

SHORT AND SWEET

Dichoptic completion, rather than binocular rivalry or binocular summation

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Abstract. When one monocular image contains a red square partly occluding a green square, and the other monocular image is the same except that the green square is partly occluding the red one, the two images resemble each other's amodal completion. Observers typically perceive two complete squares as if the red and green surfaces are transparent or penetrating each other at their overlapping image location, which never appears yellow. With this example, we introduce dichoptic completion as a perception with the following characteristics. (1) Similar to binocular rivalry, it is evoked by dichoptic stimuli with monocular images so disparate that they cannot arise from physical scenes; however, (2) it occurs when objects inferred from one monocular image are identified with, or do not conflict with, objects inferred from the other; and, consequently, (3) it is a form of perceptual superposition, distinct from the result of binocular summation or rivalry.

Keywords: dichoptic completion, perceptual inference.

We show two stimuli that evoke dichoptic completion (Meng et al 2011). One has been mentioned in the abstract (Figure 1 and Figure 2a). Another involves retinal images corresponding to the two standard alternative interpretations of a Necker cube, so that one monocular image has three differently coloured surfaces of this cube from one interpretation and the other image has three other differently coloured surfaces from the other interpretation (Figure 3a). The dominant resulting percept is of a transparent cube containing six multi-coloured surfaces, even though binocular rivalry would conventionally occur. We call these two test stimuli SQUARES and CUBES, respectively. To quantify the prevalence of dichoptic completion by these stimuli, we measured the fractions of viewing durations for various perceptual categories, and contrasted them with those evoked by control stimuli (Figure 2b and Figure 3b).

Each monocular image contains a $3^\circ \times 3^\circ$ relevant region centred in a $4^\circ \times 4^\circ$ gray (56.3 cd/m^2) square framed by a black border (2 arcmin wide). Various image patches included red (19.8 cd/m^2), green (79.5 cd/m^2), blue (11.7 cd/m^2), yellow (98.8 cd/m^2), dark grey (22.6 cd/m^2), black (0.0 cd/m^2), and white (110.0 cd/m^2) areas. All dichoptic stimuli were viewed after observers fused on the binocular fixation stimulus (white '+' with bar size $4' \times 20'$ on a black circle, diameter 20 arcmin, Figure 1) centred within the same square.

Human observers (4 male and 2 female, 23–28 years) first freely viewed each dichoptic stimulus for a few minutes to report all their perceptions, which were classified by the experimenter into three categories according to their degrees of binocular rivalry or combination, see Figures 2 and 3. Then they viewed the stimulus continuously for 5 minutes in a trial, and pressed one of the three response buttons whenever their perception started to appear like the corresponding perceptual category. After some rest, they did another trial with the two monocular images swapped with each other. Observers were asked after testing if they saw any uncategorized perceptions (none did). Fraction of accumulated time duration seeing each of the three perceptions within the 10-minute viewing duration was calculated.

