

## ***Aliens among us: Preliminary evidence of superhuman tetrachromats.***

by Ryan Sutherland

"Oh, everyone knows my colour vision is different," chuckles Mrs. M., a 57-year-old social worker, in an interview with *Red Herring Magazine*. "People will think things match, but I can see they don't." That's because Mrs. M. is a 'tetrachromat' — she sees colours that most of us don't.

The human eye can normally resolve millions of colours, though we use only three colour sensors. This three-dimensional colour vision system is unique to humans and Old-world primates, and is known as *trichromacy* (3-colour). Elsewhere in the animal kingdom, other types of colour vision abound. Insects exhibit some of the more impressive systems: bees are tetrachromats (4-colour) and can see more ultraviolet light than humans, and many butterflies are *pentachromats* (5-colour).

Genetics studies as early as 1948 suggested that it may be possible for some humans to possess tetrachromat vision. (Zorpette 2000) Recent testing has revealed the first strong evidence of people who see more colours, but many questions remain unsolved...

### ***There's more to colour than meets the eye:***

The way we perceive colour depends on the combination of the responses from cone cells in the retina. Normally, there are three different types of cone, each sensitive to a different range of colour: red, green and blue, yielding three dimensions of colour. Each of these photopigments is sensitive to a wide range of colours, but their sensitivities are peaked at the respective wavelengths. As a result, every colour (wavelength) corresponds to a unique combination of relative signal strengths from the three sensors. (see Figure 1)

In humans, the genes for green and red pigments are both located on the X-chromosome. Since women have two copies of this chromosome and men only one, deficiencies in green/red colour vision is more common among men. Some 16% of women are carriers for colour-blindness, and about 8% of men have some abnormality in colour vision. Lacking the genes for one colour yields *dichromatic* vision, normally referred to as *colour blindness*, but it is also possible, although very rare, for someone to completely lack all cone cells, causing *monochromatic* vision. There is much to learn about the

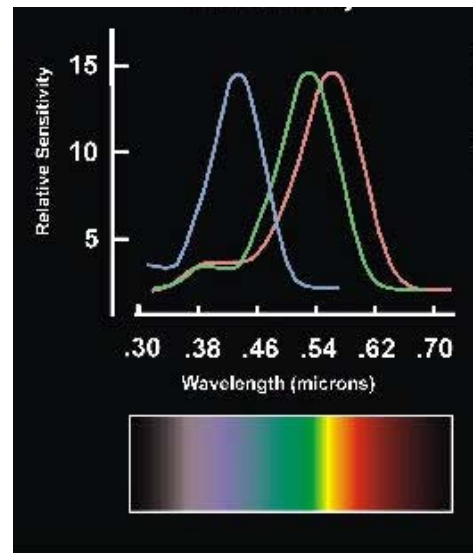


Figure 1: Human trichromatic vision.

differences in colour perception. Seeing fewer colours is not necessarily a disadvantage, and it remains to be seen whether seeing more colours will prove advantageous or not.

