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Correlation between dichromatic colour vision and jumping performance in horses

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ABSTRACT

There is general agreement that horses have dichromatic colour vision with similar capabilities to human beings with red–green colour deficiencies. However, whether colour perception has an impact on equine jumping performance and how pronounced the colour stimulus might be for a horse is unknown. The present study investigated the relationship between the colour of the fences (blue or green) and the show jumping performance of 20 horses ridden by two riders using an indoor and outdoor set of green and blue fences.

In the indoor arena, significantly more touches and faults were made on blue fences in comparison to green fences (median difference of 2.5 bars). When only touched bars were included, a significant median difference of one bar was found. Mares ($n = 4$) demonstrated more faults and had a significantly greater difference in touches and faults between the two colours than male horses ($n = 16$). Repeating the same experiment with eight horses in an outdoor grass arena revealed no significant differences between the two colours. In order to draw any definite conclusions, more research concerning the colour perception, influence of contrast with the arena surface and sex of horse is required.

Introduction

In mammalian retina, colour discrimination is mediated by colour-opponent neurones that respond with opposite polarity to signals from short (S, blue) and longer wavelength (M, green or L, red) cones (Mills et al., 2014). Different spectral cone classes are found in the visual system of most evolved vertebrates (Bowmaker and Hunt, 2006; Bowmaker, 2008). Among the vertebrates, there are monochromic, dichromic, trichromatic and tetrachromatic types of chromatic vision, depending on the different number of photopigments (Jacobs, 2009).

Several cone classes appeared very early in vertebrate evolution (at least 540 million years ago), prior to the separation of the jawed (Gnathostomata) and jawless (Agnatha) vertebrate lineages (Xian-Guang et al., 2002; Shu et al., 2003). The recently supported 'contrast theory' (Sabbah and Hawryshyn, 2013) proposed that multiple cone classes evolved in shallow water fish to maximise the visual contrast between objects and their background (McFarland and Munz, 1975). This was an interesting evolutionary feature, since primates with better colour discrimination are able to detect predators earlier against a green foliage background (Pessoa et al., 2014).

Mammals have an ancestor with achromatic vision in dim light and this is probably why most non-primate mammals have been left with only two of the four ancient vertebrate cone pigments and a high rod-to-cone ratio in their retina (Jacobs and Rowe, 2004). In addition, it has been postulated that dichromatic vision is superior to trichromatic vision at detecting camouflage when there is a colour match between the target and the background (Morgan et al., 1992) and dichromatic animals would also outperform trichromatic ones when foraging in shade (Caine et al., 2010).

The horse (*Equus caballus*) is classified as a perissodactyl mammal or odd-toed ungulate. In this order, there are still conflicting data as to which wavelengths of light (i.e. which exact colours) the animals can discriminate (Jacobs, 1993; Farrall and Handscombe, 1999; Hall and Cassaday, 2006; Hall et al., 2006). Previous studies using different methods indicated that the horse has two cone pigments (Sandmann et al., 1996; Carroll et al., 2001; Hall et al., 2006). Carroll et al. (2001) reported that the cone spectral sensitivity for the M/L photopigment of the horses has a spectral peak (λ_{max}) of 539 nm and that the best fitting S cone pigment curve had a λ_{max}

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of 428 nm. This means that the spectral sensitivity curve is slightly moved towards the left side (shorter wavelengths) compared to human beings. When the wavelength of a colour corresponds with the neutral point, the horse will not be able to distinguish it from achromatic colours such as white and grey because it stimulates both cone types equally (Roth et al., 2007). Measuring the ability of horses to see colour using a two-choice discrimination task indicated a neutral point at about 480 nm (Geisbauer et al., 2004).

Research using a pseudoisochromatic plate stimulus has been shown to be highly effective in testing colour vision in human beings and, as a result, is also being used in horses (Hanggi et al., 2007). Based on several behavioural studies, it has been reported that horses are at least dichromatic with colour vision capabilities similar to those of human beings with red–green colour deficiency. Horses were able to distinguish blue from grey, although the studies reported that one out of the four horses was unable to distinguish green from grey within the testing session (Smith and Goldman, 1999; Blackmore et al., 2008). Others have also suggested that in contrast with the colour blue, horses have difficulty in discriminating green from grey (Macuda and Timney, 1999). Furthermore, a consistent discrimination of blue and red vs. grey but not of green vs. grey has been reported in one horse (Pick et al., 1994).

Nevertheless, most horses have been shown to be able to distinguish blue from grey but have more difficulties with green. Therefore, both colours are suitable for testing the correlation between dichromatic colour vision and performance. Changing the type of arena surface (contrast with the colour) might influence results, so we performed a second experiment on another surface using a smaller group of horses. We aimed here to investigate the relationship between the colour of the fences (blue or green) and the show jumping performance of horses (two riders) using an indoor and outdoor set of green and blue fences.

Materials and methods

No permits or ethical committee approvals were required for the described study since the horses were trained in the same manner on any other daily exercise. Clinical examination of the horses was part of the routine care after a jumping exercise. The owner of the horses gave written consent and the work received institutional approval.

