The effect of color blindness on seismic interpretation

Gaynor S. Paton, GeoTeric*

Summary

The use of color is a fundamental part of seismic interpretation, yet everyone perceives color in a slightly different way, and some individuals cannot differentiate between certain colors. This study aimed to investigate the effect of color deficiency (commonly known as color blindness) on seismic interpretation.

Introduction

Seismic interpretation involves visual identification of geological features and anomalies often with the aid of attributes that isolate certain characteristics within the seismic signal. The information within the reflectivity or attribute data is displayed by mapping data values to different colours. Different mappings can be used depending on whether the goal is to differentiate gross changes such as high from low, good from bad, or to show more subtle variations such as changes in reflector orientation or frequency content, or simply to create block coloured facies maps. In all cases color perception impacts on how the information is communicated and the geological understanding that is gained. But what happens if an interpreter cannot differentiate red from green? Apart from the obvious confusion this can cause with well symbols (red for gas, green for oil), does it have an effect on their ability to interpret seismic data? The human brain is remarkably adaptive and will often compensate for a deficiency in one area with a heightened awareness in another area. So, whilst color blind people are less reliant on color discrimination do they have a heightened “awareness” to other factors, and what would those be? The principal question this study aimed to investigate was the impact that color blindness might have on interpretation effectiveness.

Color Blindness

Color blindness, or more accurately color deficiency, is caused by a reduction in the number of cones in the eye, the cells responsible for our detection of colour. Most of the population have 3 types of cones which are activated by different wavelengths of light, generally referred to as red, green and blue cones. A deficiency in any of the cone cells makes it harder to differentiate between certain colours. Most common is a deficiency in the green cones (deuteranopia), followed by red (protanopia), both of which are symptomatically similar due to the overlap of their absorption curves (fig 1b). Also possible is a deficiency in the blue cones (tritanopia), although this is very rare. Individuals who have a red or green deficiency will see red, orange, yellow and green as shades of muddy yellow, and will see pink, purple, blue and turquoise as shades of blue (Fig 1a). People who are blue deficient will see the world in shades of red and turquoise. There is general agreement that worldwide 8% of men and 0.5% of women have some form of color deficiency.

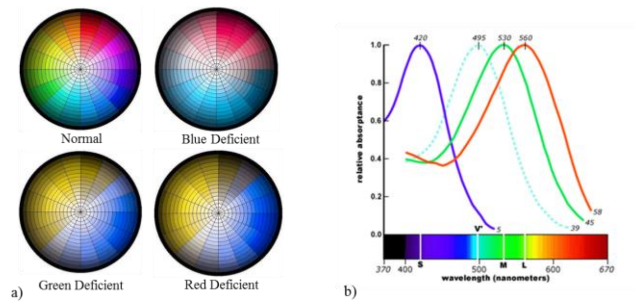

Figure 1. a) The effect of color deficiency on the colours perceived in a standard color wheel (color translation courtesy of vischeck.com), b) Normalised human photopigment absorption curves, wavelength of peak absorption in italics, number of photoreceptors measured at the end of the curve, solid line represents the response of cone cells, dotted line represents the response of rod cells (data from Dartnell, Bowman, & Mollon, 1983).

Study Participants

In this study color sensitivity was investigated using Ishihara plates which determine an individual’s ability to identify numbers within a circle containing dots of mixed size, color and tone. This is a standard diagnostic test for color deficiency and was used to identify the members of each group in this study. Our volunteers included 19 individuals with normal color vision, and 5 with a color deficiency. All participants had geoscience experience although not all of them were seismic interpreters. The age range of the participants varied from 20 to 74 years old, and the experience level also varied from students up to 30+ years of seismic interpretation.

The effect of color sensitivity on seismic interpretation

Four different interpretation tests were performed by the volunteers, each one aimed at investigating a different aspect of the decision making process that could be influenced by color perception. Each test was a task that is commonly performed as part of a seismic interpretation workflow.

Fault Orientation

The aim of this test was to ascertain whether color had an impact on the interpretation of fault orientation, and whether that differed between the two sample groups. The volunteers were shown a time slice of a Fault Detect attribute where the automatically detected faults were visible as black lines of a uniform thickness. The volunteers were asked how many fault orientations (fault strike) were present in the data. When the image was presented in black and white, both groups returned a wide range of orientations, from 2 to 8 in the normal group and 2 to 5 in the deficient group. When the question was repeated, this time with color representing the different orientations the results were more focussed, in the range of 3 to 5 for both groups. There was very little difference between the number of orientations identified by the two groups, irrespective of whether the image was in black and white or in colour. The fact that in both groups the color image resulted in a narrower range of values suggests that color may help to standardise the interpretation between individuals, irrespective of whether they have a color deficiency or not.

