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Further support for the importance of the suppressive signal (pull) during the push–pull perceptual training

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ABSTRACT

We previously designed a push–pull perceptual training protocol that effectively reduces sensory eye dominance (SED) and enhances binocular depth detection in human adults (Xu, He, & Ooi, 2010a). During the training, an attention cue precedes a pair of binocular competitive stimulus to induce dominance of the weak eye and suppression of the strong eye. To verify that the success of the protocol is due to the suppression of the signals evoked by the stimulus in the strong eye, rather than to the attention cueing per se, we employed two new push–pull training protocols that did not involve attention cueing. Instead, we used the specific configurations of the boundary contours of the binocular competitive stimulus to render the strong eye suppressed. The first, MBC push–pull protocol has a half-image with grating feature but no boundary contour in the strong eye. The second, BBC push–pull protocol has a half-image with both grating feature and boundary contour in the strong eye. For both protocols, the weak eye receives a half-image with strong grating feature and boundary contour. These boundary contour configurations ensure that the weak eye remains dominant while the strong eye is suppressed during training. Each observer was trained with both protocols at two parafoveal (2°) retinal locations. We found that both protocols significantly reduce SED and binocular depth threshold. This confirms the basis of the push–pull protocol is the suppression of the strong eye, rather than the attention cueing per se. We further found that the learning effect (SED reduction) is more effective in the BBC push–pull protocol where the suppressed half-image in the strong eye carries both grating feature and boundary contour information, than in the MBC push–pull protocol where the boundary contour information is absent from the strong eye's half-image. This suggests that the learning effect depends in part on the availability of the image attributes for processing (suppression) during the push–pull perceptual training.

1. Introduction

When the two eyes are stimulated with very different images at corresponding retinal points, only one image is perceived while the other image is suppressed by the interocular inhibitory mechanism. Typically, the choice of which image is selected for perception is based on the stimulus intensity or contrast, with the stronger image being perceived more frequently (higher predominance) (Fox, 1991; Levelt, 1965). There are some observers with clinically normal stereopsis, however, who consistently experience an image from one eye being dominant more frequently even when the two half-images have equal stimulus strength. This indicates such observers have the condition of sensory eye dominance (SED) with an intrinsic imbalance of interocular inhibition (Ooi & He, 2001; Porac & Coren, 1976; Xu, He, & Ooi, 2011c).

We have previously quantified SED by using a binocular rivalry stimulus with different intensity or contrast in the two half-images (e.g., Ooi & He, 2001; Xu, He, & Ooi, 2010a, 2011a). Fig. 1a illustrates two pairs of orthogonal gratings for measuring SED at a local retinal location (Xu, He, & Ooi, 2010a). During the test, the observer first perceives the left pair of dichoptic stimulus. The contrast of the horizontal grating in the left eye (LE) is adjusted until he/she experiences an equal chance of perceiving the vertical and horizontal gratings. This measures the LE balance contrast. Then the observer is presented with the right pair of dichoptic stimulus, and with a similar procedure, his/her right eye (RE) balance contrast is obtained. Since the contrast of the vertical grating is kept the same while measuring the LE and RE balance contrast values, one can define their difference as the SED. The eye with the smaller balance contrast is the sensory dominant (strong) eye while the fellow eye is the non-dominant (weak) eye. In this paper, we refer to the SED measured in this way as the *contrast-SED* to distinguish it from its variant, which we call the *boundary contour (BC) based SED (BC-SED).*

