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Chromatic blur perception in the presence of luminance contrast

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ABSTRACT

Hel-Or showed that blurring the chromatic but not the luminance layer of an image of a natural scene failed to elicit any impression of blur. Subsequent studies have suggested that this effect is due either to chromatic blur being masked by spatially contiguous luminance edges in the scene (Journal of Vision 13 (2013) 14), or to a relatively compressed transducer function for chromatic blur (Journal of Vision 15 (2015) 6). To test between the two explanations we conducted experiments using as stimuli both images of natural scenes as well as simple edges. First, we found that in color-and-luminance images of natural scenes more chromatic blur was needed to perceptually match a given level of blur in an isoluminant, i.e. colour-only scene. However, when the luminance layer in the scene was rotated relative to the chromatic layer, thus removing the colour-luminance edge correlations, the matched blur levels were near equal. Both results are consistent with Sharman et al.'s explanation. Second, when observers matched the blurs of luminance-only with isoluminant scenes, the matched blurs were equal, against Kingdom et al.'s prediction. Third, we measured the perceived blur in a square-wave as a function of (i) contrast (ii) number of luminance edges and (iii) the relative spatial phase between the colour and luminance edges. We found that the perceived chromatic blur was dependent on both relative phase and the number of luminance edges, or dependent on the luminance contrast if only a single edge is present. We conclude that this Hel-Or effect is largely due to masking of chromatic blur by spatially contiguous luminance edges.

1. Introduction

Blur can take many forms. For example the background scenes of photographs taken while tracking a moving object are blurred, and objects not located in the focussed plane are blurred. Blur can be a useful cue, for example in the case of motion blur for determining relative velocity and in the case of defocus blur for determining relative depth (Mather, 1997; Vishwanath & Blaser, 2010). On the other hand blur can make tasks such as reading and driving difficult.

The role of colour in blur perception has previously been investigated using isoluminant (colour-only) stimuli as well as stimuli containing both colour and luminance, as in studies that use images of natural scenes. With square-wave stimuli, blur detection thresholds are similar ($\sim 0.5'$) for isoluminant reddish-greenish and luminance defined stimuli, but significantly elevated thresholds for isoluminant yellowish-bluish stimuli ($\sim 1.5'$) (Wuerger, Owens, & Westland, 2001). It has additionally been shown that adaptation to blur causes changes to perceived blur in both luminance and chromatically defined stimuli (Webster, Mizokami, Svec, & Elliott, 2006).

The interest in using mixed colour-luminance images of natural scenes as stimuli for studying chromatic blur perception stems from a compelling demonstration devised by Hagit Hel-Or. Her demonstration was first published in Wandell (1995), and hence has been referred to as the "Wandell Effect". Hel-Or showed that when the chromatic but not luminance layer in the scene was physically blurred, there was little impression of blur, yet when the blur was the other way round there was a strong impression of blur. The effect is demonstrated in Fig. 1. The left most column of images are un-blurred, while columns 2–5 are blurred to an increasing degree. In row (d) only the chromatic layer is blurred, while in row (e) only the luminance layer is blurred. As the blur increases the images containing luminance blur appear increasingly blurred, while the images containing chromatic blur produce little impression of blur. For completeness row (a) shows the result of blurring both the chromatic and luminance layers, row (b) the result of blurring the luminance layer in isolation, and row (c) the result of blurring the chromatic layer in isolation (though due to the limits of photographic reproduction these images will unlikely be isoluminant).