Reflector orientation

DipAzi combined volumes are often used to identify structural changes including major and minor faulting, anticlines, synclines and domes (Fig 2). The color saturation represents reflector dip, and the color hue represents the azimuth, or reflector orientation. Opposing colours indicate ridges, valleys and fault drag. In this part of the study the participants were asked to draw polygons around the zones of differing reflector orientations. Some of the orientation changes in the image are abrupt, others gradually change from one to the other and all have different shades and colours within one zone (a bit like the Ishihara plates). When the polygons from the two groups are displayed, distinct similarities and differences are visible (Fig 2), suggesting that some boundaries are equally visible to the two groups whereas others are harder for the color deficient group to discern.

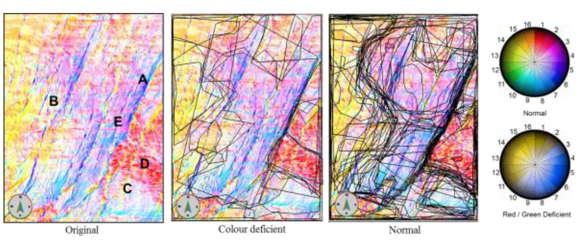

Figure 2. Interpretation of reflector orientation. Polygons drawn by individuals in each group are displayed on the test image, along with the color bar and a representation of how the color bar may be perceived by red or green deficient individuals. Letters indicate particular boundaries of interest.

The blue lineation marked “A” in figure 2 represents a fault and this was identified as an orientation boundary by both groups, as was the strong boundary “C” which shows a hue change and a saturation change. The NW-SE boundary marked “B” was also identified by both groups and the exact positioning of the boundary was equally uncertain (identified by the wide scatter of black lines). Across boundary B the reflector orientation changes from pink (hue 3) to yellow (hue 14) both of which are colors that are visible as different hues in those subjects with a color deficiency. Interestingly, the normal group extended that boundary to the south east, “E”, differentiating a zone of pink (hue 3) in the north from a zone of blue (hue 7) in the south, whereas the color deficient group did not differentiate those zones at all. For the color deficient group those zones all appeared as shades of blue and the variability within each zone masked any subtle difference between the northern and southern areas.

Stratigraphic features of interest

Identification of features of interest is a fundamental component of seismic interpretation. In this part of the study we were investigating the influence of color on identification and interpretation of stratigraphic features, by showing the participants an Envelope volume mapped onto a horizon. In that display color represents amplitude with greens and reds indicating the highest amplitude areas. The participants were simply asked to draw a polygon around “any stratigraphic feature of interest”. They were told what the volume was and what it represented (seismic amplitude) and were shown the color bar.

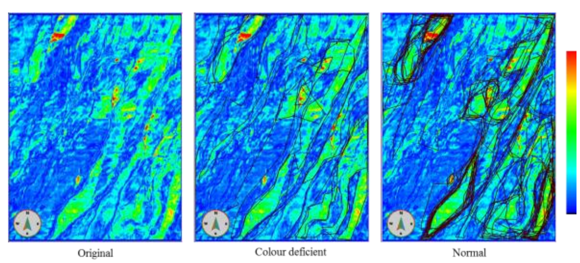

Figure 3. Interpretation of “stratigraphic features of interest”. Polygons drawn by individuals in each group are displayed on the test image.

The results showed that both groups identified the main high amplitude features (Fig 3), but the color deficient group interpreted more “channel like” features in the lower amplitude areas. In the normal group only 4% of polygons were drawn around low amplitude features (3 polygons from 2 interpreters), whereas in the deficient group 21%

were low amplitude features (6 polygons from 2 interpreters). This could suggests that the deficient group were less influenced by the bright red colours and therefore more aware of subtleties in the data, or it could simply be that those 4 individuals work in areas where low amplitude is important and they are therefore more tuned to low amplitude features. With such a small sample size it is hard to draw causal conclusions, however through conversations with the deficient group it became apparent that shape was equally important as color in attracting their attention. Any seismic interpreter will say that shape is a key consideration, but it was noticeable in the commentary during the experiment that focus was first and foremost on color in the normal group with shape being a secondary consideration. All the features identified by the normal group were also identified by the color deficient group.

Interpretation Confidence

Reducing ambiguity improves confidence in the accuracy of an interpretation. Color bars can be used to both reveal information and also to hide it. Monochromatic color bars are more effective at highlighting edges and linear features due to the avoidance of false contours (Froner et al., 2013, Paton and Henderson 2015) whereas polychromatic color bars are more effective at highlighting zones of continuity or stability of response. As color deficient individuals generally have problems differentiating between red and green (as well as other colours), and these are two of the key colours in one of the principal color bars used for attribute interpretation (the Rainbow or Spectrum color bar), we wanted to investigate whether other color bars would give individuals a greater understanding of the data. In addition, three dimensional color bars such as RGB blends have become a standard method of displaying seismic attribute data, and are generally considered to be more intuitive to look at despite being more complex and conveying more information than a single volume displayed with a linear color bar. We were interested in investigating whether a color deficiency had an impact on the effectiveness of RGB blends. Participants were shown an Envelope volume with 4 different color bars and an RGB blend of three frequency bandpass magnitude volumes. All the images showed the strength of the seismic response along a horizon which contained a channel. The participants were asked which image would give them the greatest confidence in their interpretation of the channel.