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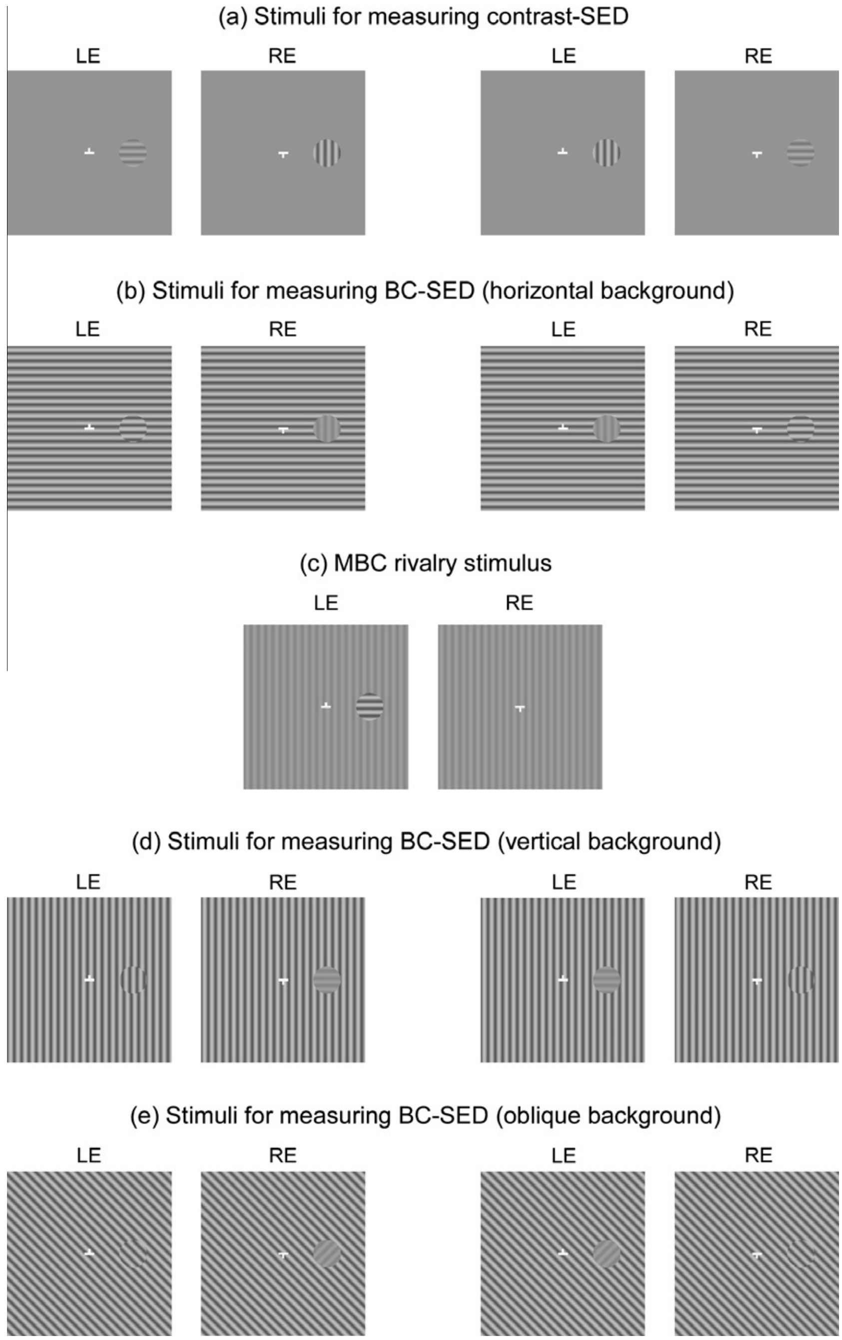

Fig. 1. (a) Two pairs of orthogonal gratings for measuring contrast-SED. The left pair of dichoptic stimulus measures the LE balance contrast, which is obtained by adjusting the contrast of the horizontal grating in the LE while keeping the contrast of the RE's vertical grating constant. The right pair of dichoptic stimulus is used to measure the RE balance contrast in a similar manner. The difference between the LE and RE balance contrast values defines the contrast-SED. (b) Two pairs of orthogonal gratings for measuring BC-SED. During the test, one keeps the contrast levels of the vertical and horizontal gratings constant while adjusting the relative phase-shift between the horizontal grating disc and its surrounding horizontal grating. In this way, the BC strength of the horizontal grating disc is varied to obtain the balance phase-shift for the LE (left pair of stimulus) and RE (right pair of stimulus). The difference between the LE and RE balance phase-shift values defines the BC-SED. (c) The MBC rivalry stimulus, which gives rise to a stable perception of the horizontal grating disc (lasting seconds). (d and e) depict pairs of orthogonal grating stimuli for measuring BC-SED. They differ from those in (b) in their grating orientations. In (d), the variable phase-shifted disc is vertical and both half-images have vertical grating background. In (e), the variable phase-shifted disc is oriented 135° and both half-images have 135° oriented grating background.

The BC-SED is measured with a different set of test stimuli, as illustrated in Fig. 1b. To obtain BC-SED, one keeps the contrast levels of the vertical and horizontal gratings constant while adjusting the relative phase-shift between the horizontal grating disc and its surrounding horizontal grating (Xu, He, & Ooi, 2010b, 2011a). In this way, the BC strength of the horizontal grating disc is varied until the observer experiences an equal chance of seeing the horizontal and vertical grating discs. The phase-shift at this point of equality is defined as the balance phase-shift. Thus, using a similar procedure as for measuring the contrast-SED, one can obtain the LE and RE balance phase-shift values, and define their difference as the BC-SED.

The contrast-SED and BC-SED measurements have a bias in characterizing the differential effects of interocular inhibition on two types of visual cortical properties for binocular surface representation, namely, the surface boundary contour (BC) and surface