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PHENOMENAL REPORT

A pink illusion

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Abstract

A white test disk is embedded in a surround that alternates, in either space or time, between red and white. Simultaneous contrast should make the disk look green, but it does not. It looks pink.

Keywords: Color vision; Motion perception: Simultaneous contrast; Induced color; Adaptation; Afterimage

To access the movies for this article, please visit the article landing page or read the html version of the article where all movies are embedded.

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It is well known that a small white disk centered in a large red field will tend to look greenish by simultaneous contrast, probably as a result of lateral inhibition in the visual system.

But here we present movies that demonstrate different versions of a counterintuitive color phenomenon. A white test region is embedded in a surround that alternates, in either space or time, between red and white. One might have expected the test region to look greenish by simultaneous contrast, but it does not. It always looks pink.

The pink movies

In Movie 1a, a white test disk and ring are centered in a rotating red and white sectored disk. Result: The white disk and ring gradually become suffused with a pale desaturated *pink*. The effect builds up over time, indicating the presence of adaptation. Why pink and not green? Simultaneous contrast would predict that the red sectors would induce green into the central disk, while the white sectors would have little or no effect. But in fact, the subjective green induced into the white sectors does in turn seem to induce a subjective pink into the central region. Both practised and naïve observers reported these results, although practised observers were more consistent.

One referee reported that the pink was visible at a low luminance, say 80 cd/m^2, but vanished at a high luminance (400 cd/m^2) – the white disk and ring still appeared white while the white sectors became vivid green.

The surround motion can be random instead of rotary. In Movie 2a, the surround is filled with twinkling random red and white dots. Once again, the test ring appears to become suffused with a pale pink. For unknown reasons, pink seems to develop more rapidly in Movie 2a than in 1a.

The surround can flicker instead of rotating and need not be larger than the white test regions. In Movie 2b the even squares of the checkerboard flicker between red and white, causing the always-white odd squares to apparently alternate between white and pink.

Next, in Movie 3a, a white cross is centered in a surround that flickers between red and white. Once again, the cross gradually turns a pale pink. Furthermore, if the flicker is stopped when the surround is white, the cross still looks pink as a pink afterimage. (The white cross has a thin outline to make the afterimage more visible: Daw, 1962; Van Lier et al., 2009).

The situation is clarified in Movie 3b, which is simply Movie 3a in slow motion. The slow, 0.5 Hz flicker allows one to make separate judgments about the cross, which now looks veridically white when it is viewed against the red surround, but looks decidedly tinged with pink during the phase when the surround is white. The pink tinge remains as a pink afterimage if one adapts to the flickering stimulus for (say) 30 sec and then switches off the flicker, leaving the surround white. A grey cross (Movie 3c) never looks either greenish or pink.

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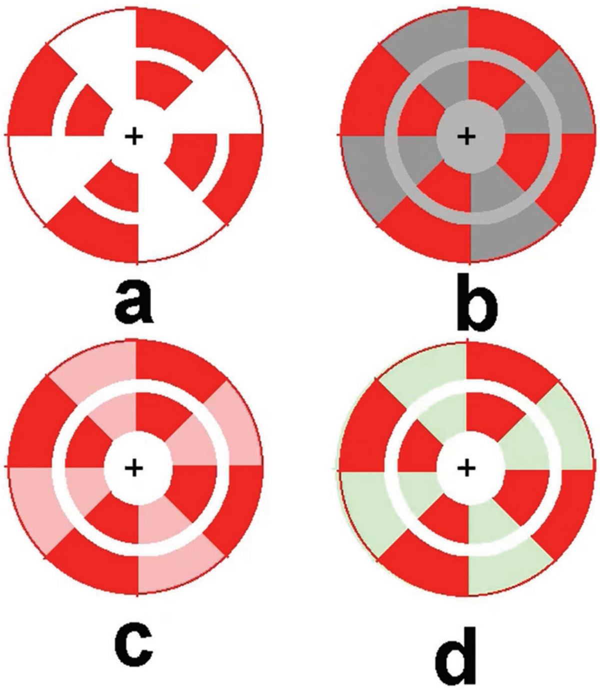
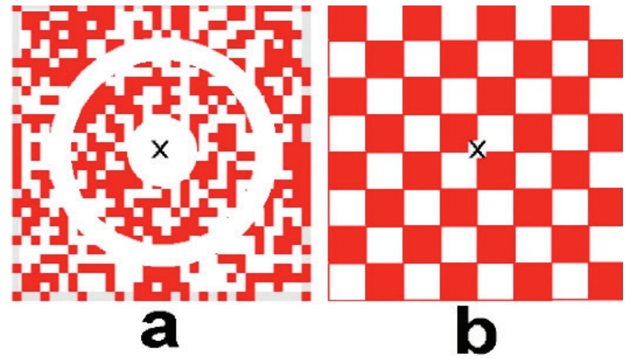


