Seeing red: hacking anaglyph 3D to manipulate visual perception

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Seeing Red extends our exploration of colour perception in print. Using the red/blue colours of the stereoscopic anaglyph 3D effect, *Seeing Red* investigates an approach that deconstructs and repurposes the functionality of this effect. The procedures and techniques are hijacked to communicate fundamentally different messages within the same image.

This investigation was inspired by our previous success in controlling perceptual experiences between audiences of varying visual acuities (colour blindness). Communication of the experiences between targeted audiences was enabled using augmented reality software on digital devices. The current work seeks to establish a similar effect for a broader audience without reliance on high-tech mediation.

The core principle of anaglyph 3D is that two slightly different, overlapped 2D images, one shifted red and one shifted blue, create a 3D simulation when viewed with filtered glasses. In *Seeing Red*, right and left eyes are individually targeted to create separate visual experiences by using colour palettes that can be effectively filtered by anaglyph 3D glasses. Within the overall compositions, hidden images are revealed to the viewer when they close their left or right eye.

The concept of intentionally providing slightly differing images to each eye which the brain would combine to mimic depth perception were explored simultaneously in the early 1830s by rival scientists and inventors Charles Wheatstone and David Brewster. Their inventions are called stereoscopes.

Because photography was still in development, both early stereoscopes relied on pairs of drawings. Many of the drawing pairs were of similar forms or objects rendered from two different angles to simulate the slightly different views from right and left eyes. These two images, whether they are drawings or photographs, are called stereo pairs. Using a stereoscope, the simultaneous viewing of the stereo pairs results in the visual perception of a 3-dimensional object (Zone, 2007).

We know that viewing slightly different images, when directed to different eyes, can create a 3D effect (Sekuler and Blake, 1990). When the stereo pairs of a stereoscope are combined into a single image, it is called anaglyph 3D. One image is printed in red, the other is printed in cyan. The printed image may look somewhat off register. For the 3D effect, a pair of glasses, with one red lens and one cyan, is worn. The red lens filters out the red image and so the eye with the red lens sees the cyan image. The cyan lens filters out the cyan image and the eye with the cyan lens sees the red image. The visual information from each eye is combined in the visual cortex of our brain to form a 3D image.

The red and cyan filters used in Anaglyph 3D were chosen because of their relationship to how our eyes perceive colour. Human eyes perceive colour through three types of light receptor on the retina called cones. The three types of cone are distinguished by the wavelength of light that they respond optimally to; there are long wavelength, mid wavelength and short wavelength cones primarily detecting reds, greens and blues, respectively. When all three types of cone are functioning correctly, we perceive the full spectrum of colours. Red and cyan filters are used to approximate a full colour image. Red targets red. Cyan, being a combination of blue and green, targets those two colours. While not a perfect parallel to our three cones, it is effective.

Repurposing Anaglyph 3D

From our previous work on colour blindness and visual perception we know that if one of the three types of cones do not function that person's perception of certain colours is different than someone with fully functioning cones (Lyons and Flatla, 2018). With this knowledge, we were able to group colours together so that the visual experiences would be radically different (but intentionally designed) dependent on one's visual abilities.

Initial experiments were done manipulating images to create different experiences for viewing through right and left eyes. Images were created where fingers moved and eyes blinked (Figure 1).

Figure 1. When wearing anaglyph glasses, eyes appear to independently blink when viewed through only the right eye and then left eye.

Artists know that visually, most people tend to group warm colours (reds and magentas) and cool colours (blues and greens) separately. Thus, contrast can be created using cool colours and warm colours. Those with fairly common red-green colour blindness exhibit different colour grouping preferences. They tend to group what others consider red and green colours together because, to them, they all appear as muddy yellows. Similarly, blues and magentas are grouped together because they all appear blue. Colour contrasts for these audiences are most easily made using blues and yellows.

So, for the typically sighted, red and magenta are a pair of warm colours. The contrasting cool colours are green and blue. For those with red-green colour blindness, blue and magenta are similar colours with both appearing blue. Colours that are visually contrasting to them are red and green, which both appear as yellow-browns.

Using this knowledge of different colour perception by these two different groups, we were able to group the colours strategically, allowing for the creation of visual messages to one audience which were camouflaged to the other.

While red-green colour blindness is caused by non-functioning red or green cones in both eyes, the anaglyph effect is created by targeting either red cones in one eye, and blue and green cones in the other, thus creating an artificial parallel to colour blindness, although different for each eye. Because of that similarity, it was hypothesised that we could create a similar way of grouping colours using anaglyph glasses.

