The Influence of Red Colouration on Human Perception of Aggression and Dominance in Neutral Settings

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Thesis submitted for the degree of Doctor of Philosophy

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January 2016

Abstract

For both humans and nonhuman species, there is evidence that red colouration signals both emotional states (arousal/anger) and biological traits (dominance, health, and testosterone). The presence and intensity of red colouration correlates with male dominance and testosterone in a variety of animal species, and even artificial red stimuli can influence dominance interactions. Depending on the context in which it is perceived, red is associated with reward (e.g., mating) or avoidance of threat. Wearing red can therefore be advantageous in romantic or achievement contexts. It may also increase the probability of winning sporting contests. Both perceiver effects and wearer effects have been proposed as sources of enhanced winning chances for competitors wearing red in sporting competitions. We tested the hypothesis that artificial (clothing) colour can exploit the evolutionary associations between red and dominance/aggression and that this link is even detectable in neutral (non-competitive) settings. The first two experiments investigated whether a person wearing red was perceived as more aggressive/dominant than one wearing blue or grey. We detected a perceiver effect for red-wearers for perceptions of aggression, dominance, and anger that was independent of a wearer effect. This confirmed that the colour red may be a cue used to predict propensity for dominance and aggression in human males. We then explored differences in handgrip strength, self- and peer-assessed dominance, and actual dominant behaviour to test the hypothesis that red-wearers are physically and mentally stronger/more dominant than their blue-wearing opponents. Red-wearers were not stronger or perceived as more dominant or taller than blue-wearers, but we found some evidence that they may have acted more dominantly. However, in an online experiment rather than in a controlled laboratory setting, we found no wearer or perceiver effects on ratings of perceived dominance, height, or strength. Possible limitations of web-based approaches are discussed. Finally, we examined the consequences of allowing participants to choose from the full colour spectrum rather than forcing them to pick from only two or three clothing colours presented. When allowed to choose from the full spectrum, participants predominantly chose red shirts to make a person appear more aggressive or more dominant. There is some qualitative evidence for an "optimal red" in that participants' choices clustered within a specific part of the red spectrum and no such clustering or colour preference was found for any of the control character traits. Overall, the results demonstrate that, in a laboratory setting, the colour red can have consistent effects on perceptions of aggression and dominance; this opens up a broad array of avenues for future work. These findings also have implications for non-academic contexts (e.g., whether wearing red can impact one's performance in achievement contexts such as sporting contests or job interviews).

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Abbreviations

ANOVA	Analysis of Variance
ANCOVA	Analysis of Co-variance
cf.	conferre
DV	Dependent variable
etc.	et cetera
e.g.	exempli gratia (for example)
HGS	Handgrip strength
i.e.	id est (that is)
IV	Independent variable
max.	maximum
n.d.	no date; not dated
Q1	Questionnaire 1
Q2	Questionnaire 2
RT	Reaction time
SD	Standard deviation
SoDi	Social distance
vs.	versus

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Note to the reader:

Throughout all of the five experimental chapters of this work, I have used the pronoun "we" as opposed to "I". The work herein is unequivocally my own in terms of hypotheses, predictions, analyses, and conclusions. The plural pronoun merely reflects the fact that, if published, the experiments within would bear multiple authorship and is used in keeping with intellectual honesty and union.

Acknowledgements

This will probably be the most thumbed page of the whole thesis, so there is a lot of pressure to get it right and I'll try not to leave anyone. I wish to express my gratitude to the following institutions in the United Kingdom and Germany which have funded my studies: Chemnitz University of Technology who awarded me a Fulbright Stipendium of the German Academic Exchange Service (DAAD), Durham University who awarded me the Durham Academic Scholarship which funded my tuition fees and the Durham Anthropology Department who awarded me several Postgraduate Bursaries that partly covered my travel expenses to conferences or fees for equipment and software programs. Many thanks also to the University of Oklahoma (USA) and the Stephenson Research and Technology Center for a proper introduction to the beauty of anthropological studies.

I would like to thank several people whose support and help were essential for the completion of my thesis: my primary supervisors Dr. Russell Hill (by now Prof.) for guiding me through this (and other) project(s). Russ, not only did you support me in difficult times with your enormous patience and kind encouragement, you also managed to make me laugh when I really did not feel like it. Thanks also to my secondary supervisor Prof. Robert Barton. Rob, your constructive criticism and kind encouragement go hand in hand in the generous amounts of feedbacks you sent me, and you always pushed me a step further. Russ and Rob, it was surely not always easy to supervise someone who is not a native speaker (and keeps whining about it), who moved to a third country just after having started the PhD project and who then struggled with what life offered. Despite all these hurdles, you always gave me the feeling that I can achieve "this" and for that I will be eternally grateful.

I am very grateful to my progression viva examiners Dr. Joanna Setchell and Dr. Rebecca Sear for suggesting (lots of!) improvements after the first 11 months of research. For my final PhD viva, I again had the pleasure to be examined by Dr. Setchell as well as Prof. David Perrett. Many thanks to both of you for a very memorable PhD viva with fantastic moments, interesting discussions, and overall a great input.

I am very thankful for the help provided by three people at the Burgundy University in Dijon without whom I would not have been able to conduct my experiments. First of all, Rémi Mencarelli, who is most importantly a friend (and comedian!), who always welcomed me with open arms, and who opened doors to me that otherwise would have been kept closed. Merci à toi, "REM"! Rachel Droux, who let me settle into the study rooms of her library which I used for two of my experiments. Finally, Pascal Schmitt, who also let me conduct one of my experiments in one of the offices in his library without ever having had any affiliation with me. We met, I explained my situation to him, and he handed me over the keys. Vous êtes tous les trois des personnes super gentilles et généreuses. Merci à jamais!

Of equal importance is the thanks owed to Dr. Mike D. Burt who spent so many hours patiently answering all my emails and solving any software problems. He also saved me from hours and hours of Photoshop retouching by introducing me to the wonders of imagemagick. By now, I do not only owe you a couple of beers but an entire brewery! Thanks also go out to Dr. Gillian Cooper who kindly helped me out assaying saliva samples which unfortunately never actually "drooled" into this thesis and to Dr. Carmen E. Lefevre.

For taking a minute, listening to a stranger, and then following me into a small room in order to participate in sometimes endless trials, I must thank each and every single participant.

In Durham I first want to express my gratitude to the people of the Anthropology Department, the administrative team and all the people I met. Special thanks to Emma, Steffi and Rasha who were my friends throughout my times in Durham, but more importantly, even after we all had left Durham. "Team Russell" (Julia, Peter, Vivien, Tash, Sam), Katy, Kat, Erika and my former colleagues at the Science Learning Center North East - you are all such lovely people.

I am extremely fortunate to have friends from all around the world who never stopped believing in me. Merci à tous mes copains à Dijon: Rémi (again) and Séverine (à la fois vous m'avez fait peur mais vous m'avez surtout toujours pousser à continuer cette thèse: "Le succès d'une thèse c'est déjà de l'avoir soustenu."), Katja (bei wem sonst hätte ich mich über so manch komisch-französische Eigenart ausheulen sollen?), Ro(w)bert and Ulrike (für ein bisschen "Heimat-Feeling" in 200 Meter Entfernung), Sabine (Noch ein Crémant gefällig?), Ina (und noch viel, viel mehr Heimat) Charlotte, Yann, Emilie, Nico, Céline, Juliette, baby-sitters and all the other "Frenchies" for all the dinners and nights out. Also thanks to my Peruvian friend Raul Tito for two (soon three) unforgettable leapyear memories!

To all my friends in Germany: Nicole, Steffi, Melanie, Jana, Celal, Heike, Christian, and Sibylle for all the moments that had nothing to do with this thesis. Thank you, Paul, for

helping me out with language issues but also for having an open ear to "the" other issue. I am very thankful for the support of my dearest friends Stefan and Susan, who constantly offered me their help and moral support. This friendship has gone "rare ways", "moved" a lot (Chemnitz-Dresden-Toulouse-Norman-Durham-Frankfurt-Dijon-Bremen-Kassel) and definitely has its own laws. Schiff ahoi, Ihr zwei!
Finally, my dear Josi, who has been on my "telephone" side almost once a week for 2-3 hours for over eight years now. You were my hardest critic and closest friend at the same time. Every week, you took me into another world - a silly world, full of gossip, "Luxusprobleme" and the little things in life. But you never forgot to encourage me and push me further. You made me question my decisions and actions, sometimes in a harsh way but always constructively and with a better outcome as the result. May "Dschungelcamp" and a "Mädels-WE" will always be one of the many things to look forward to together. It wouldn’t have been the same without you.

QOTSA, Vandaveer, Nick Cave, Evening Hymns, Annenmaykantereit, Eels, EoDM, Badly Drawn Boy, Kasabian, Feist, Woodkid, Peter Fox and so many more musicians who made copy and pasting and endless hours of restructuring data bearable.

Without my family I would not have made it this far. No words can describe how much support, strength, love and joy you have all given me. My (now!) "in-laws" who are probably still wondering how a thesis can take that long. Claire et Bernard, merci d'être une inspiration dans beaucoup de sujets hors de ce monde universitaire! Nicolas, for cheering me up with your "little stories". Oma und Opa, vielen Dank für Eure Unterstützung! My brother René and sister-in-law (now a real one!) Julia for just being who you are - wonderful folks! Julia, I'd be still copying and pasting if it wasn't thanks to you that I had considered macros. Finally, without the support and love of my parents, nothing I achieved would have been possible. You never forced me into anything and let me take the ways I wanted to go, you even let me drop out of school and it turned out to be the right decision. I will be eternally grateful and indebted to you both.

My fiancée (by now husband) Benjamin Fournet has been, and remains, a source of encouragement and forbearance through thick and thin. Thank you for joining me in the UK just so to leave it again 1.5 years later, and for diving with me into the adventures of parenthood. Thank you for paying for a roof above my head, speeding tickets, food, travel expenses, holidays, endless phone bills ("you just saw her yesterday!"), expensive clothes ("that you don't need!"), the children's "sensory toys' ("that they don't need!") and your own Birthday- and Christmas presents ("that I don't need!"). You always believed that this day would come and when I doubted it, you made me believe in it again. Hopefully, this all pays off.

Thank you, Danke, Merci! - "Diana, get a proper job now!"

For my children

Eline and Alistair

without whom this thesis would have
been completed two years earlier ;)

Chapter 1

1 Introduction

1.1 Introduction to colour in general

Humans receive the majority of information about their surroundings from sight. Being able to visualize the complexity of the environment which surrounds us faciliates our interaction with that given environment. For humans, as well as for many animals, colour is an important component of our visual input and is perceived on essentially every surface or object in our everyday life, even our dreams and nightmares come in colours (Rechtschaffen and Buchignani 1992), and play a vivid role in our conversations and decision making and even serve as national identification (Lakens 2011). The chromatic palate for those of us experiencing a normal colour vision is rich and vast and includes over 2.2 million discernable colours (Pointer and Attridge 1998, Linhares *et al*. 2008).

Researchers with various backgrounds have investigated the evolution and functional significance of colour and a large body of scientific research has been devoted to exploring various aspects of colour which lead to a strong and well-developed knowledge with a fundamental and robust literature. We know how colour is structured and defined (physics of colour), we know about the representation of colour terms in our languages (colour linguistics), we know how colour stimuli are biologically processed by the eye and the brain (colour neuroscience and physiology), we know about the different meanings of colour naming in various cultures, and we know about nonstandard colour representations (e.g., illusions, colour deficiencies, tetrachromacy, synthesia). However, when it comes to the influence of colour perception on psychological functioning (colour psychology), the literature is lacking the same robustness (Elliot and Maier 2014). Colour psychology itself is a broad domain with subsets reaching from achievement contexts (including sports, cognitive and motor performance; e.g., red enhances human performances in sports) to attraction affiliation contexts (e.g., red enhances attractiveness; see Elliot and Maier 2014 for a review). However, less work in colour psychology has been dedicated to investigating the influence of colour on psychological functioning in neutral, context-free environments in which attraction or competition are nonexistant. This lacunae is addressed in this current work in five different experiments.

But first of all, in order to get a better understanding of the benefits but also difficulties in conducting colour research, we will give a brief overview of the different theories on how trichromatic colour vision evolved in the first place.

1.1.1 Evolution of trichromatic colour vision

Colour is a function of the three properties: hue, chroma and lightness (Fairchild 2005). Each of these dimensions may separately influence perception (Camgoz *et al.* 2003). *Hue* is wavelength and is most commonly refered to as "colour" (e.g., blue, red). *Chroma* or saturation is how vivid or intense a colour is. *Lightness* or brightness or value, is how dark or light a colour is (Figure 1).

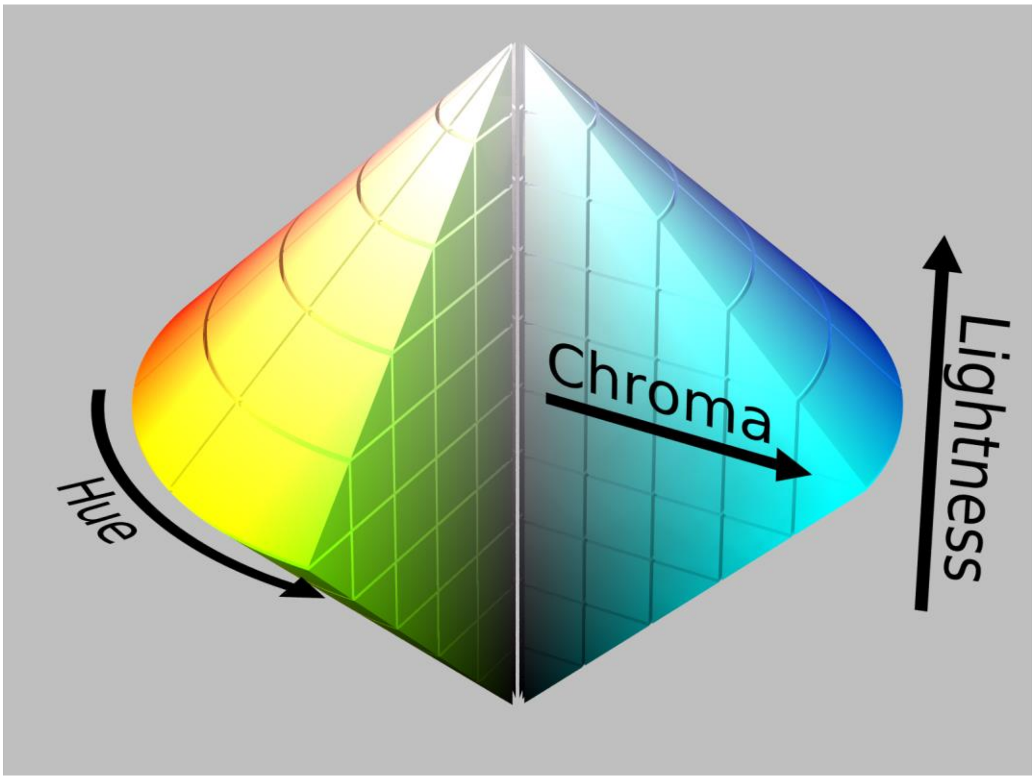


Figure 1: Differences between hue, chroma, and lightness

Talking about colour psychology is incomplete leaving the evolution of colour vision out. As colour vision evolved independently in three separate lineages of animals, researchers believe that, during evolution, colour vision was invented several times independently: one leading to colour vision of hymenoptera insects, one leading to colour vision of reptiles, birds, amphibian, and fishes, and finally, one leading to primate colour vision (Neumeyer 1991). The latter consists of two types of colour vision, dichromatic and trichromatic, with three types of cones (Jacobs 1993). The three types of human cone are two different subsystems which evolved for different reasons and that a phylogenetically recent subsystem overlaid on a much more ancient subsystem (Neumeyer 1991). Sumner and Mollon (2000) suggested that the older of these two systems predates the divergence of mammals.

The advantages of trichromatic colour vision are obvious. Direct and indirect lightening of objects in the visual environment can lead to significant variations in shadowing and lightning. Colour vision, however, is considerably less influenced by shadowing, and so will lead to a reliable discrimination of objects (Jacobs 1993). Colour also carries an important "signalling significance", permitting coding of the potential palatability of fruits or skin tones as an indication of emotional state and health (Jacobs 1993). Humans, for example, interpret skin blood colouration as an honest cue to underlying health (Stephen *et al.* 2009, for more see section 1.3.1.1).

Hypotheses as to why and how trichromatic colour vision evolved are either based on natural selection or on sexual selection. Osorio and Vorobyev (1996) suggested an adaptation, due to natural selection, that evolved approximately 40 million years ago leading to the advantage of detecting fruit against a background of leaves, hence, finding food as a potential impetus of this adaptation. Lucas *et al.* (1998) also thought that food selection, specifically leaf colour and size as potential cues, played a major role in the evolution of trichromatic colour vision as young dappled red leaves offer a better food resource than green ones. Hamilton and Zuk (1982) favoured an approach related to the advertisement of strong distinct colours as "health displays" due to pathogen resistance and mate choice. According to the Hamilton-Zuk-hypothesis, full colour can only be expressed by individuals of superior quality. Changizi *et al.* (2006) suggested an evolution of colour vision that was for the purpose of discriminating emotional states, threat displays, and socio-sexual signals of con-specifics. That is, trichromatic colour vision allowed primates to detect subtle skin colour changes based on underlying blood flow. And visual sensitivity to these skin-based regulations is highly beneficial in interpersonal interactions.

1.1.2 Historical context: theoretical work and methodological issues

"Every individual colour makes on men an impression of its own, and thereby reveals its nature to the eye as well as the mind." (Goethe 1810/1967 in Wood 1899, p. 279) - the German writer and politician Johann Wolfgang von Goethe may be the first to have had a scholarly interest in linking colour and psychological functioning. Though hardly a work of science, as the poet's ideas derived from his intuition, Goethe's "Theory of Colours" explores what psychological impact different colours on emotion and mood have. Goethe distinguished between colours inducing positive feelings such as warm, aspiring, and lively (yellow,

yellow-red, red-yellow), and colours inducing negative feelings such as anxious, cold, and disturbing (blue, blue-red, red-blue).

Goethe's prescient insights were expanded and corroborated in the twentieth century. In the 1930ies, neurologist and psychiatrist Kurt Goldstein experimented in clinical trials with the affects of colour on human's psyche. For example, his observations showed that objects presented under red light appear heavier or bigger, while under green light they appear lighter and smaller. Furthermore, yellow and red were claimed to produce forceful action and to be stimulating, whereas blue and green were claimed to produce stable and calm action, and to be relaxing.

Published in 1939, "The Organism" (Goldstein 1939) was a highly influential work of colour consultant Faber Birren, who himself published over 250 articles and more than 40 books on colour vision, colour therapy, and colour psychology (O'Connor 2011) and who cited several excerpts from Goldstein such as "under the influence of red light, time is likely to be overestimated. Conversely, under the influence of green or blue light, time is likely to be underestimated" (Birren 1961, p. 211). Birren, as well as later on Mahnke (1966), cited Goldstein’s 1942 study, which discussed the perceived stimulating effects of red and the opposite effects of green.

Red has long been identified as a special, unique colour. The British writer Havelock Ellis began his prescient essay "The psychology of red" with the following words: *“Among all colors, the most poignantly emotional tone undoubtedly belongs to red”* (Ellis 1900, p. 365).

In 1969, Swiss psychotherapist Max Lüscher developed the Lüscher Colour Test (Lüscher 1969). In this test, citing anecdotical evidence, he assigned specific affective characteristics and associations to each of his four basic colours (orange-red, bright yellow, blue-green and dark-blue). For example, "red has a stimulating effect on the nervous system, blood pressure increases, respiration rate and heartbeat both speed up; while blue has the reverse effect, blood pressure falls, heartbeat and breathing both slow down" (Lüscher 1969, p. 12). Essentially, the Lüscher Colour Test assessed colour preferences and its use in personality testing has been cautioned (Walters *et al.* 1982). Indeed, while the theories proposed by Goldstein, Birren, and Lüscher have their place in the colour literature, these theories have been superseded to a large extent. It is, however, unfortunate that contemporary empirical studies rarely, if ever, refer to these early theories and that they rarely appear in popular culture (O'Connor 2011).

At the end of the 20th century, colour research investigated theories on learned associations to colour and how these might influence cognition, affection, and behaviour. Frank and Gilovich

(1988), for example, posited that the association between the colour black and negative concepts such as death, badness and evil (Williams and McMurty 1970) prompts aggressive behaviour towards others. Similarly, Soldat *et al.* (1997) postulated that blue is associated with sadness and red with happiness, and that these colours lead to behaviour and information processing consistent with these emotional states. Finally, the focus of writing on colour and psychological functioning in the 20st century was mainly on applied questions (e.g., What colours are most fashionable? What colours induce/reduce food intake? What influence do different colours have on workspace productivity? etc.) with little interest in or reliance on theoretical contemplations (Elliot and Maier 2014). In addition to that, the majority of colour-related research carried out pre-21st century neglected to take the multidimensionality of a colour stimulus into account. Many researchers included colour stimuli in their research that appeared to their eye as acceptable exemplars of the colour they wished to present. But their assumptions were not necessarily tested in pilot projects. Other methodological issues of that time failed to time-control colour stimuli presentation or failed to exclude participants suffering from colour deficiencies (methodological flaws are further discussed in Chapter 7). It is therefore unsurprising that results from studies conducted in this era were either not supportive of hypotheses or simply inconsistent. However, the beginning of the 21st century marks a turning point for theoretical advances as well as progresses in methodological issues.

1.1.3 Recent theoretical advances

In the past decade, primary theoretical advances in the domain of colour research and human psychological functioning have in common that effects of biology have been taken into account and that research has sought to draw parallels between reaction of nonhuman and human individuals to certain colour stimuli. Even though these ideas have been present a while now and were mentioned by several scholars (e.g., Darwin 1872, Ellis 1900, Humphery 1976), new research and theoretical frameworks allow for additional insights based on contemporary knowledge from backgrounds of multiple disciplines. These frameworks have focused primarily, but not exclusively, on the colour red. Many scientists from different scholarly backgrounds have tried to determine the colour's magnitude and relevance. Psychologists, evolutionary biologists, brain scientists, sports psychologists, and business psychologists have all investigated the influence red colouring can have from very different angles.

For example, Hill and Barton (2005) emphasised a signalling function of red colouring in competitive interactions of nonhuman and human animals. Red colouration is a sexually selected trait associated with dominance in a variety of animal taxa (e.g., nonhuman primates: Setchell & Wickings, 2005; fish: Milinski & Bakker, 1990; birds: Cuthill, Hunt, Cleary, & Clark, 1997; lizards: Healey *et al.* 2007 see section 1.2). The link between dominance and red opens up the possibility that artificial stimuli (such as sports attires) may also exploit evolved responses to natural red (see section 1.3). If so, wearing red in aggressive sports competitions such as combat sports may function as a dominance signal and may lead to enhanced performance attainment. Other researchers investigate the signal value of human and nonhuman skin colouration in the context of mate choice and attraction. In humans, skin redness due to oxygenated (redder) blood is a signal of increased aerobic fitness (Armstrong and Welsman 2001) and testosterone produces enhanced facial redness in aggressive encounters, whereas fear leads to paler skin (reduced redness) which can be caused by reduced levels of testosterone (Ferrucci *et al.* 2006). Associations between social dominance and facial skin redness in nonhuman primates (e.g., Setchell and Dixson 2001) were also found among humans as apparent facial aggression and dominance is enhanced with increased skin redness (Stephen *et al.* 2012).

Finally, some theorists put forward a colour-in-context-theory (Elliot and Maier 2012, for more see section 1.3.3) that acknowledges biologically-based and socially learned sources of colour effects and meanings. As such, the same colour can produce different, even opposite effects and meaning depending on the context in which it takes action. To give an example, red can carry a positive meaning (status or sexual receptivity) and appetitive implications (sexual desire) in the context of romance and mating, but it can also carry a negative meaning (failure) and aversive implications (avoidance motivation) in achievement contexts. In any case, a colour that can cause ambiguous feelings merits a closer consideration.

1.1.4 Focus point: the colour red

"The effect of this colour [red] is as peculiar as its nature. It conveys an impression of gravity and dignity, and at the same time of grace and attractiveness."

(Goethe 1810/1867)

Of the chromatic colours, red has recently evoked interest in researchers from various backgrounds and has received a great amount of attention in the emerging, empirically based literature. In particular, a growing body of evidence of the colour psychology literature has made a convincing case that colour is not just about aesthetics, but also about meaning. Remarkably, infants at the age of 4-5 months already show a preference for the colour red by looking longer at reddish hues as compared to other colour hues (Adams 1987, Bornstein

1975, Franklin *et al.* 2010), and the first word related to chromatic colour a language acquires is "red" (after the achromatic colour "white" and "black"; Berlin and Kay 1969). Red is eye-catching, no matter if it indicates an emergency or if it announces that a ripe fruit is edible (Judd 1907, see also Regan *et al.* 2001). As humans of western societies, we associate the colour red with signs of vigilance (warning signals, alarms, stop signs etc.), danger, threat, caution and “error”-markings in school, but also with romantic, passionate feelings (Mahnke 1996, Kaya and Epps 2004, Moller *et al.* 2009). As such, red is linked to love and amorous feelings as well as to danger and both associations seem to follow a phylogenetic history as individual differences in colour preferences exist cross-culturally (Hurlbert and Ling 2007). The association of red with sexuality and attraction, and related social practices of red heart shaped Valentine Day's gift boxes or red lingerie and lipsticks originate from biological predispositions of red as a sign of reproduction and sexuality (Barelli *et al.* 2007, Waitt *et al.* 2006).

Red is often thought of as intense and bloody, but also warm and passionate (Kaya and Epps 2004). Encountering red in various ways may thus, depending on the context, cause dissimilar feelings in us as both positive and negative emotions are associated with the colour. Compared to that, other colours seem to be less ambiguous and more definite with black, for example, being related to death, badness and evil in almost all cultures (Williams and McMurty 1970). Adams and Osgood (1973) carried out survey in 23 different cultures and postulated an affective salience of the colour red. Mostly, red is perceived as active and black as passive. However, both colours are considered to be strong. Still, one would assume that different colours in general have different meanings in different societies and cultures, and indeed they do. There is one important exception, however, and red shows puzzling universality across cultures: similarities in emotional states associated to red identify it as the colour of aggression, passion, anger, energy and imminent danger (Greenfield 2005, Pravossoudovitch *et al.* 2014), even in such a way that warning signals and emoticons are most effective when displayed in red (Changizi *et al.* 2013).

The following two parts of this introduction explore and describe research and findings about the colour red in its natural (2.) and in its artificial (3.) existence.

1.2 (Red) Colouring in natural environments

1.2.1 Dominance, social status … and the colour red

Historically, red goes hand in hand with authority, wealth and high status (see Elliot *et al.* 2010). An anecdotal example is that amongst classical Romans the most powerful men were “the ones who wear red” (Greenfield, 2005). Consequently, seeing an individual wearing red led to the impression of this individual being powerful and this association is then passed on to others. One could argue therefore that the link between red and high status could be a mere product of social learning. However it is more likely that there is an innate predisposition to link the colour red with dominance.

1.2.2 Dominance hierarchies in male primates

For many years, ethological studies have focused on the formation, maintenance and biological and behavioural implications of dominance hierarchies in various animal taxa. Koyama (1967) and Hausfater (1975) both define primate dominance in terms of directionality of aggressive and agonistic actions whereas others define dominance in terms of approach and retreat behaviour (Rowell 1963, Seyfarth 1976). These definitions are helpful to differentiate between dominant and subdominant individuals in dominance interactions that occur between at least two individuals, most often in dyads. Consequently, dominance hierarchies emerge within a group when dyadic interactions are repeated (Pellegrini 2002). Immediate benefits of high dominance result in the access to resources, such as territory, food or mates (Hawley 1999, Pellegrini 2002).

Dominance hierarchies are also well established in hominoid primates, which include humans (Ghiglieri 1987) who attribute dominance in others very rapidly (Carre *et al.* 2009). Research including the analysis of speaking time in groups with same-sex strangers revealed that men form persistent dominance hierarchies within only 5 minutes (Mast 2001). But displays of dominance are also valuable for intersexual relations. For example, women value resource control in a potential mate and analysis of lonely heart columns reveal that men are more likely to advertise their personal status in terms of resource control (Pawlowski and Dunbar 1999, Koziel and Pawlowski 2003). Control of resources is strongly linked with dominance (Hawley 1999), reproductive success and access to females is positively correlated with rank attainment and women regard resource controlling (dominant) men as highly attractive (Mueller and Mazur 1998). An example of the Yanomamö people living in the Amazon basin demonstrate that these effects are found cross culturally. Aggressive behaviour and physical bravery is linked to male Yanomamis' social status. The killing of another, preferably rival man leads a Yanomamö male to attain a special rank. The more he kills, the more his killing reputation increases, the more he climbs the rank ladder. And the more a man is influential and respected in a Yanomamö village, the greater is his access to females and the number of offspring he has. This ultimately links reproductive success with social status in a group (Chagnon 1967, Borofsky 2005).

1.2.3 Natural signals of male dominance

A variety of physical measures have been put forward to be associated with male dominance. For example, masculine facial and vocal characteristics are both indices of men's dominance (Perrett *et al.* 1998, Boothroyd *et al.* 2007, Jones *et al.* 2010, Watkins *et al.* 2010a, 2010b, Puts *et al.* 2006, 2007). In concordance with rodents species' preferences for the odour of dominant males (e.g., Mossman and Drickamer 1996, Gosling and Roberts 2001), women in their fertile phase find dominant men's odour sexier than the odour of less dominant men (Havlicek *et al.* 2005). Height is also an index of dominance and Watkins *et al.* (2010a) found that taller, more dominant men are less sensitive to cues of dominance in other men (this is further explained in Chapters 4 and 5 with regard to red colouring). Thus, these previous findings suggest that male dominance correlates with masculine characteristics (Puts 2010) and may be therefore beneficial due to its attribution with attractiveness (Sadella *et al.* 1987), sexual opportunities (Mazur *et al.* 1994), and social status (Mueller and Mazur 1996). This lead researchers to conclude that dominance might serve as an honest signal of quality in men (Mueller and Mazur 1997). Specifically in competitive encounters, the tendency to dominate is a risky strategy associated with higher levels of testosterone, which may reduce immunocompetence (Folstad and Karter 1992, Muehlenbein and Bribiescas 2005; see also Hews and Moore 1997, Owens and Wilson 1999). Therefore, dominance could reliably indicate male condition.

To date, research on human male dominance has mainly focused on physical traits influencing the perception of other's dominance (human voices and faces), or cues that are correlated with these traits, such as indicators of physical aggression, physical strength, social status and reproductive potential (e.g., Mueller and Mazur 1996, Perrett *et al.* 1998, Rhodes *et al.* 2005, Puts *et al.* 2006, Boothroyd *et al.* 2007, Fink *et al.* 2007). Much less research has combined studies on dominance perceptions and artificial colour manipulation, even though findings from animal studies have suggested an interplay.

1.2.4 Dominance, social status, competition and red colouration in observational studies

Since Darwin (1876) noticed that an angry male mandrill flushes even deeper red, a variety of research has focused on animal colouration. In general, males use sexually selected signals to advertise their physical abilities in intrasexual agonistic encounters. As both winners and losers of aggressive encounters can suffer from costly injuries, individuals displaying before engaging in a fight lower potential costs of such conflicts (Maynard Smith 1982, Vehrencamp 2000). Wickler (1968) called ornaments that demonstrate competitive abilities, hereby resolving conflicts without engaging in an actual fight, “badges of status”. Animal colour has been put forward as a possible signal indicating male quality (Gerald 2001). If the intensity of colouration can reliably indicate condition, then coloured attributes could be helpful to assess males in terms of potential risks in contests or in terms of potential benefits associated with mate choice. Research has demonstrated that vivid colours act as honest signals of animal quality in a wide range of vertebrates (Maynard Smith and Harper 2003). Studies on birds have been fruitful in the context of signalling colour and display. A variety of phylogenetically diverse bird species have bare skin areas that flush deeper red while individuals engage in aggressive encounters. This reddening is a result of skin perfusion with oxygenated blood (Negro *et al.* 2006, Bamford *et al.* 2010). The colour of bare skin in unfeathered heads of lappet-faced vultures (*Aegypius tracheliotos*) for example can flush from pink to dark red in just a few seconds (Mundy *et al.* 1992). It has been suggested that the red colouration designates contest ability in vulture gatherings as adult animals (sex not specified) with pale heads winning fewer agonistic interactions with conspecifics with flushed heads (Bamford *et al.* 2010). The colour of bird's plumage also conveys some information about condition. For example, Pryke and Griffith (2006) investigated the Gouldian finch (*Erythrura gouldiae*), a species found in three genetically-determined head morph colours (red, yellow, and black). Red-headed male birds were the most aggressive (Pryke and Griffith 2006, Pearce *et al.* 2011) and, even when experimentally blackened (for more see section 1.3.2.1), animals with naturally red-headed morphs persistently dominated their black- and yellow-headed conspecifics. Similar differences in dominance-relations were also found among female morphs (Pryke 2007). Both male and female birds avoided initiating conflicts with artificially and naturally occurring individuals of the aggressive red morph (Pryke and Griffith 2006, Pryke 2009, Pearce *et al.* 2011). This demonstrates that displays of red colouring may facilitate potential risk assessment in specific contests, at least among some bird species. However, colour displays are quite rare among mammals and only some primates display bright secondary sexual colouration, usually on the anogenital area or on the face (Dixson 1998). Nevertheless, researchers were able to report a relationship between dominance rank and the intensity of colouration. For example, social status in male vervets (*Chlorocebus aethiops*) is predicted by differences in blue scrotal colouration (Gerald 2001) and male drills' (*Mandrillus leucophaeus*) groin colour correlates with dominance rank (Marty *et al.* 2009). The red colouration on rump, sexual skin and face of male mandrills (*Mandrillus sphinx*) correlates positively with rank and androgen levels (Wickings and Dixson 1992, Setchell and Dixson 2001, Setchell *et al.* 2008) and males were observed to lose their colour once they lose their top rank (Setchell and Dixson 2001). Female mandrill's redness, in contrast to males, is not related to measures of rank (Setchell *et al.* 2006a). Thus, a male's current androgen status and his competitive abilities is represented by its red colouration that functions as an honest signal to male conspecifics regarding dominance and fighting ability and may thus deter lower-ranked males from costly conflicts (Setchell and Wickings 2005, Setchell *et al.* 2008). Notably, the costs involved in direct fights between males are very high and similarly coloured males are more aggressive towards each other than differently coloured males (vervets: Gerald 2001, mandrills: Setchell and Wickings 2005). Hence, colour is suggested to advertise status and resolve conflicts by discouraging aggression between rival males.

