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Size and shape after-effects: Same or different mechanism?

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ABSTRACT

The shape-frequency and shape-amplitude after-effects, or SFAE and SAAE, are shifts in the perceived shape-frequency and perceived shape-amplitude of a sinusoidal test contour following adaptation to a similar-shaped contour. These shape-effects are the shape analogs of the well-known size after-effect discovered by Blakemore and Sutton (1969), so it is possible that they are mediated by a size-sensitive mechanism. We tested this possibility by comparing the magnitudes of SFAEs/SAAEs elicited by contour/edge adaptors with those from luminance grating and line-grating adaptors. The rationale was that if the shape after-effects using the two classes of adaptors were similar, then they would likely be mediated by the same mechanism. We found that the SFAE and SAAE were greatly reduced when using luminance and line grating adaptors, suggesting that the SFAE and SAAE are not mediated primarily by either first- or second-order size-sensitive mechanisms. Based on previous studies we conclude that SFAEs/SAAEs are mediated by mechanisms primarily sensitive to curvature.

1. Introduction

An important tool in the study of shape perception is the shape after-effect. In this phenomenon, the perceived shape of an object is altered following adaptation to an object of slightly different shape (Anderson, Habak, Wilkinson, & Wilson, 2007; Bell, Gheorghiu, & Kingdom, 2009; Bell & Kingdom, 2009; Blakemore & Over, 1974; Gheorghiu & Kingdom, 2007a, 2008, 2009; Gheorghiu, Kingdom, Thai, & Sampasivam, 2009; Regan & Hamstra, 1992; Suzuki, 2001, 2003; Suzuki & Cavanagh, 1998). Two shape after-effects, the shape-frequency and shape-amplitude after-effects, or SFAE and SAAE, have been recently employed to study various aspects of curvature coding in human vision. The SFAE and SAAE are the perceived shifts in respectively the shape-frequency and shape-amplitude of a sine-wave-shaped contour following adaptation to a sine-wave-shaped contour of slightly different shape-frequency or shape-amplitude. As with other spatial after-effects such as the tilt after-effect (Gibson, 1933; Magnussen & Kurtenbach, 1980a, 1980b; Wenderoth & Johnstone, 1988) and size after-effect (Blakemore & Campbell, 1969), the perceived shifts in the SFAE and SAAE are always in a direction away from that of the adaptation stimulus. Gheorghiu and Kingdom (2007b) provided evidence that both the SFAE and SAAE are mediated by curvature-sensitive mechanisms rather than by mechanisms sensitive to local orientation adaptation, periodicity or global shape. However, it is still possible that the shifts in shape-amplitude and shape-frequency observed in the SAAE and SFAE are not a result of curvature adaptation per se, but of a general size adaptation process that has the effect of stretching or shrinking parts of the sinusoidal contour in the direction of the shape modulation or in the direction orthogonal to it. Blakemore and Campbell (1969) showed that adaptation to a luminance grating caused a shift in the apparent spatial frequency of a test grating away from that of the adaption spatial frequency. The SFAE can be considered to be the shape analog of this version of the size after-effect. The question however is whether it is more than just an analog, but is mediated by the same mechanism. The aim of this communication is to determine whether or not this is the case.

It is widely accepted that the size after-effect reported by Blakemore and Campbell (1969) is mediated by cortical channels selective to luminance spatial-frequency (Blakemore & Nachmias, 1971; Blakemore, Nachmias, & Sutton, 1970; Blakemore & Sutton, 1969; Burton & Ruddock, 1978). Readers can experience both the shape and size after-effects in Fig. 1. If one moves ones' eyes back and forth along the horizontal markers between the pair of adapting stimuli (left), and then transfer one's gaze to the central spot on the right, the two test patterns will likely appear to have a different shape-frequency (Fig. 1a), shape-amplitude (Fig. 1b) and size (Fig. 1c). An important property of all these after-effects is that they survive phase randomization during adaptation.

Are there *a priori* reasons for supposing that the SFAE and SAAE are manifestations of size after-effects? If they are manifestations, they should, for example, have properties in common. The size after-effect is broadly selective for orientation (Blakemore & Nachmias, 1971; Blakemore et al., 1970; Burton & Ruddock,