In the normal group the vast majority of the participants felt the RGB blend would give them the greatest confidence in their interpretation, whereas in the deficient group the results were more uniformly spread across 3 color bars (Fig 4). It appears that within the deficient group there is no strong color bar preference. Again this was backed up in conversations with the group where they indicated they regularly rotated the color bars used for seismic interpretation in order to see the information most effectively.

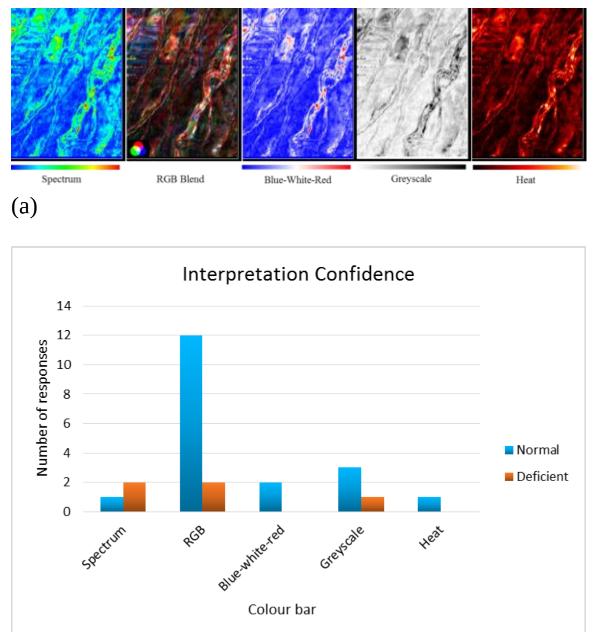

Figure 4 Interpretation confidence in relation to the color bar used to display the information. a) the same data displayed with different color bars, b)the number of responses per color bar to the question of interpretation confidence.

Discussion

Color is an integral part of how we interpret everything that we see, and it is also fundamental to how we communicate with each other, especially when trying to transfer information through reports, presentations and meetings. It is very easy to forget that not everyone in the audience will perceive color in the same way as we do, and therefore what appears obvious to us in an image, may be ambiguous to the person we are talking to.

What this study has shown is that there are differences in how individuals with a color deficiency interpret seismic data when compared to individuals with full color vision. What was also apparent during the study, which is hard to capture in anything other than an anecdotal form, is how the interpreters from both groups tried to “work out” what was going on in the image. It wasn’t simply a case of seeing a color and drawing around it, many were trying to figure out the context of the color they were seeing, and how it related to the other colours (and features) around it. It was their assumed understanding of the bigger picture that influenced their decisions on the answers they gave. Therefore one of the conclusions from this study, which is supported by both the fault orientation and the polygon experiments, is that an awareness of the context of the image that is being interpreted is as important as how the image is displayed. This was important for both groups in the fault orientation experiment, and especially important for the deficient group in the stratigraphic features experiment. Interestingly the RGB blended images were no more challenging for the color deficient group to interpret than the linear color bars when looking at gross scale features (data not shown). However one of the advantages of RGB blends is in revealing subtle variations and compartmentalisation within a reservoir which are indicated by specific changes in colour, rather than by saturation or shape. It is anticipated that in these circumstances color deficient interpreters will not be able to differentiate the zones as effectively, and that is perhaps an area to investigate in a follow up study.

It should be noted that this study has some significant limitations which prevents more definitive conclusions being drawn. Firstly, the sample size is low so we are unable to carry out meaningful statistical analysis of the results. Another consideration is the light under which the test was performed. Not all the participants were tested at the same time or place and the lighting in the different test locations differed. This can have a significant impact on how we perceive color (just think of the black/blue or white/gold dress that was an internet sensation during 2015), although in this instance its impact is likely to be limited as we were not asking individuals to identify colours specifically but features represented by the colours. An interesting outcome of this study is the compensation mechanisms that the color deficient group used in order to try and understand the colours they were seeing and to interpret them effectively, either using shape as the primary hook for spotting a feature, or using changes such as subtle faults to infer changes in reflector orientation. It would be interesting as the next steps for this study to see what happens when those compensation mechanisms cannot be used. For example, looking at subtle variations in an RGB blend to show reservoir heterogeneity, this will not necessarily conform to any anticipated shape, and the variations may be gradual and in any direction within the three dimensional color space of an RGB blend (a bit like the reflector orientation study but without the faults as a guide). Likewise, looking at simple blocked facies maps, where discrete colours represent specific rock properties, how easy is it for color deficient individuals to match the color in the reservoir image with the color key on the side of the image?

All interpretations are a matter of opinion, using an understanding of the available data, mixed with prior knowledge and experience. Color deficient individuals have a different way of seeing an image and this results in an alternative interpretation based on a different weighting of the available information. Perhaps more important is the consideration during meetings and presentations that what jumps out to normal sighted people is not necessarily the most obvious feature to someone with a color deficiency.

Acknowledgements

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EDITED REFERENCES

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