1.2.5 Sexual selection and colour

Natural selection is based on an individual interacting with its environment, whereas sexual selection is directed by other members of the individual's species. Sexual selection consists of two components: *intrasexual selection* refers to the competition for mates between members of one sex, which can lead to the evolution of large body size or weaponry, whereas *intersexual selection* tends to promote the evolution of ornaments or behavioural displays and typically members of one sex choose mates of the other sex to mate with (Darwin 1876, Andersson 1991, Wich *et al.* 2004, Ridley 2004). Reproductively relevant traits are prime factors for selection, since successful reproduction is essential for any evolutionary process. Any trait or attribute that assists the spread of an individual's genes in the next generation results in the selection and the spread of that attribute within a given population. Traits that promote the likelihood of frequent and successful mating are important factors of selection (Andersson 1991, Ridley 2004). The combined processes of intra- and intersexual selection promote the spread of "attractive" attributes from one generation to the other within a given population, assuming that these attributes have a genetic basis. However, there are three alternative theories as to why a trait becomes attractive to the opposite sex and these three theories are not necessarily incompatible. Take the classic example of the peacock's showy, colourful and symmetrical tail. According to the Handicap Hypothesis, the attractive trait (here: the peacock's tail) signals the ability of an individual to remain healthy and survive despite the costly ornament (Zahavi 1975, Hamilton and Zuk 1982, Folstad and Karter 1992, Wedekind and Folstad 1994). Here, the peacock advertises a strong immune system as the resources needed for the growth of a bright and colourful tail would otherwise be invested in the functionality of the immune system. The peacock hereby indicates his ability to survive and thrive despite the impaired immune functionality which, therefore, must be very strong and consequently an attractive trait given the heritability of the immune system. An alternative theory is the Good-genes sexual selection theory (Trivers 1972, Zahavi 1975[1], Hamilton and Zuk 1982, Moller 1999) which claims attractive traits signal an individual's genetic quality. That means in our example of the peacock, that its healthy immune system is more likely to resist pathogens and parasites that would otherwise dull the bird's colours or interfere with its ontogenetic trajectory towards symmetry. To simplify the tautology, the peahen considers the peacock's tail to be "attractive" because of the genetic benefits mating with such a male bird would bring to the peahen's offspring (Andersson 1991, Moller 1999). A third theory is that an attractive trait simply remains attractive because it previously has successfully attracted mates. The peahens may thus be attracted to the peacock’s tail because it exploits an aspect of their visual system. Since females of one generation are attracted to this particular trait, it is in a peahen’s interest to ensure that her male offspring also have this trait in order to enhance the reproductive success of her sons, thus ensure the transition of her own genes into the next generation. The last theory is called the Sexy-Son Hypothesis (Weatherhead and Robertson 1979, see Kirkpatrick 1984). However, we hasten to add that detailed observation by a research team of the University of Tokyo contradicts the long-held

[1] Growing evidence illustrates females’ ability to detect and attend to specific phenotypic indicators for “good genes” in males. Zahavi (1975) argued in his hypothesis of the “handicap principle” that inherited, costly ornaments display a specific survivability of the bearer and females receive them as a signal of genetic quality, thus, mating with showy males endows them to bear potential attractive and genetically “fit” offspring (Fisher 1930). One such example is that a female may chose a mature, colourful male who has already proven himself to be of better quality since it has already survived the extra predation risk posed by its colourful plumage. Indeed, female macaques (*Macaca mulatta*) show a preference for males with a red version of the male face (Waitt *et al.* 2003). Furthermore, a brighter red colouration is associated with high levels of testosterone (Waitt *et al.* 2003), which has an immunosuppressive effect, therefore, Zahavi’s theory of mate selection for a handicap seem to be supported.

belief that male peacock feathers evolved in response to female mate choice (Takahashi *et al.* 2008). The study found no evidence that peahens choose mates according to the quality of the peacocks' tails.

1.2.5.1 Male mate choice and the colour red

Amongst mammals, nonhuman primates exhibit the most widespread variation in pelage and dermal colouration and particularly in the extent of sexual dichromatism. This suggests that colour plays an important role in communication and sexual selection (Caro 2005). In primates, females are expected to be the "choosy sex" when it comes to mate choice (see also section 1.2.5) because of extensive parental investment which is a stronger burden for females given the high costs of gestation and lactation. However, males should not be less choosy in case females vary greatly in quality, or if the preference for one female reduces a male's chance to mate with other females (Andersson 1994) due to a missed opportunity to mate with another female (Altmann 1962). In addition, sperm production is cost intensive and sperm delivery as well as sperm quality are impaired by successive ejaculations (e.g., Marson *et al.* 1989, Wedell *et al.* 2002). Thus, both sexes should have an interest in showing mate choice in order to maximize their reproductive success. This also requires a certain sensitivity to signals for a sexual partner of high quality. For example, primate sexual swellings are regarded as a costly handicap that honestly signals female quality (Pagel 1994). When female nonhuman primates approach ovulation, a reddening of the face, chest, perineum, or genitals is observed (Dixson 1983, Setchell *et al.* 2006). This is results from an increase in estrogen, which increases blood flow, thus causing the red skin. Consequently, males should choose females with prominent swellings as these females are hypothesized to be more fertile and to produce offspring of higher quality. Another such signal influencing mate choice is colour. One study has demonstrated that female mandrills prefer more brightly coloured males (Setchell 2005), and more evidence has been derived from experimental settings (e.g., Waitt *et al.* 2003; for more see section 1.3). Facial red skin colouration (ratio of red to green) in female rhesus macaques may reliably signal information about timing of fertility to male receivers, whereas hindquarter skin does not (Dubuc *et al.* 2009). Likewise, facial skin is the reddest during the follicular period of mandrills (Setchell *et al.* 2006b) and Japanese macaques (Fujita *et al.* 2004). These findings suggest that colour alone may serve as a biological sexual signal to male group members and that the visual preference for intense red skin colouring may play an important role in directing visual attention towards a potential mate (Pflüger *et al*. 2014).

Halliday (1983) defined mate choice as any behavioural pattern, shown by members of the same sex, that results in an increased likelihood to mate with certain members of the opposite sex as compared to others. It is not to be confused with mate preference, which describes only an underlying propensity to choose certain mates, but is only measurable in experimentally controlled environments with unnatural sexual accessibility (Heisler *et al.* 1987). For example, a female may have a preference to mate with a subordinate male but might be kept from doing so by a dominant male due to sexual coercion (Smuts and Smuts 1993). Five criteria must be met in order for mate choice (sexual selection) having an influence on communication (Snowdon 2004): [1] the signal must be sexually dimorphic and [2] differ between individuals of the same sex; [3] preference and discrimination (or even avoidance) by individuals of the opposite sex must occur and [4] be expressed in the context of reproduction; and [5] the result of specific preferences for certain signal must relate to reproductive success. Bright colours in male mandrills, for example, fulfill all of the 5 criteria (Setchell 2005), providing a good example of how mate choice influences communication and interactions in nonhuman primates.

Geladas (*Theropithecus gelada*) also possess a sexually selected signal: a red patch of skin on the chest and neck. Bergman and colleagues found that a) leader males, the only males with reproductive access to females, had the reddest chests, and b) within leader males, males with large units (more than 6 females) had redder chests than males with small units. These colour signals are of special importance in large, fluctuating groups with unfamiliar members (Bergman *et al.* 2009, Marty *et al.* 2009) and are as such not only important for nonhuman primates but also humans. Looking at westernized populations, many human individuals come together in large groups and live in vast, partly overcrowded cities. As such, we meet strangers on the streets, on the bus or in the street on almost a daily basis. If we are quick to make dominance attributions of others (Carre *et al.* 2009) then colour could be a valuable indicator to rapidly assess an unknown individual's condition. Consequently, if red colouration serves as a signal for male status and quality in nonhuman primates, possibly then, red colouration may exploit a perceptual bias that evolved to support rapid social judgments in humans. Skin colour seems to be a helpful way to facilitate such judgments.

1.2.6 Skin colour

Red skin is the result of a plexus of thin-walled blood vessels below the epidermis. Primates with trichromatic vision are usually bare-faced (Changizi *et al.* 2006) which allows conspecifics to detect short-term changes in health as skin colour is more labile than fur colour is (Caro 2005). As mentioned in section 1.1.1, primate trichromatic colour vision is believed to optimize the perception of changes in oxygenation and skin blood flow in conspecifics. These skin colour modulations are important indicators of the emotional change, condition, state as well as sexual and social status of the perceived conspecific (Changizi *et al.* 2006), and visual sensitivity to these specific shifts is thus of primordial importance for interpersonal communication. The visual system detects changes in both the concentration of hemoglobin (along a blue-yellow axis) and the oxygenization of hemoglobin (along a red-green axis), and these changes are associated with specific shifts in skin colouration. Greater concentration produces more blue and less yellow colouration, whereas greater oxygenization produces more red and less green colouration. Consequently, the perception of (skin) colour allows the perceiver to discern, among other things, when a conspecific is becoming ill (more concentration-based blueness) or when a potential aggressor is preparing for attack (more oxygenization-based redness). The latter is of special importance in male-male encounters as red colouration could be a signal of fitness and strength, because testosterone-induced skin vascularisation is at costs of immunocompetence and energy (Folstad and Karter 1992, Muehlenbein and Bribiescas 2005).

1.2.7 Skin colour and naturally occurring agonistic encounter

For both human and nonhuman primates red colouration is linked to high status. In addition, haemoglobin based skin that flushes red is an honest signal for health or social status or hormonal condition in at least 29 bird genera (Negro *et al.* 2006) and the colour of bare skin in unfeathered heads of lappet-faced vultures (*Aegypius tracheliotos*) can flush from pink to dark red in just a few seconds (Mundy *et al.* 1992). Therefore, avian flushing seems to reveal some information in agonistic encounters. Bare patches of skin, bill and legs not included, are present in species belonging to at least 19 different avian orders and 62 families (Negro *et al.* (2006)). Bare skin patches are typically shown in the face (37% of families), head (35%), neck (31%), the crop (10%), or in the pectoral disks of tetraonids and Old-World vultures (Mundy *et al.* 1992, Del Hoyo *et al.* 1994). It has been suggested that the red colouration designates contest ability in vulture gatherings as adult pale heads (sex not specified) won less agonistic interactions against conspecifics with flushed heads (Bamford *et al.* 2010).

Similiar findings are available from nonhuman primates. For example, mandrills' bright colouration on rump, face and genitalia is associated with high levels of circulating testosterone (Dixson *et al.* 1993, Setchell and Dixson 2001a, Setchell and Dixson 2001b) and may therefore advertise a male's ability to cope with immunosuppressive effects of high testosterone levels (e.g., Folstad and Karter 1992, see section 1.2.3). Setchell and Wickings (2005) concluded that mandrills assess a rival's fighting ability and dominance rank based on the brightness of the rival's red colouration. Female mandrill's redness, in contrary to males, is not related to rank (Setchell *et al.* 2006a) which leads to the conclusion that red colouration has a signalling function specifically in male-male competitions. Usually, the reddest mandrill male in the group is the alpha male, although it takes some time for a newly alpha male to develop its full colour (Setchell *et al.* 2008). In contrast, males will lose their colour once they lose their top rank (Setchell and Dixson 2001). These findings point to a clear association of red colouring, status and hormone levels. Elevated testosterone levels in sexually active male Japanese macaques (*Macaca fuscata*) are accompanied by increased aggressive male-male competition and also increased mating activity (Barrett *et al.* 2002), which is why red skin colouration may also be important for intersexual relations.

Red skin is a less pronounced signal in humans than it is in nonhuman primates. While blushing is a sign of social discomfort in situations of shame or embarrassment (Drummond and Quah 2001, Montoya *et al.* 2005), red skin colouration is associated with anger and dominance (Drummond and Quah 2001) whereas blanching is associated with submissiveness, fright and fear (Montoya *et al.* 2005, Changizi *et al.* 2006). Stephen *et al.* (2009a) drew parallels between nonhuman and human signal colouration in demonstrating that facial skin colouration carries cues that the perceiver uses to evaluate health, attractiveness, and dominance of others. Such artificial modifications of skin colouration in humans and nonhuman primates have lead to a variety of interesting findings about red colouration and its effects on social perception and even behaviour, and will be described in depth in the next section (1.3).

1.3 (Red) Colouring as an artificial stimuli

1.3.1 Red colouring in the context of attraction/affiliation

1.3.1.1 Skin Colour

Red colouration is frequently linked to sex and is, across cultures, associated with passion and love (Aslam 2006). It is therefore not surprising that many empirical studies have been carried out in an effort to identify whether artificial characteristics of red shades influence perceptions of attractiveness (in humans) or visual preferences (other animals).

Natural red colouring carries valuable information for nonhuman primates (section 1.2.5.1) and the animals' perception of these might be biased through artificial stimuli. Bielert *et al.* (1989) exposed male chacma baboons (*Papio ursinus*), to an ovariectomised female wearing an artificial model of a swollen female perineum (presented in eight different colours). Only the red coloured model led to an increase in copulation attempts and masturbation. Waitt *et al.* (2006) showed that male rhesus macaques looked significantly longer at red hindquarters of female conspecifics as when they had not turned red, but males did not look longer at reddened versions of faces. In contrast, female rhesus macaques do prefer males' red faces to pale faces (Waitt *et al.* 2003). However, different species may reflect different preferences. For example, Pflüger *et al.* 2014 demonstrated that red chromaticity on faces is essential to induce prolonged male interest in female Japanese macaques (*Macaca fuscata*). This suggests that sex of the intended recipient and the signalling function of red skin may vary across anatomical regions or animal taxa, but that it definitely attracts the attention of the opposite sex in some cases.

That colouration influences mate choice behaviour is also apparent in non-primate species. For instance, parasite load in three-spined sticklebacks (*Gasterosteus aculeatus*) correlates negatively with red intensity in breeding colouration (Milinski and Bakker 1990). As such, red colouration indicates the wellbeing of males and is thus a key point for the female's evaluation of mate choice. Female sticklebacks chose brightly red coloured males under colour-revealing conditions but chose males on a random basis under lighting conditions that prevented the use of colour cues.

The most powerful evidence linking red to attraction, comes from experiments involving humans. It is well known that hearts and lingerie stand for romantic and passionate attraction, that may even signal sexual opportunities in sex trade areas, also referred to as "red-light districts" (Mahnke 1996, Kaya and Epps 2004). It is, thus, less surprising that the colour red is a novel factor in studies exploring human attraction in general (e.g., Elliot and Niesta 2008, Roberts *et al.* 2010) and studies involving skin colour changes in particular. Stephen and colleagues were amongst the first to contend that facial skin colouration effectively serves as a cue to signal attractiveness, health, but also dominance (for more see section 1.3.1.1) to the perceiving individual (Stephen *et al.* 2009). Skin yellowness and skin redness are regarded positively; yellowness (presumably due carotenoids) reflects vegetable and fruit consumption, and redness (presumably due to blood oxygenization) reflects cardiovascular wellbeing (Stephen *et al.* 2009). Stephen and fellow researchers conducted experiments investigating various properties of face colour and perceptions of attractiveness and health. The overall results from a battery of tests is that faces that are lighter, yellower (due to caratenoids), and redder (due to blood perfusion) are rated as more attractive and healthier (Stephen *et al.* 2009a, 2009b, 2010, 2011, Re *et al.* 2011, Coetzee *et al.* 2012, Whitehead *et al.* 2012). Not all studies found a link between perceptions of attractiveness/health and lightness or redness (Stephen *et al.* 2009a, 2009b) and effects of participants' sex might not be unimportant (Stephen *et al.* 2012). For example, female participants enhanced male targets' aggressiveness, dominance and attractiveness by adding more red on men's faces (Stephen *et al.* 2012). More lightness, less blueness and greater redness of lips, in contrast to the rest of the face, are also viewed more attractive, specifically for female targets (Stephen and McKeegan 2010). In contrast, (artificially manipulated) labia redness on women's genitals is not linked to perceived attractiveness (Johns *et al.* 2012). It is still unclear whether women's facial skin colour reddens during ovulation or not; there is support for (Oberzaucher *et al*. 2012) and against this possibility (Samson *et al.* 2010). Homogeneity of skin colour distribution (more even skin colour) has repeatedly been reported to be positively related to perceptions of attractiveness and health and negatively related to perceptions of age in both men and women (Fink *et al*. 2006, Fink and Matts 2007, Matts and Fink 2007, Fink *et al.* 2008, 2012a, 2012b, Samson *et al.* 2010, Coetzee *et al.* 2012). What becomes apparent from these studies is that observed relations possibly emerge from selection processes and mate choice preferences. However, in perceptions of attractiveness not only on skin colour *per se*, but also perceiver sex, female participans' fertile phase, and homogeneity of the skin may play a role; without any of these factors being more important than another. More importantly, this research demonstrates that human observers are sensitive to subtle colour differences between oxygenated (bright red colour or a "ruddy" face) and deoxygenated blood (slightly bluish red colour) (Ponsonby *et al.* 1997) and consequently evaluate these differences in skin blood oxygenation as a sign of underlying health, which can then affect mate choice preferences. In addition, the perception of redder skin as healthier has been found cross-culturally in both Caucasians and black South Africans (Stephen *et al.* 2009a).

Building on evidence linking the colour red to attraction in heterosexual interactions of animals and humans, researcher Andrew Elliot and colleagues positioned that the societal use of red in the amorous context (e.g., women wearing red lipstick, "red roses" as signs of love etc.) is not random (Elliot and Niesta 2008), but might actually be rooted in our biological heritage to perceive red as a sexual signal. Moreover, it is conceivable that some colour-meanings, specifically those observed across diverse cultures and across time, are a product of social learning (via cognitive shaping and reinforcement) of an initial biologically engrained predisposition (Elliot and Maier 2014). This so called "higher-order learning" could be held responsible for extending and reinforcing the applicability of colour-associations beyond natural bodily processes (based in blood physiology) to objects in close proximity to the body (e.g., clothing) and perhaps even objects in the broader environment (e.g., portable objects, signs and signals). Consequently, a red dress (women) or red T-shirt (men) may carry sexual meaning to the perceiver, similar to the red of sexual arousal or excitation on the face and upper chest.

1.3.1.2 Clothing colour and other stimuli

Attraction may not only be influenced when colour is directly displayed on the skin, but it may also impact perceptions of attractiveness when seen in close proximity to an individual of the opposite sex. Men rate women as more attractive and sexually appealing when the women are depicted in red clothing, within a red picture border or when carrying seemingly trivial objects such as red-coloured laptops (Elliot and Niesta 2008, Lin 2014). This extended "red-effect" on perceived attraction or attractiveness was supported by subsequent research (Elliot *et al.* 2010, 2013, Roberts *et al.* 2010, Jung *et al.* 2011a, 2011b, Guéguen 2012a, Pazda *et al.* 2012, 2013, Schwarz and Singer 2013). Some experiments only found the effect for young female targets (Schwarz and Singer 2013), whereas others did not find the effect in some control conditions (Roberts *et al.* 2010, Jung *et al.* 2011b), and others not at all (Purdy 2009).

The "red-effect" is not limited to individual's perception, but may also be detected in actual behaviour. Men tip waitresses wearing red more generously (Guéguen and Jacob 2012, 2013a), are more likely to give a lift to red-wearing hitchhikers (Guéguen 2012b), approach women wearing red lipstick faster (Guéguen 2012c), and are more likely to get in contact with women displaying red in their profile picture on a dating website (Guéguen and Jacob 2013b). Men also walked faster to an ostensible interview about dating when the female interviewer was wearing red (Meier *et al*. 2012), and sat closer to and asked more intimidate questions of a women in red (Niesta *et al.* 2010). Whether women and men's perception of attractiveness is equally effected by red colouring remains to be conclusively investigated (see Elliot and Niesta 2008, Roberts *et al*. 2010), but with regard to actual behaviour, the effect seems to be specific to male individuals (Guéguen and Jacob 2012, 2013a, Guéguen 2012b).

Red also seems to play a fundamental role in the attractiveness perceptions of women wearing makeup (e.g., Graham and Jouhar 1981, Cox and Glick 1986, Cash *et al.* 1989, Workman and Johnson 1991, Mulhern *et al.* 2003, Nash *et al.* 2006, Richetin *et al.* 2007, Jacob *et al*. 2009).

Both women and men rate women wearing colour cosmetics (including red) as being more attractive than those unmade-up (Huguet *et al.* 2004, Law Smith *et al.* 2006, Etcoff *et al.* 2011). Again, men's behaviour seems to be specifically affected as men contacted a female confederate sitting in a bar more often and quicker when the women was made-up than when she was not (Guéguen 2008), they also are more helpful and tip more favorably when waitresses used make-up whereas female patrons did not behave equally (Jacobs *et al.* 2009). Women seem to be conscious about men's preferences as women regard themselves as more attractive when exhibiting red relative to blue (Burtin *et al.* 2011) and women prefer red clothes both in real-life and imagined scenarios more than men do (Prokop and Hromada 2013). Additionally, women interested in casual sexual relationships are more likely to display red than women interested in marital, long-term relationships (Elliot and Pazda 2012) and are over three times more likely to put on a pink or red shirt when they are at peak fertility than women that are not at high-conception risk (Beall and Tracy 2013). This preference for red colouring (but not for other colours) in mating game scenarios was only significant for women (Prokop and Hromada 2013). An explanation for this could be that women use red to attract potential mates in a similar way to nonhuman primates. This mediation of the "red-effect" also works the other way around in that men rate red displaying women to be more sexually receptive which consequently faciliates men's perception of a women's sexual desirability and attractiveness (Guéguen 2012a, Pazda *et al.* 2012). Not only red but also black facilitates men's perception of attractiveness (directly or indirectly) (Roberts *et al.* 2010, Pazda *et al.* 2013). For example, black enhances a women's perceived fashionableness and black (and red) influences perceived attractiveness mediated through its influence on perceived fashionableness (Pazda *et al*. 2013). This "black-effect" is, however, not reflected in men's actual behaviour towards women (Guéguen 2012b, Guéguen and Jacob 2013a, 2013b). Type of clothing could have a moderating role. For example, a sexy dress might produce a ceiling effect that eliminates or at least minimizes the influence of red; a stronger effect on rather ordinary clothes such as T-shirts could be expected.

Women are also shown to rate men wearing a red T-shirt (compared to four other chromatic colours and white) as being more attractive, even when clothing colour is obscured from raters (Roberts *et al.* 2010). Similar results were found by Elliot *et al.* (2010) with colour being displayed either on T-shirts or on picture borders. Women walk faster to get interviewed about dating when the interviewer of the opposite sex is wearing red (Meier *et al.* 2012).

Unfortunately, no data is yet available on women's actual behaviour and findings regarding the sex-specificity of the "red-effect" are ambiguous, with some suggesting that it is specific to women rating men, and others suggesting a generalizability across gender (Roberts *et al.* 2010, Elliot *et al.* 2010).

Some research points to possible moderators of this "red-attraction-effect" for women that are worthy of consideration. Same-race preferences (Wartenburg *et al.* 2011), obscured and modified colours (Roberts *et al.* 2010, for more see Chapter 5, section 5.2), women's cycle status (see Penton-Voak *et al.* 1999 for relevant associations between fertility status and dominance cues), a man's status (Elliot *et al.* 2010), and the type and intensity of red. The latter point is important since it can be a disadvantage for women's judgments of attractiveness as a pinkish, light red may cue feminity in men, and a vivid, intense red may cue aggressiveness (see also Chapter 2, section 2.5). In regards to attractiveness perception, the optimal red for female raters may be one that does not signal aggression but that is strong enough to elicit attraction (see Jensen-Campbell *et al.* 1995). In what ways the detection and perception of aggressive or dominant cues play a role regarding red colour stimuli, is elaborated in the next section.

1.3.2 Red colouring in the context of competition and achievement

1.3.2.1 Findings from the animal kingdom

From fishes, birds and lizards to nonhuman primates, red colouring carries important information of an opponent's condition and ability which can be vital in agonistic encounters (see section 1.2.4). Recent studies have used artificial red stimuli to elicit specific responses in the context of competition. This has helped to reveal some interesting dominance interactions in intra-sexual competitions. For example, when head colour of male Gouldian finches was artificially altered, the red-headed phenotype continued to dominate other morphs, which suggests an intrinsic aggressiveness (as opposed to a learnt association) of red-headed phenotypes (Pryke and Griffith 2006; although see results from lizards in Healey *et al.* 2007). Both male and female birds avoided initiating conflicts with artificially and naturally painted individuals of the aggressive red morph (Pryke and Griffith 2006, Pryke 2009, Pearce *et al.* 2011). Cuthill *et al.* (1997) demonstrated that the arbitrary and seemingly trivial assignment of differently coloured leg bands to zebra finches (*Taeniopygia guttata*) can greatly affect reproductive success, parental investment, mortality rates, sex ratio, and mate preferences. When red and green leg bands were assigned, red-banded males dominated green-banded males (see also Seguin and Forstmeister (2012) for a meta-analysis on colour bands). This suggests that artificial colours can exploit innate responses to a natural stimuli, at least in birds, not only in the context of sexual preferences (section 1.3.1.1) but also but also in the competitive context. Initial results from an inter-species study further confirmed this notion in primates: when rhesus macaques had the chance to steal food from different keepers, the animals avoided keepers in red shirts as opposed to those wearing green or blue shirts (Khan *et al*. 2011). With red clothing colour having such a profound effect between two different species, it might be hypothesised that the colour red of an individual's clothing should also signal aggression and dominance in a similar manner to another human being (see section 1.3.2.3). Reasons for this might be an evolved psychological predisposition to behave submissively to a red coloured opponent (Hill and Barton 2005) and a subconscious motivation to avoid the colour red as it was found to negatively affect human performance in various contexts (e.g., Elliot and Maier 2007).

1.3.2.2 Individual motor- and cognitive performance

In achievement situations, viewing red can impede and individual's performance on challenging tasks that demand flexibility and mental manipulation (Elliot *et al.* 2007). According to the researchers, red is associated with danger and failure, and evokes avoidance motivation in such contexts, which consequently undermines performance. In a series of experimental studies, the researchers proved that participants viewing red before or during an analogy, anagram, and math tasks performed worse than those viewing green or achromatic control colours. Subsequent research has further demonstrated this "red-effect" using additional chromatic and achromatic controls and other kinds of challenging cognitive tasks (e.g., language proficiency, working memory, verbal reasoning, creativity, Stroop tests and other attentional interference; Ioan *et al.* 2007, Maier *et al.* 2008, Lichtenfeld *et al.* 2009, Mehta and Zhu 2009, Gnambs *et al.* 2010, Elliot *et al.* 2011, Jung *et al.* 2011b, Yamazaki and Eto 2011; although see Larsson and von Stumm 2015). Some found that “seeing red” was a particular distractor for men in competitive situations (Ioan *et al*., 2007, Gnambs *et al*. 2010, 2015), whereas other researchers have not found an effect using control conditions (Mehta and Zhu 2009, Yamazaki 2010, Jung *et al.* 2011b, Lichtenfeld *et al.* 2012) or ambient office wall colours (Küller *et al*. 2009, Bakker *et al.* 2014). Some tests resulted in evidence suggesting that viewing yellow may have detrimental effects on certain types of challenging cognitive tasks (Yamazaki 2010, Kumi *et al.* 2013) and that green or blue may have benefits for creative performances (Mehta and Zhu 2009, Küller *et al*. 2009, Lichtenfeld *et al.* 2012), but this research domain has received only little empirical attention.

Avoidance motivation can facilitate performance on detail-oriented, basic cognitive tasks requiring flexibility or minimal mental manipulation (Friedman and Förster 2010), and Mehta and Zhu (2009) supported the proposal that red facilitates performance attainment in such tasks (e.g., proofreading, cf. Küller *et al.* 2009). More research has found that red facilitates performances in tasks involving basic motor strength (Elliot and Aarts 2011), target-shootings (Sorokowski and Szmajke 2011), and overlearned motor actions (Larionescu and Pantelimona 2012). But red may also weaken performance on tasks involving basic strength tests (Payen *et al.* 2011, see also Chapter 4), cycling (Briki *et al.* 2015) and goal-directed motor movements (Williams *et al.* 2011). Other factors than task type may be important and demand close considerations as moderators and boundary conditions may warrant the influence of red on cognitive performance (the task's difficulty level or individuals' ability, culture, or sex). Moderateness of these factors (e.g., a moderately difficult test) seem most likely to exhibit the "red-effect" (Elliot and Maier 2014, see also Gnambs *et al*. 2010 for an example regarding sex moderation).

In terms of possible mechanism(s) underlying the "red-effect" on performance, a number of experiments has demonstrated that red colouration is implicitly associated with danger and failure in achievement situations (Mehta and Zhu 2009, Moller *et al.* 2009; although see Rook 2014) and, for example, using a red pen activates concepts of failure and error (Rutchick *et al.* 2010). Essays evaluated with a red pen are marked with more errors and are awarded lower grades than when they were marked with a blue pen (Rutchick *et al.* 2010). Not surprisingly teachers are evaluated less positively when they mark students' work with red versus aqua ink (Dukes and Albanesi 2013). Thus, red writing on essays seem to demoralize students as they immediately relate it to their own mistakes. Interestingly, participants using a red (relative to black) pen are more likely to complete words in a way that its content is failure-relevant (e.g., wro_ as "wrong" rather than "wrote"; "fail" rather than "fair" for fai_; Rutchick *et al.* 2010). Red has also been suggested to carry negative valence by default (Elliot and Maier 2014) as it is associated with affective experience and negative content in situations where no content is present or no ability is evaluated (such as medical studies or tests on snacking; e.g., Gerend and Sias 2009, Moller *et al.* 2009, Chien 2011, Magee 2012, Piotrowski and Armstrong 2012).

Perceiving the colour red in achievement contexts prior to or during a specific task has been demonstrated to induce avoidance behaviour and motivation in a variety of studies using a number of different indicators: left relative to right frontal cortical activation, selecting easy rather than moderately difficult tasks, global relative to local processing, knocking fewer times on the door of an experimental room, walking slower to an evaluative meeting, decreased heart rate variability, less risky investment decision making, and moving physically away from a cover sheet of an ability test (Elliot *et al.* 2007, Elliot *et al.* 2009, Lichtenfeld *et al.* 2009, Maier *et al.*, 2009, Mehta and Zhu 2009, Meier *et al.* 2012, Rutchick *et al.* 2010, Elliot *et al.*, 2011, Tanaka and Tokuno 2011, Gillebaart *et al.* 2012, Klinger and Gilad 2013, Shavit *et al.* 2013). Avoidance motivation has been declared as a mediator of the link between the colour red and performance attainment and there are enough data to support this role (Maier *et al.* 2008, Lichtenfeld *et al.* 2009, Mehta and Zhu 2009).

1.3.2.3 Competitive sports performance

In recent years, researchers have investigated the effects of colouration in one very specific global phenomenon: *human sports competition* (Kocher and Sutter 2010, Wiedemann *et al.* 2012 in Appendix VII). Sports are ubiquitous in human cultures and are valued as a form of physical competition (Chick and Loy 2001, Llaurens *et al.* 2009). Having triumphed in 17 German Cups and 25 German Championships, F.C. Bayern Munich is by far the most successful German football club. Manchester United and Liverpool dominate the roll call of the English Premier League, while Ajax Amsterdam is Netherlands' most decorated team. These successful football teams are also united by a second characteristic; all have red as the primary colour on their signature football strip. Although this could easily be construed as pure coincidence, recent evidence suggests that clothing colour may play an important role in deciding sporting contests. The worldwide appeal of sports such as football or rugby has led economists and psychologists to devote an increasing body of research to sports. Recently, there has also been an increase in research examining sport from an evolutionary perspective. The first evidence that red might function as a dominance cue and therefore influence the outcome of sporting contests was provided by Hill and Barton (2005). Their analysis was based on four combat sports (taekwondo, boxing, Graeco-Roman wrestling and freestyle wrestling) at the 2004 Olympic Games. During this competition, red or blue uniforms were randomly assigned to competitors based on their position in the draw, providing a natural experiment. If colour had no effect on outcomes, an equal number of red and blue winners would be anticipated. Instead, Hill and Barton (2005) found that wearing red was associated with a significantly increased probability of winning, with 55% of all bouts won by competitors in red. Wearing red appeared to tip the balance between winning and losing in close contests: significant effects were found when competitors were closely matched (60% red winners), but not in more asymmetric encounters (see Seife n.d. for a replication attempt relying on the 2008 Olympics contradicting Hill and Barton's findings). This was particularly the case for male competitors (Barton and Hill 2005),

but not in more asymmetric encounters. Subsequent studies have provided substantial support for the role of red colouration in determining sporting outcomes. A review of English football data found an association between teams wearing red shirts and long-term success (Attrill *et al.* 2008). Since the Second World War, red teams have provided more champions and averaged higher finishing league positions than teams in other colours. Most significantly, within cities with more than one team, red teams have significantly outperformed their non-red neighbours over the 55 year period (Attrill *et al.* 2008). Greenlees *et al.* (2010) found that penalty takers were the least successful when they were opposed to a goalkeeper wearing red, supporting Greenlees *et al.*'s (2008) earlier finding that penalty takers in red shirts are perceived to possess character traits such as confidence, assertiveness and composure to a greater extent than those in white shirts. Ilie *et. al* (2008) examined advanced and experienced players in a first-person-shooter online computer game. Despite reflecting competition in an artificial computer-generated environment their results showed striking parallels to those of Hill and Barton (2005).

The red advantage has susequently been tested in rugby and football leagues in England and other countries and yielded mixed results. Piatti *et al.* (2012) confirmed the red advantage in the Australian National Rugby League but restricted it to the top teams in the league. Allen and Jones (2012) examined a more recent data set than that analyzed by Attrill *et al.* (2008), and confirmed an advantage for red-wearers in general, but not for home games of equal team abilities. No evidence in archival analyses was found for red boosting team performances in the North American National Hockey League (Caldwell and Burger 2011) or elite football leagues in Spain, Poland, and Germany (Szmajke and Sorokowski 2006, Kocher and Sutter 2008, Garcia-Rubio *et al.* 2011). It is possible that the red advantage in sports is present in some countries but not all and that it functions perhaps as a learnt, culturally specific associations to red (see also Lakens 2011) that may either boost or weaken an inherent meaning. Likewise, a red win effect may be more evident in individual-, one-on-one competitions (Kocher and Sutter 2008) or in combat sports rather than collaborative, team sports (although see Pollet and Peperkoorn 2013[2]).

