Haidinger’s Brushes

Some people can ‘see’ the polarization of skylight, (predominantly blue wavelengths scattered by air molecules in the atmosphere) and some can’t. The reason for that is obscure. Most visual abilities, like 3D binocular processing, are widely shared. In this case the ability to see Haidinger’s brushes against a blue sky appears to be due either, to failure to suppress an annoying anomaly at the visual processing stage, or to real differences in the arrangement of blue sensitive cones on the macula. Since the reported appearance of the brushes varies with observers this account will be illustrated with simulations that match as far as possible what the writer sees.

Haidinger’s brushes

A polarizing filter on its own or with an additional blue filter intensifies the effect and can be used as a first step to unaided observation.

Fig 1 - A small sheet of Polaroid and a book of ROSCO colour filters used for the demonstrations described below.

Bright white clouds in an overcast sky provide an intense extended source of white light that contains all wavelengths from the violet to the red. The personal observations illustrated below were made in mid-morning on an overcast day at KVIS with the sun at 50-55 degrees elevation. The colours shown in figure 2 below were first described in 1844 by an Austrian Geologist, Wilhelm von Haidinger, who called them ‘brushes’ because they resemble the outline of the double-ended shaving brushes used at the time.

1 Polaroid (with no additional colour filter)

A Polaroid filter was held close to the eye. After 5-10 seconds it was rotated 90º giving the brushes shown below that spanned 3º against the clouds.

Fig 2 – Haidinger's brushes against white cloud immediately after Polaroid rotation.

In figure 2 a faint blue horizontal brush is crossed at right angles by a stronger yellow brush. The yellow brush appears to span about 3º in the sky, which is the angular size of the central circular region of the retina called the macula. Some people claim that the blue is an enhancement illusion because of the transition to yellow but as will be seen below this is not the case. The brushes are an effect on the macula, and cannot be photographed. Figure 2 is a simulation that matches as closely as possible what the writer observes. Over five seconds the brushes in figure 2 faded as the retina became desensitized. Rotating the Polaroid 90º restored and rotated the pattern. The cycle could be repeated any number of times.

As will be seen below the blue brush results from the detection of blue light with electric vector in that direction (horizontal in figure 2). Failure to detect this polarization at right angles leads to the yellow brush (yellow being the absence of blue in the background spectrum of white light).

2 Polariod with a yellow filter: ROSCO #15 (Deep Straw)

Observing clouds through a Polaroid with a yellow filter such as ROSCO #15 (Deep Straw) that removes all wavelengths of less than 500 nm produces no effect when the polaroid is rotated. The same result follows if a red filter is used. The negative results are common to all observers, showing that the observation of brushes is confined to blue-violet wavelengths shorter than 500 nm. Only blue sensitive cones on the macula are involved.

3 Polariod with a magenta filter: ROSCO #58 (Deep Lavender)

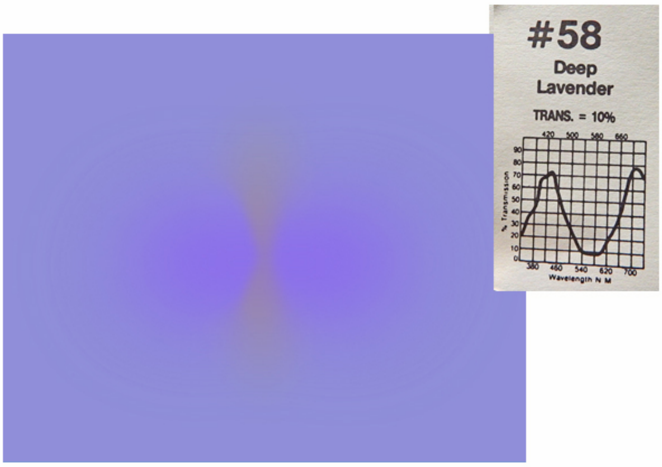

Fig 3 – brushes seen by the writer immediately after Polaroid rotation with ROSCO #58.

The Lavender filter leaks in the green region of the spectrum and more in the red. The response of the eye is approximately normal and is less than 4% at 450 and 670 nm. The blue brush is relatively stronger and than in figure 2, has a magenta tinge, and is more extensive. The yellow brush is dull and more violet than in figure 2.