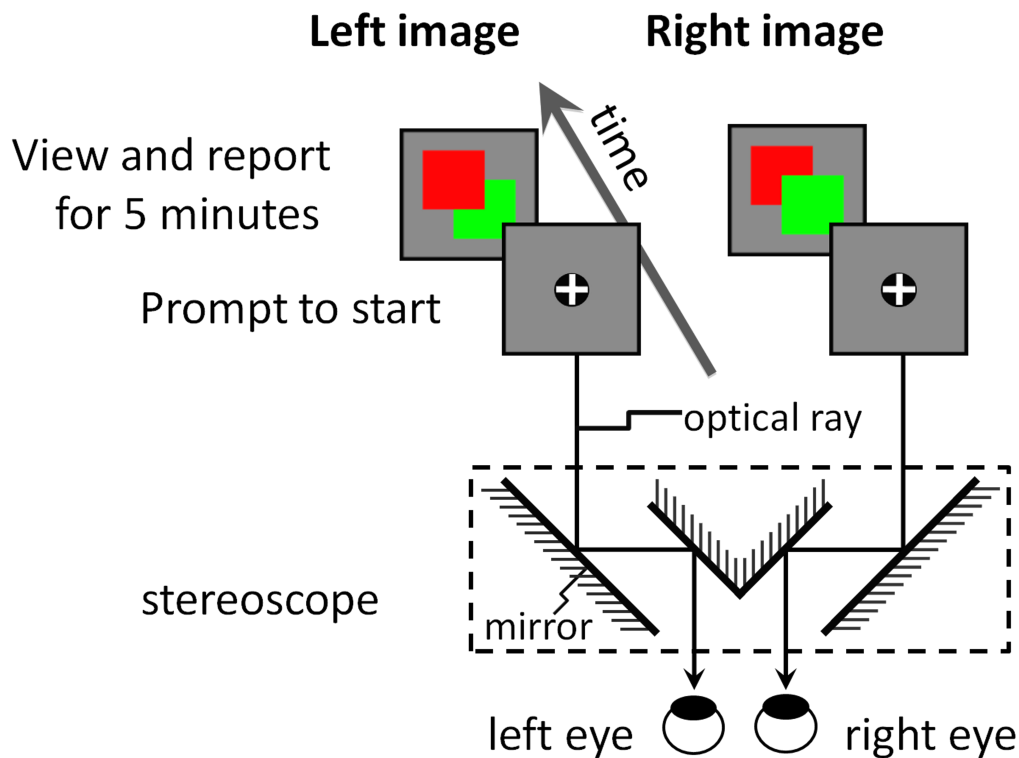


Figure 1. A schematic of the apparatus and stimuli. Mirrors brought the dichoptic images on a cathode ray tube (CRT) monitor to the two eyes.

Contrary to the expectation that binocular rivalry (including patchwork rivalry) dominates perception when two very disparate monocular images are viewed (Blake 2001; Kovacs et al 1996), in our test stimuli, dichoptic completion tends to be the dominant perception. This is insensitive to the choices of surface colours, according to our observation. Moreover, disparity between the red and green squares in SQUARES has a limited effect on the prevalence of dichoptic completion (Meng and Zhaoping 2011).

Non-rivalry between two very different monocular images in our examples can also be evoked by stimuli from physical scenes. For example, view an apple about 60 cm from you; hold a finger between the apple and yourself, and adjust its position such that roughly only the left/right half of the apple is projected into your left/right eye. The apple is perceived as whole, because its image in the left eye is the amodal completed portion of that in the right eye, making the apples inferred from the left and right images identified with each other. This identification of, or non-conflict between, objects inferred from the two monocular images is the same as an essential requirement for dichoptic completion. We believe that the brain mechanism for inferring this whole apple is what makes dichoptic completion possible, even though we never experienced such stimuli (eg, Figure 2a and Figure 3a) in physical scenes.

In SQUARES, object identification occurs because each monocular image contains the amodal completed portion of the other one. In CUBES, the two images are no longer amodal completed versions of each other. Dichoptic completion thus involves object completion more general than amodal completion, when the unspecified but consistent details of the inferred objects from one image appear in the other image.

Many questions remain to be answered. For example, one may ask whether and how dichoptic completion can be affected by attentional control, experience, knowledge, or by spatial, temporal, chromatic, and achromatic intensities of the stimuli. Complementary to