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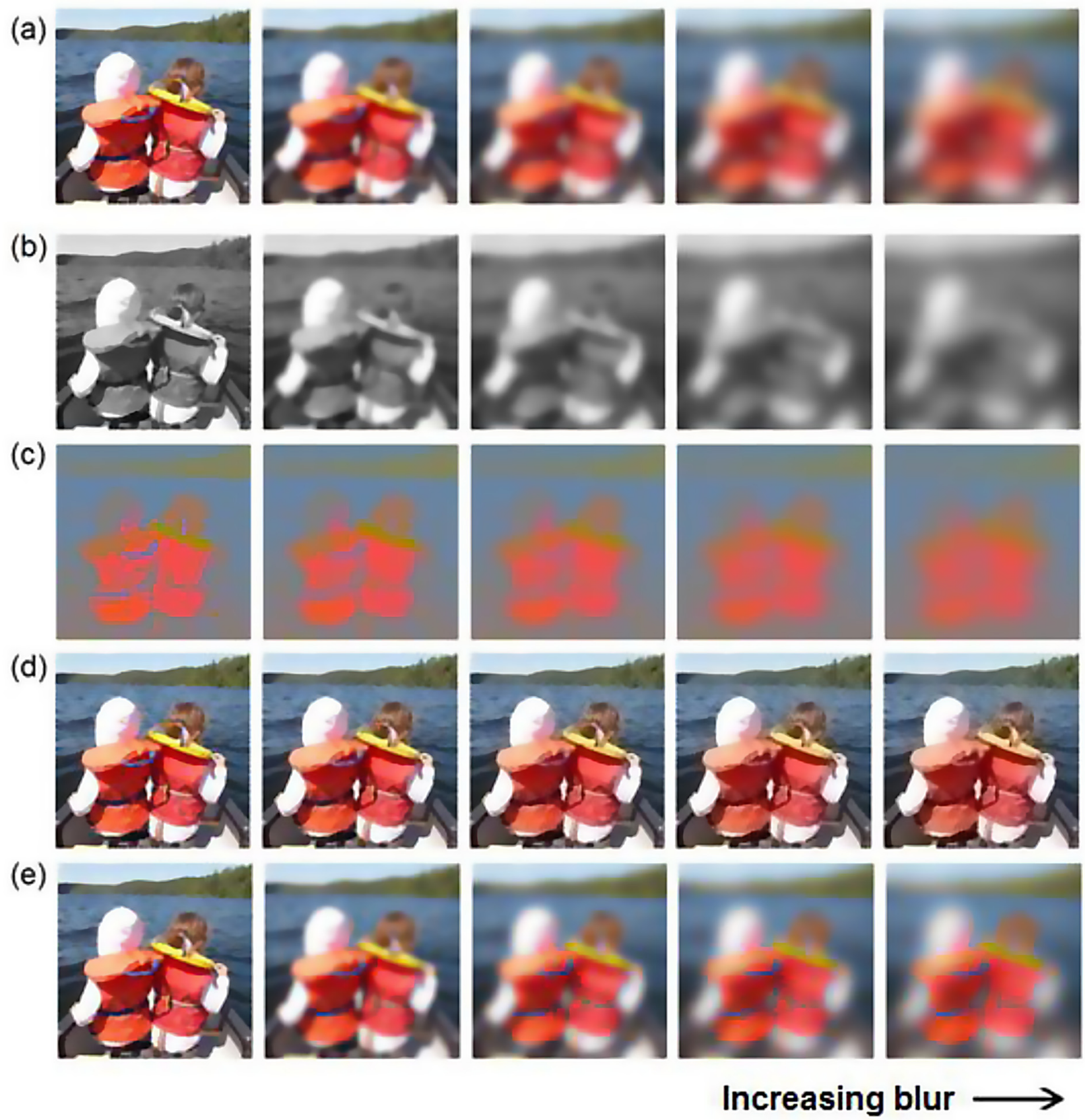

Fig. 1. An image subject to different blur manipulations (rows), with no blur (column 1) and increasing blur from column 2 to 5. Images in (a) are the original images containing both chromatic and luminance information; (b) luminance-only images; (c) isoluminant images; (d) chromatic-blur-only images; (e) luminance-blur-only images. Images in row (d) do not illicit an impression of a blurred scene.

2. Sharman, Mcgraw, and Peirce (2013) vs. Kingdom, Bell, Haddad, and Bartsch (2015)

Two recent studies, based on psychophysical data, have offered different explanations for the effect in Fig. 1. Sharman et al. (2013) found that thresholds for detecting chromatic blur were higher in normal compared to isoluminant images of natural scenes. Conversely, luminance blur detection thresholds in the same scenes were largely independent of whether or not chromatic information was present. Two important controls were performed. First, to control for the fact that there is typically less chromatic than luminance contrast in natural scenes (Rivest & Cavanagh, 1996) Sharman et al. equated the two types of contrast. Second, to control for the possibility that there is more high frequency structure in the luminance compared to chromatic layer, they swapped the chromatic and luminance layers. Upon re-testing, both controls yielded the same pattern of results as in the initial experiments. Sharman et al. suggested that the sharp luminance edges in the image masked the blur in the spatially aligned chromatic edges, due to a process similar to that mediating the Boynton illusion (for an example see Stockman & Brainard, 2009), in which a yellow edge appears to spread into the space around an undulating black contour. Thus according to Sharman et al., reduced chromatic blur perception in natural scenes is caused by masking of chromatic blur by spatially contiguous luminance edges.

An alternative explanation for the effect was proposed by Kingdom et al. (2015). Kingdom et al. measured perceived blur differences rather than blur detection thresholds. They employed fractal textures composed of two superimposed layers of densely packed, but not spatially correlated, Gabor patches. One layer's