Hill and Barton (2005) posited that the red advantage might be evolutionary/biologically engrained and that individuals are psychologically predispositioned to react submissively to a

[2] Results from the Ultimate Fighting Championships (UFC) do not support a "red winning effect" (p = .386) when five categories of short colours were compared. However, the results are not very reliable do to the methodological limitations (e.g., influence of logos) of the study that diluted the "red-effect".

red-wearing opponent. Consequently, red adornments (even artificial ones like sports attire) should raise an individual's excitement level, increasing its striving for dominance, high status, and "willingness to fight". Therefore, these characteristics may influence the results of sports competitions and facilitate competitive outcomes.

An alternative explanation was proposed by Rowe *et al.* (2005), who argued that blue judogi worn in judo competitions have an performance advantage over white judogi due to visibility differences between contestants (see also Matsumoto *et al.* 2007). However, Dijkstra and Preenen's reanalysis (2008) revealed that the study was confounded and that no such effect existed. Furthermore, blue was not tested against red in these studies. For example, in Recours and Briki's research (2015, virtual contestants facing an opponent in red reported higher levels of cognitive anxiety, while those exposed to an opponent wearing blue reported higher levels of self-confidence. This supports the notion that red is related to the avoidance (and blue to the approach) motivational system (e.g., Elliot *et al.* 2011, for another example see Briki *et al.* 2015) because self-confidence and competitive anxiety are related to performance in sports (e.g., Woodman and Hardy 2003). Yet another explanation for the "red-advantage" in sports could be that referees' are biased and favour red-wearers (for relevant findings see Hagemann *et al.* 2008, Krenn 2014, Sorkowski *et al.* 2014).

Also other colours, such as the presence (black) or absence (white) of achromatic colours have been associated with aggressiveness in sports contests (Frank and Gilovich 1988) or with referees' perceptions of aggressiveness. More recent, methodologically stronger research appears to support this observation (see Tiryaki 2005, Caldwell and Burger 2011, Webster *et al.* 2012.)

The "red-effect" is most prominent with males (Barton and Hill 2005), which is consistent with Hill and Barton's explained mechanism that red enhances one's testosterone levels, aggressiveness, and dominance. Consistent with this account are several studies linking being affiliated with or wearing red (relative to achromatic or other chromatic controls) to a self-perception of being more intimidating, aggressive, powerful, and threatening (Feltman and Elliot 2011, Ten Velden *et al.* 2012) and exhibiting a greater performance strength, higher testosterone levels, and a higher heart rate (Farrelly *et al.* 2013, Dreiskaemper *et al.* 2013; although see Hackney 2006 and Briki *et al.* 2015).

Viewing red (as in opposing a red-wearer) could have an equally important influence as wearing red. Study results regarding this distinction of wearing and viewing red, demonstrate that targets presented in red colours are rated as being more likely to win a competitions, more competitive, brave, aggressive, and dominant (Sorokowski and Szmajke 2007, Little and Hill

2007) or show a general association between the colour red and aggression, anger or interpersonal hostility (Tharangie *et al.* 2009, Tharangie *et al.* 2011, Fetterman *et al.* 2011, 2012, 2015, Bagchi and Cheema 2012, Guéguen *et al.* 2012, Young *et al.* 2013). Other studies attempting to differentiate perceiving red from wearing red demonstrated that individuals wearing red are perceived to be more assertive, intimidating, competitive, and dominant (Greenlees *et al.* 2008, Feltman and Elliot 2011, Ten Velden *et al.* 2012; although see Furley *et al.* 2012; see also Chapter 2 and Wiedemann *et al.* 2015 in Appendix VI).

It is still unclear whether the red advantage exists due to a wearer effect, perceiver effect, or a referee bias. All three explanations may have merit, and they may complement rather than conflict each other. This doctoral thesis investigates the first two possibilities. All chapters and experiments examine the effects red clothing colour can have on perception. Additionally, Chapters 3 and 4 also investigate whether wearing red (relative to blue and/or grey) yields any effect on the wearer himself and whether the signal can be transferred to perceivers via an online-experiment (Chapter 5), both in a natural context (Chapter 3) and in a more competitive setting (Chapter 4). Why the sort of context matters, is described in the next section.

1.3.3 Colour-in-context theory

From the above mentioned literature, we can clearly state that red has a double meaning: it may signal either opportunity or threat, depending on the context. Elliot and Meier (2012) put forward a theory which draws on biology and social learning and offers a theoretical account of the link between colour and psychological functioning (Elliot and Maier 2007, recently suported by Kuniecki *et al.* 2015). The core premise of the *colour-in-context-theory* is that the influence of colour on cognition, affect, and behaviour varies as a function of the psychological context in which the colour is perceived (Meier *et al.* 2012). Some responses to colour seemed to be due to the repeated pairing of a colour and particular experiences, messages, and concepts. However, others represent an biologically and evolutionary engrained predisposition that is shaped and reinforced by social learning. These colour associations are shown to be extended beyond natural processes (e.g., blood flow) to objects in close proximity to the body (e.g., clothes, various accessories). This explains why red viewed on the face increases perceived attractiveness, but also when viewed on a dress or a T-shirt. As the name of the theory discloses, both the psychological and the physical context in which colour is viewed influences its meaning and, consequently, reactions and responses to it. A potential mate in a red shirt may be perceived as being more attractive (context here:

romance/sex), but a red-wearing individual might also be regarded as less competent (context here: job interview) or as physically superior (context here: sports competitions). This allows for a variety of testable hypotheses, however, it remains unknown how a specific hypothesis connects to a broader understanding of colour associations in general. Emerging research precisely predicts and explains associations of colour and psychological functioning in specific contexts (Buechner *et al*. 2014, Pazda and Greitemeyer in press), but the exact nature of the underlying psychological mechanisms continues to lie hidden. Furthermore, it is not clear if red affects the same responses and behaviours differently depending entirely on the context in which it is perceived, or more precisely, what if *no* context is available? What is needed is research that is independent of context comprehensively demonstrates the concepts (the) colour (red) is associated with and with which concepts it is not. Therefore, 4 out of 5 experiments in that thesis were conducted in context-free environments.

Chapter 2 compares red with another chromatic (blue) and another achromatic colour (grey) and demonstrates with what character traits red is associated with and with which it is not. Chapter 2 is then extended in that we distinguish between wearer- and perceiver-effects in a laboratory setting (Chapter 3) and in a web-based study (Chapter 5). Chapter 4 allows to investigate wearer- and perceiver-effects of red clothing colour in an experiment that involved a physical competition. Chapter 6 extents this research and investigates whether or not wearing red can be clearly linked to aggression and dominance in humans when the full colour spectrum is available for participants to chose from. That way, we can extent theoretical work that was, until now, limited in scope in terms of range of hues and direction of influence (for more criticism on theoretical frameworks, see a very recent review by Elliot 2015). Elliot (2015) points out that a majority of experiments have focused on the hue red, given its prominence in the society, on the body, and in nature. Our research in Chapter 6 is to our knowledge the first to use the whole colour spectrum to examine possible associations with the perception of certain personality attributes. Chapter 7 summarizes and discusses the work outlined in the previous chapters and also highlights some methodological considerations. The following and final part of this work contains the appendices which primarily include the instructions forms, consent forms, and questionnaires used for each experiment respectively. Other appendices are the RGB-values for the stimuli used in Chapter 2 (Appendix I); a test for colour-blindness (Appendix II); Appendix V includes an equation in order to explain how circular statistics work and depicts the full colour set of all 100 stimuli used in Chapter 6; the Wiedemann *et al.* (2015) publication in Biology letters (Appendix VI);

the Wiedemann *et al.* (2012) book chapter (Appendix VII); and finally, a pilot-study about red colouration in a rowing competition is explained in Appendix VIII.

Chapter 2

2 Wearing red enhances perceived dominance, aggression and confidence

2.1 Abstract

Red colouration is a sexually selected trait associated with dominance in a variety of animal taxa, and has similar psychological and cultural associations in humans. Both natural and artificial red stimuli have been found to exploit these innate biases. Because human skin redness varies with health, hormones and emotional state, we hypothesised that artificial red stimuli may exploit a perceptual bias that evolved to support rapid social judgements. In order to test this we experimentally investigated whether wearing red influences perceived personality attributes relative to blue or grey clothing, and whether results vary with gender. One hundred subjects (50 males and 50 females, average age 22.97) rated digitally manipulated photos of men for trustworthiness, aggression, dominance, and confidence on a 7-point scale. Each image was presented on a computer screen in three chromatically manipulated conditions (red, blue and grey), adjusted for luminance. Participants also categorised the emotional state of these stimuli. Main effects of colour were found for perceived aggressiveness, dominance, and confidence. Red stimuli were rated as more aggressive, more dominant and more confident than blue or grey stimuli. For dominance there was a significant interaction between stimulus colour and sex of rater, with males but not females showing a significant effect. In a categorisation test, images were significantly more often categorised as "angry" when presented in the red condition. The results from this experiment add to the growing body of evidence demonstrating an effect of the colour red on human social perception, consistent with the sexual selection hypothesis whilst not excluding possible cultural influences of the associations between red and aggression/dominance.

2.2 Introduction

Several researchers have suggested that red clothing colour has a significant influence on human perception and cognition in the context of sports competition (Hill and Barton 2005, Greenlees *et al.* 2008, Greenlees *et al.* 2010), virtual or imagined combats (Ilie *et al.* 2008, Feltman and Elliot 2011) and sexual attraction (e.g., Elliot and Niesta 2008, Roberts *et al.* 2010). An explanation for this associates red colouration with dominance and aggression (Hill and Barton 2005) in a manner also seen in finches (Pryke and Griffith 2006). However, no study has yet investigated if such artificial red stimuli (clothing colour) could also bias the perception of aggression and dominance in a neutral setting free of competitive factors or associations with attraction, nor whether red influences decoding of emotional expressions. The present study intends to fill this gap and investigates how digitally manipulated T-shirt colour may influence rapid social judgements. Hereby, participants are presented with stimuli displaying the upper body of men whose T-shirt colours are digitally manipulated. Colour is a function of the three properties chroma (saturation), value (or lightness), and hue (e.g., blue, red), and each of these dimensions may separately influence perception. The complexity behind this goes beyond this work, but it should be mentioned that, where applicable, sophisticated measurements and the control for chroma and lightness properties are necessary (Elliot and Aarts 2011, for more information see section 7.6). In this study, the aim was to test an effect of hue (redness) whilst saturation and luminance were controlled for.

With the help of a simple rating experiment we test whether wearing red influences perceived personality attributes and/or emotional states relative to blue or grey clothing colour. Red is compared to blue as both colours are commonly used in human sports competitions, whereas grey allows for a comparison of red and blue with an achromatic colour. As red, blue is a basic colour and a unique set of retinal cones is sensitive to blue wavelengths (Goldstein 1995). Blue is also the second most common colour amongst football teams (Kocher and Sutter 2008) and blue and red are the two colours compared in previous colour research of combat sports during the Olympic Games (Hill and Barton 2005). The achromatic colour grey was chosen to represent a neutral contrast to red and blue.

Whilst research of colour perception and its effects in competitive situations shows that an effect of red colour is more likely to occur amongst men (Hill and Barton 2005, Ioan *et al.* 2007), this study also aims to investigate if and how participant sex may influences perception outside of a competitive situation.

2.2.1 Hypotheses and predictions

Hypothesis 1: The colour a stimulus is presented in influences the judgements of personality attributes.

Prediction: Whether the target in a stimulus is presented in a red, grey or blue T-shirt significantly influences ratings of perceived trustworthiness, aggression, dominance, and confidence.

Hypothesis 2: Since research indicates that red colouration influences human perception and behaviour (e.g., Elliot and Niesta 2008), ratings of personality traits and the categorisation of emotional states for red-wearing targets should be different to those for blue- and grey-wearing targets.

Prediction 1: In line with Greenlees *et al.*'s (2008) finding that red-wearing penalty takers are perceived to possess character traits such as confidence, assertiveness and composure to a greater extent than those in white shirts, we predict that stimuli presenting a red-wearing target will be perceived as

a) less trustworthy,
b) more aggressive,
c) more dominant, and
d) more confident

than stimuli displayed in grey or blue colours.

Prediction 2: We further predict that the emotional state of a red-wearing target will more often be perceived as angry (and less often as happy, frightened, or neutral) than when the same target is wearing blue or grey.

Hypothesis 3: Since the effect of red is reported to be unequal in men and women (e.g., Hill and Barton 2005, Little and Hill 2007), we hypothesise that the participant's sex will influence the ratings of personality traits.

Prediction: Men will be more sensitive to red-wearing stimuli as an indicator for dominance and aggression. No predictions are made for the ratings of trustworthiness and confidence.

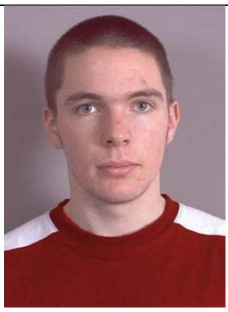
2.3 Methods

2.3.1 Participants

One hundred and four female and male students or staff members [mean age 23.28, SD = 4.92, range from 18 to 49 years] were approached either in or around the Durham Anthropology Department and asked if they had 15 to 20 minutes time to participate in a rating experiment. Participation was voluntary but a variety of non-monetary rewards were used as an incentive to recruit participants and then offered after the performance. None of the one hundred and four participants (52 females, 52 males) reported a colour vision deficiency. The data of four participants (two female, two male) were excluded from statistical analysis as they correctly guessed the purpose of the study either whilst being tested or afterwards. The mean age of the remaining 100 participants was 22.97 years [SD = 4.22, range from 18 to 40 years]. Ethical approval was given by the Durham Anthropology Department's Research Ethics sub-committee.

2.3.2 Stimuli

Dr. Mike Burt and colleagues from the Durham University Psychology Department developed the stimuli. Photographs were either retrieved from the internet (six images) or taken with the target directly looking into the camera (14 images). Pictures with most "neutral" or "angry" recognizable expressions were selected following a pilot study by Frigerio *et al.* (2002). From the 20 stimuli, one half depicted an angry, the other half a neutral facial expression (see Figure 2). With the use of *Micrografx Picture Publisher 10* the stimuli's clothing was digitally changed from its initial colour to red, blue and grey. The red versions of all 20 stimuli are summarised in Figure 2. The clothing colour was first desaturated and luminance adjusted so that they appeared mid grey (producing the grey stimulus). The hue and saturation were then adjusted to produce the three coloured images (see Appendix I for RGB-values). The test was run in Microsoft® Excel for Windows® XP, where the participant's responses were automatically and anonymously stored in a separate spreadsheet saved under the participant's subject number. As personal information and participant's responses are always kept separately from each other, anonymity is guaranteed at all times.

			
1-Emotion: anger Source: photo	2-Emotion: anger Source: photo	3-Emotion: anger Source: internet	4-Emotion: anger Source: internet
			
5-Emotion: neutral Source: photo	6-Emotion: neutral Source: photo	7-Emotion: neutral Source: photo	8-Emotion: neutral Source: internet
			
9-Emotion: neutral Source: internet	10-Emotion: neutral Source: photo	11-Emotion: anger Source: photo	12-Emotion: neutral Source: photo
			
13-Emotion: neutral Source: photo	14-Emotion: anger Source: photo	15-Emotion: neutral Source: photo	16-Emotion: anger Source: internet

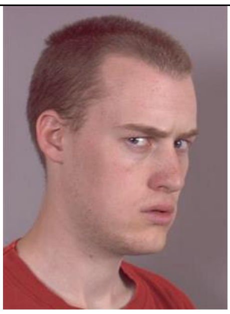
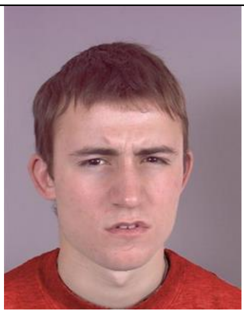
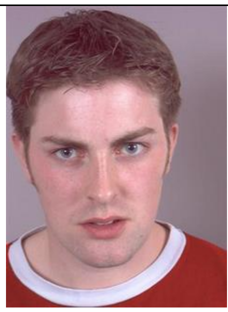
			
17-Emotion: anger Source: photo	18-Emotion: anger Source: photo	19-Emotion: neutral Source: internet	20-Emotion: anger Source: photo

Figure 2: Red versions of all stimuli

2.3.3 Design and Procedure

Stimuli were presented on a calibrated computer screen in a windowless room (D120) with constant neon strip-light illumination in the Anthropology Department, Durham University. All participants were tested under the same light conditions. Once recruited, participants read the instruction sheet *(*Appendix I*)*, signed an informed consent and filled in a brief demographics questionnaire containing questions about participant's sex, age and possible eye-defects (Appendix I). The reason we asked whether or not participants had a normal vision or suffered from any sort of eye-disease was to detect whether participants were colour blind or not. The reason we did not simply ask participants whether or not they were colour-blind was that we wanted to keep them naïve without revealing that the study was actually about colour. Running the questionnaire after the test would have rendered this problem irrelevant but we wanted to avoid that participants devote too much of their valuable time and then not be able to include their data. Following that, each participant saw in random order the head and upper torso of 20 men (see Figure 3) wearing clothes in red, blue, or grey (total = 60 images).

The participant was then asked to provide ratings of trustworthiness, aggression, dominance, and confidence, via mouse click, on a 7-point scale with each paired adjective being at either end of the scale. The paired adjectives which would accompany each individual stimulus were as follows:

(1) “trustworthiness” (1 = extremely trustworthy, 7 = extremely untrustworthy)
(2) “aggression” (1 = extremely aggressive, 7 = extremely friendly)
(3) “dominance” (1 = extremely submissive, 7 = extremely dominant)
(4) “confidence” (1 = extremely confident, 7 = extremely unconfident)

It was decided to use a seven point scale as it has been found that with seven alternatives to choose from, participants will tend to use the whole range, whereas with smaller 5-point scales and larger 9-point scales, it has been found that all the alternatives do not tend to be used with the same frequency and the answers tend to be clustered to certain areas of the scale (Osgood *et al.* 1957). Finally, participants were asked to choose an emotional state (angry, happy, frightened, neutral) that best described each of the images. It was not possible for the participant to move on to the next stimuli unless all adjective pairs had been scored and the emotional state question had been answered. Following the test, participants were asked whether they were aware of the purpose of the study (Appendix I) and were then debriefed, thanked, and dismissed.

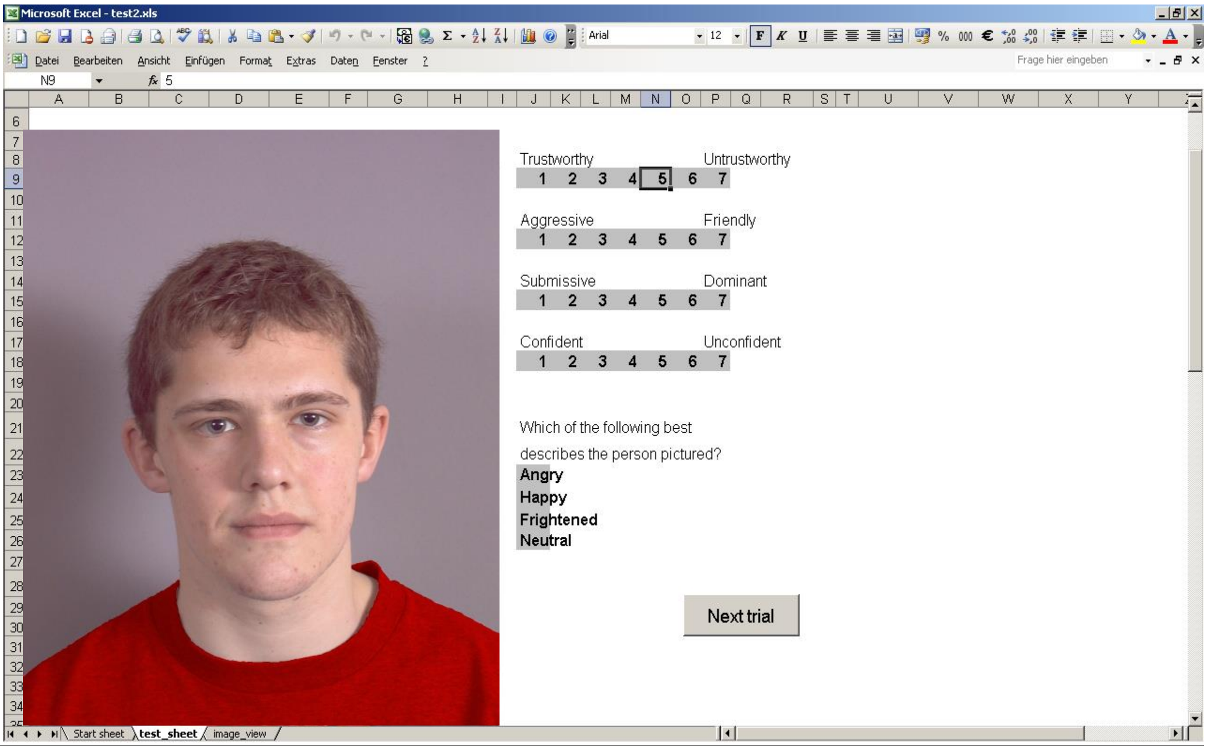


Figure 3: Screenshot of the original experimental setting

2.3.4 Statistical analysis

Statistical analysis was carried out using Microsoft® Excel for Windows® XP and IBM SPSS version 19. Variables were coded so that low numbers represented low trait values (1=extremely untrustworthy/friendly/submissive/unconfident) and high numbers represented high trait values (7=extremely trustworthy/aggressive/dominant/confident).

For each personality attribute, we calculated mean scores awarded by each rater to the twenty images seen in blue, grey, and red. With colour as a factor, the variables trustworthiness, aggression and dominance had a skewness ranging from -.672 to .214., see Table 1. Hence, there are no significant deviations from normality as skewness values between -2 and +2 are acceptable to prove a normal distribution (George and Mallery 2010).

	N	Mean	Std. Deviation	Variance	Skewness
blue trust	100	3.73	.446	.199	.082
grey trust	100	3.73	.436	.190	.214
red trust	100	3.69	.442	.195	.148
blue aggression	100	4.26	.395	.156	-.449
grey aggression	100	4.23	.397	.158	-.556
red aggression	100	4.36	.353	.125	-.051
blue dominance	100	4.33	.426	.182	-.179
grey dominance	100	4.30	.413	.170	-.285
red dominance	100	4.40	.412	.170	-.672
blue confidence	100	4.52	.446	.199	-.205
grey confidence	100	4.45	.421	.177	-.411
red confidence	100	4.58	.410	.168	-.017

Table 1: Descriptive statistics for each personality attribution separated by colour

A repeated measures one way analysis of variance (ANOVA) with colour as the within-subjects variable and sex as a between-subjects variable was conducted to test if colour and sex had an influence on the ratings of the four personality attributes. The Mauchly's test was used to determine whether sphericity could be assumed. If this assumption was violated, the Greenhouse-Geisser correction, which is a conservative correction and minimizes risk of Type I error (Field 2009), was applied. When results of ANOVA were significant we used simple contrasts and Bonferroni pairwise comparisons to compare differences amongst the three colours. If sex was found to have a significant effect on ratings. Another ANOVA for each sex separately considered was carried out.

For emotional states, we calculated scores on how often each emotional state was selected for each image (N = 20) in each colour condition. Shapiro-Wilk tests revealed that all variables were non-normally distributed (all $ps \leq .009$). As normal distribution could not be assumed, the non-parametric, Friedman's ANOVA statistical test was performed to test for differences between several related groups in the case of repeated measures (Field 2009). If the result of the Friedman's ANOVA was significant, a follow up comparison using Wilcoxon signed rank test was carried out.

2.4 Results

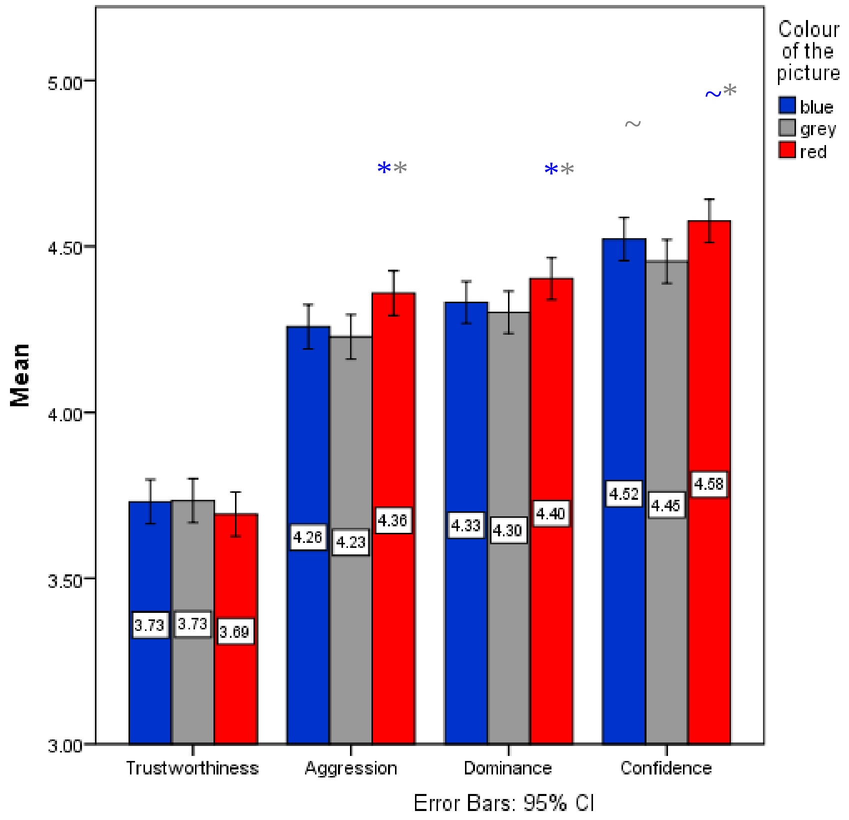
2.4.1 Personality attributes

We tested H1 that the colour a stimulus is presented in influences the ratings of personality attributes. Figure 4 depicts the mean scores for each personality attribution separated by colour. Regardless of sex, raters perceived targets in red shirts as more aggressive and more dominant as when they were shown in a blue or grey shirt; red-wearers were rated more confident than grey-wearers. This is consistent with the first part of our second hypothesis but will be further on explained in more detail for each personality attribute.

For each personality attribution, we tested H1 if colour had an influence on ratings and H2 (Prediction 1) if ratings were different for red stimuli compared to those for blue and grey stimuli. If ratings differed with sex was also tested for (H3).

2.4.1.1 Trustworthiness

Main effects for colour on the perception of trustworthiness ($F(2, 98) = 1.095$, $p = .339$) and interaction effect between colour and sex ($F(2, 97) = .803$, $p = .451$) were not significant. Results from the test of between-subjects effects revealed that ratings did not differ with sex ($F(1, 98) = 1.223$, $p = .272$). Pairwise comparison did not show that red-wearers were rated differently than blue-wearers ($p = .664$) or grey-wearers ($p = .486$), neither did ratings for blue and grey-wearers differ ($p > .999$). To summarise the results for perceptions of trustworthiness, neither H1 nor H2 (prediction 1) or H3 are supported.



Mean scores (+ error bars are automatically computed in SPSS with a 95% confidence interval) of 100 participants judging twenty images seen in three different shirt colours for four different personality traits. Asterisks (*) denote significant differences (p <. 05) between the relevant colour and the colour of the asterisk.
Tildes (~) denote marginal significant (p <. 07)between the relevant colour and the colour of the tilde.

Figure 4: Mean scores awarded for all four variables

2.4.1.2 Aggression

The analysis for perceived aggression demonstrated a main effect of colour (F (1.747, 172.934) = 12.101, p < .001). Pairwise comparison revealed that red-wearing targets were rated significantly more aggressive than blue- (p = .005) and grey-wearing targets (p < .001) whereas ratings for blue stimuli did not differ from ratings for grey stimuli (*p* = .519). Female participants rated red-wearing targets to be more aggressive than grey-wearing targets (*p* = .025), while male participants judged red-wearing targets to be more aggressive than targets wearing blue (*p* = .007) or grey (*p* = .003, Figure 4). Hence, H1 and H2 are supported as colour had an influence on judgements of dominance and red-wearing targets were perceived to be significantly more aggressive than blue- and grey-wearing targets. Even though men rated red-wearers more dominant than blue-wearers, both women and men rated red-wearers to be more dominant than blue-wearers which leads to the conclusion that H3 needs to be rejected for the variable aggression.

2.4.1.3 Dominance

The analyses yielded a main effect of colour (F (2, 98) = 5.821, p = .004) on perceptions of dominance. Pairwise comparison revealed that red-wearing targets were perceived as more dominant than grey-wearing targets (p = .003). The difference between ratings for red- and blue-wearers was close to significance (p = .063). Ratings for blue stimuli did not differ significantly from ratings for grey stimuli (p = .704). An interaction effect between colour and sex (F (2, 97) = 3.511, p = .044) was found and tests of between-subjects effects revealed that dominance ratings differed between male and female participants (F (1, 98) = 8.629, p = .003). Thus, ratings differed significantly with sex. Colour did not influence female raters' perception, $F(2, 48) = 1.425$, p = 0.251, but males' ratings were significantly influenced by colour, $F(2, 48) = 6.939$, p = .002, with targets wearing red being rated more dominant than targets wearing blue (p = .010) and grey (p = .002). Ratings for targets wearing blue did not differ from those wearing grey (p > .999).

In sum for the variable dominance, H1 and H2 are supported as colour had an influence on judgements of dominance and red-wearing targets were perceived as significantly more dominant than blue- and grey-wearing targets. H3 is also supported as male participants perceive red-wearing men as the most dominant whereas colour did not influence the ratings of female participants.

2.4.1.4 Confidence

The analysis of perceived confidence revealed a significant effect of colour (F (2, 98) = 6.924, p = .002). Pairwise comparisons showed that raters judged targets wearing red as more confident than when wearing grey (p = .001) but not when wearing blue (p = .208). Results between blue and grey-wearing targets revealed no significant difference for ratings of confidence (p = .077).

No interaction effect between colour and sex was found (F (2, 97) = 1.291, p = .280), however, tests of between-subjects effects revealed that confidence ratings differed with sex (F (1, 98) = 8.923, p = .004). For female raters, colour influenced how confident the person depicted was perceived (F (2, 48) = 6.960, p = .001) with red-wearers being perceived as more confident than grey (p < .001) wearers. There was no statistical difference between red and blue stimuli (p = .322) but blue-wearing targets were perceived significantly more confident than grey-wearing targets (p = .021). Men’s ratings, on the contrary, were not significantly influenced by colour (F (2, 48) = 2.553, p = .078).

In sum for the variable confidence, H1 is supported as colour had an influence on judgements of confidence. H2 is partly supported as red-wearing targets were perceived to be significantly more dominant than grey-, but not blue-wearing targets. H3 is not supported.

An overview of which hypotheses for which personality attribute was supported and which was not, can be find in Table 2.

	Hypothesis 1	**Hypothesis 2** *Prediction 1*	**Hypothesis 3**
Trustworthiness	rejected	rejected	rejected
Aggression	supported	supported	rejected
Dominance	supported	supported	supported
Confidence	partly supported*	partly supported	rejected

** N. sign. for the ANCOVA incl. eye-defect (yes/no) and age*

Table 2: Overview hypotheses Chapter 2

2.4.2 Emotional states

I tested H2 (Prediction 2) that a red-wearing target will more often be categorized as angry (and less often as happy, frightened, or neutral) than the same target wearing blue or grey. For each target stimuli ($N = 20$), we calculated how often the stimuli was categorised as angry/happy/frightened/neutral for each given colour (3). Friedman's ANOVA revealed that colour only had a significant effect on how often a stimulus was categorized as "angry" (see Table 3 and Figure 5).

	angry	**happy**	**frightened**	**neutral**
N	20	20	20	20
Chi-Square	13.861	1.387	1.238	1.000
df	2	2	2	2
Asymp. Sig.	**.001**	.500	.538	.607

Table 3: Test statistic of Friedman's ANOVA for emotional states showing that colour influenced only how often a stimulus was categorized as "angry", categorizations for the other three emotional states are not affected by the shirt colour a target was presented in

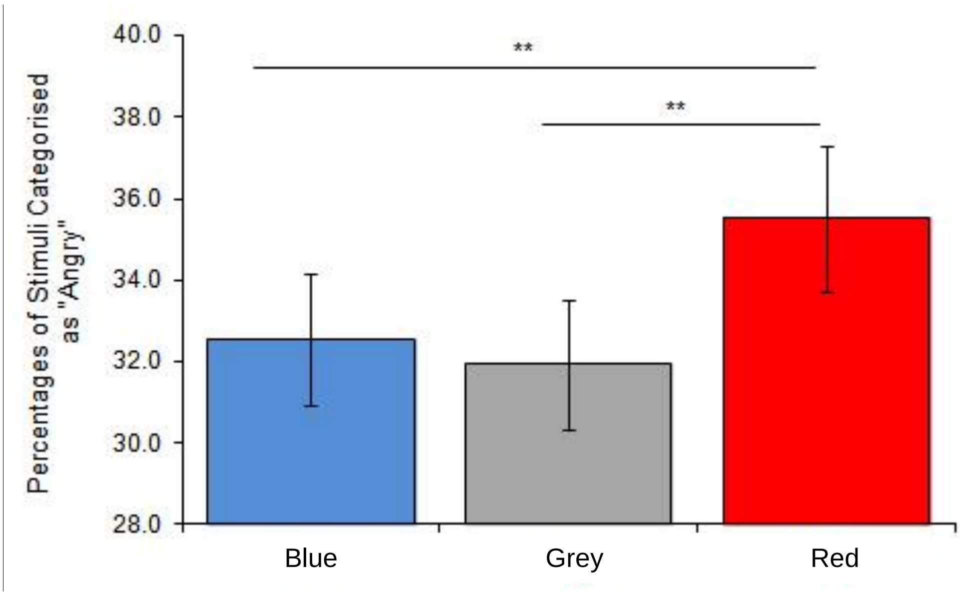


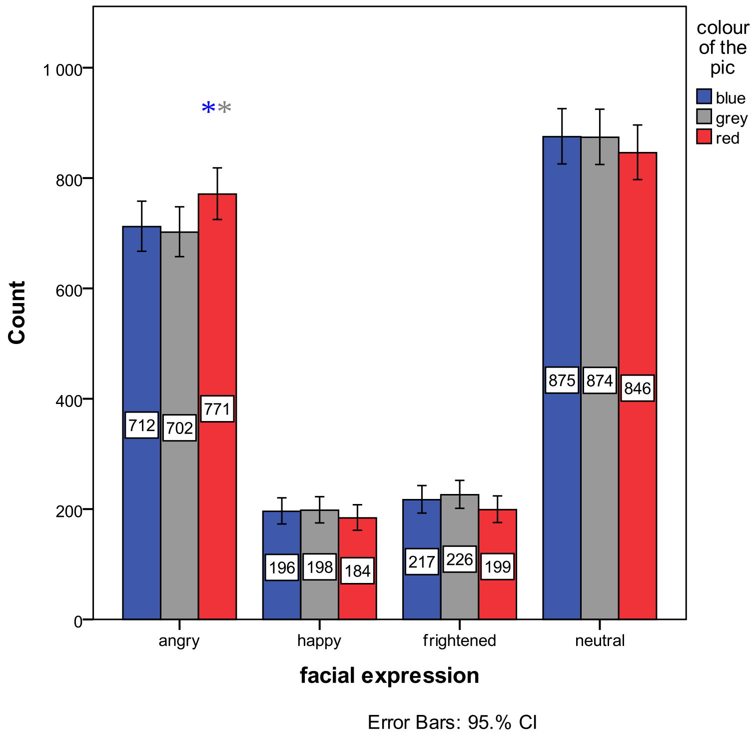
Figure 5: Percentage of stimuli categorised by each subject as 'angry' for the three colour conditions, $**p < .01$. Error bars indicate 95% CIs.