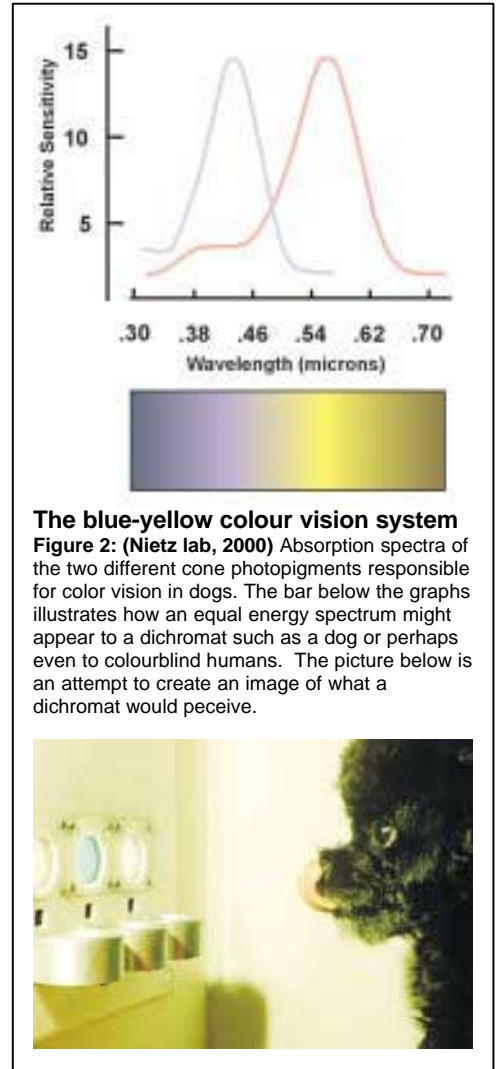
Colour-blindness was not even recognized until the 18th century, probably because so little artificial colour existed. Indeed, colour-blind humans seem to be at an advantage in searching against a background of natural foliage, such as picking berries or hunting animals. Similarly, the U.S. military have found that colour-blind soldiers can sometimes see through camouflage that fools everyone else. Furthermore, some cases suggest that people who are colour-blind may develop other sensitivities, such as Joseph O'Neil, an amateur astronomer whose colour blindness seems to have heightened his "night vision", with the unfortunate consequence of making his eyes overly sensitive to bright sunlight. (Hambling 2001)

Studies of perception throughout the animal kingdom reveal countless cases of genetic variation affecting visual perception. The majority of these cases involve impaired perception, but a select few suggest enhancements of visual perception. For example, squirrel monkeys are generally *dichromatic*, but research carried out in 1986 showed that many females possess genes that make them *trichromatic*, giving them a wider range of colours than their companions. (Hambling 2001) In theory, an analogous genetic process can have the same effect on humans.

Although humans see using three colours, there are actually two distinct colour systems at work. The primary system is the Blue-Yellow System, and is by far the oldest in evolutionary history, dating back about 800 million years. (Neitz 2001) This system forms the foundation of visual perception in nearly all known cases in animals and insects, and is the sole system in *dichromats*. In higher-level chromates, this system is layered with other visual systems, but of these, only the *trichromat* system of humans and similar primates is reasonably well understood. In this system, the Yellow diverged into a separate system of red and green. The Red-Green system operates independently of the Blue, while the Blue relies on the average of the Red-Green system, which is effectively a phantom Yellow. (see Figure 3) The result is a Red-Green system and a Blue-Yellow system built out of only *three* photopigments (red, green, and blue), hence it is called *trichromacy*. Recent studies reveal that a *third* system may have emerged based on either the Red or Green, producing *tetrachromacy*.

**Genetic possibility of tetrachromacy in humans:**

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Colour blindness is caused by a genetic mistake in which a photopigment gene is lost or replaced. The genes for the red and green photopigments are adjacent to each other on the X chromosome, while blue is way off by itself on another chromosome. During egg formation, the genes from the females' two X chromosome mix, and since the red and green photopigment are so close together, there is a chance of them getting mixed up. The most common error is that one of them will get left out. But by a genetic phenomenon called X inactivation, it can happen that the green of one X chromosome can replace the red of the other X chromosome, resulting in an X chromosome with TWO greens (or vice versa). A crucial fact in this process is that the two green genes will NOT be completely identical, although they will be similar enough to cause colour-blindness in the child. If a male inherits the malformed X chromosome, he will surely be colour-blind, but if the child is female, she will be a *carrier* of a malformed X chromosome. Here it gets interesting. When a female carrier of a mixed up X chromosome creates an egg, the new X chromosome may keep BOTH green genes, while also carrying the red gene. The result may be a tetrachromat, a person with a fourth photopigment between red and green. This process may in fact be the foundation of how the yellow diverged into the red-green colour system – a large enough genetic shift could create two exclusively distinct photopigments, providing the foundation for a secondary visual system.

**Looking for human tetrachromacy:**

For years, Dr. Gabriele Jordan and Dr. John Mollon of the University of Cambridge have been trying to confirm the existence of tetrachromats, by scouting for women who have had a son with a specific type a colour-blindness (namely, duplicate green or red photopigment genes). In one exercise, potential tetrachromats were asked to find a mixture of green and orange light that matched a particular shade of yellow-orange. For normal trichromats there should be a whole range of matches, but for a tetrachromat the added dimension means there would only be one combination that matched exactly.