Movie 1. (a) Rotating red and white sectors make central white disk and ring look pink. (b) Rotating sectors are red and equiluminous grey instead of red and white. Grey sectors adapt to look brilliantly green, as predicted by Kirschmann's Third Law. But they induce very little pink into pale-grey central areas (or into white or mid-grey central regions, not shown). This is inconsistent with double-contrast theory. (c) Rotating sectors are red and pink instead of red and white. Pink sectors gradually adapt until they look white, at which point the central region looks very pale pink. This is inconsistent with double-contrast theory. (d) Static figure, not a movie. Pale green sectors mimic the subjective green induced into rotating white sectors in (a).

Previous illusions

Similar effects have been described earlier in the study of afterimage filling-in by Van Lier et al. (2009) and a few years later also by Anstis et al. (2012). In Van Lier's afterimage filling-in phenomenon, a colored starlike figure alternated with different outlines. It appeared that pink colors outside the subsequently presented outline, induced a pink color inside that outline. In fact, the original stimuli were designed such that the net color effect was increased by having inducing complementary colors inside and outside the subsequent outlines. As Anstis et al. (2012) wrote: 'The color inside the outlined area leads to a complementary colored afterimage. However, the color outside the outlined area also leads to an afterimage inside the outlined area, but with a color similar to its original color. The latter effect is the result of contrast induction of the afterimage across the outline (Anstis et al., 1978)'. The effect of the inducing colors outside the outline is very much like the checkerboard display in



Movie 2. (a) Surround of twinkling random red and white dots induce pink into central region. (b) Checkerboard: even squares flicker red/white, making the white odd squares gradually look pink.

Movie 2, or the more recent color dove illusion by Barkan and Spitzer (2017).

Discussion

Here are three possible explanations, which may not be mutually exclusive.

Don Macleod has suggested (personal communication) a 'double-contrast' account: perhaps the rotating red sectors in Movie 1a induce a pale green into the rotating white sectors, which in turn induce pink into the ring. So on this hypothesis the greenish contrast color in the white sectors induces the complement of the complement, that is, the color of the red sectors, into the center. This is simulated in Movie 1d, where the white sectors are physically a faint green to mimic the effects of adaptation in Movie 1.

Thus, the rotating red and white segments provide more 'red' on average at all locations apart from the central area and the ring. If the red receptors adapt over the first 10 sec then the net signal from the white sector areas is green (which is what we see). This induces a pink color into the center area and ring. But why would the pale greenish (physically white) sectors induce colors more strongly than the saturated red sectors? One possibility could invoke Kirschmann's (1891) Third Law: color induction is greatest when test and inducing fields are equiluminous. So according to Kirschmann's Third Law, grey sectors equiluminous with the red sectors should look strongly green – which they do, following some adaptation. But inspection of Movie 1b shows that these strongly (though subjectively) green sectors fail to induce much pink into the central areas. This goes against the double-contrast theory.