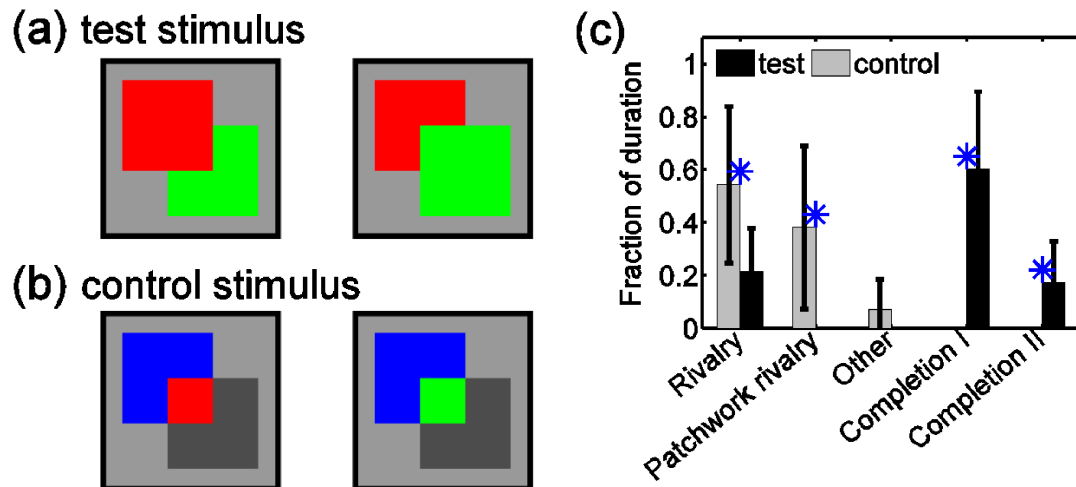


Figure 2. Stimuli and results for test stimulus SQUARES (a) and its control stimulus (b). Two $2^\circ \times 2^\circ$ squares overlap by $1^\circ \times 1^\circ$. For (a), the three possible perceptual categories are rivalry (a monocular image), completion I (two complete squares penetrating each other), and completion II (two complete squares overlapping transparently). For red/green image area in (b), the categories are rivalry (a monocular image), patchwork rivalry (red-green patches), and other (perceiving yellow or dark pink). (c) Averaged fractions of accumulated durations across observers for five possible perceptual categories, error bars indicate standard deviations. For each category, a blue star indicates a significant difference (matched-sample t -test, $p < .05$) between the fraction for the test and that for the control stimulus.

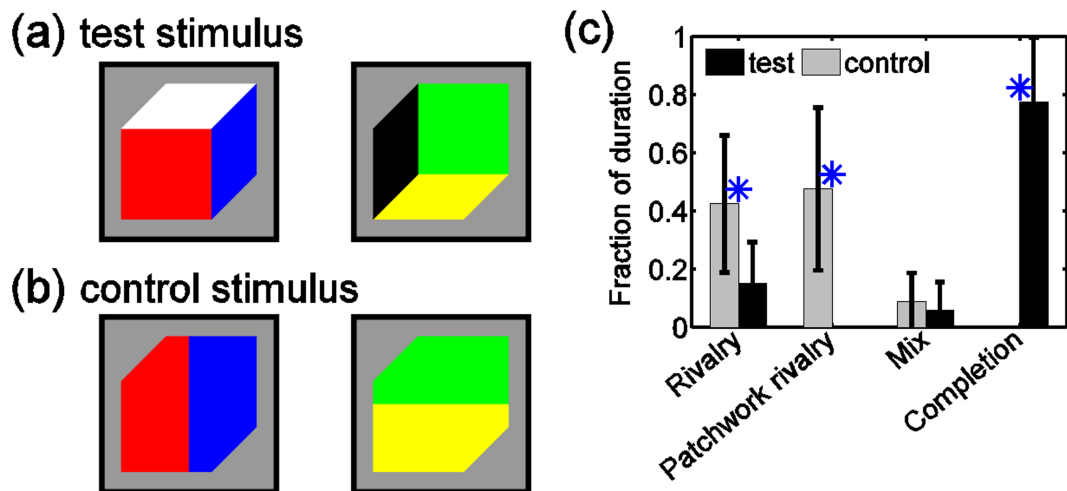


Figure 3. Stimuli and results for test stimulus CUBES (a) and its control stimulus (b), in the same format as in Figure 2 above. The squares are $2^\circ \times 2^\circ$ in size, and the rhomboids are 1° thick. For (a), the three possible perceptual categories are rivalry (a monocular image), mix (seeing two protruding cubes, each with three faces), and completion (seeing a transparent cube with six faces). For (b), the categories are rivalry (a monocular image), patchwork rivalry (one plane with 3–4 patches), and mix (seeing two parallel surfaces in depth). The 'mix' perceptions are not categorized as 'completion' because two, rather than one, objects were seen.

binocular rivalry, dichoptic completion can be a useful probe into brain mechanisms for perceptual inference, which constructs the most likely scene from the monocular images, regardless of whether these images could actually arise from the perceived scene.

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