A follow up comparison using Wilcoxon signed rank test was carried out to compare if the amount an image was categorized as "angry" differed between two colours. A target presented in a red shirt was categorized as "angry" more often than when presented in blue ($Z = -2.685$, $p = .007$) or grey ($Z = -2.896$, $p = .004$). How often an image was categorized as "angry" did not differ between the colour blue and grey ($p = .203$). Colour significantly affected the perceptions of angry stimuli amongst female ($\chi^2 = 12.471$, df = 2, $p = .002$) and male raters ($\chi^2 = 10.812$, df = 2, $p = .004$), see Table 4.

	grey - blue	**red - blue**	**red - grey**
Z	-1.274	-2.685	-2.896
Asymp. Sig. (2-tailed)	.203	**.007**	**.004**

Table 4: Test statistic of the Wilcoxon signed-rank test for images categorized as "angry", red wearing targets were categorised as "angry" significantly more often than grey- and blue-wearers

As can be seen from the graph in Figure 6, from 6000 categorizations made, stimuli were mostly categorised as either neutral (N = 2595) or angry (N = 2185). They were far less often categorised as happy (N = 578) or frightened (N = 642). From a quantitative point of view, raters categorized images presented in red more often as "angry" (*sign.*) and less often as "happy" (*n. sign.*), "frightened" (*n. sign.*) or "neutral" (*n. sign.*) than images in blue or grey. These results are in line with H2 (Prediction 2), however, categorizations for red stimuli were only significantly different from blue and grey stimuli for the categorization of angriness.



Overall counts (+error bars indicate 95% CIs) of 100 participants categorizing twenty images seen in three different shirt colours as angry, happy, frightened or neutral. Asterisks (*) denote significant differences (p < .05) between the relevant colour and the colour of the asterisk.

Figure 6: Emotional state awarded for each colour the picture was presented in

Furthermore, female and male raters did not deviate from these results when sex was taken into account. Colour significantly affected the results amongst female (χ^2 = 12.471, df = 2, *p* = .002) and male raters (χ^2 = 10.812, df = 2, *p* = .004). In sum, amongst all images categorised as "angry", red images were significantly more often selected than blue and grey stimuli.

2.4.2.1 Angry versus neutral facial expression

Male targets presented in the 20 stimuli either displayed a neutral (*N* = 10) or an angry (*N* = 10) facial expression (see section 2.3.2). We performed an analysis of covariance (ANCOVA) to test whether the intended facial expression in images would influence the rating. For all four personality attributes, ratings differed significantly depending on whether the facial expression was angry or neutral (F (1, 1998), all *ps* $\leq$ .001). No interaction effect between colour and emotional state was found (F (2, 1997), all *ps* $\geq$ .103).

We then analyzed the data using repeated measures ANOVA (with colour as within-subjects variable) separately considered for stimuli with intended neutral respectively angry facial aggression (see results in Table 5). For all ratings of neutral faces, colour significantly affected the ratings of all four personality attributes. Only aggression and confidence were affected by colour for all those images displaying an angry facial expression.

	neutral facial expresssion				angry facial expression			
		Error				Error		
	df	*df*	*F*	*Sig.*	*df*	*df*	*F*	*Sig.*
Trustworthiness	2	97	3.289	**.038**	2	97	.014	.986
Aggression	1.987		7.284	**.001***	2	97	10.337	**<.001*~**
Dominance	2	97	8.904	**<.001*~**	2	97	1.006	.366*
Confidence	2	97	5.050	**.007~**	2	97	3.496	**.031**

* asterisks denote a significant main effect of colour for male participants
~ tildes denote a significant main effect of colour for female participants

Table 5: Separated results of the repeated measures ANOVA for neutral vs. angry facial expression

The results of Friedman's ANOVA for emotional states can be found in Table 6 (note that the 2x2 Chi Squared Test does not include a Yates' Continuity Correction). It is again only for pictures categorized as "angry" that colour had a significant influence (neutral facial expression, p = .011) respectively a trend influence (angry facial expressions, p = .058).

Intended facial expression		angry	happy	frightened	neutral
neutral	***N***	10	10	10	10
	Chi-Square	8.970	.162	2.118	2.513
	df	2	2	2	2
	Error df	97	97	97	97
	Asymp. Sig.	**.011**	.922	.347	.285
angry	***N***	10	10	10	10
	Chi-Square	5.692	2.240	1.448	3.486
	df	2	2	2	2
	Error df	97	97	97	97
	Asymp. Sig.	.058	.326	.485	.175

Table 6: Test statistic of Friedman's ANOVA for emotional states separated by intended facial expression (neutral/angry)

2.5 Discussion

This study set out to test whether artificial red clothing colour biases the perception of personality attributes and emotional states and whether or not results vary with gender. In extension to previous research including rating experiments with an interest in clothing colour and its effects (Elliot and Niesta 2008, Greenlees *et al.* 2008, Feltman and Elliot 2011, Roberts *et al.* 2010), this is the first attempt to test these perceptual biases outside of the competitive, achievement or sexual context.

As hypothesised (H1), the colour a stimulus was presented in did make a significant difference to how dominant, aggressive and confident (but not trustworthy) the person in display was perceived. These main effects were still apparent for ratings of aggression and dominance, even after controlling for confounding variables (eye-defect, age, etc.). As further predicted (H2, Prediction 1), targets wearing red received the highest ratings and were rated significantly more aggressive and more dominant than blue- and grey-wearing targets. In the categorisation test, images were significantly more often categorised as “angry” when presented in red (H2, Prediction 2). Hypothesis 3 that ratings may vary with participant sex is only supported for the variable dominance.

The association of aggression and red colour has implications for both females and males, which is in line with Little and Hill’s (2007) results, but men’s and women’s perceptions differed in regard to ratings of dominance and confidence. Women seem more sensitive to red colour as revealing confidence properties whereas male participants seem more sensitive to red as a signal of dominance. The latter is in line with the prediction (H3) as it has been suggested that dominance may be most salient to men in judgements of potential physical combats with other men (Little and Hill 2007) in order to estimate a male conspecific’s quality (Setchell and Wickings 2005, Pryke and Griffith 2006). The results of this study, however, show that a competitive scenario is not necessary for men to receive the dominance signalling properties of red colouration. Instead, whilst men’s size and masculine facial and vocal characteristics are well-known indices of dominance, (Buunk *et al.* 2008, Perrett *et al.* 1998, Boothroyd *et al.* 2007, Jones *et al.* 2010a, Jones *et al.* 2010b, Puts *et al.* 2006, 2007), red shirt colour seems to be a novel factor in dominance displays as it elicits a perceptual bias in men towards dominance properties in other men. A recently published paper confirms this notion: regardless of perceiver sex, messages delivered by a male communicator wearing a red sweater or tie were judged to be more accurate than when the retail employee wore a white sweater or a blue tie (Bashir and Rule 2014). Bashir and Rule conclude that they provided evidence that nonverbal cues that signal dominance, such as red clothing colour, can influence judgements of persuasive communication in the retail business.

Results showed that clothing colour did not influence how dominant female participants rated men. In contrast, male participants were sensitive to red clothing as a signal of dominance in other men. Such sex differences, with men but not women being sensitive to dominance cues, are predicted by sexual selection. Watkins and colleagues suggested that sexual differences in dominance sensitivity is context-related with men's dominance perception being specialized on direct competition for mates and women's dominance perception functions to ensure physical safety (Watkins *et al.* 2013). This further explains why women rated red-wearing men as more aggressive. Whereas the association of red and aggression may be best interpreted for males in terms of intersexual competition, its importance for women might be best explained as a result of intersexual selection. For example, female participants who were allowed to manipulate men's facial skin redness increased it the most to maximise apparent aggression, only then dominance and the least for attractiveness. These differences may mirror a trade-off between the benefits to females of preferring a dominant male and the costs of associating with an aggressive partner (Stephen *et al.* 2012a). An explanation for this relates red as an indicator of aggression to mate choice. For example, women’s fear of crime leads them to prefer long-term mates who are physically formidable and aggressively dominant (Snyder *et al.* 2011). Hence, red colouration does not only signal attractiveness to women (e.g., Elliot *et al.* 2010) but also reveals aggressive potential of male mates. However, if women judge a man’s aggressiveness in favour for him to be either picked or avoided as a partner, is beyond the scope of this thesis. But either scenario may explain why female participants responded positively to red stimuli as a sign of aggressiveness in men. Future research is encouraged to assess in what way red-wearing men may send different signals, especially in regard of dominance, to male and female audiences.

While most studies compare the effects of the colour red with another colour on one judgement (e.g., attractiveness) using a between-subjects design, we investigated the effects of three different colours on four personality judgements and on one categorical judgement using a within-subject design. Within-subject designs have several benefits and two particularly important ones are mentioned here. First, within-subject designs allow to control for individual differences such as visual disabilities, which are of great importance in colour studies, and can therefore be a source of unwanted noise. Second, this design enabled us to directly compare red with other colours but also explore the relationship of colour effects amongst two other colours. This is of special importance as proposed functional interpretations for associations of red with dominance (Hill and Barton 2005, Little and Hill 2007), attractiveness (Roberts *et al.* 2010) and mating (Elliot and Niesta 2008) can only be conclusive if other colour combinations are compared as well (Rowe *et al.* 2005). As such, the current study does not only prove that red images resulted in higher ratings for aggression and dominance, they also show that ratings for blue and grey images did not differ significantly. Hence, solely the colour red is to be credited for an influencing effect of colour on judgements of aggression and dominance. The downside of this multiple-colour approach is that participants may easier get an idea about the study's aim. However, when participants were asked whether they could guess the nature of the experiment, like Roberts *et al.*'s participants (2010), most seemed surprised and slightly amused when they learnt about the purpose of the experiment. Only four out of 104 participants correctly guessed the study's aim and their data were thereon excluded from statistical analysis. Additionally, randomisation of image presentation minimizes the risk of colour awareness on ratings. We can, thus, be confident that the present results reflect a red-effect that takes place outside of participants' conscious, which consequently allows us to clearly document a link between red colouration and human perception. However, despite the advantageous use of within-subject designs, it remains to be seen whether similar results might be found when manipulating colour in a between-subject manner (Chapter 4).

An important issue to keep in mind when investigating the red-effect is that, depending on context, red can either impair performance (on IQ tests: Elliot *et al.* 2007) or enhance performance (in face-to-face competition: Hill and Barton 2005). Even though the latter finding resulted from real-life competitions and established an interesting new area of research, Hill and Barton's findings from the Olympic Games in 2004 were restricted in a way that they could not compare achromatic to chromatic colours, nor could they control for brightness or saturation. The methodology used in this study here enabled to clearly demonstrate that viewing red had an influence on individual's perception, and this was relative to an achromatic colour (grey) but also relative to another chromatic colour (blue).
However, whilst the here proposed results demonstrate an influence of artificial red colouring on social perception of others, it is equally possible that self-perception of a red-wearer is affected. So far only a few studies have examined this possibility. Feltman and Elliot (2011) tested whether red had an influence on the perception of threat and relative dominance on either *red-wearers themselves* or on *opponents viewing red*, and revealed that there is a bidirectional effect. Participants imagining wearing red (relative to wearing blue) perceived themselves as more threatening and dominant; participants in the blue condition also perceived their red opponents as more threatening and dominant. Thus, red affects the perception of the person viewing a red opponent *and* the person wearing red itself. Even

though these findings result from an imagined face-to-face competitive context, it does demonstrate the possibility that individuals could be cognizant of displaying. And indeed, they are - at least in the mating context. For example, young women perceive themselves as sexually more attractive when they chose to wear a red relative to a blue outfit for an imagined dinner (Schwarz and Singer, under review). And targets wearing red when photographed appeared to be more attractive than when wearing white (Roberts *et al.* 2010). Intriguingly, raters awarded higher attractiveness scores even to targets whose shirt colour had been altered from red to white as compared to targets who originally wore a white shirt when being photographed. In other words, the colour (red) clearly has a strong effect on the wearer at least in the light of human attraction. Elliot *et al.* (2010) put forward an explanation to this and suggested that, depending on the situation, wearing red could subtly enhance a man's regard of his own power and status and consequently influence his thoughts and actions. A red-wearing individual, thus, may play a more aggressive football or flirt more assertively on a date, hence, the effects of red colouration in sports (e.g., Attrill *et al.* 2008) and studies of perceived attractiveness (e.g., Elliot and Niesta 2008).

With regard to the results of the emotional state categorization, male and female participants categorised red-wearing targets significantly more often as "angry" when presented in the red condition. This result is in line with the findings of Penton-Voak *et al.* (unpublished data) that colour biases even categorical determination of angry facial expression as the red hue is associated with a bias towards angry judgements. Furthermore, Fetterman *et al.* (2011) showed that priming anger concepts (versus sadness) led participants to be more likely to perceive the colour red. Individuals were also more likely to perceive the colour red when anger was evoked in themselves. Taken together, findings here suggest a clear association between the colour red and perceptions of anger possibly related to the role of facial reddening as a natural signal of anger (Osgood 1960). These biases could be due to evolutionary and cultural associations of the colour red with aggression and dominance similar to those seen in competitive interactions of nonhuman animals.

The here reported results of anger-red categorisations are further in line with Fetterman *et al.*'s results from 2012 where they showed that red font colour facilitated the categorisation of anger words, but not fear or neutral words. Additionally, participants made faster anger categorisations when the font colour was red as compared to grey. These results confirm and reinforce the specialty of the redness-anger association and lead to the question why perceptual redness and anger could possibly be linked. 1.) Linguistically, people often refer to anger in terms of perceptual redness (e.g., "seeing red"). Whether colour-related metaphors really have such a strong influence needs to be further tested (Fetterman *et al*. 2012). 2.) Of all emotions, anger seems quite likely the one that best predicts behaviours intended to physically harm another person (Berkowitz 1993). As further elaborated in the main introduction of this work (Chapter 1), red is often used as a signal of danger in our everyday life (fire trucks, stop lights, stop signs, etc.). From this perspective, it is understandable why anger metaphors refer to red, why red is associated with anger in many cultures (Needham 1973), and why the present results including anger categorisations are so robust in nature. 3.) Anger and redness might also be linked for physical reasons. Facial flushing when angry increases redness in both males and females (Drummond 1999, Drummond and Quah 2001), and red faces are perceived as dominant and angry rather than fearful (Drummond 1997). The relationship between facial expressions of anger and impressions of dominance is now well documented (e.g., Hess *et al.* 2000, 2005). As such, individuals expressing anger are generally perceived as more dominant than those expressing fear or sadness (Hess *et al.* 2005). Regardless of the reason for redness-anger associations, the results here support these associations in that red T-shirt colour facilitated anger categorisations more so than grey or blue shirts did.

2.5.1 Limitations and future research

I want to highlight some methodological limitations of this research which must be considered and preferably eliminated in future research. First, asking participants to judge 60 pictures for five attributes was probably very taxing. Even though randomisation of stimuli presentation was ensured, we cannot fully rule out that participants became tired or bored over the course of the experiment. It might be therefore sensible to adopt a methodology similar to Roberts *et al.*'s (2010) study design in which each participant rated 60 images for only one property (attractiveness). Additionally, it should have been disclosed beforehand that participants would see each target several times as this sometimes resulted in confusion. Secondly, stimuli differed to some extent in how much of the desired colour was displayed on the upper body. The application of reasonably uniform stimuli would be more appropriate. That means, all images should be retrieved from the same source and preferably produced under controlled conditions in frontal view. Targets should all wear the same shirt colour as a basis so that RGB values can be equally manipulated for each colour condition (see Chapters 5 and 6). Thirdly, given that participants imagining wearing blue perceived their red opponent as more threatening (and dominant: Feltman and Elliot 2011) a rating for how threatening participants perceived the targets may have been more relevant than ratings for perceived trustworthiness. Finally, we cannot exclude that ratings of female participants would have been somewhat different if they had rated female targets. Unfortunately, the design of the present study with stimuli presenting exclusively male faces did not permit an examination of intrasexual effects within female raters, which gives scope for further research.

Additionally, as the findings of Feltman and Elliot (2011) and Schwarz and Singer (2013) result from imagined human interactions, experiments applying methodologies closer to live competitive performances are needed. Yet, experimental control while controlling for lightness and chroma of clothing colour at the same time, is needed but presents challenges. We therefore suggest that one way to control for the directionality of the "red-effect" could be to ask participants not only to rate the target's perceived dominance but also self-perceived dominance (for example, see Chapters 3 and 4). If the effect was bidirectional then we would expect that participants rate a red-wearing target more dominant relative to themselves. If then shirt-colour was also controlled for in actual participants, it could be expected that self-perceived dominance would be higher in red-wearing participants rating differently coloured targets.

In summary, the overall implication of the findings of the present study are that clothing colour affects perceived aggression, dominance and confidence and that specifically red targets are perceived as significantly 1) more aggressive (by male and female raters), 2) more dominant (male raters) and 3) more confident (female raters) than targets dressed in blue (1 and 2) and grey (1-3). Colour-associations for aggression and dominance were only apparent for the colour red, indicating that blue does not seem to be more associated with aggression or dominance than grey is. Furthermore, both men and women categorised red-wearing targets significantly more often as angry than blue- and grey-wearing targets. For the first time outside of the sexual, achievement or competitive context, it is shown that red clothing colour biases the judgements of personality attributes and that men are more likely to perceive red colouration as an indicator of dominance than women do.

Chapter 3

3 Distinguishing between wearing and perceiving red clothing colour and its effects on dominance attribution

3.1 Abstract

Both perceiver effects and wearer effects have been proposed as a source of enhanced winning chances for red wearing opponents in sportive competitions. This is the first study outside of the sports context to test wearer *and* perceiver effects with participants actually wearing differently coloured T-shirts rather than just imagining being in a red or blue colour treatment group. The aim of this study was to investigate whether the shirt colour a participant wore influenced how dominant he perceived *himself* to be and how dominant he perceived *other* men to be. 99 male participants (average age 24.35, SD = 6.34) were randomly assigned to wear a blue, grey or red T-shirt. Self-perceived dominance was assessed using the IPIP-dominance questionnaire. To test how participants perceived others, they rated digitally manipulated photos of men for dominance on a 7-point scale. Each image was presented in three chromatically manipulated conditions (red, blue and grey), adjusted for luminance. Results indicated that the colour red did affect men's ratings of dominance in other men, supporting a perceiver effect of red colouration. In contrast, the colour a participant wore did not influence neither how dominant he perceived other men nor himself, thus, contradicting a wearer effect of red colouring. The results demonstrate an effect of the colour red on human social perception in a laboratory setting whilst not excluding the possibility that an actual male-male competition could still trigger a wearer effect.

3.2 Introduction

To date, there is no clear consensus in the literature as to why red colouration could enhance a competitor's chance of winning. The so called "red advantage" in human sports competition could arise either by boosting confidence in red-wearers, and so acting on the *wearer*, or by intimidating opponents, with red thus acting on the *perceiver* (Hill and Barton 2005). Based on this assumption and their study results from 2011, Feltman and Elliot postulated a bidirectional effect; participants imagining wearing red (relative to wearing blue) perceived *themselves* as more threatening and dominant, whereas participants in the blue condition perceived their *red opponents* as more threatening and dominant. Thus, red is suggested to affect the perception of the person viewing a red opponent *and* the person wearing red itself. However, participants only imagined wearing red and blue and the colour they were actually wearing during the experiment was not controlled for. Nevertheless, this could have been influential.

To our knowledge, no study has yet tested wearer *and* perceiver effects with participants actually wearing different shirt colours[3]. Furthermore, previous rating experiments with an interest in clothing colour and its effects were either related to competition (Greenlees *et al.* 2008, Feltman and Elliot 2011) or mainly focused on the role of red in mate choice and attraction (Elliot and Niesta 2008, Roberts *et al.* 2010). Thus, despite a series of recent high-profile colour studies; there still remains a dearth of knowledge about the impact of red clothing colouration on social perception and dominance perception in particular. The present study was conducted to fill this gap by focussing on red and its dominance signalling properties. Feltman and Elliot's (2011) study is extended by adding another, neutral colour (grey) and by having participants wear differently coloured T-shirts. The aim was to investigate whether the shirt colour a participant is wearing influences

a) how dominant he perceives *himself* and
b) how dominant he perceives *other* men.

For reasons mentioned earlier (sections 1.3.2.2 and 2.2.1), this study focuses on male participants only.

[3] Please note that Dreiskaemper *et al.*'s study of 2013 was not yet published by the time the present research was planned and carried out. In their study, participants underwent neutral, red and blue colour treatment groups while performing in a staged combat.

3.2.1 Hypotheses and predictions

Hypothesis 1 (H1): Colour viewed on others influences dominance ratings (*perceiver effect*).

Prediction: Individuals presented in red T-shirts will be rated more dominant than those in grey or blue.

Hypothesis 2 (H2): Colour worn influences dominance ratings (*wearer effect*)

Prediction: Red-wearing participants (relative to grey and blue-wearing participants) will rate stimuli overall less dominant as the red colour enhances the perception of their own dominance.

Hypothesis 3 (H3): Colour worn influences self-rated dominance (*wearer effect*).

Prediction: Red-wearing participants will score higher than participants wearing grey or blue T-shirts on the questionnaire assessing psychological dominance.

3.3 Methods

3.3.1 Participants

102 male students or staff members [mean age 24.28, SD = 6.34, range from 17 to 57 years] were approached either in or around the library at the Department of Economy and Management at the University of Dijon in France.

The study included a covert element. That is, participants were initially told that they would participate in a study entitled *"Fashion Design and Psychology"* for a joint master's course in the UK. Prospective subjects had also been told the purpose of the study was to test how different fabrics, worn directly on the skin, affected their feelings and emotions towards themselves *and* others. This cover story provided a plausible reason for participants to change into the T-Shirts provided as part of the study. Ethical approval was given by the Durham Anthropology Department's Research Ethics sub-committee.

A variety of non-monetary rewards were used as an incentive to recruit participants and were then offered after the performance. None of the 102 participants reported a colour vision deficiency, which is surprising given that approximately 1.7–8.9% of Northern European men are affected by colour blindness (Floris and Dejala 1978).

The data of three participants in total were excluded from statistical analysis. One of them had not understood the rating experiment and randomly clicked through the images. Two participants correctly guessed the purpose of the study. The mean age of the remaining 99 participants in the final data set was 24.35 years [SD = 6.47, range from 17 to 57 years]. Participant ethnicity was as follows: 80 Caucasians, 9 Black or Afro Americans, 2 Hispanics, 2 of mixed race, 6 other/unspecified.

3.3.2 Stimuli

Twelve stimuli out of the 20 stimuli already used in a previous study (see Chapter 2) and two new stimuli (see Figure 7), hence 14 stimuli (11 with neutral facial expressions, 3 with angry facial expressions) in total, were selected for this study. The main criterion for an image to be chosen as a stimulus for this study was that the target's shirt had to display only one colour at a time. That is, that besides of a small white collar, no other colours were displayed on the target's torso (see Chapter 2, Figure 2, images 6-13, 15, 17-19). The test was run in Microsoft® Excel for Windows® 7, where the participant's responses were automatically and anonymously stored in a separate spreadsheet saved under the participant's subject number.

Stimuli were presented on a calibrated *hp*® laptop screen in a library room with constant neon strip. All participants were tested under the same lighting conditions.


1- Source: photo


2- Source: photo

Figure 7: Red versions of two new stimuli

3.3.3 Dominance questionnaire

Following previous studies on men's dominance (e.g., Havlicek *et al.* 2005) ten items of the 11-item dominance subscale in the IPIP (http://ipip.ori.org/ipip/; Goldberg 1999) were presented to each subject. The questions in the scale (on a 5 point scale from 1, *'I don't agree at all'*, to 5, *'I agree very much'*), were: *I often try to outdo others (1); I am quick to correct others (2); I impose my will on others (3); I demand explanations from others (4); I want to control the conversation (5); I am not afraid of providing criticism (6); I challenge others'*

points of view (7); I lay down the law to others (8); I put people under pressure (9) and a negative keyed *I hate to seem pushy (10).*
To ensure that the French versions of the items correctly represented the English versions, all items were translated into French and then "back-translated" by a native English speaker who had been living in France for over 20 years. The only negatively keyed item was later excluded from statistical analysis to improve internal consistency.

3.3.4 Design and procedure

After obtaining informed consent, participants carefully read the main instructions of the experiment and then drew one lot which supposedly indicated the treatment group (cotton, silk or wool) they allegedly belonged to. In reality, cotton was indicated on all three lots. Participants were randomly assigned to three different colour conditions (blue, grey, red) in a between-subject design. T-shirts from Fruit of the Loom© were heavy cotton, plain and devoid of any pictures, writing, or logos (see Figure 8).


Figure 8: Grey version of Fruit of the Loom© T-shirts

After the experimenter had left the study room, participants changed into the T-shirt they had been given. Next, participants were asked to fill in a questionnaire about how the fabric they were now wearing made them feel as well as the dominance questionnaire Q1 (Appendix II). Meanwhile, the experimenter (always dressed in black) took hidden note of which colour the participant originally wore when recruited.
The next part of the study was a rating experiment in order to assess participants' feelings towards *others*. Instructions for the rating experiment were handed out and the rating experiment started. Raters were instructed beforehand that they would see each individual several times. They were asked to provide ratings of dominance for each image, via mouse click, on a 7-point scale anchored by scores of 1 (not at all dominant) and 7 (very dominant). In random order, each participant saw the head and upper torso of 14 men wearing a blue,

grey or red T-shirt (total = 42 images). It was not possible for the participant to move on to the next stimuli unless he had ranked the current image. It is worth mentioning that the program in which the test ran had a minor bug as participants sometimes had to click outside of the scale first before the rank they awarded logged in correctly. However, in personal communications with the participants afterwards, no one reported that this affected the participant's decision, nor did it disturb them in any way.

After participants had finished the rating experiments, they were again asked to complete the previous questionnaire on their feelings towards the worn fabric and their psychological dominance (Q2, Appendix II). Participants then filled in a brief demographics questionnaire (including age, height, ethnicity, country of birth (COB), visual defects, etc.). Finally, participants were asked what they thought the purpose of the study was. All participants were then debriefed by reading a written explanation of the study's purpose and an explanation as to why a cover story had been used. Once participants knew about the full purpose of the study, they were given the opportunity to withdraw their data if they wished so. This was, however, never the case. When participants did not have any further questions, they changed clothes and were allowed to leave. If, however, participants wished to be notified about the study's outcome via email, they had been informed that, in that case, their identity was no longer anonymous. However, their data remained anonymous since email address, personal information and data were kept separately and could not be linked to one another.

3.3.5 Statistical analysis

Mean scores awarded by each rater to the 14 images seen in red and each of the other two colours were calculated. Mean dominance scores for grey stimuli were not normally distributed (Shapiro-Wilk test, p = .031) whereas dominance scores for red (Shapiro-Wilk test, p = .74) and blue stimuli (Shapiro-Wilk test, p = .93) did not deviate from normality. However, mean scores for all picture colour and shirt colour combinations did not differ from a normal distribution (Shapiro-Wilk test, all *ps* > .141, see Table 7).

The data were analyzed in IBM SPSS version 19 using analysis of variance (ANOVA) for repeated-measures with colour as the within-subject variable. When results of ANOVA were significant simple contrasts and Bonferroni pairwise comparisons were used to compare differences amongst the three colours.

	shirt colour worn	Shapiro-Wilk		
		Statistic	df	*Sig.*
mean of all ratings for blue stimuli	blue	.977	33	.719
	grey	.978	33	.727
	red	.972	33	.538
mean of all ratings for grey stimuli	blue	.950	33	.141
	grey	.981	33	.815
	red	.964	33	.330
mean of all ratings for red stimuli	blue	.973	33	.597
	grey	.962	33	.319
	red	.979	33	.745

Table 7: Test of normality shirt colour by means of ratings per colour

A reliability analysis was conducted to measure the consistency of the dominance assessing questionnaire (Cortina 1993, Field 2009). Cronbach's alpha for Q1 ($\alpha = .710$) was lower than for Q2 ($\alpha = .747$). It was decided to delete item 10 which slightly increased the Cronbach's alpha (Q1α = .714, Q2α = .783). Participants scored a value between 14 and 42 on Q1 and between 10 and 41 on Q2. High scores on the subscale indicate high dominance. Scores for Q1 are not normally distributed (Shapiro-Wilk test, $p = .021$), whereas scores for Q2 do not deviate from normality (Shapiro-Wilk test, $p = .272$). However, since different groups are to be compared, it is necessary to test whether scores are normally distributed within each treatment group (Field 2009). All scores are normally distributed when shirt colour is taken into account (see Table 8).

One-way ANOVA was used to detect whether dominance scores differed between T-shirt treatment groups. For further analyses of covariates, an independent *t* test was used when different colour treatment groups were compared and a paired *t* test was used to compare means of Q1 and Q2 (all participants).

	shirt colour worn	Shapiro-Wilk		
		Statistic	df	*Sig.*
psychological dominance QUESTIONNAIRE 1	blue	.938	33	.065
	grey	.951	33	.151
	red	.970	33	.469
psychological dominance QUESTIONNAIRE 2	blue	.954	33	.187
	grey	.956	33	.219
	red	.962	33	.294

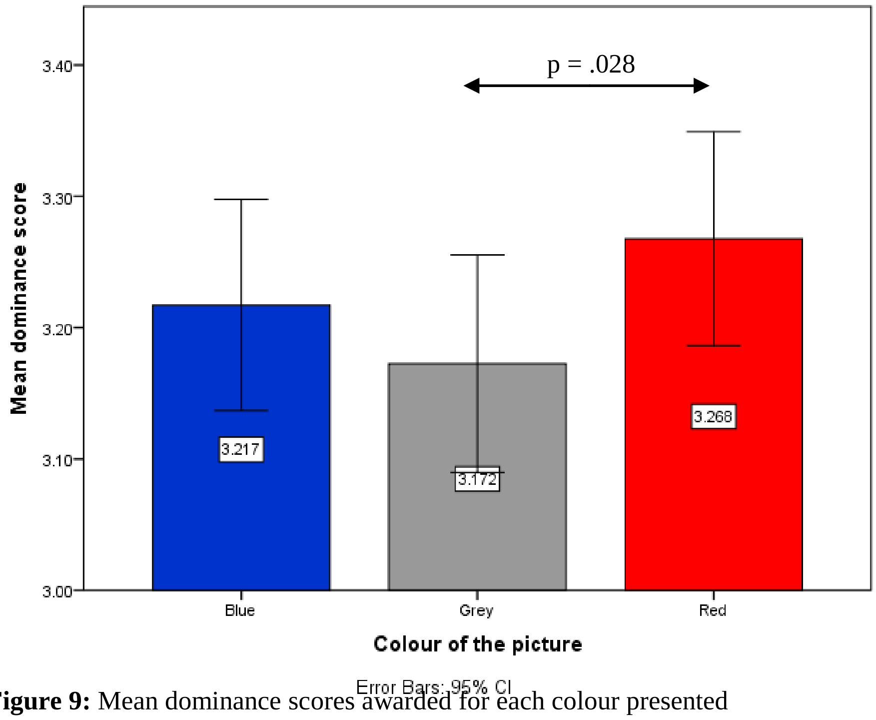
Table 8: Test of normality for Q1 and Q2 separate for shirt colours

3.4 Results

3.4.1 Dominance ratings of the stimuli

I tested H1 that the colour a stimulus is presented in influences dominance ratings. Variances of the between-condition differences were equal (Mauchly's test for sphericity; p = .388). A repeated-measures analysis of variance (ANOVA) with colour as the within-subject variable was conducted which yielded a main effect of colour (F (2, 96) = 3.517, p = .034) on perceptions of dominance.

Figure 9 depicts the mean dominance scores for each colour of the picture. Regardless of shirt colour worn, raters awarded highest dominance scores to stimuli in which targets wore red. As predicted, red stimuli were perceived more dominant than blue and grey stimuli. This difference was, however, only significant between red and grey stimuli (p = .028). No statistical difference was found between red and blue stimuli (p = .652) or between blue and grey stimuli (p = .645).

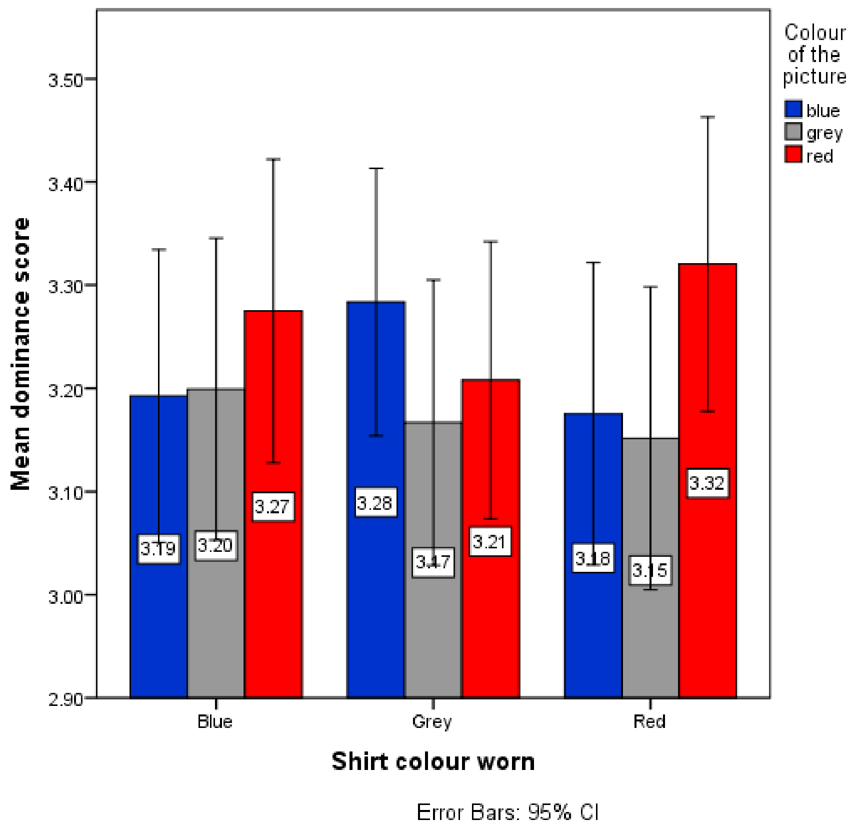


Mean scores (+ error bars indicate 95% CIs) of 99 participants judging fourteen images presented in three different shirt colours for dominance.