The experiment showed that the potential tetrachromats were much more finicky about declaring a match to be exact, and made different matches to others. "I want to be able to add more orange to the mixture, not red," said one subject. "It's the wrong kind of orange," said another, "it looks

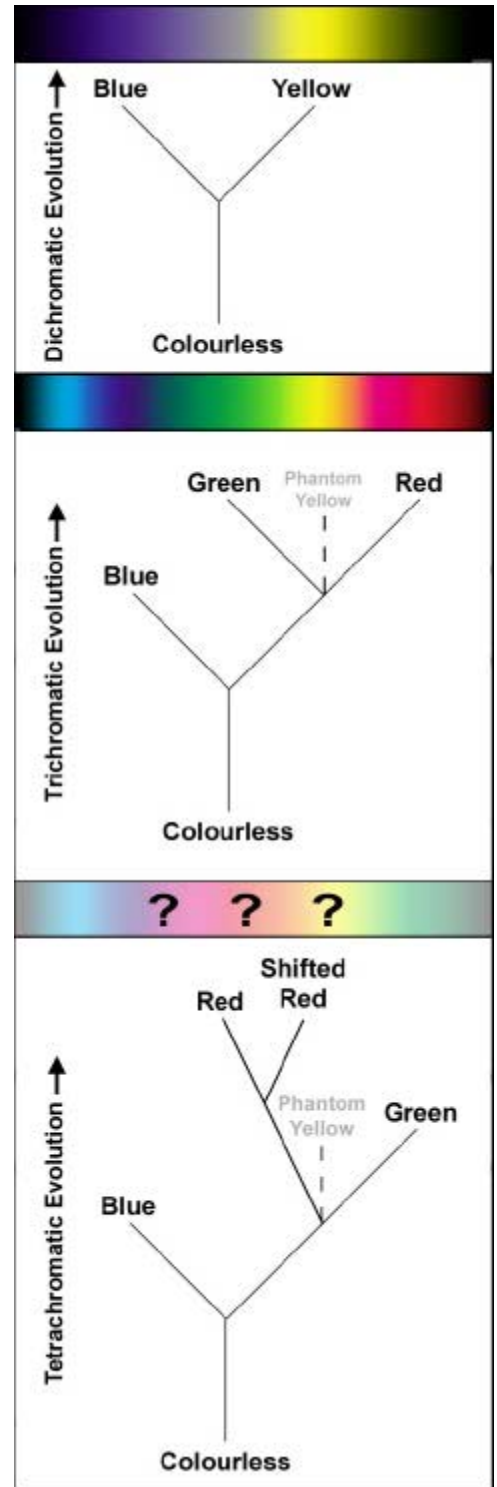


Figure 3: Chromate evolution.

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rather pink when I add more red." This suggests they can make real colour distinctions between shades that look identical to the rest of us. The now famous tetrachromat "Mrs. M.", took part in Dr. Jordan's experiments in 1993, exhibiting exceptionally accurate colour vision. "People will think things match, but I can see they don't."

Dr. Jordan, now at the University of Newcastle, remains reluctant to declare positive identification of tetrachromacy, claiming that further testing is essential. It is difficult to be sure the results of testing are accurate, since the experimenter cannot distinguish the test signals.

### ***Cognitive implications:***

It might seem obvious that an extra photopigment automatically leads to the perception of new colours. However, the presence of an extra photopigment is only half of the battle. Very little is known about whether the brain can actually make use of the extra colour signals. This question is especially important since the genetic process described above would yield a fourth photopigment that is very close to either red or green, such that the effect on perception may be barely noticeable.