4 Polariod with a deep-blue/violet filter: ROSCO #385 (Royal blue)

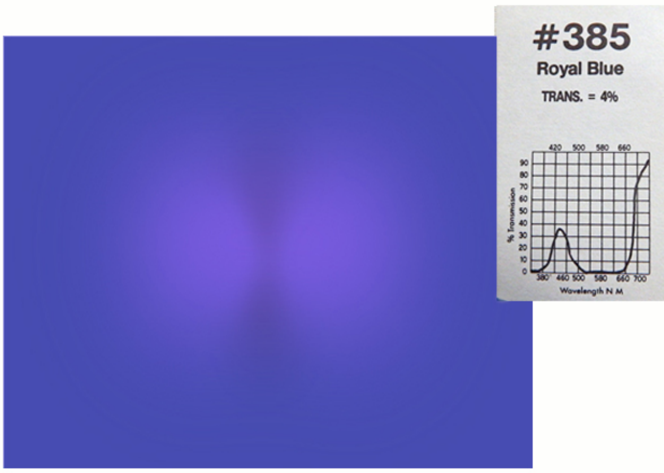

Fig 4 – the brushes seen by the writer immediately after Polaroid rotation with ROSCO #385.

ROSCO #385 transmits only 4% of the available white light and leaks very little in the green/red region. The blue brush is more extensive, nearly circular, and has a magenta tinge. The perpendicular brush, (seen as yellow in the absence of blue light against a white background), is now dark. With this filter the author sees the blue brush flash a bright light blue for half a second or so after rotation. It then quickly fades to the colour shown in figure 5.

Figures 3 and 4 show the effect of progressively removing background light of longer wavelengths. The yellow brush (due to the failure of the macula to detect blue) fades and eventually becomes dark as almost all green to red background light is removed.

After effects

The appearance of the brushes shown in figures 2-4 alters over 5 to 10 seconds as the photoreceptors on the macula become saturated. The effect is similar to the retinal fatigue that leads to after images in complimentary colours. Deliberately conditioning the macula by looking at the background through a selected filter before observing the brushes with ROSCO #48 and a rotating polaroid gives the colour changes below.

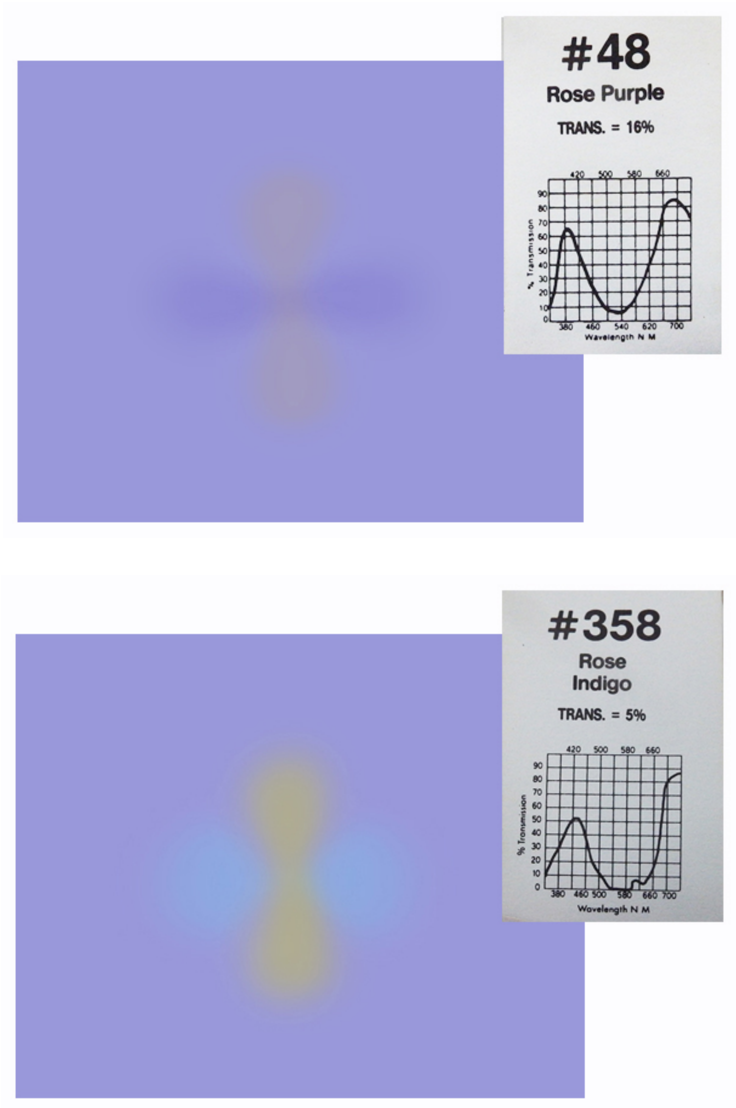

Fig 5 – brushes seen by the writer immediately after Polaroid rotation with ROSCO #48 without conditioning (above) and with 5 seconds of conditioning with #358 (below).