Participants

In the first study, 20 Warmblood jumping horses (four mares, five stallions, 11 geldings), with a mean age of 4.7 years (range 3–8 years) were used in the study. Their mean jump height was 93.5 cm (range 50–110 cm; Table 1). In the second study, eight Warmblood horses were used with the same age range and the same jumping capacity. In both experiments, half of the horses were ridden by a female rider and the other half by a male rider. The two riders competed at an international level and trained the horses daily. Both riders completed the course of 6 × 6 fences (Fig. 1) with all horses. The following day and 1 month after the experiment, all horses were examined by the attending veterinary surgeon who reported that they were in a healthy state.

Colorimetry

The colours examined in the present studies were dark blue and dark green, which are both most frequently provided by Wilgenhof, one of the largest bar and fence distributors for equine show jumping competitions in Belgium and The Netherlands (Fig. 2A). For the ease of verbal colour communication, systems were developed based on the psychosensorial factors of colour vision in human beings, such as the Munsell and Natural Colour System (NCS).[1] For commercial colour matching in industry, Reichs Ausschuss für Lieferbedingungen (RAL) numbers are frequently used as a quality mark.[2] In the present study, the RAL number and NCS number are documented and spectral curves were measured for both colours. Green was documented as RAL 6002 and NCS 5338-G22Y (Fig. 3A). In the NCS notation, the first two digits indicate the amount of black into white, which was 53% in this case. The second set indicates the chromaticity (or saturation), which was 38% for the green. The blue colour had a RAL number of 5010 and NCS notation of 4547-R88B (Fig. 3A). The same reasoning gives us a 45% perceived blackness and a chromaticity of 47%.

Table 1
Details of the 20 horses used in the indoor experiment.

Rider	Horse	Sex	Age (years)	First colour of the alternating colour sequence	Time	Height of fence (m)[a]
Female	H1	G	3	Green	3 min 5 s	0.5
	H2	G	5	Blue	2 min 33 s	1.1
	H3	G	6	Green	2 min 33 s	1.1
	H4	G	6	Blue	2 min 27 s	1.1
	H5	M	5	Green	2 min 29 s	1.0
	H6	S	4	Blue	2 min 30 s	1.0
	H7	G	6	Green	2 min 26 s	1.0
	H8	M	4	Blue	2 min 31 s	0.9
	H9	S	4	Green	2 min 24 s	0.9
	H10	M	4	Blue	2 min 28 s	0.9
Male	H11	M	4	Green	2 min 90 s	0.5
	H12	S	4	Blue	2 min 44 s	1.1
	H13	G	8	Green	2 min 31 s	1.1
	H14	G	4	Blue	2 min 44 s	1.0
	H15	G	4	Green	2 min 35 s	0.9
	H16	G	5	Blue	2 min 28 s	0.9
	H17	G	4	Green	2 min 26 s	0.9
	H18	S	5	Blue	2 min 27 s	0.9
	H19	S	4	Green	2 min 29 s	1.0
	H20	G	4	Blue	2 min 40 s	0.9

M, mare; G, gelding; S, stallion.

[a] The height (of the fence measured in metres) was adjusted to the individual capability of each horse.

A colour is uniquely defined by its spectral curve, which is called the 'fingerprint' of a colour. Applying an illuminant (spectral radiation of the source) and the $\bar{x}$, $\bar{y}$, $\bar{z}$ colour matching functions of the standard observer, XYZ International

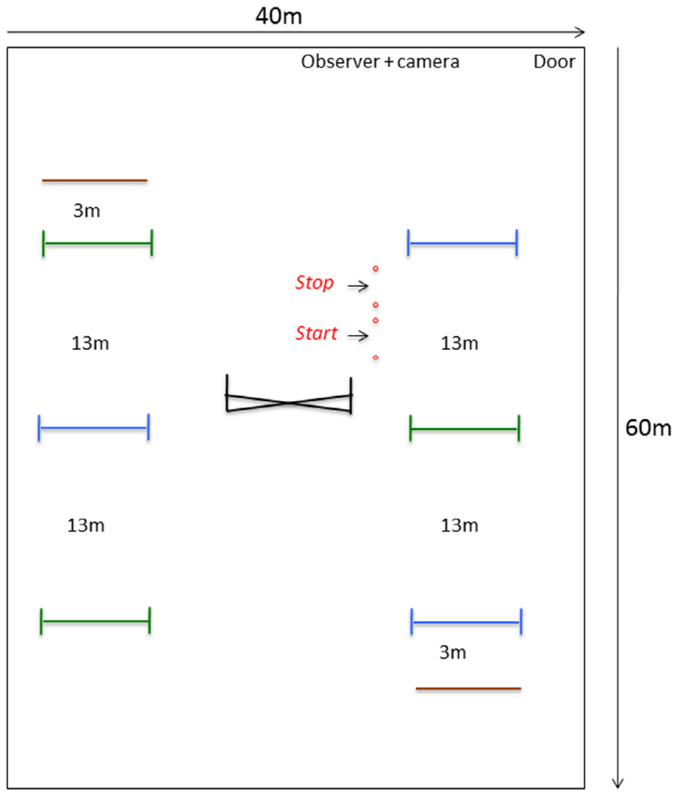

Fig. 1. Schematic overview of the experimental design.

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[1] See: http://www.ncscolour.co.uk/ (accessed 6 July 2014).

[2] See: http://www.ral-farben.de/?&no_cache = 1&L = 1 (accessed 6 July 2014).