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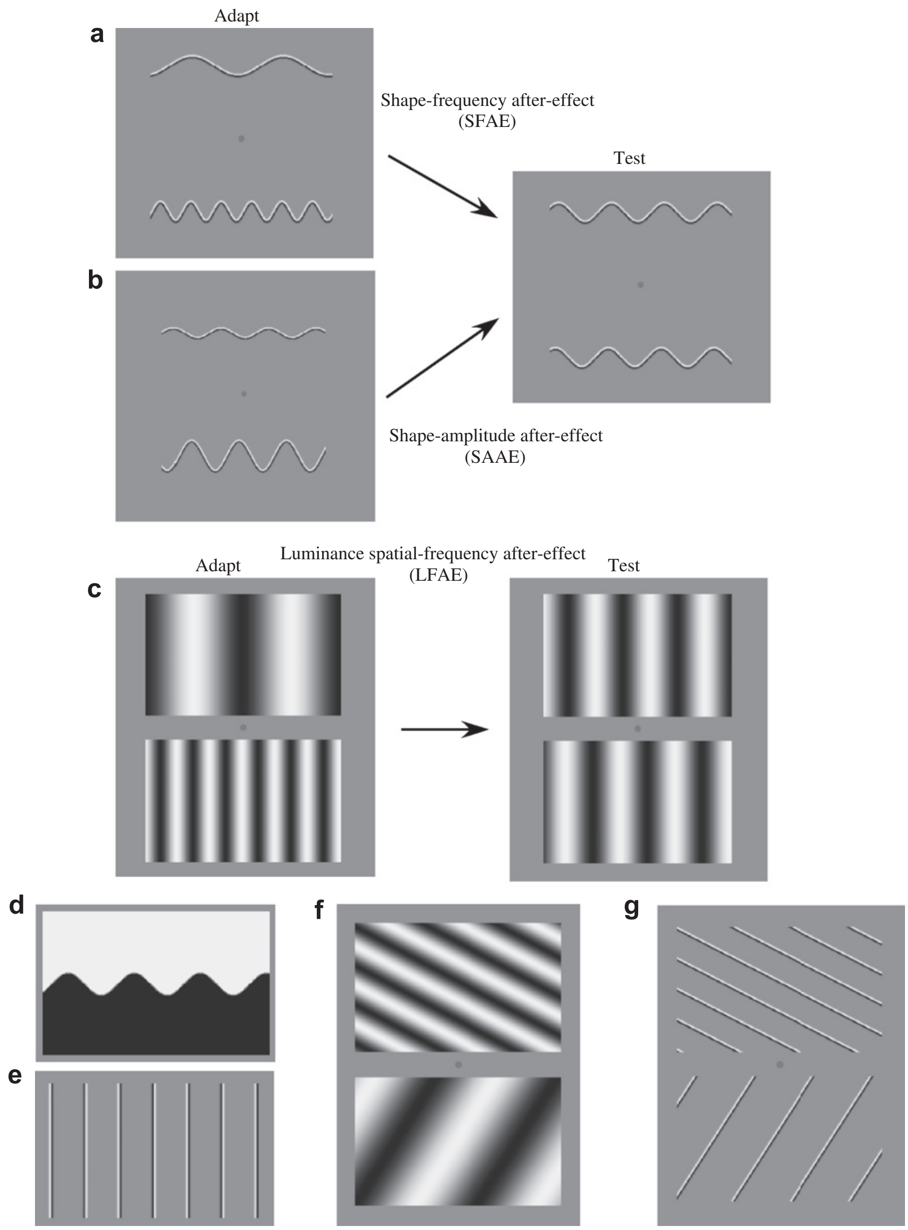

Fig. 1. Stimuli used in the experiments. One can experience: (a) the shape-frequency after-effect (SFAE) and (b) the shape-amplitude after-effect (SAAE) by moving one's eyes back and forth along the markers located midway between the pair of adapting contours (left) for about 90 s, and then shifting one's gaze to the middle of the test contours (right). (c) The size, or luminance spatial-frequency after-effect that is the apparent spatial frequency shift observed after adaptation to slightly different frequencies. (d–g) Example stimuli: sine-wave-shaped edge (d); line grating (e); oriented sine-wave luminance gratings adaptors (f), and line-grating adaptors. The sine-wave luminance and line gratings were oriented at 32 and 62° either to the right (+) or to the left (−) from the vertical.

1978; Heeley, 1979), spatial frequency (Blakemore & Nachmias, 1971; Blakemore et al., 1970; Nishida, Motoyoshi, & Takeuchi, 1999) and luminance-polarity or phase (DeValois, 1977). It increases with both adapting contrast and adapting duration (Blakemore et al., 1970). With regard to color selectivity, Virsu and Haapasalo (1973) reported a color-selective difference in the adaptation effect when using alternating adaptation to different colors and spatial frequencies. However, because they also found some transfer of the size after-effect between adaptor and test patterns that differ in color they concluded that the size after-effect was not color specific. More recent studies (Hardy & De Valois, 2002) have shown that both color-selective and color-non-selective mechanisms are involved in the size after-effect. The SFAE and SAAE are also selective for luminance polarity, luminance spatial-frequency and color direction (Gheorghiu & Kingdom, 2006, 2007a). On the other hand, the size after-effect shows an interocular transfer of about 60% (Bjorklund & Magnussen, 1981; Blake, Overton, & Lema-Stern, 1981) whereas the SFAE and SAAE shows an interocular transfer greater than 90% (Gheorghiu et al., 2009). The SFAE and SAAE are more-or-less contrast independent, though the largest after-effects are observed when adaptor and test contrasts are the same (Gheorghiu & Kingdom, 2006). Nishida et al. (1999) found that direction of motion had no influence on the magnitude of the size after-effect over a wide range of spatiotemporal frequencies, though there was a small degree of selectivity at low spatial and high temporal frequencies (0.5 c/deg, 8 Hz). Gheorghiu, Kingdom, and Varshney (2010) on the other hand found that both SFAEs and SAAEs were selective to global motion direction across a wide range of temporal frequencies though predominantly at high shape temporal frequencies. We also found that both shape