Figure 9: Mean dominance scores awarded for each colour presented

Next, we tested H2 whether shirt colour worn had an influence on how dominant stimuli were perceived, regardless of the colour a stimulus was presented in. Mean dominance ratings for the stimuli were identical across shirt colour treatment groups ($\bar{x}_{blue,\ grey,\ red}$ = 3.22). The one-way ANOVA with shirt colour as a factor confirmed what could be expected from the above mentioned means; a result far from significance (F (2, 96) = .006, p = .994).

A further follow-up ANOVA with picture colour as the within-subject variable and shirt colour as between-subject variable found no support for H2 that dominance ratings would differ depending on which shirt colour the participant wore, $F(2, 96) = 1.875$, $p = .147$. No interaction effect between picture colour and shirt colour worn was found ($F(4, 192) = 1.528$, $p = .196$), indicating that the T-shirt colour participants had been assigned to did not influence their perception of other men's dominance. Shirt colour had no effect on how dominant targets were rated ($F(2, 96) = .001$, $p = .999$). A further one-way ANOVA revealed no significant difference between the three treatment groups ($F(2, 96) = .006$, $p = .994$). Figure 10 depicts mean ratings of dominance separated for each T-shirt colour worn by participants and colour of the picture.



Mean scores (+ error bars indicate 95% CIs) of 99 participants (of which 33 wore blue, 33 grey, and 33 red T-Shirts) judging fourteen images presented in three different shirt colours.

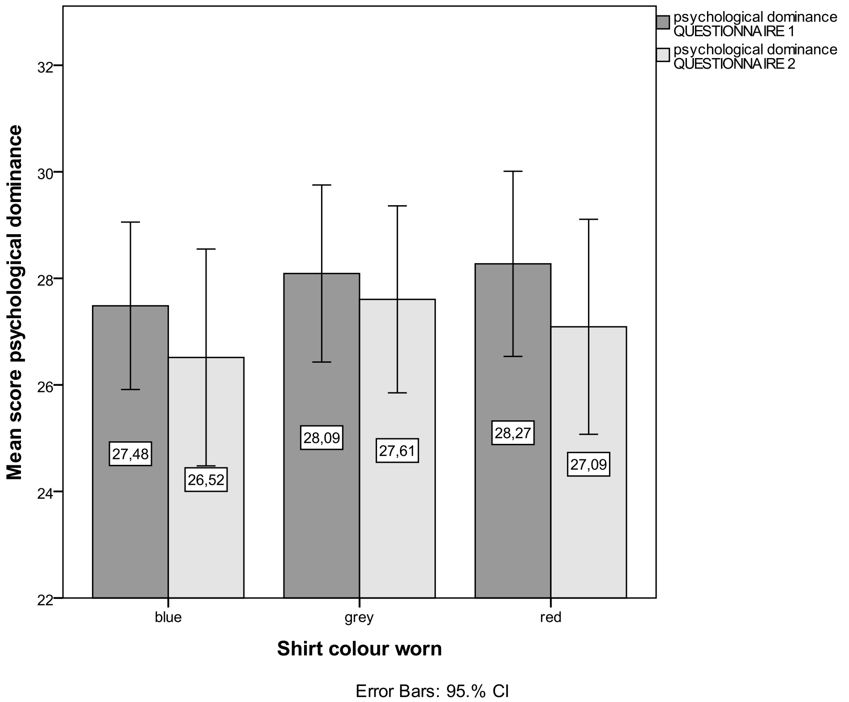
Figure 10: Mean dominance scores awarded for each colour presented separately for each shirt colour worn

To summarise the results for perceptions of dominance in men wearing differently coloured T-shirts, H1 is partly supported but H2 needs to be rejected.

3.4.2 Psychological dominance (questionnaires)

Regardless of shirt colour worn, a paired samples *t* test revealed a statistical difference between the mean scores of Q1 ($\bar{x}$ = 27.95, SD = 4.641) and Q2 ($\bar{x}$ = 27.07, SD = 5.435), *t*(98) = 3.453, *p* = .001. Overall, male psychological dominance assessed by the questionnaire was higher before participants had rated the dominance of other men (presented in the stimuli).

I tested H3 whether shirt colour influences men's psychological dominance. A one-way ANOVA with shirt colour (blue vs. grey vs. red, see Figure 11) as a factor revealed no significant differences in how dominant men perceived themselves in either of the questionnaires (Q1: F (2, 98) = .257, *p* = .774); Q2: F (2, 98) = .328, *p* = .721).



Mean scores (+ error bars indicate 95% CIs) of 99 participants (of which 33 wore blue, 33 grey, and 33 red T-Shirts) reached in Q1 and Q2 assessing psychological dominance.

Figure 11: Mean psychological dominance scores in Q1 and Q2 separate for shirt colour treatment groups

Even though we did not put forward a prediction in that matter, it was investigated whether male psychological dominance assessed by the questionnaire correlated with mean dominance ratings for stimuli. No significant result for either of the questionnaires (Q1: r(99) = -.017, *p* = .866; Q2: r(99) = .017, *p* = .866) was found. Q1 and Q2 correlate significantly (r(99) = .885, p < .001) with each other. The analysis was repeated for each colour condition separately but revealed again no significant correlations (all *r*'s (33) ranged from -.091 to .207, all *ps* ≥ .248).

A further question that arises with self-perception of dominance is: do taller men perceive themselves as being more dominant? In a recent review, Stulp *et al.* (2012) concluded that height ostensibly serves as an index of physical dominance. After having excluded three outliers (mean participant height $^{+}/_{-}$ 2 SD), a bivariate correlation did not reveal a relationship between participant body height and dominance scores assessed in Q1 (r(96) = .104, *p* = .314)) and Q2 (r(96) = .076, *p* = .463)), also not when the analysis was carried out separately for shirt colour worn (all *ps* ≥ .451).

In sum for the results section, neither H2 nor H3 are supported. H1 is partly met with red stimuli being rated as significantly more dominant than grey stimuli (but not blue stimuli). These results indicate that a *perceiver effect* is more likely to explain a “red advantage” in competitors than a *wearer effect*.

3.5 Discussion

The present study aimed to distinguish between *wearer* and *perceiver effects* of red clothing colour and its relation to dominance attributions towards oneself and others. In extension to Feltman and Elliot (2011), we added a very important methodological component in that participants did not only imagine wearing a specific colour but actually did touch and wear differently coloured T-shirts while they assessed their own dominance and that of others. As hypothesised (H1), the colour a stimulus was presented in did make a significant difference on how dominant the person in display was perceived. As further predicted, targets wearing red received the highest dominance ratings. However, only the difference between dominance ratings of red ($\bar{x}$ = 3.27) and grey ($\bar{x}$ = 3.17) stimuli was significant. Thus red stimuli where not perceived as being significantly more dominant than blue stimuli ($\bar{x}$ = 3.22) which is surprising given the results from the previous chapter (Chapter 2, section 2.4) in which only the results of 50 male participants (as compared to 99 male participants here) were included to the statistical analysis. In the preceding chapter, red stimuli were rated as significantly more dominant than blue and grey stimuli. Even though the results of this study are not as strong as the preceding results, they do follow the same trend and confirm recent studies showing that clothing colour influences social perception, and that these effects may arise trough a *perceiver effect*.

We found no support for a wearer effect by using the new and innovative variable of real T-shirts worn by all participants. Hypotheses 2 and 3 were both rejected as wearing red T-shirts neither led to different dominance perceptions in other men (H2), nor did red-wearers feel significantly more dominant than participants in the grey or blue treatment group (H3). No matter which T-shirt colour a participant wore, the average dominance score awarded for stimuli (regardless of stimulus colour) was identical across treatment groups ($\bar{x}_{blue,\ grey,\ red}$ = 3.22). This rather surprising result suggests that T-shirt colour worn by participants did not influence how dominant other men were perceived.

In contrast to previous findings stating that red displaying individuals felt "stronger" (Ten Velden *et al.* 2012), more intimidating and more dominant (Feltman and Elliot 2011) than differently coloured opponents, we did not find any statistically significant difference between red-wearing participants and others in terms of self-perceived dominance (H3). In sum, the fact that there was no effect of the T-shirt colour men wore on how dominant they perceived others or themselves (*wearer effect*), suggests that the colour red seems to act on the opponent (*perceiver effect*). However, it remains at least the possibility that results could be different in the context of male-male competitive interactions and future research is in demand to explore this possibility. Some premature results indicate that, at least in a staged combat, assessed strength before the fight and heart rate during the fight were significantly higher when a participant wore a red jersey (Dreiskaemper *et al.* 2013). However, results from real-life competitions would give further insights on how physical parameters may differ with shirt colour.

It is important to note that distinctions have been made between perceptions of *physical* and *social dominance* (e.g., Puts *et al.* 2006). However, Watkins and his fellow researchers (2010b) found that masculinised versions of men's faces were perceived as both more socially and more physically dominant, than feminised versions. In other words, men did not differentiate between other men's social and physical dominance, at least not for masculine facial cues. Even though social and physical dominance may overlap, Watkins *et al.* (2010b) suggested that social dominance may be more closely linked to physical dominance in men than it is in women as feminine versions of women's faces were perceived to be more socially dominant than masculine versions.

Although the dominance subscale of the IPIP supposedly measures men's *social* dominance, scores on the dominance subscale of the IPIP were found to be positively correlated with men's baseline T levels (Carre *et al.* 2009) and have been used to identify dominance in men in previous research (e.g., Havlicek *et al.* 2005). These findings suggest that the IPIP-scores measuring dominance may also correlate with men's *physical* dominance though direction of causality is unclear.

Consistent with the idea that there may be some overlap between indices of men's physical and social dominance, the correlation between the dominance subscale of the IPIP, an apparent index of men's social dominance, and men's dominance sensitivity appears to be very similar to the correlation between men's height, an apparent index of men's physical dominance, and their dominance sensitivity (Watkins *et al.* 2010b).

3.5.1 Limitations

No participant reported a colour vision deficiency, which normally affects approximately 1.7–8.9% of Northern European men (Floris and Dejala 1978). It is possible that with the end of the military service in France in 2002, young men are nowadays less likely to be tested for colour blindness. Thus, it remains at least the possibility that a small subset of participants in this study were indeed colour blind. This uncertainty could, however, be reduced with a small test for colour blindness at the end of the experiment and should therefore be considered in future research (see Chapter 4). Additionally, even though almost all participants were equally affected by the small bug in excel, it should be ensured that participants can rate stimuli without further distractions.

Participants were simply asked to rate men's dominance. This was, however, neither defined nor further explained. Previous research (e.g., Fink *et al.* 2007) has reported high inter-rater agreement for dominance judgements of this type suggesting that raters and participants interpret such instructions in a consistent manner. However, a more detailed description of dominance may be appropriate and helpful to avoid confusion. For example, following Watkins *et al*. (2010b), physically dominant individuals could be described as "someone who would be likely to win a fistfight with another person of the same sex" and socially dominant individuals could be described as "someone who tells other people what to do, is respected, influential, and often a leader" (p. 968). This difference may be even more important for research including colour manipulations and male-male competition. Finally, an argument could be made that a questionnaire assessing dominance should have an equal number of both positively and negatively keyed questions (see Chapters 4 and 5). However, the dominance subscale of the IPIP is commonly used to assess psychological dominance in individuals (e.g., Havlicek *et al.* 2005).

3.5.2 Future research

The fact that red-wearing participants were not significantly more dominant than others raises the question about whether this difference would have become significant if the setting of this study had been a competitive one. In other words, it might take some sort of male-male competition to trigger self-perception of dominance in differently coloured males. To test at least the possibility could build an interesting frame for future research (see Chapter 4).

Roberts *et al.* (2010) found that clothing colour effects in studies about attractiveness were not limited to the positive influence of red but also black. The colour black has been associated with aggression in criminals (Vrij 1997) and athletes (Frank and Gilovich 1988), and it remains a possibility that black is also related to dominance. It is suggested that investigating this possibility, as well as others (e.g., subtle methodological differences among studies), are important topics for future research on colour manipulations in dominance perception. Information about height and self-perceived dominance of the person depicted in the stimuli (see Chapter 5) itself could also yield interesting results as to how these factors may play a role in mutual judgements of dominance.

Chapter 4

4 Wearing either red or blue wields no influence on strength measures, dominance, height and strength estimation or social spacing

4.1 Abstract

Wearing a red sports attire is believed to be advantageous in competitive situations but the possible reasoning behind it remains untold. The goal of this study was to investigate whether the shirt colour a participant wore had an influence on measures of handgrip strength, self-perceived dominance, size of the personal comfort zone, height and strength estimation in opponents, and resource monopolisation. 120 male participants (average age 20.08) were randomly assigned to wear either a blue or a red T-shirt. Self-perceived dominance was assessed pre- and post colour manipulation. Maximum handgrip strength in kg and preferred social distance (SoDi) from each participant's opponent was measured in 10cm-steps. To test for resource domination, the total number of items taken and the order ($1^{st}/2^{nd}$) in which participants picked up an item from a reward box were recorded. There was good evidence that red-wearers took significantly more items out of the reward box than blue-wearers did. Colour had no significant influence on any of the other measures. This study indicates that wearing red may influence resource domination without affecting physical strength, social spacing or perceptions of own dominance - at least not in a laboratory setting. We further highlight the difficulties of distinguishing between wearer- and perceiver effects in experiments including strength comparisons between two opponents wearing different shirt colours. The role of proximity on the perception of red stimuli is also discussed.

4.2 Introduction

In a laboratory setting, red-wearing men did not feel significantly more or less dominant than men that had been assigned to wear grey or blue (see Chapter 3). Here we test whether adding a component of male-male competition to the experimental procedure causes such effects by triggering different self-perceptions of dominance. In this way it may be possible to further differentiate between perceiver and wearer effects of red colouration. A first attempt to do so in a same-sex competitive situation was carried out by Feltman and Elliot (2011). Their methods included mutual evaluations of how dominant and threatening participants perceived their differently coloured opponent in an imagined Taekwondo match. Feltman and Elliot demonstrated a *bidirectional effect* of wearing versus viewing red: wearing red enhanced one's own self-perception of dominance and threat, whereas viewing an opponent's red enhanced the perception of his dominance and threat. Though these findings are based on an imagined rather than a real-life competition, it raises the question whether men need to feel some sort of real competition in order for a wearer or perceiver effect to operate. This is at least possible bearing in mind that a sports team or person wearing red is more likely to win a physical contest than a sports team or person wearing another colour (Hill and Barton 2005, Attrill *et al.* 2008). To test whether an individual wearing a red jersey has an advantage over his opponent, Dreiskaemper *et al.* (2013[4]) investigated the effects of jersey colour before, during, and after a staged combat fight. Measurements of athletes' physical parameters of heart rate and maximum force (leg-strength) were obtained once in a control situation while participants wore neutral jerseys (neither blue, nor red), once while wearing red fighting against a blue opponent, and once while wearing blue fighting against a red opponent. Fighters also used a so-called smash stick as fighting equipment that was blue or red respectively. Results indicated that physical parameters differed with jersey colour worn. Both strength before the fight (p = .026) and heart rate during the fight (p < .001) were significantly higher when a participant wore a red jersey (Dreiskaemper *et al.* 2013). These findings demonstrate that red seems to enhance a competitor's heart rate and strength, whereas no similar effect of blue jerseys could be found. The experiment reported here ties in with Dreiskaemper's study whilst further focusing on the differences between red-wearer's and their opponent's perception.

[4] Please note that this paper was not yet published by the time the present research was planned and carried out.

In response to other researchers calling for work that distinguishes between *viewing red on an opponent* and *wearing red oneself* rather than just focussing on win/lose outcomes (e.g., Attrill *et al.* 2008), the present study also includes perceptions of strength and height in red-wearing opponents (perceiver effect) and self-perceived dominance in red-wearing individuals (wearer effect). It further investigates whether wearing red or blue influences social spacing, notably the distance in which one person feels most comfortable to stand from another. We also look at whether participants behave differently facing a box full of non-monetary rewards depending on the shirt colour they wear.

4.2.1 Handgrip strength

If wearers are actually influenced by jersey or shirt colour, it is important to test whether this is reflected in changes in measurable physiological correlates (e.g., testosterone, for more see Hackney 2006) or motor skills (such as strength output, e.g., Dreiskaemper *et al.* 2013). So far there has been little empirical work to test this and imprecise colour manipulations in the work that has been done (Elliot and Aarts 2011, Elliot and Maier 2014). Given the link between red and threat (e.g., Setchell and Wickins 2005, Changizi 2009, Feltman and Elliot 2011), and threat and motor action (e.g., Carretié *et al.* 2009), Elliot and Aarts (2011) examined how the perception of red stimuli influences velocity and force of motor output in a pinchgrip task, finding an effect of viewing red in the participant's environment (e.g., a red coloured study room) on motor output.

Payen *et al.* (2011) designed a study in which participants had to perform a maximum muscle contraction while viewing either red, an achromatic control colour, or a chromatic control colour. Results demonstrated increased strength development while viewing red, but no significant difference in peak amplitude of power. Their results support the idea of a link between basic motor output and seeing red which was earlier proposed by Elliot and Aarts (2011). In two different experiments, Elliot and Aarts demonstrated that viewing red facilitates pinchgrip force, as well as handgrip force and the velocity of that force. This outcome is specifically intriguing as participants only very briefly encountered either chromatic or achromatic colour contrasts that were placed on the background of an introduction or on the participant number. This experiment thus provides a link between exposure to colour stimuli and basic motor functioning in humans and gives reason to believe that opponents wearing red may also have an advantage in strength output over their blue-wearing opponents. The current study was designed to test this possibility by measuring handgrip strength (HGS), a measure of overall physical strength (Davis *et al*. 2000), with the use of a simple handgrip dynamometer.

HGS was chosen as a potential marker for dominance as it was found to correlate with other muscle groups (Rantanen *et al.* 1994, Xiao *et al.* 2005). The very recent study of Dreiskaemper *et al.* (2013) demonstrated that red-wearing fighters were indeed stronger than blue-wearing fighters but these results were independent of the colour the opponent wore. When participants performed the strength test, they were facing a neutrally coloured wall and not their opponent. This may demonstrate a wearer effect of red colour but the researchers cannot exclude that a perceiver effect could have been equally influential. Additionally, sample size was very small (N = 28) and the authors called for work to replicate their results.

4.2.2 Social distance and avoidance behaviour

Clothing colour influences library patrons' perception as to how approachable they thought a hypothetical librarian was (Bonnet and McAlexander 2012). Librarians displayed in white and blue shirts were rated more approachable than those wearing red shirts. With reference to Hill and Bartons' findings (2005), it is likely that red shirts might be perceived as less approachable as they convey traits of dominance. Besides its relation to dominance, red is also reported to have a negative impact on one's performance in achievement contexts (Elliot et al. 2007, Gnambs et al. 2010, Mehta and Zhu 2009). Short presentations of red have been found to worsen results in IQ tests and to significantly reduce motivation (Elliot *et al.* 2010). This reduced motivation elicited by red stimuli can even cause study participants to lean further away from a computer screen or knock fewer times on a door to gain entry after briefly being shown a red rather than a green test cover sheet (Elliot *et al.* 2009). That red colouration leads to avoidance is even apparent in interactions between nonhuman species and humans shirts (Khan *et al.* 2011, see section 1.3.2.1). Applying this to human interactions, we predict that a person would maintain a larger distance to a red- than to a blue wearing person as opponents displaying red may trigger an evolutionary engrained association of red colouration and threat stimuli. For example, viewing an opponent's red enhances the perception of his dominance and threat (Feltman and Elliot 2011). An explanation for this could be a phylogenetically basic avoidance/defense system responsible for processing and responding to a threat-relevant stimulus (Dickson and Dearing 1979, Masterson and Crawford 1982). According to Elliot and Arts (2011), this avoidance/defense system is thought to be based in a network of largely subcortical structures (e.g., the basal ganglia and the amygdala) that detect threat stimuli and trigger autonomic activity required to support empathic and urgent movement away from imminent danger to ensure safety and survival (Lang *et al.* 1990, Carretié *et al.* 2009). Research with humans demonstrated that threat stimuli activate the amygdala and basal ganglia and produce voluntary motor behaviour of greater velocity (Coombes *et al.* 2005) and higher force (Coombes *et al.* 2006) than that produced by a neutral or appetitive stimulus. Elliot and Aart's (2011) findings show that the colour red operates as a threat stimulus in a commensurate way. If this also applies to red clothing colour then avoidance behaviour in humans could also become evident through social spacing in between individuals wearing red relative to another colour. This assumption, however, contradicts research that has shown that a person wearing red is regarded as being more attractive and sexually desirable by a member of the opposing sex (Elliot and Niesta 2008, Roberts *et al.* 2010, Elliot *et al.* 2010). This does not mean that this person is more approachable *per se* but it can be assumed that others at least wish to approach the individual they find attractive as movements towards physical proximity are a behavioural sign of attraction in heterosexual interactions (Hatfield 1984). And this is precisely what Niesta *et al.* (2010) found to be the case when their male participants chose to sit closer to where they thought a women dressed in red (as opposed to blue) was about to sit later on. As we have already seen in earlier chapters, the effects of colour are very much context dependent and what holds true in heterosexual interactions may not be applicable in same-sex interactions. Presumably then, red clothing colour may lead to increased inter-sexual-attraction but may result in a totally different behaviour, namely avoidance, in intra-sexual interactions, precisely between male actors. Whether or not this avoidance behaviour may become apparent in social spacing remains to be investigated.

The study of the human use of space within the context of culture is called *proxemics* and was first pointed out by the anthropologist Edward T. Hall (1966). Just like colours, proxemics is a very important aspect of non-verbal communication. Each person has its own personal space, an invisible boundary around their body, in which other people may or may not be prevented from entering. For example, we may feel uncomfortable and step further away to increase the distance to another person if this person breaks our invisible boundary. Personal space is not rigid and changes constantly, depending on environmental factors, the person's emotional state and cultural background, and the relationship between the actors (Hall 1966, Hall and Hall 1990, for a review see Hayduk 1984).

4.2.3 Resource domination

The final part of this study was an attempt to trigger and consequently observe dominant behaviour in a laboratory setting. In examining colour and dominant behaviour in humans, there is good reason to start with dominance assessing questionnaires, as they are the most straightforward to apply and, in many cases, to interpret. However, dominance assessed through questionnaires might still be distinct from actual behaviour expressing dominance, and an examination of behaviour represents a more direct test of parallels between nonhuman and human functioning with regard to dominant behaviour. Many studies have shown that dominant behaviour in animals manifests in resource monopolization and that artificial colour manipulations may reinforce this behaviour (e.g., Pryke and Griffith 2006). For example, studies with captive Gouldian Finches revealed intra-specific behavioural differences related to the expression of genetically determined black and red head-colour morphs. The socially dominant red birds outcompete their black conspecifics for access to food (Pryke and Griffith 2006, Pryke 2007). Likewise, male zebra finches that had been assigned red leg bands successfully monopolized food resources against green-banded males (Cuthill 1997). If red functions as a status signal of dominance and intimidation in animals (Pryke 2009), then there is possibly an alternative to measuring competitive success between blue- and red-wearing participants than just grip strength (section 4.2.1).

We therefore intended to test whether shirt colour worn had an influence on a participant's actions to monopolize non-monetary resources presented in a reward box at the end of the experiment. Given the scarce, almost non-existent literature on studies using similar methods, there was some uncertainty of whether this test would work or not. Observing dominant behaviour is usually of interest for social group interactions when dominance hierarchies arise or leadership styles are studied by organizational psychologists (e.g., Kalma *et al.* 1993). Consequently, this was a first attempt to try and test wheather shirt colour worn had an influence on dominant behaviour and wheather this could be reflected using a testable behavioural component.

4.2.4 Hypotheses and predictions

In addition to the physical component of the present study (see 4.2.1), participants are also assessed for social dominance by applying a self-assessing dominance questionnaire before and after the colour manipulation. The aim is to detect possible wearer effects and examine their interaction with participants' height, since research has shown that physical height is significantly correlated with dominance (Melamed 1992) and dominant men are estimated taller than less dominant men (Marsh *et al.* 2009). Here, it is tested whether the relation between height and dominance becomes even more pronounced given the relation between dominance and red colouring.

To test whether wearing red leads to avoidance behaviour (in terms of larger social spacing, see 4.2.2) within same-sex dyads, participants of randomly matched pairs in this study will be given the chance to choose a distance from the other participant in which they feel comfortable having a conversation. Using a stop-distance procedure (e.g., Hayduk 1984), the present study investigates whether the distances chosen by pairs of participants were different depending on the shirt-colour each participant was randomly assigned to.

Finally, a behavioural component in order to observe dominant behaviour, was added (see 4.2.3). At the end of the experimental setting both participants were placed in the exact same distance to a box containing a variety of food and beverages. It was predicted that red-wearing participants would be more likely to take something first (and also more items) and that blue-wearing participants would be more likely to give way, and allow red-wearers to take something first.

Based on the aforementioned links between height and dominance, dominance and colour, and colour and strength perception in others, the relation of these variables is further examined in this study. The experiment tests whether the shirt colour a participant is wearing influences

a) handgrip strength,
b) how tall he estimates his opponent and how tall he is estimated by his opponent,
c) how dominant a participant perceives himself, and how strong or weak he perceives his opponent in comparison to himself.
d) measures of social spacing.
e) resource domination.

Based on the above, the following hypotheses are advanced:

Hypothesis 1 (H1): Colour worn influences strength outcome (*wearer effect*).

Prediction 1: Red-wearing participants are more likely to squeeze a handgrip dynamometer with higher maximum force than blue-wearing opponents.

Hypothesis 2 (H2): Colour perceived on others influences strength and height perception (*perceiver effect*).

Prediction 2: Individuals wearing red T-shirts are more likely to be estimated taller than they actually are, whereas individuals wearing blue T-shirts are more likely to be estimated shorter than they actually are.

Prediction 3: Red-wearing participants are more likely to be classified as "being stronger" by their blue-wearing opponents than vice-versa.

Hypothesis 3 (H3): Colour worn influences the distance within which an individual feels comfortable to have a normal conversation with the other participant (*wearer/perceiver effect*).

Prediction 4: Blue-wearing participants are more likely to choose a greater distance from red-wearing participants (*perceiver effect*) than vice-versa (*wearer effect*).

Hypothesis 4 (H4): Colour worn influences self-rated dominance (*wearer effect*).

Prediction 5: After colour-manipulation, red-wearing participants are more likely to score higher on the questionnaire assessing psychological dominance than participants wearing blue T-shirts.

Hypothesis 5 (H5): Colour worn influences participants' actions to monopolize resources.

Prediction 6: Red-wearing participants will be more likely to take something first out of the reward box and blue-wearing participants will be more likely to give way, and allow red-wearers to take something first.

Prediction 7: Red-wearing participants will take more items out of the "reward box" than blue-wearing participants.

4.3 Methods

4.3.1 Participants

120 male students [mean age 20.08, SD = 2.53, range from 17 to 29 years] were approached in a library at the University of Dijon, France. The study included a covert element. That is, participants were initially informed that the study was about the *science of physiological and behavioural recordings* (HGS, odour tests, facial features, social distance). The information that T-shirts would be used later on for odour tests provided a plausible reason for participants to change into the T-Shirts they were given as part of the study. Ethical approval was granted from the Department of Anthropology Research Ethics sub-committee at Durham University. Those 89 participants who wished to be informed about the outcome of this experiment received an email presenting the study's main results seven month after data collection had been finished (24 emails were undeliverable).

A variety of non-monetary rewards were used as an incentive to recruit participants. None of the participants reported health problems that may have affected grip strength measurement. Two participants reported a colour vision deficiency, which was confirmed by a simple colour test at the end of the study. It was nevertheless decided to keep the data of persons affected with colour blindness as participants reported that the deficiency only affected their sight in specific colour tests but not their everyday lives. Yet it might still be possible that the deficiency affected these participants' physiological perception parameters. We hasten to add that the magnitude and significance levels of the here reported results remain the same with these participants excluded. Furthermore, both participants correctly indicated their own and their opponent's shirt colour. None of the participants correctly guessed the purpose of the study.

4.3.2 Dominance questionnaire

The dominance questionnaire used in this experiment is a modified version of the 11-item dominance subscale in the IPIP (http://ipip.ori.org/ipip/; Goldberg 1999) and was generated and tested by Mileva and Little (under review, personal communication). The questionnaire was presented twice to each subject, once pre-colour manipulation (Q1, Appendix III) and once post-colour manipulation (Q2, Appendix III). The questions in the questionnaire (on a 5 point scale from 1, *'I don't agree at all'*, to 5, *'I agree very much'*), were *I try to surpass others' accomplishments (1)*[5]*; I am quick to correct others (3); I demand explanations from others (5); I am not afraid of providing criticism (7); I lay down the law to*

[5] Numbers *(1)* to *(12)* denote the order in which items were presented on the dominance questionnaire

others (9); I get my own way (11). One improvement of this modified version is that it presents an equal number of negatively keyed items: *I do not try to outdo others (2); I do not impose my will on others (4); I do not want to control the conversation (6); I do not challenge others' points of view (8); I do not put people under pressure (10); I hate to seem pushy (12).* To ensure that the French versions of the items correctly represented the English versions, all items were translated into French and then "back-translated" by a native English speaker who had been living in France for over 20 years. For statistical analysis, items 3, 5, 7, and 8 were later on excluded to improve internal consistency (see section 4.3.9).

4.3.3 Design and procedure

T-shirt colour (blue/red), the side participants took during the tests (left/right), the handgrip dynamometer they used (no. 1/no. 2), the order in which participants were photographed and the order in which they chose the social distance, was randomly (www.random.org) assigned. It was furthermore made sure that each participant in the red condition stood as often on the right or left side as blue-wearing participants did.

Participants first read the instructions (Appendix III) for the experiment, signed the informed consent sheet (Appendix III) and completed the dominance questionnaire for the first time (pre-colour manipulation: Q1, Appendix III). Meanwhile, the experimenter (always dressed in black) took hidden note of the participants' personal clothing colour (top only). After the experimenter had left the study room, participants changed into the T-shirt they had been given. T-shirts from Fruit of the Loom© were heavy cotton, plain and devoid of any pictures, writing, or logos (see Figure 8 in Chapter 3).

4.3.4 Handgrip test

Next, participants took the side and handgrip dynamometer they were assigned to and stood facing each other at a distance of 1 m. Handgrip strength was measured in kilograms, using two separate dynamometers with the handle adjusted to the medium position (CAMRY Model: EH101, Zhongshan Camry Electronic Co. Ltd, Guangdong, China). After a brief familiarisation with the device, participants were instructed to squeeze the dynamometer as hard as possible with the right hand and then with the other. Measurements were recorded on three separate squeezes from each hand, alternating between right and left hand. Maximum HGS of the three trials was recorded for subsequent analyses[6]. To avoid winner-loser effects between trials, participants received no feedback regarding their own or their opponent's grip force until the very end of the experiment.

[6] Results are identical when other measures, such as HGS at 1st trial, were used.

4.3.5 Social distance test

The next part of the study included a measurement of the distance one participant would choose to stand from the other. A grid with a total length of 3 m and 10 cm gradations was taped to the floor. The participant randomly assigned to be the first to choose his personal comfort zone, was instructed to stand on one end of the grid. He then indicated to the second participant where he should install himself so that the first participant felt comfortable for a conversation. Distance in 10 cm-steps was recorded. Following that, participants completed the dominance questionnaire for a second time (post-colour manipulation: Q2, Appendix III).

4.3.6 Photographs[7]

Those participants who agreed having a picture taken of their face and upper torso (N = 96) were seated in front of a white background. Three colour digital images of each participant's face were taken.

4.3.7 Reward box test

In the next step, both participants were positioned side by side with each other in a distance of 2.5 m from a non-transparent box (35x21x24 cm) standing on a table. The box contained a variety of confectioneries, fruits, and non-alcoholic beverages. The side (left/right) on which they were standing was randomly assigned. Both participants were standing with the back to the reward box whilst facing the instructor. They were thanked for their participation and allowed to take as much as they wanted out of the box. Participants then turned around and approached the box. The order in which the two participants took something out of the box, as well as the total number of items taken, was recorded.

4.3.8 Demographics questionnaire

At the end of the study, participants filled in a brief demographics questionnaire (Appendix III) assessing age (years), body weight (kg), height (cm), ethnicity, visual defects, and handedness. Participants were also asked to estimate the height of their opponent (cm) and to state whether they thought the other opponent was stronger/weaker/the same in comparison to themselves. The questionnaire further assessed how well participants knew each other (very good/a bit/not at all). Colour-blindness was tested for using a simple colour-test (http://www.augenarztonline.eu/index-Dateien/PatienteninformationenFarbe.htm, see Appendix III) in which participants had to write down the numbers displayed in three images.

[7] For the sake of completeness of the methods section, it is mentioned that pictures of participants were taken. However, the images will not be of importance for this chapter and will not be referred to hereafter.

The final question assessed what they thought the purpose of the study was and whether or not they wished to be informed about the study's results.

If participants wished to be notified about the study's outcome via email, they were informed that, in that case, their identity was no longer anonymous. However, their data remained anonymous since email address, personal information and data were kept separately and could not be linked to one another.
Finally, participants read a written explanation as to why a cover story was used and what the purpose of the study was. Once participants knew about the full purpose of the study, they were given the opportunity to withdraw their data if they wished so. This was, however, never the case. Participants then learned their results from the handgrip test and got changed.

4.3.9 Statistical analysis

Kolmogorov-Smirnov (K-S) goodness-of-fit tests separately for colour worn were used to test whether the data were normally distributed. The results are displayed in Table 9. Positively skewed, not normally distributed data were log-transformed to normalize the distributions. In cases where the data within only one colour was not normally distributed (e.g., body weight) the data for both colours were log-transformed so that a normal distribution could be assumed ($p > .05$) and then used for further analysis. Hence, only the data for max. HGS were not log-transformed. The data were analyzed in IBM SPSS versions 19 and 20.