Movie 1c provides further evidence against the double-contrast hypothesis. This movie is the same as Movie 1a, except that the red and white sectors are now red and pink. During steady fixation, successive contrast from the

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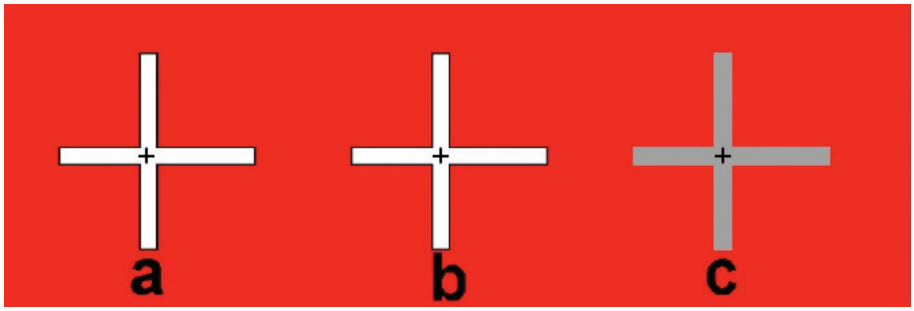

Movie 3. (a) Surround flickers between red & white. Central white cross gradually looks pink. (b) Surround now flickers slowly, at 0.5 Hz. Result: White central cross looks pink but only when surround is white (which looks greenish), not when surround is red. (c) Central cross is now grey, equiluminous with red. This cross never looks greenish, despite Kirschmann's Third Law, and it never looks pink. This is inconsistent with double-contrast theory.

red sectors gradually reduces the saturation of the pink sectors until these eventually look white. Careful observation of the central white test region shows that it now looks a very pale pink. The effect is small but the induced hue is undeniably pink and not greenish. But notice that at this point the rotating sectors contain neither physical green nor subjective green, so there can be no double-contrast. (It is true that if inspection is prolonged further, the pink sectors do start to look greenish).

Brian Rogers (personal communication) has proposed instead that hypothetical boundary detectors become adapted. Consider that a vertical red/white edge can be sensed by a pair of hypothetical opponent channels, one channel tuned to a red/white edge, the other to a white/red edge. In the absence of a chromatic edge both channels will be silent, or if they do fire they will fire at the same rate and cancel out, since they inhibit each other. (Red vs. white can be generalized to long vs. medium wavelengths). Consider a white/red edge on the right side of the white cross in Movie 3b. While the surround is red, inspection will stimulate and adapt out a white/red detector, leaving unscathed the opponent red/white detector. This will make the cross look pink during the white phase of the surround. While the surround is white, no further adaptation will occur, but this white phase provides a brief afterimage of the phase when the surround was red.

This is similar to a well-known phenomenon: if one fixates steadily on white letters in a red surround and then switches one's gaze to a white test field, the resulting afterimage consists not of white letters on a green surround but of red letters on a white (or possibly faintly green) surround. This phenomenon was reported by Ferree and Rand (1933) and extensively studied by Anstis et al. (1978). And, just as in Anstis et al. (1978), it can be true that the induced effects (in surrounded areas) can be stronger than the color in the inducer area. This story does not require that any subjective green is ever perceived.

Given these phenomena, we can propose two plausible 'pink routes'; adaptation to the red sectors in Movie 1a produces a negative afterimage (green) that induces its complementary color (pink) into the central region; or else the subjective green already induced into the central region has a negative afterimage, which is again pink. In both cases the pink color induced into the central region is enhanced by the outlines (Daw, 1962) and presumably is therefore much more visible than any intermediate greenish tint.

A third hypothesis would invoke anchoring. If the white sectors in Movie 1a are always interpreted as 'white', then when adaptation makes them greenish they will still be labelled as 'white', making the unadapted central white disk to be assigned as 'pinker than white'. And if one fixates a point in the surround of Movie. 1, such as the letter 'a' or 'b', the sectors still look white but careful observation shows that the background as a whole, where there are no disks, does look a pale pink. So the influence of the white sectors extends far out into the much larger area of the surround.

Clearly the mysteries of the pink illusion are not yet fully resolved.

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