To understand how colours shift when filtered red or cyan, and how to group them effectively, we started with a spectrum of 10 colours: red (E52421), medium violet (A6529A), dark purple (624595), light blue (3EC0F0), dark blue (2D509F), grey blue (438DCC), blue green (6BC0AD) green (6CB646) yellow (F3E600) and orange (F49819).

A 2 x 5 square grid pattern was created in Adobe Illustrator. Each one of the 10 squares was assigned one of the 10 colours.

To be able to do a side-by-side evaluation of the anticipated colour shifts viewed through the lenses of the anaglyph glasses, a simulation of the colour shifts was created in Illustrator. The resulting colours did not match what was observed when looking through the anaglyph glasses. The idea of doing analysis of the colours on the computer screen was abandoned. Instead, each of the 10 colours was viewed on its own and then with an eye looking through the red lens of the glasses. Illustrator Color Picker was used to identify the red-shifted colour in each case, to generate a new palette of 10 red-shifted colours. The same process was applied to the original 10 colours using the cyan lens of the anaglyph glasses to generate a second new palette of 10 cyan-shifted colours. In most cases, the baseline colours had to be adjusted to maximise the visual impact of all three sets of colours. This was an iterative process.

The expanded, refined colours and the colours they shifted to when observed through the red and cyan lenses of anaglyph glasses are described in Table 1.

Table 1. Baseline, Red-Shifted and Cyan-Shifted Colour Sets

Original Colour	Red Lens	Cyan Lens
Pink (EC6798),	Bright Light Red	Medium Red
Red (E5087E),	Bright Light Red	Dark Red
Orange (EF7715)	Red	Orange
Yellow (F1E511)	Orange	Yellow
Green (6CB646)	Light Blue	Green
Light Blue (40C0F0)	Dark Blue	Light Blue
Medium Blue (0CB0DD)	Dark Blue	Light Blue
Dark Blue (009ABC),	Dark Blue	Medium Blue
Violet (B399C9)	Medium Red	Medium Blue
Medium Grey (888988)	Light Blue	Dark Blue
White (FFFFFF).	Light Red	White

With this information we can break colours down into groups that look like reds when filtered with the red lens, and those that look blue when filtered with the cyan lens. Additionally, we can identify colours that are neither red nor blue when filtered. This is documented in Table 2.

Table 2.

Original Colour	Filtered Red Looks Red	Filtered Cyan Looks Red	Filtered Red Looks Blue	Filtered Cyan Looks Blue
Pink	X	X		
Red	X	X		
Orange	X			
Yellow	X			
Green			X	
Light Blue			X	X
Med Blue			X	X
Dark Blue			X	X
Violet	X			X
Med Grey			X	X
White	X			

This exercise demonstrated that, for the most part, whether filtered red or cyan, reds remain red and blues remain blue. Helpfully, violet looks red when filtered red and blue when filtered cyan. Orange shifts red when filtered red. Green shifts blue when filtered red. Grey shifts blue when filtered red or cyan. White shifts red when filtered red but remains white when filtered cyan.

To create images to be viewed through the red lens, we contrasted colours that appear red and blue when filtered red. The red colours are pink, red, yellow, orange, white. The contrasting blue colours are green, light blue, medium blue, dark blue, grey.

Images to be viewed by the cyan lens would also contrast red and blue colours when filtered cyan. The red colours are pink and red. Where red and blue imagery overlapped, violet was used because it shifts both red and blue.

Moving from RGB monitor colours to CYMK print colours caused colours to shift. The effect some colours had when viewed on the monitors would not reproduce once digitally printed. Adjustments and compromises were required. Compounding the gamut issues was ambient light and the differences between brands of anaglyph glasses. Through careful observation and adjustment, colours were fine-tuned to be optimal for prints viewed in daylight with minimal effect caused by variations in glasses quality. The final colour set documented above reflects those adjustments.

Initial Tests

The first test that grouped colours into perceived reds and perceived blues was a grid made of 32 x 32 squares. Repeated medium blue and violet squares made up rows that alternated with rows of repeated green and red squares. The intent was to create a gingham pattern which when filtered red would appear as a series of vertical stripes. When filtered cyan, the composition would look like horizontal stripes. The test gave the anticipated results (Figure 2).