For the multiple-item questionnaire assessing men's psychological dominance, a reliability analysis was conducted to measure the internal consistency of the questionnaire (Cortina 1993, Field 2009). Cronbach's alpha for Q1 (α =.651) was lower than for Q2 (α =.682). In order to increase the internal consistency, it was decided to delete items 3, 5, 7, and 8 which slightly increased the Cronbach's alpha (Q1α = .708, Q2α = .730). Participants scored a value between 12 and 32 on Q1 and between 12 and 30 on Q2.

Pearson correlation (*r*) was used to assess the relationship between handgrip strength, physical measures, age, and dominance scores. Since samples come from matched pairs of individuals, dependent paired *t* tests (*t*) were used to compare means between colour treatment groups for related variables. Independent *t* tests were used to compare means between colour treatment groups for independent variables (e.g, participant height). Categorical variables were analysed using non-parametric tests (McNemar's chi-square test for binomial distributions). Studentized deleted residuals of max. HGS are used as this residual is measured in standard units which is based on the difference between the adjusted predicted value and the original observed value (Field 2009).

	Shirt colour worn	N	*Sig.*
age	blue	58	<.001*
	red	58	<.001*
body weight in kg	blue	58	.031*
	red	58	.200
height in cm	blue	58	.008*
	red	58	.200
height in cm estimated for opponent	blue	58	.036*
	red	58	.003*
maximum force in kg gripped (max. HGS)	blue	58	.200
	red	58	.200
social distance in cm	blue	58	.006*
	red	58	<.001*
number of items taken	blue	58	<.001*
	red	58	<.001*
psychological dominance QUESTIONNAIRE 1	blue	58	.090
	red	58	.046*
psychological dominance QUESTIONNAIRE 2	blue	58	.028*
	red	58	.067

* A normal distribution cannot be assumed

Table 9: Results of the Kolmogorov-Smirnov test per colour treatment group

4.4 Results

4.4.1 Descriptive statistics

Participants' (N = 120) body weight ranged from 50.0–112.0 kg (M = 70.55kg; SD = 10.43), height from 160.0–194.0 cm (M = 178.43 cm; SD = 6.40), and handgrip strength ranged from 26.4–67.8 kg (M = 45.93; SD = 8.25). Social distance chosen by participants ranged from 10.0–120.0 cm (M = 50.9 cm; SD = 17.61).

4.4.2 Handgrip strength

Six participants were excluded from the analysis of handgrip strength as they performed too poorly in the handgrip test. That is, the participants gripped more than 5kg less than the amount indicated by the dynamometer's manufacturer as a "healthy" performance for a man of a given age-group. As a result, the data of twelve opposing participants (6 pairs) were excluded from the statistical analysis of HGS using paired *t* tests and ANCOVAs.

A paired samples *t* test failed to reveal a statistically significant difference between the mean max. HGS of red (M = 47.0kg, SD = 7.59) and blue (M = 46.8kg, SD = 7.87) wearing participants, $t(53) = -.199$, $p = .843$.

There were significant correlations between physical measures and mean handgrip strength (log_weight: $r(118) = .353$, $p < .001$; log_height: $r(118) = .244$, $p = .008$; log_age: $r(118) = .242$, $p = .008$). It was therefore decided to include these variables as covariates for assessment of associations between handgrip strength, shirt colour and perceived attributes to test whether participants' weight, height or age had any influence on HGS.

A unifactorial between subjects ANCOVAs (colour condition: blue vs. red) on max. HGS (DV) with participants' body weight, height and age (all log-transformed) as covariates was conducted. The result from the *t* test above was confirmed as colour had no significant influence on maximum grip force ($F(1, 103) = .029$, $p = .866$). Whereas age significantly influenced participants' strength output (log_age: $F(1, 103) = 6.197$, $p = .014$), the covariates log_weight ($F(1, 103) = 3.326$, $p = .071$) and log_height ($F(1, 103) = 1.856$, $p = .176$) had no influence[8]. Pearson correlation revealed that log_age and HGS did not significantly correlate within blue-wearers (log_age_{blue}: $r(54) = .242$, $p = .08$) but did within red-wearers (log_age_{red}: $r(54) = .339$, $p = .012$). Hence, older red-wearers gripped with more strength.

Even though blue-wearers won 30 and red-wearers only 24 out of 54 competitions, there is not a statistically significant difference in the proportion of blue-wearers being winners and the proportion of red-wearers being winners, McNemar's $\chi^2(1, N_{pairs} = 54)$, $p = .497$. This result remains the same after an analysis including raw HGS scores as well as winners and losers controlling for height and weight using studentized deleted residuals.

In sum, hypothesis 1 that T-shirt colour worn influences strength output is not supported.

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[8] The ANCOVA was repeated using the studentized deleted residuals of max. HGS (that is, max. HGS residuals independent of participants' height and weight) which yielded similar results (shirt colour: $p = .873$, log_age: $p = .018$).

4.4.3 Height and strength perception in opponents

4.4.3.1 Height perception

During a brief conversation, participants of participant pair 19 orally communicated each other's body size and was therefore excluded from the following analysis of height perception as the revelation of actual body height falsified a proper estimation of height.

One could assume that participants used their own height as a reference point to estimate there opponents height. However, the two variables did not correlate ($r_{log}(118) = .035$, $p = .727$), therefore, an independent *t* test (using log-transformed data) was conducted. Actual participant height was subtracted from estimated height (how tall each participant was estimated) and an independent *t* test was used to test whether colour had an effect on the estimation of body size. This was not found to be the case ($t(116) = -1.345$, $p = .181$).

Separately for T-shirt colour, a paired samples *t* test revealed no statistically reliable difference within blue-wearers between the mean of their actual height (M = 178.92 cm) and how tall they were estimated (M = 178.75 cm), $t(58) = .318$, $p = .752$. The same applies for the difference between the actual (M = 177.81 cm) and the estimated height (M = 177.76 cm) within red-wearers, $t(58) = .098$, $p = .923$.

4.4.3.2 Strength perception

In 28 out of 60 occasions, red-wearing participants were perceived as stronger (weaker: 7times; same: 25times) whereas blue-wearing opponents were perceived as stronger in only 23 occasions (weaker: 12times, same: 25times). We predicted that red-wearing participants were more likely to be classified as "stronger" by their blue-wearing opponents than vice-versa (prediction 3)[9]. However, McNemar's chi-square statistic suggests that there is not a statistically significant difference in the proportion of red-wearers being perceived as stronger and the proportion of blue-wearers being perceived as stronger, McNemar's $\chi^2(1, N_{pairs} = 60)$, $p = .5$.

Physical appearance is likely to have been influential on participants' mutual strength evaluations. However, individuals judged as stronger were not significantly heavier (M = 74.24 kg) or taller (M = 179.22 cm) than individuals that were perceived as weaker (M's = 71.05 kg/177.58 cm), $t(68)$, $ps \geq .136$. That excludes the possibility that participants regarded as either stronger or weaker differed significantly in height or weight. However, an individual might compare one's own height/weight to the opponent's height/weight and might then,

[9] After the handgrip test, participants were asked to state whether they thought their opponent was stronger/ weaker/ the same in comparison to themselves. This variable is hereafter called "own strength compared".

depending on the differences, judge the opponent as either stronger or weaker. Indeed, regardless of shirt colour worn, participants who evaluated their opponent to be stronger, were significantly smaller (M = -5.30 cm) and lighter (M = -7.46 kg) than individuals that perceived their opponent as weaker (independent *t*-test, t_{weight} (68) = -2.638,
p = .01; t_{height} (68) = -2.869, *p* = .005). To control for this discrepancy, the McNemar's chi-square test was reanalyzed with only those opposing pairs that matched in size and weight[10] (N_{pairs} = 22, for results see section 4.4.3.4).
Results from a one-way ANOVA with max. HGS as DV revealed that "own strength compared" to opponent significantly influenced strength output of individuals (F (2, 107) = 3.631, *p* = .03). A further analysis was conducted to test whether the interaction between shirt colour worn (blue vs. red) and strength evaluation of the opponent (as being stronger vs. weaker vs. equally strong) influenced participants' strength output. A 2x3 ANOVA revealed no such interaction (F (2, 114) = .286, *p* = .752) but showed that the evaluation of an opponent's strength significantly influenced HGS (F (2, 114) = 4.095, *p* = .019). Pairwise comparison revealed that participants squeeze significantly harder when they perceived their opponent to be weaker (5.8 kg more, *p* = .011) or as equally strong (3.35 kg more, *p* = .041) compared to those who perceived their opponent to be stronger. Although the interaction was not significant, there is some suggestion that colour may play a role in explaining these effects, since they only appear present for red wearers (F (2, 57) = 3.363, *p* = .042) whereas own strength compared to the opponent did not significantly influence max. HGS within blue-wearing participants (F (2, 57) = 1.153, *p* = .323).
Subsequent pairwise comparison revealed that red-wearing participants who thought their opponent was weaker gripped on average 6.6 kg more than red-wearing participant who perceived their blue-wearing opponent to be stronger (*p* = .023), see Figure 12.

Shirt colour did not affect the strength or body height perception in opponents. Therefore, hypothesis 2 needs to be rejected. However, judging an opponent as being stronger, weaker or equally strong significantly influenced how hard red-wearers would squeeze the handgrip dynamometer.

[10] Pairs were classified as “matched pairs” when the two opponents did not differ more than 10kg in body weight and 6 cm in height.

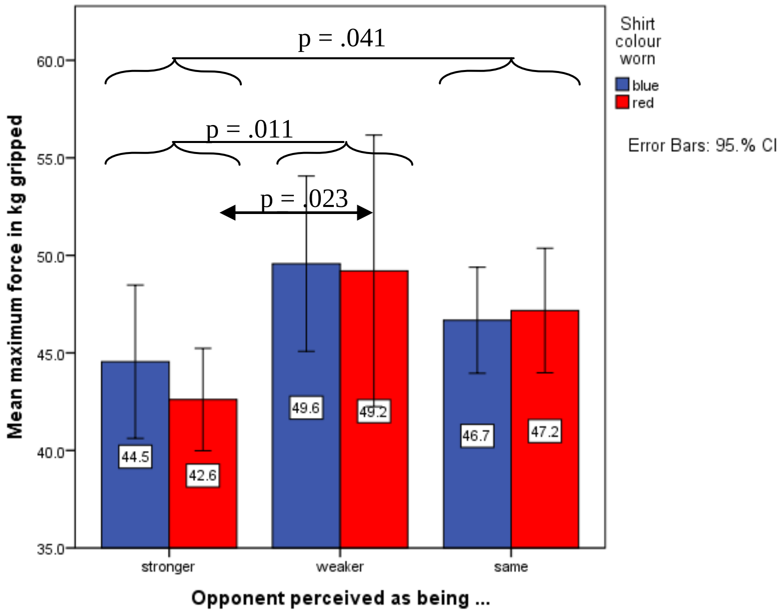


Figure 12: Mean HGS separately displayed for shirt-colour worn and strength evaluation of participants' opponent, error bars indicate 95% CIs

4.4.3.3 Social distance

It was predicted (prediction 4) that blue-wearers would choose to stand farther away from their red-wearing opponents than vice versa. Descriptive results show that blue-wearing participants chose a larger distance from their red-wearing opponents (M = 51.17 cm) than vice versa (red-wearing participants: M = 50.63 cm). However, results from the matched paired samples *t* test (always using log-transformed data in this section) revealed that this difference was not significant ($t(59) = -.453$, $p = .653$). Assuming that height differences within pairs could be influential, the test was repeated with 30 in height matching pairs (within a range of +/- 6 cm height) which revealed a non significant result ($t(29) = < .001$, $p > .999$) as participants of both treatment groups chose the exact same distance of 52.83 cm to their opponents. A bivariate correlation analysis confirmed that SoDi did not correlate with participant's actual height ($r(120) = .022$, $p = .815$), nor with height estimated in opponents ($r(118) = -.016$, $p = .846$). Thus participant's choice of distance from their opponent was not influenced by their own body height or by their perception of their opponent's height.

Even though the order in which participants chose their preferred social distance from the other participants (SoDi_order) was randomised, the second participant to choose the distance might have taken the first participant's measure as a reference point. Indeed, distances of the first and second choosing participants are highly correlated ($r_{log}(60) = .666$, $p < .001$) but results of an ANCOVA with log_SoDi as DV and shirt colour and SoDi_order as fixed factors showed that there were no main effects for shirt-colour ($F(1, 116) = .075$, $p = .784$) or SoDi_order ($F(1, 116) = 1.574$, $p = .212$), neither was there an interaction effect between shirt colour worn and SoDi_order ($F(1, 116) = 2.042$, $p = .156$).

The distance in which one chooses to stand from another individual very much depends on whether the individuals are acquainted or not (Hall 1966). Results of a one-way ANOVA showed that the variable ‘how well participants knew their opponents’ (very well/a bit/not at all) had a significant effect on the distance participants chose from their opponent (‘very well’: M = 44.12cm < ‘not at all’: M = 54.17cm < ‘a bit’: M = 56.31cm; $F(2, 117) = 7.429$, $p < .001$). Bonferroni post-hoc test revealed that this difference was significant between those who knew each other well and those who knew each other "a bit" ($p = .003$) and between those who knew each other well and those who did not at all ($p = .035$, see Figure 13).

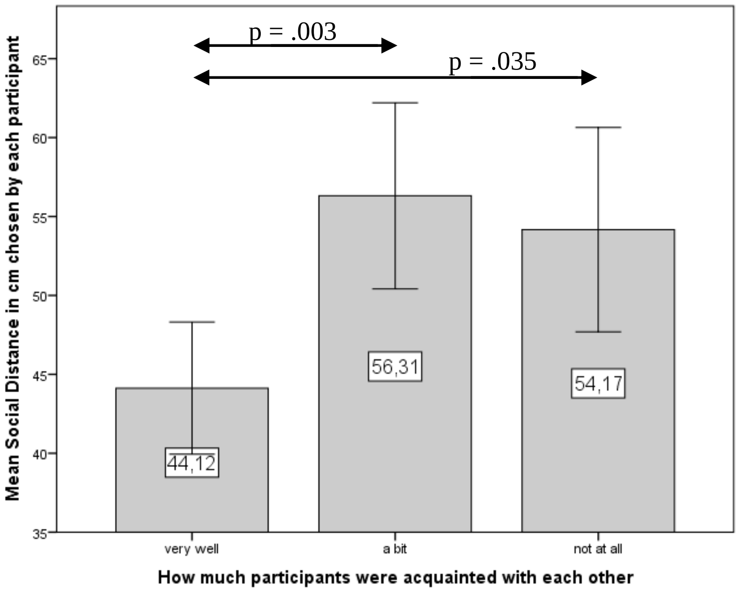


Figure 13: Mean social distance depending on how well each opposing pair knew each other, **e**rror bars indicate 95% CIs

Following that, the categories were reduced from three to two with one category representing all participants who knew one another "very well" (N = 48) and the other representing those who knew one another "a bit" and not at all (N = 72). A 2x2 ANOVA with this dichotomous category ("very well" vs. "not very well") and shirt colour again revealed a main effect for the variable ‘how well participants knew their opponents’ ($F(2, 116) = 15.092$, $p < .001$).

Participants that knew each other "very well" stood 11.29 cm closer to each other than those who did not (pairwise comparison, $p < .001$). No main effect was found for shirt colour worn ($p = .499$) but a marginal significant effect for the interaction of shirt colour with the variable 'how well participants knew their opponents' ($p = .052$). As can be seen in Figure 14, blue-wearers stood closer to their opponents when they knew each other well (M = 40.79cm) but retreated if this was not the case (M = 58.55cm). One-way ANOVAs for each colour separately with the two acquaintance-categories as independent variable revealed that this difference is significant amongst blue-wearers ($F(1, 58) = 14.345$, $p < .001$) whereas it did not play a role whether red-wearers did know their opponent very well or not ($p = .136$).

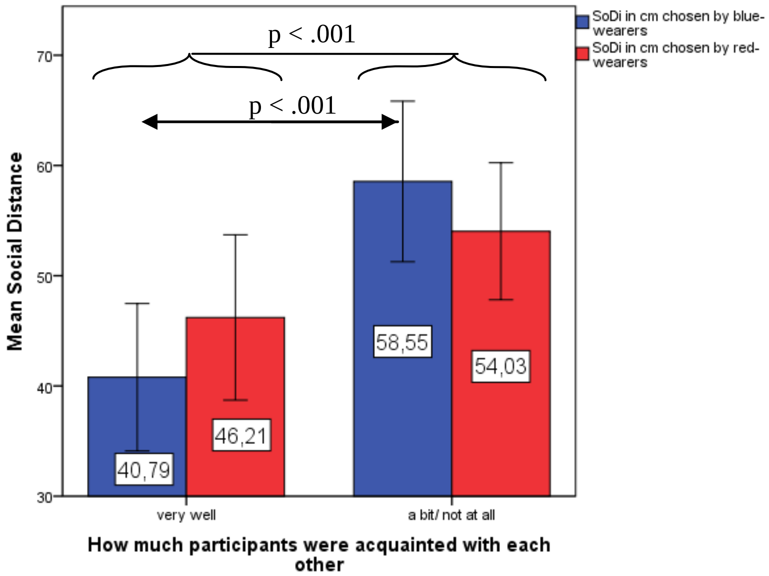


Figure 14: Mean social distance depending on how well each opposing pair knew each other (2 categories), separately for shirt colour worn, **e**rror bars indicate 95% CIs

In a next step, using paired *t*-tests, it was tested whether red and blue-wearers differed within groups that knew one another either well or not. Ten pairs had to be excluded from this analysis as the two participants of each pair were in disagreement about the nature of their relationship to each other (for example, one participant would tick off "very well" whereas the other one would attest that they had known each other only "a bit"). The data were then analysed separately for pairs that knew each other either "very well" or not using matched pairs samples *t* tests. Whether participants wore red or blue T-shirts did not influence SoDi within pairs that knew each other either very well ($t(18) = -1.657$, $p = .115$) or those who did not ($t(30) = 1.607$, $p = .118$)[11].

In sum, there is only very scarce support for hypothesis 3. Blue-wearers chose a significantly greater distance from their red-wearing opponents when they did not know their opponent very well relative to when they knew them well.

4.4.3.4 Self-rated dominance

Scores presenting the difference between Q2 (post-colour) and Q1 (pre-colour manipulation) were calculated to test hypothesis 4 whether the colour manipulation led to a change in participants' dominance scores. One pair was excluded from the analysis as both participants did not fill in the questionnaire post-colour treatment.

Both treatment groups had slightly higher dominance scores after colour manipulation (blue: +0.18 ($M_{Q1} = 21.31$; $M_{Q2} = 21.49$); red: +0.11 ($M_{Q1} = 22.81$; $M_{Q2} = 22.92$) but the paired samples *t* test revealed no significant difference between colour treatment groups ($t(58) = -.662$, $p = .523$).

A repeated-measures ANOVA for each colour separately was used to compare the means of Q1 and Q2. Results indicate that dominance scores in Q2 did not differ significantly from the dominance scores in Q1 for either colour treatment group ($F_{blue}(58) = .433$, $p = .513$; $F_{red}(58) = .093$, $p = .762$).

In between Q1 and Q2 the participants underwent the handgrip and SoDi test. In the following section, it was tested whether the outcomes of these tests or assumptions of win/loss influenced the dominance differences between colour conditions. Note, that we did not put forward specific hypotheses or predictions for interaction effects between win/loose and colour, yet we wanted to investigate these.

Even though participants received no feedback as to whether they had won or lost the handgrip competition until the very end of the experiment, it was tested whether a change in self-perceived dominance differed between winners and losers, both between and within colours. Figure 15 depicts that winner's and loser's self-perceived dominance did almost not change at all amongst blue-wearers. In contrast, dominance in red-wearing winners increased (M = +0.65) but decreased in red-wearing losers (M = -0.33). However, an independent *t*-test

[11] We agree that the evaluator's judgment of familiarity matters, however, we decided to drop 10 pairs in order to be able to correctly categorise the familiarity of these pairs and investigate how familiarity, SD, and shirt-colour interact.

showed that this difference between losers and winners within red-wearers is not a significant one, $t(57) = 1.649$, $p = .105$). Overall, the change in self-rated dominance between winners and losers did not differ significantly neither between colour groups nor within colour groups (all $ps \geq .105$).

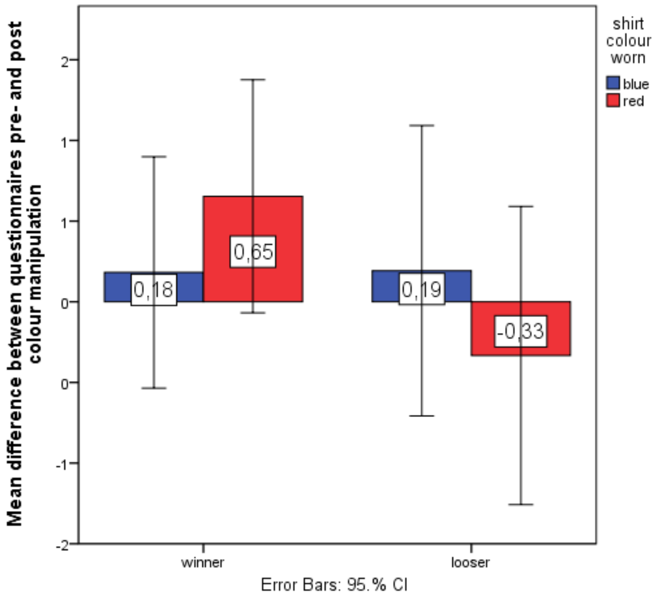


Figure 15: Change in self-perceived dominance between pre- and post colour manipulation for red- and blue-wearing winners and losers of the handgrip test

However, the same analyses were repeated with all pairs that a) evaluated each other as equally strong ($N_{pairs} = 10$) and b) matched in height and weight ($N_{pairs} = 22$). Again, only the red-wearers went through the biggest change in self-perceived dominance depending on whether they lost or won the handgrip competition. Even though sample size was drastically reduced, dominance in red-wearing winners significantly increased ($M_{a)} = +1.00$; $M_{b)} = +1.27$) but decreased in red-wearing losers ($M_{a)} = -1.20$; $M_{b)} = -1.27$); $t_{a)}(8) = 2.750$, $p = .025$; $t_{b)}(20) = 3.055$, $p = .006$; see Figure 16a and 16b. For an overview of the results in this paragraph see Table 10.

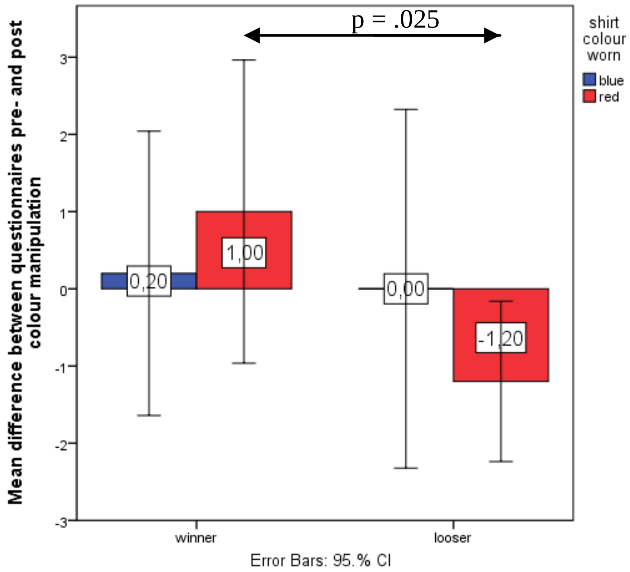


Figure 16a: Change in self-perceived dominance between pre- and post colour manipulation for red- and blue-wearing winners and losers of the handgrip test amongst 10 pairs that perceived each other as equally strong

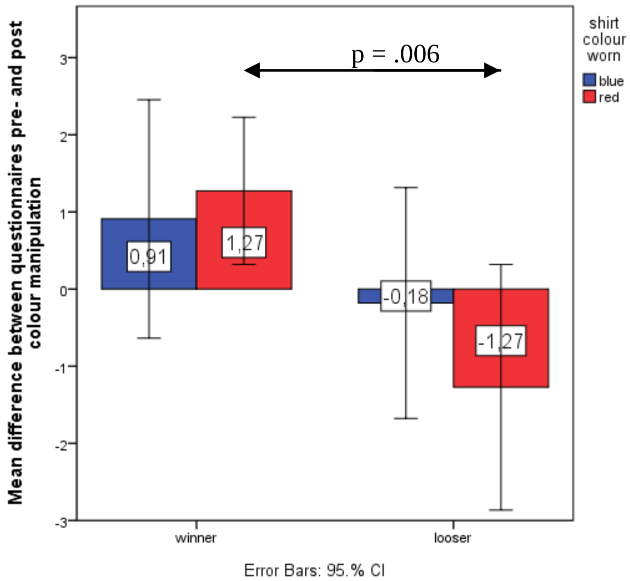


Figure 16b: Change in self-perceived dominance between pre- and post colour manipulation for red- and blue-wearing winners and losers of the handgrip test amongst 22 pairs that matched in height and weight

			N	Mean change dominance	t	df	Sig.
Full data set	Blue	winner	33	.18	-.019	57	.985
		looser	26	.19			
	Red	winner	26	.65	1.649	57	.105
		looser	33	-.33			
Pairs evaluated as "equally strong"	Blue	winner	5	.20	.187	8	.200
		looser	5	.00			
	Red	winner	5	1.00	2.750	8	**.025**
		looser	5	-1.20			
In height&weight matching pairs	Blue	winner	11	.91	1.130	20	.272
		looser	11	-.18			
	Red	winner	11	1.27	3.055	20	**.006**
		looser	11	-1.27			

Table 10: Mean change in dominance amongst analyses using the full data set and two subsets, results are reported separately for each shirt colour worn

The relationship between dominance scores and other variables was further assessed. Controlling for participant body weight, height, and age as possible confounds, maximum handgrip strength did not correlate with dominance pre-colour manipulation ($r_p(113) = .134$, $p = .153$) or post-colour manipulation ($r_p(113) = .142$, $p = .130$). Number of items taken out of the reward box and SoDi did also not correlate with dominance scores of Q1 or Q2 (all *r*'s<.169, all *ps* ≥ .067). Furthermore, SoDi did not correlate with "change in dominance" (difference between Q1 and Q2), $r(118) = .128$, $p = .169$.

In sum, dominance scores did not change over time or with colour manipulation and red-wearing participants overall did not have higher dominance scores than blue-wearing participants. Winning or losing the handgrip test did not significantly affect participants' self-perceived dominance when all participants were included in the analysis. However, amongst pairs matched for height and weight and also amongst pairs that evaluated each other as equally strong, dominance in red-wearers who won the handgrip competition significantly increased but decreased in red-wearing losers. Overall, predictions of hypothesis 4 are not supported. However, in pairs with participants being physically similar to each other (or at least when participants perceived each other as similarly strong), red-wearers' dominance increases or decreases depending on their win-lose-status.

4.4.3.5 Reward box test

In 34 out of 60 occasions, red-wearing participants were faster to take an item out of the reward box than blue-wearing participants were. This is in line with prediction 6 (H5), however, McNemar's chi-square statistic shows that there is no statistically significant difference in the proportion of red-wearers being first to take something out of the box and the proportion of blue-wearers being first, McNemar's $\chi^2(1, N_{pairs} = 60)$, $p = .366$.

In line with prediction 7, red-wearing participants took on average more items (M = 3.02, SD = 2.08) out of the reward box than participants in the blue condition (M = 2.67, SD = 1.67) did. A paired samples *t* test (log-transformed data) revealed that this difference is significant, $t(57) = -2.074$, $p = .043$.

Hypothesis 5 needs to be partly rejected. Prediction 6 that participants with red T-shirts will take something first out of the reward box is not supported. There is sufficient evidence that participants in the red condition took more items out of the box than participants in the blue condition did (prediction 7).

4.4.4 Summary Results

Hypothesis 1: Colour worn influences strength outcome (wearer effect)	**Prediction 1**	Red-wearing participants are more likely to squeeze a handgrip dynamometer with higher maximum force than blue-wearing opponents.	*No support*
Hypothesis 2: Colour perceived on others influences strength and height perception (perceiver effect).	**Prediction 2**	Individuals wearing red T-shirts are more likely to be estimated taller than they actually are, whereas individuals wearing blue T-shirts are more likely to be estimated shorter than they actually are.	*No support*
	Prediction 3	Red-wearing participants are more likely to be classified as "being stronger" by their blue-wearing opponents than vice-versa.	*No support*
Hypothesis 3: Colour worn influences the distance within which an individual feels comfortable to have a normal conversation with the other participant (wearer/perceiver effect).	**Prediction 4**	Blue-wearing participants are more likely to choose a greater distance from red-wearing participants (perceiver effect) than vice-versa (wearer effect).	*No support*
Hypothesis 4: Colour worn influences self-rated dominance (wearer effect).	**Prediction 5**	After colour-manipulation, red-wearing participants are more likely to score higher on the questionnaire assessing psychological dominance than participants wearing blue T-shirts.	*No support*
Hypothesis 5: Colour worn influences participants' actions to monopolize resources.	**Prediction 6**	Red-wearing participants will be more likely to take something first out of the reward box and blue-wearing participants will be more likely to give way, and allow red-wearers to take something first.	*No support*
	Prediction 7	Red-wearing participants will take more items out of the "reward box" than blue-wearing participants.	*Supported*

Table 11: Overview of hypotheses, predictions and results of Chapter 4

4.5 Discussion

This study used multiple tests within a single experimental setting in order to investigate the direct effects of shirt colour on participants wearing either red or blue shirts. The study consisted of several parts to test whether there is a relationship between shirt colour worn and the following parameters: handgrip strength, self-perceived dominance, size of the personal comfort zone, height and strength estimation in opponents, and resource monopolisation. Results only showed some influence of shirt colour on measures of social distance and resource domination.

Physical strength measures obtained using handgrip dynamometers were independent of the shirt-colour participants had been assigned. Participants wearing red were neither stronger nor did they outcompete their opponents more often than blue-wearers did (prediction 1). This result is in contrast to a recently published study demonstrating that wearing red influences physical parameters of the wearer (Dreiskaemper *et al.* 2013). Even though strength was measured in a similar fashion to Dreiskaemper *et al.*'s study (they used a leg-dynamometer), the experimental design differed substantially from that used here. Whereas Dreiskaemper *et al.*'s participants underwent both colour conditions, participants here were assigned to only one colour treatment group. Consequently, the method employed here did not allow to control for colour effects, of both blue and red colour, on each individual separately. That means, we cannot exclude that a blue-wearing individual in our study could have been stronger (or weaker) if we had tested him wearing red later on. For that reason, it may be sensible to also record the baseline HGS of each participant wearing a neutral colour, that way assessing whether HGS increased or decreased when individuals were again assessed wearing blue or red. Both studies have in common that two opponents wearing differently coloured shirts/jerseys were put in a situation involving male-male competition. Though the types of competitions are very different (a physical fight versus a handgrip test), both studies failed to demonstrate an influence of outfit colour on win or lose outcomes, thus, failing to provide further support for a "red win" effect (Hill and Barton 2005, Attril *et al.* 2008). However, given that participants in Dreiskaemper *et al.*'s combat study were novices and that our study did not involve a direct physical competition, it is still possible that Hill and Barton's proposed "red win" effect does hold true in that wearing red can be advantageous in actual sports contests where winning and losing has financial and prestigious implications for athletes. Presumably, wearing red is of even greater importance in sporting competitions in which two opponents fight each other in direct physical battles (Sorokowski and Szmajke 2011), especially since the impact of colour turned out to be low in team sports and was merely verified elsewhere (Smajke and Sorowski 2006, Kocher and Sutter 2008, Caldwell and Burger 2011, García-Rubio *et al.* 2011). Thus, the magnitude of a "red-effect" may vary as a function of one-on-one versus team competition (Kocher and Sutter 2008), or combat versus collaborative sport as well as real-live versus laboratory based competitions.

Whereas wearing red or blue did not yield higher or lower strength measures, it is important to emphasize that simply viewing a red stimulus influences strength output in humans and also that the total time of exposure to it is of great importance. Some studies demonstrate a strength enhancing effect of viewing red when participants were only briefly exposed to a red stimulus (Elliot and Aarts 2011) or when participants viewed the colour for more than 30 seconds or even constantly throughout the experiment (jersey-colour study: Dreiskaemper *et al.* 2013; light studies: Green *et al.* 1982, O'Connell *et al.* 1985). Hamid and Newport (1989) indicated that viewing blue has the opposite effect of red as the exposure to blue light decreased strength output in study participants. Thus, there are two competing predictions concerning the effects of being exposed to red versus being exposed to blue. Presumably then, if perceiving red or blue on an opponent has a stronger or at least equal effect as wearing red, it is unlikely to detect strength differences in opponents wearing either red or blue. Using a control colour, such as grey, may be helpful to separate the two competing predictions.
Furthermore, results from other colour research studies are inconclusive and not all studies show that the exposure to red enhances strength. For example, viewing red prior to a strength test inhibits the rate of force development (Payen *et al.* 2011) and no significant difference in HGS was found between participants being alternately assigned to a Baker-Miller pink room and to a red room (Profusek and Rainey 1987). Other studies exploring the effects of observed light colours report similar results (Ingram and Lieberman 1985, Keller and Vautin 1998). These examples of the available literature show that results regarding the psychological and physiological effects of colour have been inconsistent. Consequently, it is difficult to distinguish between wearer- and perceiver effects in studies where there is no control colour used. We hypothesized that the colour worn would influence strength output and therefore demonstrate a wearer effect of red colouring. Because participants faced each other in close proximity (in 1 m distance) while exerting the handgrip test and were thus simultaneously exposed to their own and their opponent's shirt colour, effects of the colour observed could be as important as effects of the colour worn. Red may enhance strength output in the perceiver

or wearer whereas blue can have a relaxing, strength inhibiting factor. The present results cannot rule out either possibility and it is possible that red-wearers were more influenced by the relaxing factor of their blue-wearing opponents than by the strength enhancing forces of their own shirts. For example, Dreiskaemper *et al.* (2013) were able to rule out that effects of observed colours could have been influential on individuals' strength output as participants faced a neutrally coloured wall and not, contrary to our study, their differently coloured opponent. That way it was possible to pin down a strength enhancing effect of the colour red in those participants performing in red shirts and not those viewing red on their opponent's jersey.

Likewise, it is possible that we were unable to detect a colour effect as participants had not worn their coloured shirts for a long enough time for either of the colours to take its effects on grip strength for instance. For example, participants in Dreiskaemper *et al.*’s study (2013) were presumably much longer exposed to their own and their opponent’s colour as all participants were first assigned to their coloured combat protectors, then had the fighting rules explained to them, then had their strength and heart rate measured and only then engaged in the combats (personal communication with Dr. Dennis Dreiskaemper). Participants of the study here were also already wearing their shirts and faced each other while we explained the use of the handgrip dynamometer, but this exposure may not have been long enough (less than 5 minutes). It might thus be sensible to extant the total time of colour exposure prior to competition to allow for more conclusive results regarding the effects of clothing colour on handgrip strength.