Both brush sets in figure 5 were observed through #48. Preconditioning the eye with a yellow filter (ROSCO #15) had no effect on the brushes. Preconditioning with #358 greatly changed the colour and shape of the blue and enhanced the yellow.

Preconditioning with a Polaroid-#358 combination gave a pale blue brush in one direction only indicating involvement of oriented blue photoreceptors in the conditioning process. The difference is remarkable given the short conditioning time and the small difference in the blue/violet transmission of the filters. Multiplying the response of the eye with wavelength by the percentage filter transmission maintains the similarity of the two filers. Twenty seconds rest is required to return the appearance of the brushes from the lower to the upper view in figure 5 and then the cycle can be repeated. The result suggests that there may be two different types of blue photoreceptor molecules in the blue cones on the macula, or there may be two different populations of blue sensitive cones. *Trials with different filter combinations and different observers are required before any definitive statements can be made.*

Observations against a blue sky

The writer has a long history of looking for the brushes in the sky and what follows is a personal account.

> *I first became aware of the existence of brushes on reading a book of demonstrations in Physics by Julius Sumner Millar in the early 1970's.*
> *The yellow brush was always clearly defined when I used a rotating Polaroid against a blue sky. The blue was visible but fainter (figure 6).*

Fig 6 – the brushes immediately after Polaroid rotation, seen against a blue sky with no additional filter.

> *For 20 years (before I reached the age of 50) I looked on many occasions for the brushes 90 degrees from the sun without a Polaroid but failed to see them. After the age of 50 I began to find a reliable faint yellow brush pointing towards the sun in the late afternoon. The yellow brush was always there: always faint, narrow, appeared after 5 to 10 seconds of looking, and always pointed towards the sun. Two colleagues informed me that they saw a blue brush in the sky but I was unable to see the blue (without a Polaroid) and assumed that my eyes were in some way different, failing to see blue unless the light was completely polarized.*

Fig 7 – the faint naked-eye yellow brush seen on many occasions by the writer overhead in the late afternoon.

I was experimenting with filters and made the observations reported above over several days. It occurred to me to try again to find both brushes overhead near sunset without a Polaroid. To my surprise after five seconds of looking at the narrow yellow brush the blue appeared: relatively bright, of a stronger blue than the sky, and the yellow had strengthened and enlarged to match the blue. See figure 7 for a simulation that reproduces a reasonable approximation of the colour and shape of the brushes but not their luminance.

Fig 8 – both naked-eye brushes now seen by the writer overhead in the late afternoon, and at other times.

The simulation in figure 8 was made in layers with the yellow brush formed from the blue by inversion.

Now, after having seen them once, both brushes are in the sky near sunset and at other times during the day. My experience has suddenly changed after having looked at brushes through filters and making the simulations in figures 2-7. The most likely explanation is that the visual processing function of my brain has suddenly failed to suppress the blue brush. The abrupt change in perception has been dramatic and cannot be explained by having learnt to pay attention, by having learnt what to look for, or by uncontrolled changes on the retina.

We are mistaken to think that we 'see' with our eyes. Those who regularly suffer visual disturbance with migraines know about the overriding importance of the processing functions of the visual cortex. So do the rare individuals with brain damage who can see water but not water in motion, and my grandfather who suffered what was described as sudden, permanent, psychosomatic blindness.

Routine procession in healthy individuals removes floaters, blood vessels in front of the retina, and the blind spot. Random dot stereograms are rendered as layered 3D images with holes and tilted layers by processing. Stereograms with complex random areas degraded by blurring or omission are reconstructed in the brain as sharp complete 3D images, independently of conscious thought or control. The visual system makes its own decisions. All of these functions are common to the vast majority of individuals.

It appears that my brain has suddenly stopped eliminating the annoying brush that slightly obscures the sharp clear central view of a bird in flight in a clear blue sky. I suspect that many people do not see the brush in the sky because their visual system treats it in the same was as blood vessels, floaters, and the blind spot and eliminates it from the reconstructed image. What I now see has been processed out of my view (against my conscious effort) for most of my life.

Future work

If the analysis above is correct, given the dependence of the appearance of the brushes on the viewing conditions and recent history of light on the retina, and the suggestion that the visual processing functions remove the brush unless it is too bright to be ignored, the individual variations reported may have more to do with processing issues than with differences in the construction of the retina. A study is suggested with a large sample of individuals under carefully controlled conditions to determine the relative importance of the competing factors. It may be found that since the ability serves no useful function, evolution has not produced similar structure on the macula, but given the similarity in the visual systems of individuals in other respects that is unlikely.