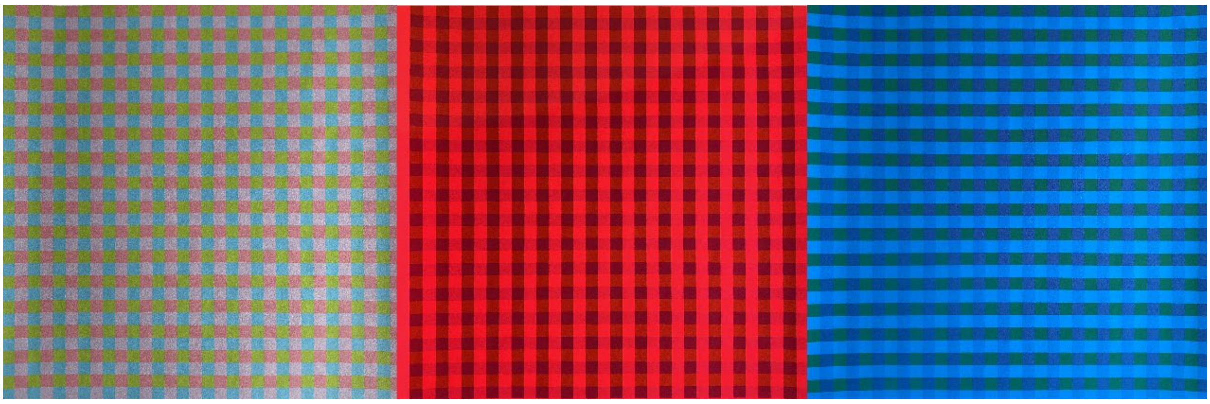

Figure 2. Left: Photograph of original pattern. Centre: Red filtered photograph of original pattern. Right: Cyan filtered photograph of original pattern.

Having established that simple conflicting messages could be communicated to each eye, more complicated hidden imagery was attempted.

A composition of nine squares, laid out 3 by 3, was created. Each square contained related compositions testing combinations of contrasting colours. Each, when viewed through the red filter, the cyan filter and unfiltered, appeared strikingly different (Figure 3).

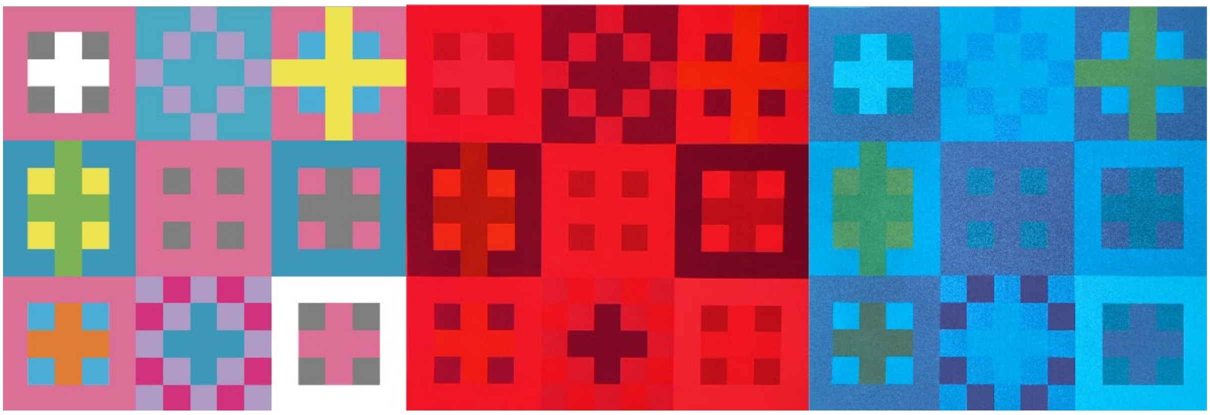

Figure 3. Left: Original layout. Centre: Red filtered photograph. Right: Cyan filtered photograph.

Conclusion

The initial experiments have promising results. Both image and colour experiments reveal imagery can be created that not only targets individual eyes with anaglyph glasses, but when viewed unfiltered through both eyes create cohesive images. The variety of colour explored here was limited. A greater range of hues, shades, tints and tones may reveal enhanced effects. If similarly created imagery is to be viewed on its own, cyclical environmental lighting (full spectrum, tinted red, tinted cyan) may be a substitute for the anaglyph glasses. Finally, appropriate imagery, which moves from proof-of-concept layouts into multi-layered expressive images, will be best placed to utilise these results.

References

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