It was further hypothesized that red-wearing participants were more likely to be estimated taller than they actually were and also more often regarded as stronger in comparison to how the blue opponent perceived himself. However, no significant difference in height estimation was found between colour treatment groups (prediction 2). Of course, a failure to demonstrate a connection between shirt colour and height estimation does not necessarily mean that the effect is non-existent. Results here included mutual evaluations of height between participants wearing either red or blue. Future research could investigate whether colour plays a role in height estimations when participants are asked to rate differently coloured actors displayed in images that do not reveal full body size (Chapter 5). Furthermore, presenting images with reversed colours (e.g., an actor originally wearing red being displayed in a blue shirt) could be of further interest in detecting whether the colour displayed affected estimations of height judges (Hagemann *et al.* 2008, for more see Chapter 5).

Even though red-wearers were perceived as stronger on five occasions more than blue opponents (prediction 3), this difference was not significant. Results showed that personal evaluation and strength comparison to the opponent was of special importance to red-wearers as they squeezed harder when they perceived a better chance of winning. Perceiving an opponent as weaker resulted in red-wearers gripping on average 6.6 kg more than red-wearers who thought their opponent was stronger. This result is surprising if one expects that perceiving an opponent as stronger could lead the alleged "underdog" to put all of his power together to push his chances of a victory. However, the opposite could also be true in that the evaluation of being the weaker part leads the underdog to resignation, consequently putting less effort in trying to outcompete his allegedly superior opponent. Similar strategies are observable in red deer (*Cervus elaphus*) for example, where the red deer stags use roaring contests to assess each other's fighting ability. Consequently, the weaker animal backs off from full confrontation and thereby avoids potential costs of injuries (Clutton-Brock and Albon 1979). Judging someone elses' or one's own performance is a central task for most individuals involved in sports competitions (Plessner and Haar 2006) or election campaigns (Sabatier *et al.* 1987). In the strategic interaction characteristic of most competitive situations, it is crucial that opponents are able to assess accurately the strength and resources of their adversaries. An accurate knowledge of opponents' advantages and probable strategies is necessary for determining how to successfully counter them. Allocating scarce resources to fight someone perceived as stronger makes little sense unless one is reasonably sure that the opponent is indeed beatable. And an accurate assessment of opponents' resources (and one's own) is necessary if one is to maximize chances for success (e.g., Preuschoft and van Schaik 2000). Allocating too few resources will lead to defeat, allocating too many is wasteful. Arguably then, red-wearing participants who perceived their opponent as weaker "wasted" their strength. However, participants were only asked to evaluate each other's performance *after* the handgrip test had been already performed, not beforehand. Consequently, factors such as the opponent's facial expression, exertion and endeavor could have also been influential in how strong a participant was evaluated later on by his opponent. Thus, future research could assess strength evaluations in relation to colours pre- and post-performance. Simply put, the here presented result could also be interpreted in that individuals wearing red accurately assessed their opponent, and did so more successfully than blue-wearers did. For what it matters in this research here, no proof was found that the colour worn had any influence on whether an opponent was evaluated as being physically superior or not.

Several studies provided empirical support for the relationship between red and avoidance behaviour in achievement context (Elliot *et al.* 2009, Meier *et al.* 2012). This led us to the hypothesis 3 that, immediately after the handgrip test (similar to an achievement context) was finished, blue-wearers would choose to stand further away from red-wearers than vice versa (prediction 4). This hypothesis was not supported and results were independent of participants' own height and their perception of their opponent’s height. The only variable that did make a difference in social spacing was a competing pair's level of acquaintance. Whether an individual knew his opponent very well or not was of special importance to blue-wearers as they stood significantly further away from their red-wearing opponents when they did not know him very well relative to when they knew him well. We did not generate any hypotheses about the relation of colour and social distance and its interaction with how well opposing participants knew each other. However, it does not seem that blue-wearers' decision to stand closer to someone they knew was influenced by their opponent's red shirt colour. Further tests would be necessary to investigate whether blue-wearers perceived a red-wearing opponent they did not know very well as more "threatening", thus avoid him using a larger interpersonal space. Including other colours into this test would allow to determine whether this pattern is only obvious when blue-wearers face red-wearers or whether they adapt the same strategy when being opposed to differently coloured opponents.

Participant’s baseline of self-perceived dominance was tested whilst they were wearing their own clothes (pre-colour manipulation) and once after they had changed into red and blue respectively (post-colour manipulation). We were not able to confirm Feltman and Elliot’s study results (2011) that wearing red enhanced one’s own self-perception of dominance (hypothesis 4, prediction 5). Whether participants had lost or won the handgrip competition did also not affect their dominance scores, specifically not their change in self-rated dominance (the difference between Q2 and Q1). However, when two different subsets of the full data was used (1. equally strong and 2. in height and weight matching pairs), it appeared that dominance scores in red-wearers significantly increased when they had won the handgrip test whereas dominance scores significantly decreased when they had lost the handgrip-test. This pattern occurred without red-wearers certainty of having won or lost the competition as they only learnt about their performance at the very end of the experimental setting. Again, the here exposed difference occurred within the red colour treatment group only but no significant effect emerged between colour treatment groups. Thus, given the fact that wearing either red or blue did not significantly influence results from the handgrip test or the dominance questionnaires lead us to the conclusion that adding a competitive component, even though not a very physical one, did not trigger a wearer effect. This confirms the results from the previous chapter in which a wearer effect of red colouration was also not supported.

The final part of this study was an attempt to trigger and consequently observe dominant behaviour between two participants since behavioural indicators of dominance have been relatively scarce in the literature. We predicted that red-wearers would more often be the first to take something out of the reward box than blue-wearers (hypothesis 5, prediction 6). This was indeed the case (34 times versus 26 times) but results failed to be significantly different between colour treatment groups. We further predicted that red-wearers would on average take more items out of the box than their counterparts wearing blue (hypothesis 5, prediction 7) and did find evidence for this. One could argue that this effect is simply due to the fact that those individuals who took more items out of the box were, regardless of the colour they wore, more dominant. However, as the number of items was not found to be correlated with participants' dominance ($p > .130$), the possibility that simply more dominant individuals "dared" to take more, can be ruled out. Hence, this actually documents a "red-effect" independently of participants' dominant character. Even though these results have to be interpreted with caution, what can be taken along from this test is at least the possibility that interpersonal dominance could also be measureable using a behavioural component and that actual dominant behaviour may not always be reflected in psychological questionnaires. Though colour effects were irrelevant in his research, Stulp (2013) conducted a similar series of studies in which he demonstrated that height predicts interpersonal dominance during brief dyadic interactions in natural settings. For example, when two individuals simultaneously approached a narrow passage in a street, the shorter individual was more likely to give way and let the taller individual take precedence (Stulp 2013). Furthermore, when a tall confederate walked against the flow of people in a busy street, pedestrians were more likely to give way but also less likely to collide with him than when the confederate was of shorter statue (Stulp 2013). This demonstrates that at least in same-sex dyads, height is positively related to interpersonal dominance. We agree with Gert Stulp that interpersonal dominance may also be observable in, for example, non-verbal interactions.

However, even though we did find that red-wearing participants took on average more items out of the box, it is yet too early to state that red-wearers monopolize food in an analogous fashion as animals do (Cuthill 1997, Pryke and Griffith 2006, Pryke 2007). Furthermore, given the nature of the observational setup, we were unable to assess whether blue-wearing individuals were more likely to give way, red-wearing individuals actively took precedence towards the box, or both. More research could focus on measuring dominance with behavioural indicators rather than using psychological questionnaires only.

Furthermore, we note that the statistical approach we used is questionable in a sense with which we did not adjust the alpha-level in the bonferroni post-hoc-test. The *p*-value leading to this significant result is .043, however, multiple tests were used in this chapter (seven predictions all comparing red with blue) and it could be argued that the appropriate alpha would be therefore .007. Consequently, if the *p*-value gets too low, it is much more difficult to find a significant relationship. On the other hand, we are aware that finding a significant effect like the one we found here, could be very well due to chance, which is a problem when multiple tests are used (Hochberg 1988, Bland and Altman 1995). On the other hand, others have questioned whether correcting for multiple testing is helpful as the correction methods might increase type II errors (Perneger 1998, Nakagawa 2004). Although we do not apply corrections for multiple tests here, we want to highlight that only our final result is concerned as all others were non significant. Further research would therefore do well to evaluate significant relationships also on the basis of substantial effect sizes.

4.5.1 Limitations and future research

Finally, we stress some of the most important limitations in this study. First of all, as for most studies carried out on university campuses, the average age and the diversity in educational levels of participants was low. However, the use of mostly undergraduate participants seems not only a limitation but also a strength. It is a strength in that many studies on the "red-effect" in the competitive context focused on experts or professional athletes, and the present research therefore is more representative of the general population. Undergraduates, on the other hand, represent only a small part of the general population (Feltman and Elliot 2011). Generally, more research should utilise samples with greater variety in terms of socioeconomic status, educational level, and also age to allow for a greater generalizability of results. On the other hand, there is less to control for in terms of extraneous variables, which again credits research using undergraduates.

Secondly, participants were asked to indicate to the second participant where he should install himself so that the indicating participant felt comfortable for a conversation. This itself is already an action than implies one participant giving the other participant "orders". Most often, participants indicated a distance but then autocorrected this distance as they felt the other participant was too close/far. Consequently, the method we applied may also display each participant's courage to overtly correct his preceding choice and maybe demand the other participant to move closer/away one more time. Though results might not have been much different, we suggest that such measurements are better to be taken whilst the first (indicating) participants moves either away or towards the other participant himself. That way, the choosing individual may re-think and alter his decisions several times, thus, allowing for a more precise distance that better reflects his actual choice. Furthermore, a more precise analysis of dominant behaviour could be achieved by using videos, thus, further looking at body posture, eye contact, voice pitch changes, etc. (e.g., Puts *et al.* 2006, Carney *et al.* 2010).

Thirdly, it may generally be sensible to match opponents for height and weight in studies measuring physical competitions. If, however, dyad matching is methodologically impossible, the average difference in height and weight between two competing individuals of each pair should always be taken into account. This can be done by either using subsets with pairs of similar anthropometric attributes (given that sample size then still is large enough to allow for statistical claims) or by using residuals of strength measures. Where applicable, it may also be sensible to control for the level of acquaintance between opponents as we have seen that at least the results for social spacing very much depend on this.

Fourthly, even though the content of the reward box was not visible from the outside and content was diverse, personal preferences or aversion for certain items in the box may play a role in how fast and how much participant took something out of the box. Even though we paid close attention to the content of the box being more or less the same for larger items (e.g., candy bars and fruits), there was always an uncontrolled variety of smaller items (e.g., confectioneries) in the box. Furthermore, the colour worn may have also been influential on the speed with which participants walked (Meier *et al.* 2012) and it could be of further interest to test how the shirt colour worn is related to walking pace.

Finally, participants were asked to estimate their opponent's height but not dominance. This could have been, however, an important indicator of a perceiver effect and could further allow to either support or refuse Feltman and Elliot's (2011) notion of a bidirectional effect of wearing vs. viewing red. Therefore, the perception of the opponent's dominance should always be a variable collected in this kind of research.

Chapter 5

5 In an online survey, wearing or perceiving red wields no influence on perceptions of dominance, height or strength

5.1 Abstract

Previous rating experiments conducted in controlled laboratory settings demonstrated that individuals in red are perceived as more aggressive and dominant than when wearing blue (e.g., Wiedemann *et al.* 2015) but there is still uncertainty whether this is due to a perceiver- or a wearer effect. The study here allows to test for either of these possibilities but also whether these two effects interact with each other. We further tested the robustness of the previously presented "red-effect" across different methods and extended its exploration from a laboratory- to a web-based approach. In addition, raters' perception of targets' dominance, height and handgrip strength was for the first time compared to the actual data of targets. Two hundred and ten participants (140 women) aged M = 29.27 years (SD = 10.9) rated online photographs of men for perceived dominance, height and strength on a 7-point scale. Each target (N = 20) was presented twice, once wearing the original, photographed, shirt colour (red or blue) and once in the colour-manipulated version. Targets photographed in red, regardless of whether they appeared to be wearing blue or red, did not receive higher ratings than those originally photographed in blue. Neither a perceiver-, nor a wearer effect, nor an interaction of these effects was detected. Even though these results are rather unexpected, they add to a growing body of research in colour psychology and demonstrate that results around the "red colour effect" in neutral contexts might be more easily detected in controlled laboratory settings. Possible limitations of the survey and the advantages and disadvantages of web-based experiments are discussed.

5.2 Introduction

In previous chapters (Chapters 2 and 3), it was demonstrated that in a laboratory setting red-wearing targets were rated as more dominant than blue- or grey-wearing individuals. For these two experiments, there was no specific information about the male targets in display available. That is, physical markers such as height and weight or character traits such as a targets' dominance or confidence were unknown both to the participants rating these targets but also to the examiner.

Since height has been found to be positively related to interpersonal dominance (Stulp 2013) and dominance is associated with red colouration in a variety of animal taxa (e.g., nonhuman primates: Setchell and Wickings 2005, Khan *et al.* 2011, fish: Milinski and Bakker 1990, birds: Cuthill *et al.* 1997; humans: Wiedemann *et al.* 2015), it is possible that the perception of the actual physical information of a person (such as actual height and handgrip strength) can be biased through shirt colour. It is hereby of specific interest to test whether shirt colour plays a role in making first impressions in order to estimate an unknown individual's height, strength or dominance - attributes that are all important when it comes to assessing, for example, an opponent in antagonistic dyads or sports competitions (see section 1.2.2).

The following chapter sets out to investigate whether or not T-shirt colour biases perceptions of physical parameters and/or character traits. In doing so, actual data on height, strength and dominance[12] score of the male target are put in relation to the perceptions of this male by participants rating the target online.

To date, very little has been done to differentiate perceiver and wearer effects outside of the competitive context. Roberts *et al.* (2010) explored this matter in the romantic context and revealed a positive effect of targets being photographed in red that was independent of the presented (perceived) clothing colour. Specifically, targets who wore red while being photographed received higher ratings for attractiveness than those who wore white while being photographed but had been made to appear as though they were wearing red. On the other hand, those originally photographed in red were also perceived as being more attractive when shirt colour was digitally modified to white compared to targets photographed actually wearing white. The authors concluded that clothing colour influences wearers in the same way as it influences raters, at least regarding the judgments of attractiveness. Whereas the

[12] Hereafter referred to as "characteristics" when all three attributes (height, strength and dominance score) are mentioned

literature is scarce on whether and how red could act on either wearer or perceivers in rather neutral situations, Roberts *et al.*'s findings open up the possibilities that similiar effects could be found for judgments of physical traits, even in a neutral context. We now know that, outside of the competitive context, individuals in red are perceived as more dominant and aggressive (Wiedemann *et al*. 2015, see Chapter 2), but little is known about the effects of red on the wearer itself. Here we aim to fill this gap. Following Wiedemann *et al.* (2015), we compare the effects of the colour red versus blue on certain characteristics, but we extend this to differentiate between wearing and perceiving red. Hereby images were used in which the colour manipulations were obtained not only by digital colour alteration but also by target participants actually wearing differently coloured clothing.

We adopted a method that has gained increasing importance during the last decade of psychological studies but also various other applied domains: computer- and web-based experiments (Bartram 2006). The latest software used to create web-based tests and questionnaires even allows the integration of coloured elements such as green or red progress bars. Such seemingly trivial elements can have important consequences in achievement contexts (Gnambs *et al.* 2010), thus, adding to a growing body of evidence revealing detrimental effects of red on fluid intelligence measures (e.g., Elliot *et al.* 2007). When it comes to web-based studies, one important question to ask is whether laboratory studies translate to home or office computer use. Whereas in laboratory settings, the experimenter can control various physical aspects such as standard lighting conditions and calibrated monitors, these aspects vary for each internet user in web surveys. However, reliability and validity of web-based studies were found to be equivalent to lab studies (i.e., Dandurand *et al.* 2008, Musch and Klauer 2002, Preckel and Thiemann 2003). This also applies to colour psychology studies. Gnambs *et al.* (2010) were able to report similar negative effects of the colour red in achievement contexts when participants used their home computers as compared to studies in controlled laboratory settings.

5.2.1 Objectives and hypotheses

The research presented in this chapter was guided by the following objectives. First, we extend previous results on the association of red colouration and dominance perceptions from laboratory based research to the field of web-based studies. Second, possible effects of wearing red versus wearing blue are investigated and also whether the *wearer effect* does indeed outweigh the perceiver effect (Roberts *et al.* 2010). We therefore predict, that if a wearer effect occurs, originally red-wearers are expected to receive the highest ratings relative to originally blue-wearers. If, however, the *perceiver effect* is stronger, than it can be expected that ratings should be the highest for targets displayed in red, regardless of the original shirt colour worn. Thus, we predict a significant main effect for colour and interactions with perceiving and wearing either red or blue. Based on the above, the following hypotheses are advanced:

Hypothesis 1 (H1): Roberts *et al*. (2010) demonstrated a positive effect of being photographed in red that is independent of the presented (perceived) clothing colour. We hypothesize that a *wearer effect* is detected.

Prediction 1: Red-wearing individuals will be estimated more dominant, taller and stronger than they actually are.

Prediction 2: The wearer effect is stronger than the perceiver effect. That means, those targets who originally wore red when photographed will be perceived more dominant, taller and stronger than those targets also displayed in red but being originally photographed wearing blue.

Hypothesis 2 (H2): A *perceiver effect* is detected.

Prediction 2: Individuals displayed in red will be estimated more dominant, taller and stronger, no matter the colour he was photographed in.

Prediction 2: The perceiver effect is stronger than the wearer effect. That means, targets displayed in red (no matter the original colour worn) will receive higher ratings for dominance, height, and strength than those displayed in blue.

5.3 Methods

5.3.1 Stimuli

Those participants who agreed having a picture taken of their face and upper torso (N = 96, (see Chapter 4) were seated in front of a white background. Three colour digital images of each participant's face were taken with a CANON EOS 500D reflex camera at high resolution (2,352 x 1,568 pixels, jpg file format) under standardized light conditions in frontal view. Participants were asked to look directly into the camera, remove any facial adornment and present a neutral facial expression. In order to optimize the quality of the pictures and to produce a greater uniformity across all target persons, the pictures were post processed by the photographer. First, a cutout was selected to standardize the size of the head and upper torso in the picture (there were slight deviations due to differences in head sizes, neck lengths, shoulder width and hairstyle). With the aim of having equal distances to the image borders, photographs were cropped above each target's hairline, at the very right and left end of the shoulders and below the collar. Second, twenty photographs (ten participants being photographed in red, ten participants being photographed in blue) were selected for this study (see Figure 17). The main criterion for an image to be chosen as a stimulus for the online survey was that the target's facial expression had to be neutral. Using Adobe Photoshop CS6, the stimuli's clothing was digitally altered from its initial colour to red or blue respectively (see Figure 18 for an example set). The hue and saturation were then adjusted to produce the coloured images (see Appendix IV for RGB-values). A total of 40 images were thus presented in the experiment.

			
Participant 4	Participant 7	Participant 18	Participant 39
			
Participant 41	Participant 45	Participant 53	Participant 56
			
Participant 64	Participant 65	Participant 66	Participant 76

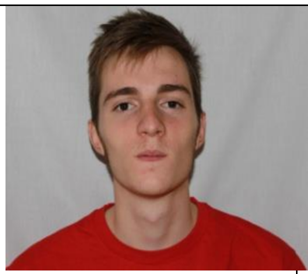
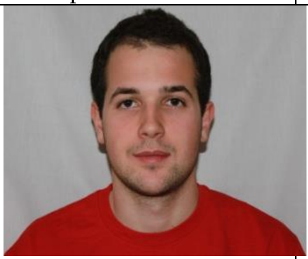
			
Participant 79	Participant 80	Participant 81	Participant 82
			
Participant 84	Participant 93	Participant 96	Participant 113

Figure 17: Original coloured versions of all stimuli presenting 20 men who participated in the previous experiment (Chapter **4**)

Original blue coloured T-shirt while being photographed:		Modified red version:	
Original red coloured T-shirt while being photographed:		Modified blue version:	

Figure 18: Original (left) and modified (right) coloured versions of participants 4 and 41

5.3.2 Procedure

The study was run online on a web base of the University of Stirling (https://jfe.qualtrics.com/form/SV_cHG5WFRpQQSofhr). The test was set up in a way that photographs were presented randomly but no one target was followed by the same target. For example, if one target was presented in its original blue T-shirt, survey participants could not see the same target immediately after wearing a red shirt as there was a minimum gap of one photograph.

Once the participant clicked on the link that led to the webpage, an instruction sheet *(*Appendix IV*)* appeared. Next, the first photograph appeared (see Figure 19 for an example). Each survey participant saw the head and upper torso of 20 male targets wearing either red or blue (total = 40 images). The image was centred in the middle of the monitor with the three questions being presented below the photograph. Survey participants were asked to provide ratings of all three characteristics on a 7-point scale. Depending on each participant's computer screen, questions became visible by scrolling down. A total of three questions were presented:

Question 1 - How dominant do you think this person is?
Answers ranged from "not at all dominant" to "extremely dominant".

Question 2 - Compared to the average man, do you think this person's height is ... ?
Answers ranged from "considerably below average" to "considerably above average".

Question 3 - Compared to the average man, do you think this person's hand grip strength is...?
Answers ranged from "considerably below average" to "considerably above average".

Participants could not move on to the next stimuli unless all three questions had been answered. Following the ratings of all 40 images, participants were presented with the dominance questionnaire used in previous experiments (see Chapter 4, 4.3.2) and entered their demographic data (sex, age, height, weight, visual defects, nationality, and ethnicity). Participants were then asked to express their ideas regarding the purpose of the study. Finally, they were thanked, debriefed and given the chance to enter the prize draw. Participants' responses were automatically and anonymously stored in a separate spreadsheet saved under the participant’s subject number.

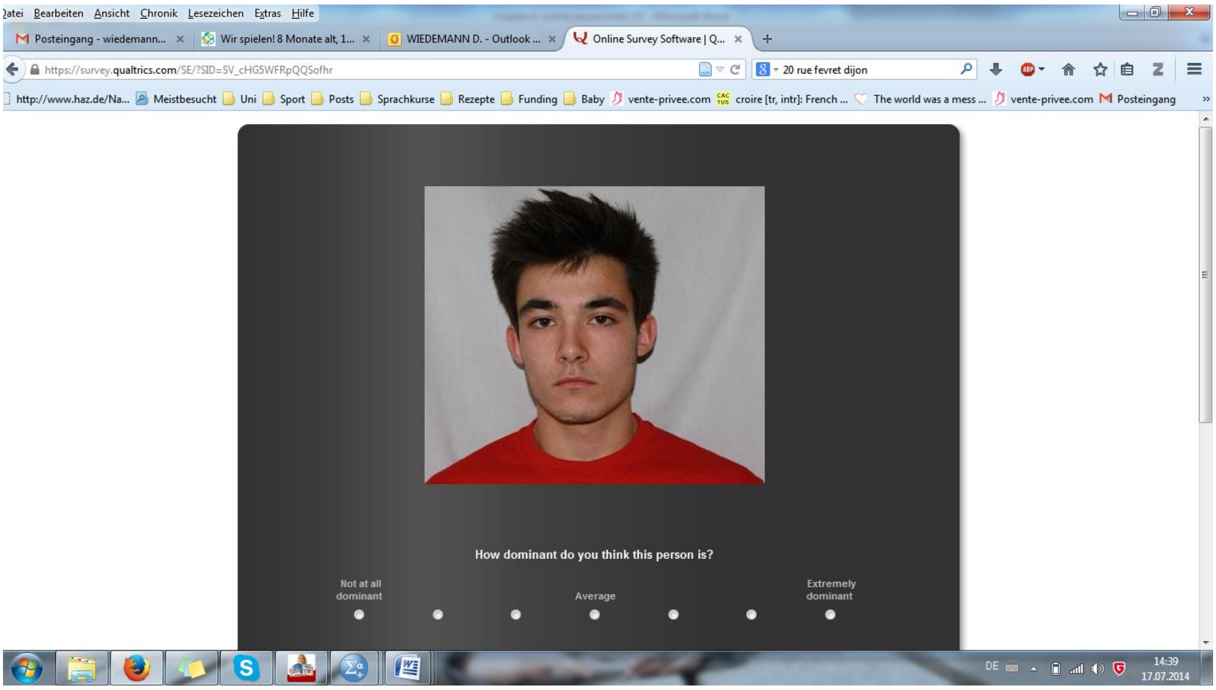


Figure 19: Presentation of the online study in a Firefox web browser

5.3.3 Participants

Participants were recruited worldwide on Facebook® (see Appendix IV), via email and on student databases in the United Kingdom. All materials were presented online and were accessed by the participants via the web browser of their home or university computers or wherever they habitually connect to the internet. 282 participants started to take the online survey in which they had the chance of winning £30. Participants who did not fully complete the test (22.7%), those who correctly guessed the purpose of the study or those who reported a colour vision deficiency were excluded. One participant was excluded as he rated all images the same. This left 210 participants for statistical analysis (140 females, 69 males, 1 of unknown sex; mean age = 29.27 years, SD = 10.9 years). Ethical approval was granted from the Department of Anthropology Research Ethics sub-committee at Durham University. Those participants who wished to be included in the prize-draw at the end of the study were able to leave their email address. In that case, they were informed that their identity was no longer anonymous in the case where email addresses revealed their actual names.

5.3.4 Statistical analysis

Linear mixed models were used to analyse the data in IBM SPSS version 20. Three different models for each dependent variable (ratings of dominance, height, and strength) were run. As fixed factors we included sex, original colour (red or blue), perceived colour (blue or red). As random factors, we included target's actual dominance score (respectively height in cm and handgrip strength in kg for the other two models) and picture ID (target).

Picture ID was included because observations within a target cannot be assumed to be independent. Including the identity of the participant as a random factor did not change our results (results are not reported). For the model investigating the ratings on height (dominance), we also included participants' height (dominance score) as a covariate.

For the multiple-item questionnaire assessing participant's psychological dominance, a reliability analysis was conducted to measure the internal consistency of the questionnaire (Cortina 1993, Field 2009). The analysis yielded a Cronbach's alpha of $\alpha = .706$. It was not necessary to delete items in order to increase the internal consistency. Participants scored a value between 19 and 53 (highest possible score was 60) on the dominance questionnaire.

5.4 Results

Mean scores for each of the three characteristics in all possible colour presentations are displayed in Table 12. Neither original colour worn (*ps* ≥ .805), nor perceived colour (*ps* ≥ .593) influenced ratings of perceived dominance, height, and handgrip strength. We cannot detect a wearer effect (H1) of red colouration on targets, nor a perceiver effect (H2) of red colouration on participants in the online experiment. We can also exclude that wearer- and perceiver effects acted in a joint fashion as there is no interaction effect between the two (*ps* ≥ .394).

		Dominance	**Height**	**Strength**
Original colour photographed in	blue	3.91	4.48	4.23
	red	3.90	4.40	4.28
Perceived colour	blue	3.91	4.44	4.25
	red	3.90	4.45	4.25

Table 12: Mean scores for dominance, height and strength ratings

No main effect for colour was detected (see results Table 13). That means, that ratings of dominance (height/strength) did not differ between colour treatment groups.

It was only found that female participants rated targets significantly taller than male participants did ($p = .011$) but this effect was not moderated by original colour worn ($p = .588$), nor by perceived colour ($p = .641$).

Ratings of:	Dominance		Height		HG Strength	
	F	*Sig.*	*F*	*Sig.*	*F*	*Sig.*
Sex	.063	.802	6.404	**.011**	.395	.530
Original colour (OC)	<.001	.991	<.001	.987	.061	.805
Perceived Colour (PC)	.007	.935	.285	.593	.047	.829
OR x PC	.727	.394	.160	.690	.258	.611
Sex x OC	2.902	.089	.293	.588	.195	.658
Sex x PC	.316	.574	.217	.641	.993	.319

Table 13: Statistical results from the three separate linear mixed models

5.5 Discussion

This chapter attempted to investigate the robustness of the "red-effect" elucidated elsewhere in this thesis (Chapters 1-3) whilst merging from standardised lab studies into less controlled web-delivered surveys. It was of special interest to test whether or not physical attributes such as a target's height or strength measured in a previous experiment (Chapter 4) could be transmitted via an image and how colour manipulations may bias these perceptions. The methodological design further allowed us to distinguish between possible wearer- and perceiver effects.

Regardless of the colour targets were photographed in, participants' ratings of perceived dominance, height, and strength did not differ significantly between targets originally wearing red or blue, and also not between targets depicted in manipulated versions of red and blue. We were not able to reproduce Roberts *et al*.'s (2010) proposed "red-wearer effect" outside of the romantic context. Targets photographed in red, regardless of whether they appeared to be wearing blue or red, did not receive higher ratings than those originally photographed in blue as colour had no significant influence on any of the ratings. We furthermore found no support for a "red perceiver effect", which would have meant that targets displayed in red, regardless of whether they were originally photographed in blue or red, had received higher ratings than targets appeared to be wearing blue. Again, perceived colour did not influence participants' ratings of any of the three variables. However, it is likely that the "red-effect" might have been detected in a more competitive framing, as for example Ten Velden *et al.* (2012) and Feltman and Elliot (2010) demonstrated. For now, we were not able reproduce these effects in a context-free environment, although our approach to conduct this research online might have had tremendous effects as well.

5.5.1 Disadvantages of the web-delivered approach

This chapter was designed to take previously reported positive results of a "red-effect" from traditional laboratory-based research to internet-mediated studies. As compared to highly controlled laboratory settings, web-delivered research often offers various advantages, including reductions in research expenses and time, improved sample heterogeneity, greater ease of gathering time-intensive date, environmental benefits, automisation of data entry and basic analyses, reduced barriers to research access for participants, and increased ease of participant recruitment (Birnbaum 2001, Murray and Fisher 2002, Nosek and Banaju 2002, Fraley 2003, Hanggi 2004, Ferna'ndez *et al.* 2004, Skitka and Sargis 2006, Hoerger *et al.* 2009). These advantages, however, are accompanied by a set of methodological, ethical, and technical risks (Kraut *et al.* 2004). Elliot and Maier's (2014) main argument against conducting colour research on web platforms (such as Mechanical Turk) is that colour presentation is device dependent and therefore colour matching impossible. It is true that, in a web-based approach, it is impossible to control colour cues as strictly as in a laboratory. Participants of this study accessed the study material at home on their private computers or wherever they habitually connect to the internet. Some participants may have used tablets to access the study. This brings us to a main limitation of this study. As different monitor types with different settings transfer same colour settings differently, the exact saturation or hue of the displayed colour blue or red may have varied slightly from one participant to the other. Furthermore, it cannot be ruled out that some internet users worked with a distorted colour display due the malfunctioning computer settings whereas others maybe sat on perfectly colour calibrated monitors. Colour perception is not only a function of hue, chroma, and lightness, but also of factors such as general environmental surroundings, presence of other colours in the immediate background, viewing angle and distance, and the type and amount of ambient light (Hunt and Pointer 2011, Brainard and Radonji'c 2014, Fairchild 2015). This is, however, in the present study less important as reds would have been still red to all and blues, blue. Nonetheless, the size of the monitor or the size of a smart phone image for example could have caused problems as individual differences in expression for example would have been rendered redundant and perhaps undermined size assessments. However, if effects are detected with proper methodological designs, and despite the aforementioned technical variance and despite of all kinds of real-world variance, then the argument for the effect and its generalizability is stronger, because of the additional variance in web-based approaches.

Another issue of web-delivered research is participants' honesty. The data of 210 participants were included in the here presented research. We detected one participant who clearly clicked through all the trials in using only "4's" But "clicking through" could be a general problem for web-based approaches as it is difficult to assess participants' motivation. In addition, web-based studies lack personal interaction which also might be a potential source of fraud. Nevertheless, it is hard to imagine what motivation participants could have in fooling the experimenter (Honing and Reips 2008, Honing and Ladinig 2008). However, where possible, steps against repeat responders should be taken (Gosling *et al.* 2004) in order to avoid that participants simply click through the study material several times in order to optimize their chances of winning in the prize draw.

For the present study, we discuss two major weaknesses of web-delivered studies: dropout rate and cultural differences. First, participant dropout is a complication of web-delivered studies as it has negative consequences on our understanding of participants' motivation for voluntary contribution and also generalizability. That is, as the number of participants dropping out increases, the sample completing the full survey potentially becomes less representative of the entire recruited population, which then leads to a decreasing generalizability of the results. In particular, a dropout rate of 10% is expected, with another 2% of participants dropping out discontinuously per 100 survey items administered (Hoerger 2010). The here presented survey involved about 150 survey items but has a higher than average dropout rate (22.7%). We can only assume that there might have been technical problems or that boredom led most of the participants to drop out early. However, there are ways and means to improve voluntary participation. Hoerger (2010) suggested to break-up surveys into two parts. Part one involving the gathering of demographic data and consent, and part two involving the completion of the survey. This would allow disinterested individuals greater opportunity to discontinue voluntarily. Second, dissimilar usage of measurements units (e.g., cm versus feet, kg versus lbs) due to online participants' different nationalities represents a disadvantage of this survey. In particular, it would have been ideal to compare targets' actual data of dominance-, height- and strength measures to absolute values estimated by the survey participants. However, measurement units for height and weight for example differ between countries. This made it difficult to formulate the survey questions (see section 5.3.2) in a way that they would be applicable for every single participant, regardless of his or her origin. For that reason, it was decided to standardize the data entry by presenting a 7-point Likert scale as response option to all of the three questions. However, this had the disadvantage of loosing valuable information in that absolute values could not be compared to each other and correlations were not a possible mean of statistical analysis. This brings us to the topic of accuracy, which is the ability to accurately estimate physical formidability (resource-holding potential or fighting ability) in other members of the group (Parker 1974, Sell *et al.* 2009). The human neurocognitive acrchitecture has indeed been proven to include mechanisms that are well engeneered to detect formidability in others. For example, similar to our study, Sell *et al.* (2009) used weight lifting machines or hand dynamometers to measure upper-body strength and found that participants successfully assess men's strength from static visual images (presenting either the upper body or the face). They further contested that upper-body strength was a better predictor of target's perceived strength than body weight, whereas Holzleitner and Perret (2016) concluded that size may be a more effective cue to strength. The average accuracy with which individual participants rate targets is very important to the outcome of these studies and could thus be valuable for our research domain as well. We notice that the statistical analysis with a hierarchical linear model (HLM) as used by Sell *et al.* 2009 provides better information about rater's accuracy than the linear mixed models we used. Future research on this area would do well in adopting Sell *et al*.'s approach in order to be able test participants' accuracy or simply the attention with which they were doing the task.

