superimposed onto all stimuli, and remained in view throughout each session.

We did not use vertical cyclopean motion stimuli for the same reason as Shadlen and Carney [3], i.e. they would probably have stimulated larger vergence eye movements. Although we surrounded our stimuli with a strong border, the Shadlen-Carney stimulus within the border is binocularly uncorrelated along the direction perpendicular to the stimulus orientation, so there might have been a tendency for the observer's vergence control system to try to match up the images in the two eyes by changing the vergence in a direction perpendicular to the stimulus. This would have changed the $\pi/2$ radian spatial phase difference between the eyes, thereby disrupting the stimulus. Since vertical vergence adjustments are known to be smaller than horizontal ones [17,18], this effect was minimized by using horizontal stimuli.

Adaptation Stimuli

Experiments 1 and 3 used processed natural image adaptors. 78 grey-scale images were selected from a previously described set [4]. The central 768 × 768 square of pixels was extracted, and the grey levels rescaled to give a flat distribution of contrast values (as defined in Equation 1) from −1 to +1. This rescaling avoided any luminance artifact when comparing conditions with and without negative images, and also ensured that both eyes would be adapted to the same mean luminance level, even in the anticorrelated condition. The rescaled images were vignetted with a circular Tukey contrast window with a central flat region of diameter 672 arcmin, tapering (with a raised cosine edge) to an outer diameter of 768 arcmin. Experiment 2 used 1D horizontal or vertical noise adaptors with identical spatial window and border to the test stimulus; the amplitude spectra had a $1/f$ profile, and were scaled to maximum displayable contrast. For both natural image and 1D noise adaptors, corresponding negative adaptors (used in the anticorrelated adaptation conditions) were created by reversing the signs of the image contrast values. Adaptation stimuli were presented to the two eyes in different combinations to create anticorrelated, uncorrelated, correlated+ or correlated– binocular adaptation stimuli, as described in Figure 3.

The correlated– condition of experiment 1 was a control condition to rule out the possibility that any difference between anticorrelated and correlated+ conditions was due to the use of negative natural images per se in the anticorrelated condition, rather than because of the difference in interocular correlation. The data from the correlated+ and correlated– conditions in this experiment were very similar, so the correlated– condition was dropped from experiment 3, which used the same natural image adaptors as experiment 1. In experiment 2, the distinction between correlated+ and correlated– was not meaningful, so there was just a single correlated condition in this experiment.

Procedure

The experiments were carried out in a dark room. The procedure is illustrated in Figure 2. Each session started with an initial adaptation sequence, in which 32 different binocular adaptation stimuli of the appropriate type were presented for 1500 ms each. The first trial began immediately after the offset of the last of the initial adaptation stimuli. Each trial consisted of a top-up adaptation sequence, followed by the test stimulus. The border around the test stimulus remained in view for 500 ms after offset of the test stimulus to prevent masking of the test stimulus by the offset of the border; then the border disappeared, leaving only the fixation stimulus. The observer then reported whether the test stimulus appeared to be drifting upward or downward, and the next trial began shortly after the response. Within a session, the S_+ direction was upward on half of the trials (randomly selected), and downward on the other half. Observers received no feedback.

In experiments 1 and 2, the top-up adaptation sequence was always the same type of adaptation as the initial adaptation sequence, and consisted of four randomly selected stimuli presented for 1500 ms each, either natural image adaptors (experiment 1) or horizontal or vertical 1D 1/*f* noise (experiment 2). In experiment 3, the initial adaptation sequence always followed the same format as the uncorrelated condition of experiment 1, but the top-up adaptation switched between correlated+ and anticorrelated on alternate trials within a session. In this experiment, the top-up adaptation consisted of a single randomly selected stimulus, presented for a duration that varied between sessions (0, 2, 8, 32, 128, or 512 frames at 1/120 s per frame).

Experiments 1 and 2 had 100 trials per session (except for observer RJ, whose sessions in experiment 1 contained 40 trials); experiment 3 had 96 trials per session, to allow full counterbalancing of S_+ direction and assignment of signals S_1 and S_2 to left and right eyes for each of the two top-up conditions within a session. Observer PBH performed one session for each condition of experiment 1, and one session for each top-up duration in experiment 3. RJ performed 5 sessions for each condition of experiment 1. The remaining observers performed two sessions for each condition of experiments 1 and 2, and four sessions for each top-up duration in experiment 3. In experiment 3, the number of trials for 0 frames top-up duration was always twice that for the other conditions (i.e. 96 versus 48 for PBH and 384 versus 192 for the other observers) because, in this case, the two adaptation conditions were identical, so every trial in the session counted towards the same condition.

Before performing experiment 1, each observer was given a few practice sessions (at least one with correlated and one with anticorrelated adaptation). Practice sessions were identical to the main sessions of experiment 1 except that they had only 20 trials. These sessions continued until the observer felt confident at performing the task. Task performance did not appear to correlate with the number of practice sessions. Although KAM (who responded in the predicted direction on nearly every trial in experiment 1) had had a great deal of experience with these stimuli, observer AB (who also showed a strong effect) had received only two practice sessions (less than any other observer), and was completely unaware of the purpose of the experiment.