"For years now, scientists have known that some fraction of women have four different cone photopigments in their retinas. The question still remains, however, whether any of these females have the neural circuitry that enables them to enjoy a different -- surely richer -- visual experience than the common run of humanity sees. "If we could identify these tetrachromats, it would speak directly to the ability of the brain to organize itself to take advantage of novel stimuli," says Dr. Neitz. "It would make us a lot more optimistic about doing a gene therapy for colour blindness." " (Zorpette 2000)

Jeremy Nathans, a pioneer in colour-vision research at John Hopkins University School of Medicine agrees that if a person were born with four photopigments, the brain would wire itself to accommodate all four channels of visual stimuli. He cautions, however, that the fourth photopigment must not have a peak in sensitivity that is too close to the peaks of either the red or the green photopigments, else the difference may fall within normal genetic variability. (see Figure 4) Already, the genetics underlying colour vision are surprisingly variable; "The variety in photopigment genes in people with normal colour vision is enormous," Dr. Neitz reports. Even if the brains of tetrachromats successfully wired themselves for all four channels, the result might be only mildly superior colour vision. (Zorpette 2000)

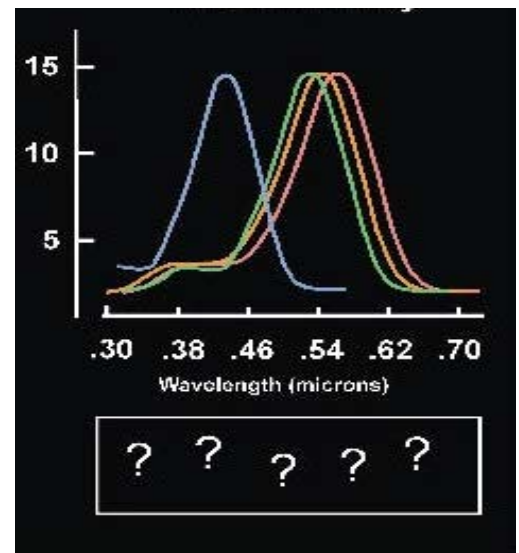


Figure 4: Human tetrachromatic vision. (Neitz lab, 2000)

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### ***What would it be like to be a tetrachromat?***

Unfortunately, in this day and age it would likely be very frustrating, especially since most tetrachromats are likely unaware of their unique abilities. In time, though, this may change as we learn about what it is and how to recognize it. Besides the genetic, cognitive, and philosophical interest in learning something new about perception, the brain, and the evolution of our species, tetrachromacy suggests many practical possibilities, but also psychological concerns.

What advantages would a tetrachromat have? It's hard to say, though Gabriele Jordan suggests thinks superior skin tone distinction, such that a tetrachromat mother may be able to more easily spot if her child is flushed or pale. No doubt, tetrachromats would be capable of far superior colour-matching. Unfortunately, the modern world is geared up exclusively for trichromat perception. To a tetrachromat, television and photography would fail to reproduce colours correctly. Computer monitors, paper inks, clothing dyes, and even artwork would not be perceived as intended. But this could be a good thing, making tetrachromats invaluable for jobs involving colour comparison, such as authenticating artwork and pattern matching, or for recognizing subtle distinctions in skin tones for patient diagnosis, mood reading, lie detection, and make-up artistry. In addition to seeing more colours, a tetrachromat might possess a red photopigment shifted slightly further into infrared wavelengths, enabling them to see beyond the natural limit of human perception, allowing for cat-like night-vision, and perhaps even directly perceiving hints of body heat.

Perhaps the most interesting consequence of tetrachromacy for cognitive studies, is the potential for faster information processing by the visual system, since there would be four channels open for sensory data exchange. If so, wealthy couples might start rushing to the labs to engineer female babies with tetrachromat vision. Sorry, but guys will have to wait a while longer.

In time, providing that the brain's neural circuitry is sufficiently plastic, it might be possible to retroengineer tetrachromat vision by gene therapy, or use the same process to restore colour to blindsight patients. However, this plasticity would also open the floodgate on perceptual relativism. Even our understanding of colour-blindness could change dramatically, since any male or female who even carries a shifted red or shifted green may develop an additional or otherwise unique neural pathway. How such a pathway would affect perception remains completely uncertain – a supposedly colour-blind male may in fact be trichromat but perceive less distinction between 'red' and 'green', or be unable to make any distinction under certain lighting conditions such as fluorescent light, while perform perfectly well in natural sunlight.

The possibility of tetrachromacy leaves many questions hanging in the air. But while we're at it, why stop at *tetrachromacy*? ■

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