The decision to carry out an experiment in the laboratory or via the web often is a trade-off between the ability to generalize widely if an effect is detected and the wish to accurately control a high number of factors. Overall, both laboratory based and internet based research bring up issues of methods and designs that need careful attention. While some of these issues were shown to be similar in both research approaches, the advantages of ecological validity and a potentially large number of participants, makes web-delivered experimenting a full-grown alternative (Honing 2008) and existing research points at the validity and reliability of internet-based data (i.e., Dandurand *et al.* 2008, Musch and Klauer 2002, Preckel and Thiemann 2003). However, future investigations especially in colour research, may profit from a combination of experiments conducted in the laboratory and online. We therefore consider this experiment as an addition to those presented in the other chapters of this work and also as test as to whether online experiments could be a useful tool for our research domain.

Chapter 6

6 Participants explicitly associate the colour red with aggressiveness and dominance

6.1 Abstract

Naturally occurring red colouration correlates with male dominance and testosterone in a variety of animal species, and even artificial red stimuli can influence dominance interactions. In humans, wearing red increases the probability of winning sporting contests and red-wearers are more often categorized as "angry" and are perceived as more dominant and more aggressive than targets wearing blue or grey. We investigated whether these associations still hold true when participants are given a free choice of colours across the whole colour spectrum. It is further examined if and how clustered choices are around a particular red value and whether other character traits show any such clustering as well. Hereby, we extend previous research in related fields that restricted participants to a forced choice between only 2-5 pre-selected colours. Fifteen photographs with male targets were used for this study. One hundred women and men (average age 25.35) selected a T-shirt colour amongst 100 colour hues in order to develop targets' dominance and aggression, but also generosity, punctuality, nervousness and ignorance. Because the nature of the data is circular, directional (circular) statistics were employed for data analyses in order to complement linear statistics. Results show that participants predominantly chose red shirts to make a person appear more aggressive and more dominant, with subjects' modal frequencies being narrowly concentrated around the mean representing the colour red. None of the other traits were associated with red or showed such a high density of frequencies around the mean. Men applied the colour red significantly more often than women did, and did so significantly faster for the trait 'dominant'. These findings strongly support and greatly extend previous findings on the signalling function of red for aggression and dominance. This suggests that the colour red may be a cue used to predict propensity for aggression and dominance in human males.

6.2 Introduction

All three components of colour (hue, chroma, and lightness) influence emotional responses (Suk and Irtel 2008). Yellow and red are considered to be stimulating and to produce forceful action, whereas blue and green are considered to be relaxing and to produce stable and calm action (Goldstein 1942). Goldstein's vaguely formulated ideas were the basis for subsequent research that built on his ideas through the lens of arousal and wavelength. Specifically, shorter wavelength colours such as blue and green are thought to be experienced as cool or calming, whereas longer wavelength colours such as orange and red are thought to be experienced as warm or arousing (Nakashian 1964, Valdez and Mehrabian 1994). The latter colour has recently evoked a lot of interest in the colour reserach domain and a growing body of literature demonstrates that wearing red may lead people to either behave differently (Guéguen and Jacob 2012, 2013a, 2013b, Niesta *et al.* 2010) or to be perceived differently (Wiedemann *et al.* 2015). For example, women viewed within a red picture border or women wearing red were rated as sexually more desirable as when presented in a different clothing colour or when presented in a picture framed in white or grey (Elliot and Niesta 2008). Male job applicants wearing a red tie were rated less likely to be hired and participants viewed a red-wearing person presented in a photograph to be less intelligent than when presented in green (Maier *et al.* 2012). It seems that clothing colour and first impression making are related and a person is more likely to be perceived as aggressive, dominant and angry when wearing red (Wiedemann *et al.* 2015). What these examples have in common, is that participants were presented with different images showing the same target being displayed in two (e.g., Niesta *et al.* 2010), three (Wiedemann *et al.* 2015) or six (Roberts *et al.* 2010) different colour hues. The colour spectrum, however, consists of far more colours (e.g., Newton 1666 in Whiteside 1967) and humans can perceive approximately 10 million different colours (Judd and Wyszecki 1975), creating scope for a much larger range of colour associations than what has been previously investigated. The study here aims to efficiently exploit all possible primary, secondary and tertiary colour hues and is to our knowledge the first to assess the link between social perceptions and clothing colour using a more fine-grained set of colours to choose from. It allows participants to be more active but also more free to choose differently for each trial instead of simply rating targets for certain character traits when these are presented in only 2-5 different colours. Following from findings of studies exploring the link between red and aggression and dominance in nonhuman primates (e.g., Milinski and Bakker 1990, Setchell and Dixson 2001, Khan *et al.* 2011), birds (Cuthill *et al.* 1997), and humans (e.g., Hill and Barton 2005, Stephen *et al.* 2012a, Wiedemann *et al.* (2015), we aim to test the robustness of these associations amongst humans. Given a free choice of colours across the whole spectrum, do participants associate the colour red with 'aggressiveness' and 'dominance' (Wiedemann *et al.* 2015). If so how clustered are choices around a particular red value? Do other character traits show any such clustering as well? Whether or not participants show a preference for a particular red value representing aggression or dominance could at least open up the possibility that there is an "optimal red" (Wiedemann *et al.* 2015) related to biological signalling of these traits. On the basis of the aforementioned literature, we predict that responses to dominance and aggression will be more probable in the red part of the colour wheel and frequencies will be very much clustered in that part. Other character traits used as control will not show such a strong and particular association to any colour and will therefore show greater variance with frequency choices being much more dispersed around the colour wheel. We therefore expect that participants pick T-shirts of the red hue range in order to make a person appear as aggressive or as dominant as possible. Furthermore, men are more distracted when "seeing red" than women are (Ioan *et al.* 2007) and relative colour associations differ with sex of the judge (Little and Hill 2007). Also, Wiedemann *et al.* (2015) reported that men, but not women, were sensitive to red as a signal of dominance. Consequently, we expect that sex differences on participants' responses might occur.

6.2.1 A new methodological approach

Because associations between certain traits and colour cannot be restricted to only 2-5 hues, experiments need to expand to the full range of colour, which consequently demands for a new and innovative methodological approach than those previously known in the field. The study presented here therefore aimed to adopt a methodology that provides a more graduated and fine-grained test, originally inspired by facial morphing studies (e.g., Tiddeman and Perrett 2002). For example, Stephen *et al.* (2012a) used face-shaped masks that allowed for manipulations of facial colours in equal positive and negative steps from the original redness of a humans face, leading to the finding that facial redness was enhanced to maximise perceived aggression, dominance and attractiveness. In the current study, participants were given a more active role in their decision making as they were given the chance to actively tell *us* what colour *they* thought best represents for example 'dominance' instead of being forced to chose among a small amount of colours. Hereby, participants were given the chance to chose among 100 colours present in the colour spectrum in order to add to a certain character trait or variable by choosing the appropriate T-shirt colour of a presented target, allowing for a far more robust design. This is of special importance since that way we could exclude that aggressiveness and/or dominance are possibly associated with, for example, yellow or violet, colours that are generally not proposed to participants in such sort of experiments. It also allows to explore how strong the proposed association of red colouration with dominance and aggression (Wiedemann *et al.* 2015) is as we can directly test the distribution of colour choices around the entire colour wheel. If, for example, participants' choices are tightly clustered within the red range but no further peaks are visible within the other colour ranges, we can conclude that the association is quite strong. Being able to investigate the strength of this association is novel and requires a different statistical approach, namely circular statistics. As can be seen in Figure 20, colours are arranged around a circle and are presented in degrees ranging from 0° to 360° degrees. This new approach led to a data set that greatly differs from linear data and, thus, needs to be analysed with software programs that allow the analysis of circular data.

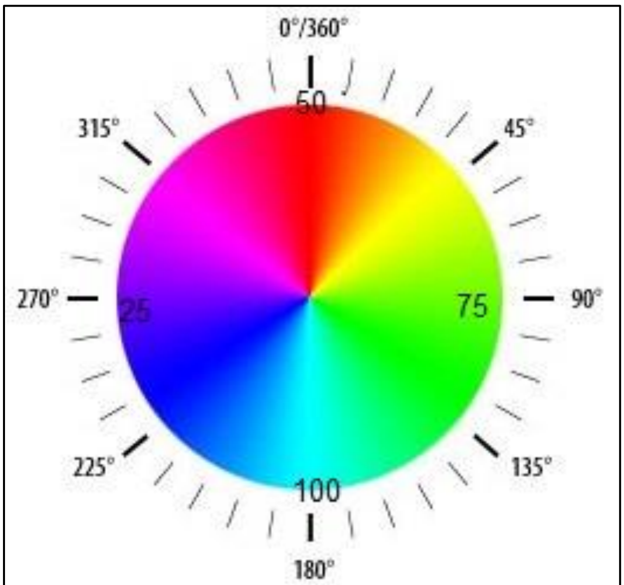


Figure 20: Colour wheel with angular dispersion. Numbers (25, 50, 75, 100) on the circle correspond to frame numbers (for example, frame 50 corresponds to 360°/0°, frame 51 corresponds to 3.6°, frame 52 corresponds to 7.2° and so on)

6.2.1.1 Circular (directional) statistics

For linear data, 0 is the origin and values to the right of 0 are positive and to the left are negative. A value of 360, for example, is relatively far from the origin. This is very different for angular data, where the angles 360° and 0° define the exact same point on the unit circle. Where for linear data a linear variable defines a specific point on the real line, for circular data, each degree or angle defines a specific point on the circumference of the unit circle (Pewsey *et al.* 2013) and there is no true zero and any designation of high or low values is arbitrary. Therefore, this type of data is referred to as being circular and diverse scientific fields work with it. Examples of circular (directional) data are various and include temporal periods (e.g., time of day/week/month/year), rotations, compass directions, wind directions or directions of flight of birds (e.g., Kubiak *et al.* 2007, Hassan *et al.* 2009, Blaser *et al.* 2013, Hart *et al.* 2013).

Directional data are substantially different from linear data and require specialized techniques and tools (Jammalamadaka and Sengupta 2001) since many of the usual linear statistical measures and techniques are often misleading, if not entirely meaningless. Directions are usually recorded as angles expressed in radians or degrees (Appendix V equation 1) measured with two senses of rotation (clockwise or counterclockwise) from some origin called zero direction (Mardia and Jupp 2000, Jammalamadaka and Sengupta 2001). It is therefore necessary to respect the periodicity of directional data and abandon standard technical techniques considered for linear data.

To illustrate why it would be misleading to treat circular data as linear data, suppose we asked five participants to indicate their favourite colour with a computer mouse click on Figure 20, and we would collect the five following angular responses: 2°, 4°, 180°, 350°, and 360°. Using linear statistics, the population mean (μ) of these five angles is 179.2 and the standard deviation (SD) is 176.4 (Appendix V equation 2 and 3 respectively). This would tell us that, on average, our participants preferred the colour green-blue. The (circular) mean vector (μ) in our example is 358.67° and a circular SD of 58.24° (Appendix V equation 4 and 5 respectively). That way, we learn that participants preferred, on average, the colour red. From this example it becomes clear that a circular statistics software program is needed in order to analyze the angular data present in this chapter. Only that way we can create diagrams that allow us to precisely look at the distribution of colour choices of all main colour hues in relation to certain character traits. This is not only important to strengthen the link between red colouring and aggression and dominance, it is also novel in the field.

6.2.2 Colour and reaction time

Moller and colleagues (2009) documented the presence of associations between hue and a specific meaning. Specifically, red is negatively associated with success and general positive words, and positively associated with failure and general negative words. More importantly, these associations were documented via reaction time. For example, participants were faster categorizing failure and negative words presented in red versus green or white. The authors state that these results add to the idea that red may serve as a signal warning the perceiver of imminent danger that consequently requires the mobilization of resources for action (Elliot *et al.* 2009). Elliot and Aarts (2011) obtained evidence that the presence of the colour red, as compared with grey and blue, enhances motor processes, such as the strength and time of a reaction. This is to be expected as the colour red plays an important role in the defense/avoidance system of vertebrates with trichromatic vision which elicits a rapid response to a possible threat. Previous studies indicated that red induces higher levels of arousal than does blue (Ali 1972, Jacobs and Hustmyer 1974) and the average reaction time to red is also faster than to blue (Pieron 1952, Elliot and Aarts 2011, Guéguen *et al.* 2012; although see Díaz-Román *et al.* 2015). In contrast, blue (rather than yellow or red) induces feelings of relaxation and so reduces perceived waiting times (Gorn *et al.* (2004). When participants were asked to estimate the time duration of the presentation of a red versus a blue screen, reaction times of the red screen were faster for both men and women but only male participants overestimated its duration (Shibasaki and Masatakai 2014). As a result of the fact that time is distorted for men and that men also seem to be more easily distracted by red than women are (Ioan *et al.* 2007), we hypothesize a relation between reaction time, the colour red and sex. In accordance with studies showing that the effect of red is sex dependant (Barton and Hill 2005, Ioan *et al.* 2007, Gnambs *et al.* 2010) male and female participants are expected to react at different speeds when choosing red T-shirts, specifically when the traits aggression and dominance evaluated.

6.2.3 Predictions

Prediction 1: Participants will explicitly associate 'aggressive' and 'dominant' with the colour red. We have no specific prediction whether or not any of the other traits will be associated with a particular colour, though we do not expect it to be red.

Prediction 2: The dispersion of the responses for 'aggressive' and 'dominant' will be less than for the control variables. In other words, participants' choice will be much more dense around the mean vector for the traits 'aggression' and 'dominance', whereas the frequency distributions for the other four traits will be much more spread out.

Prediction 3: Given that men are more sensitive to red signaling dominance than women are (Chapter 2), red should be chosen more often by males than females and this effect should be strongest for aggression and dominance.

Prediction 4: Men will choose red T-shirts more rapidly than women do.

Prediction 5: For the traits 'aggressive' and 'dominant', men will chose red T-shirts more rapidly than women do.

6.3 Methods

6.3.1 Stimuli

Fifteen stimuli were chosen as basis of this study. All targets were photographed by the investigator as part of a previous experiment (Chapter 4), and some were used in the Online Experiment of the previous chapter (Chapter 5 - Online Experiment). Detailed methodological explanations of the creation of the stimuli can be found in Chapter 5, section 5.3.

6.3.1.1 Stimuli manipulation

In previous experimental settings, the area of colour displayed differed slightly as targets differ in shoulder width and body height. In the current study, a T-shirt mask was applied to every face/neck to ensure that the amount of colour in display is the exact same across targets and across colours. We used Java psychomorph (Version 6), a software for manipulating images of faces in a variety of experiments (e.g., Tiddeman and Perrett 2001, Chen and Tiddeman 2010), to "align" images with faces in the same orientation and eyes at the same level. The cropped versions of the original images (Chapter 5, section 0) were modified with a face-shaped prototype mask for male facial features (available on the psychomorph webstart launch page: http://users.aber.ac.uk/bpt/jpsychomorph/) was applied to each stimulus individually to align all of the images. The image manipulation starts by positioning a number of points marking the positions of specific such as the mouth, nose, eyes, or the outline of the hair in a portrait photograph features ("delineation", unpublished manual of psychomorph). These feature points (fiducial points, see below Figure 21, left hand side image) can then be used to define the shape of the image. Once all images had been delineated, an average image of all the stimuli was created (Figure 22). Using this average image as a basis, all 15 images were then "aligned".

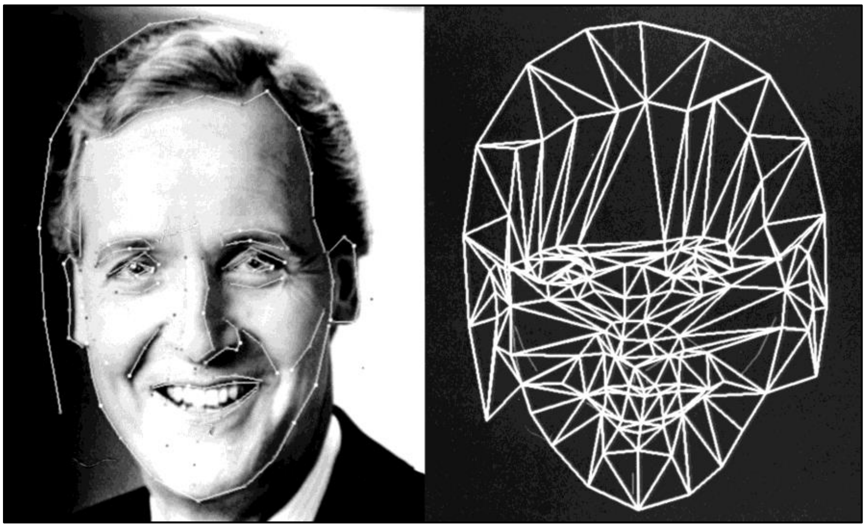


Figure 21: An example image with the fiducial points marked out (left hand side) and a diagram of the tessellations between the fiducial points (right hand side).

(a) (b)

Figure 22: (a) Average male image created out of 15 stimuli presented in figure 24 and (b) prototype T-shirt mask

Following that, a T-shirt prototype mask was created in Adobe Photoshop® version CS6 (Figure 22 (b)). All faces (including hair parts and neck) from the aligned images were cut out and put on the T-shirt prototype mask. That way it was ensured that the area of colour display (the T-shirt) was equally distributed across stimuli, the background was plain white and images were all of the same size (800 x 673 pixels). A full set of all targets used here in this study can be found in Figure 23.

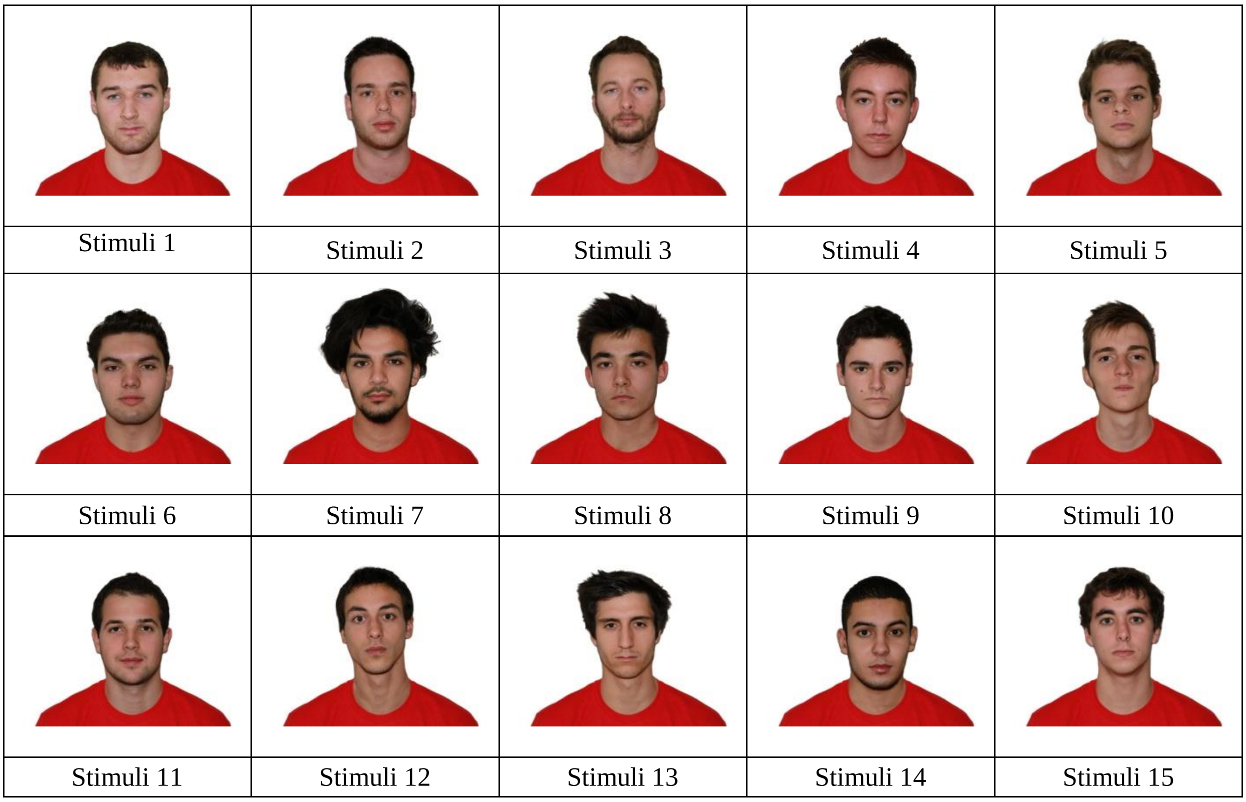


Figure 23: Red coloured versions (frame 50) of all stimuli presenting 15 men who participated in a previous experiment (Handgrip Experiment, Chapter 4; see Appendix V for a full set of 100 images)

6.3.1.2 Stimuli colour manipulation

The software ImageMagick® (http://www.imagemagick.org/index.php) was used to create 100 different colour versions for each target's T-shirt. 100 images is sufficient to provide the participant with an effectively seamless gradation between colour-morphs, giving the impression of continuous variation. Luminance and saturation were held constant, only hue was altered. Each stimulus with the prototype T-shirt mask (Figure 22b) was used as a colour basis to produce 100 differently coloured images. Command lines were set up by Dr. Mike Burt. The program works with three arguments: '(100, 100, 100)', each '100' representing luminance, saturation and hue: '100' (for all three arguments) produces no change, thus presenting the colour of the prototype T-shirt mask. ImageMagick® rotates the colours of the image, in a cyclic manner. To achieve this the hue value given produces a "modulus addition", rather than a multiplication. A value less than 100 rotates hue in an anticlockwise direction and a value of more than 100 rotates it in a clockwise direction. Hue is circular but ImageMagick® operates with 200 gradation units. 360° degrees on ImageMagick® unit is 360/200 of a degree, which makes 1.8° degrees, leading to 3.6° degree change in hue between successive images. This was repeated for each of the 15 stimuli, resulting in 1500 (15 x 100) different colour images in total. The full sets of stimuli can be viewed in Appendix V. Figure 24 displays the colour change in ten steps for ten dimensions of the circle (each diversion covers a range of 36° degrees on a colour wheel). Images were presented on a computer screen via ImageMagick® (Figure 25, see section 6.3.4).

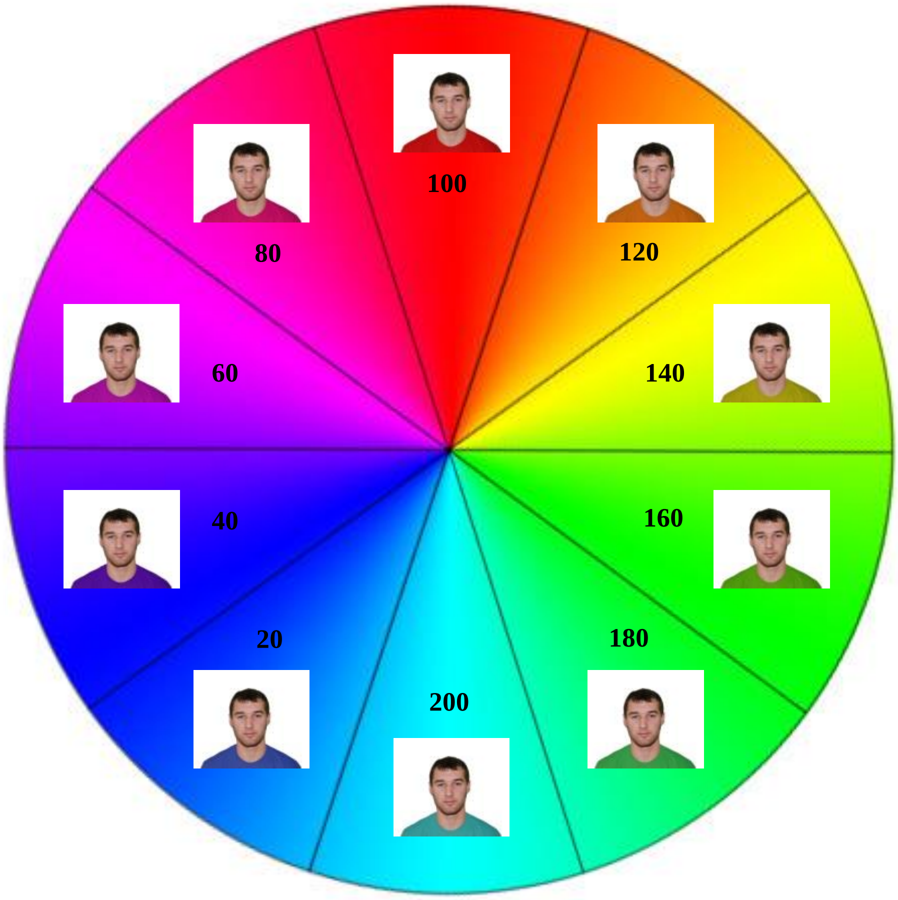


Figure 24: A colour wheel divided up in ten dimensions each covering a range of 36° degrees, the ten stimuli presented for each dimension represent the exact middle of each dimension. The basis was red (100, 100, 100), adding 100 hue units leads to the cyan coloured image (100, 100, 200) which is the same as (100, 100, 0)

6.3.2 Control variables

We compared participants' choices for the two traits 'aggressive' and 'dominance' to four control adjectives not related to aggression and dominance. They are, thus, not expected to be mirrored in participants' choice of red T-shirts. The traits are all, similar to 'aggressive' and 'dominant', active adjectives representing either positive or negative traits. The four selected adjectives are: generous, punctual, nervous and ignorant.

6.3.3 Participants

One hundred students or staff members of the University of Dijon, France [50 male, 50 female; mean age 25.35, SD = 8.46, range from 18 to 59 years], were approached in or around the library and asked to participate in an experiment on visual perception. Participation was voluntary but a variety of non-monetary rewards were offered. None of the one hundred participants reported a colour vision deficiency and none of them failed the colour vision test carried out at the end of the demographic assessment. Ethical approval was given by the Durham Anthropology Department's Research Ethics sub-committee.

6.3.4 Design and procedure

After recruitment, participants were lead into a separate room where they were seated in front of a computer screen connected to a laptop (ACER® Aspire V3-571G). Participants first read the instruction sheet of the experiment, signed the informed consent sheet, filled in a brief demographics questionnaire (Appendix V) and were then tested for colour blindness using a simple colour-test (http://www.augenarztonline.eu/index-Dateien/PatienteninformationenFarbe.htm, see Appendix III) in which participants were asked to write down the numbers displayed in three images.

Participants were then directed to concentrate on the computer screen where they read the final instructions of the experiment. The computer monitor was calibrated with the DATACOLOR Spyder 4 Pro software and stimuli presentation was under standard lighting conditions in a windowless room with neon strip-light illumination.

Each participant saw in random order the stimuli displayed in Appendix V with one of the following questions presented, again in random order (see Figure 25):

- Make this person as AGGRESSIVE as possible.
- Make this person as DOMINANT as possible.
- Make this person as GENEROUS as possible.
- Make this person as PUNCTUAL as possible.
- Make this person as NERVOUS as possible.
- Make this person as IGNORANT as possible.

To ensure that the French versions of the items correctly represented the English versions, all items were translated into French and then "back-translated" by a native English speaker who had been living in France for over 20 years.

Participants were instructed that moving the mouse led to the alteration of the T-shirt colour. Once a participant had chosen a colour it was saved by clicking the computer mouse. Each answer was saved in a separate spreadsheet in Excel. The frame number chosen (one out of 100), the name of the stimulus (target), the order in which stimuli were presented and the reaction time needed for each choice, was automatically recorded. Every time participants moved on to the next trial, the starting point (from where on the mouse was moved) and the first colour in display was randomly chosen by the program so that the starting point varied with each trial. Once all 90 questions had been answered (6 questions for all 15 stimuli), the experiment on the computer screen stopped automatically and participants were informed that that part of the study had terminated.

Participants then received a final questionnaire asking the purpose of the study[13]. This was done in order to eliminate data of participants who knew anything specific about hypothesis or who explicitly mentioned red in relation to aggression/dominance as part of our predictions. No participant correctly guessed the purpose of the study. Finally, participants were debriefed, thanked and released. From arrival until exiting the study room, the experiment took on average 19.44 (SD = 6.5) minutes.

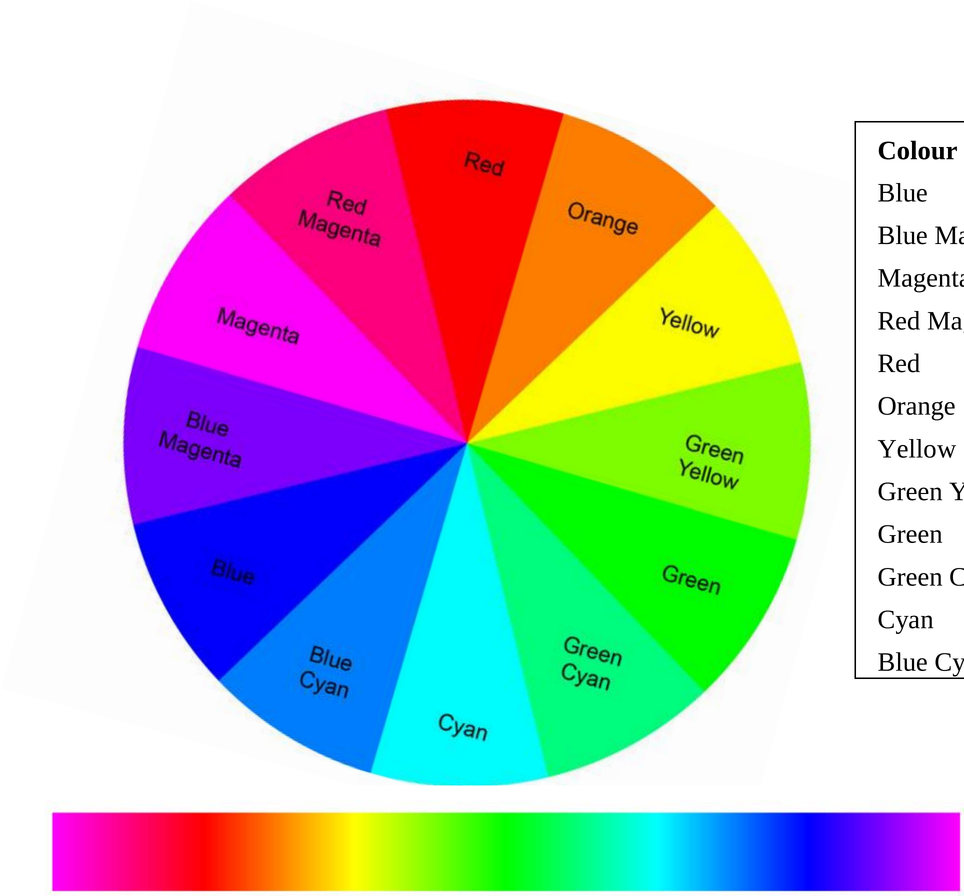
Figure 25: Screenshot of the original experimental setting, note that the present question is the French translation of "Make this person as generous as possible."

6.3.5 Statistical analysis

6.3.5.1 Classification of categories

Colour frames (1-100) were classified in 12 colour categories; three primary colours (blue, red, green), three secondary colours (magenta, yellow, cyan) and six intermediate (tertiary) colours (orange, green yellow, green cyan, blue cyan, blue magenta, red magenta) (Figure 26) (e.g., Newton 1666 in Whiteside 1967).

[13] We also asked participants another open question about their believed colour-associations but did not include this part in the chapter here. Analysis, results and discussion of it can be found in the Appendix V.



Colour	Segment
Blue	225°–255°
Blue Magenta	255°–285°
Magenta	285°–315°
Red Magenta	315°–345°
Red	345°–15°
Orange	15°–45°
Yellow	45°–75°
Green Yellow	75°–105°
Green	105°–135°
Green Cyan	135°–165°
Cyan	165°–195°
Blue Cyan	195°–225°

Figure 26: Twelve colour categories in a RGB colour wheel

6.3.5.2 Statistical analysis of predictions 1 and 2

The data were analyzed in the circular statistics software program *Oriana Version 4* (Kovach Computing Services 2011) and the circular package in *R 3.1.3*. For circular statistics, the mean of a set of angles is a vector. The length of the mean vector is called the resultant vector length (*R*) which is an indication of the spread of the sample vectors. The closer the resultant vector is to 1, the more clustered the data set is around the mean direction. The concentration is a parameter specific to the von Mises distribution (*k*), the circular equivalent to a normal distribution, and measures the departure of the distribution from a uniform distribution (or a perfect circle). It is related to the length of the mean vector (Kovach 2011). For comparisons with non-parametric circular data, Chi-square and Mardia-Watson-Wheeler tests were applied. The latter is also referred to as Uniform Scores Test (Fisher 1993, Batschelet 1981, Zar 1999, Mardia and Jupp 2000) and is used to determine whether two or more distributions are identical. Basically, the samples or data are pooled together, then sorted by increasing angles which are then evenly distributed around the circle by calculating a circular rank (or uniform score). In the case where distributions are identical, new circular ranks for the samples should be evenly interspersed around the circle, and their resultant vector *R* length should be similar and short. Significant differences between the *R*s leads to a large *W* test statistic and the rejection of H_0 of identical distributions (Kovach 2011). However, there is a problem with interpreting these results as the test looks for any differences between distributions, which could be mean, dispersion, or bimodality/multimodality. Even with highly significant results, one cannot distinguish whether this is because of differing means or dispersion. For that reason, the Wallraff test (*H*) was applied which tests for circular homoscedasticity (e.g., Pewsey *et al.* 2013). The null hypothesis is that distances are equal across the six traits. The test proceeds by computing the angular distances from a reference angle, in each group. The angular distance between two angles is called the circular range. Following that, the distances are compared with a usual rank sum test (Kruskal-Wallis; prediction 1). When rejecting the null hypothesis of the Kruskal-Wallis test, then at least one sample stochastically dominates at least one other variable. The null hypothesis of the Kruskal-Wallis test is that the mean ranks of the groups are identical but this does *not* mean that the means are the same.

Rayleigh's Uniformity Test (Zar 1998, Mardia and Jupp 2000) calculates the probability of the null hypothesis that the data are distributed in a uniform manner. The *Z* value is calculated as $Z = nR^2$, where n is the number of observations and *R* is the length of the mean vector. A longer mean vector (and the resulting larger value of *Z*) means greater concentration of the data around the mean, and thus less likelihood of the data being uniformly distributed. A probability of $p < .05$ indicates that the data show evidence of a preferred direction and that they are not distributed uniformly (prediction 2).

Each participant provided 90 data points (15 stimuli x 6 traits), resulting in a total of 9000 data points for analysis. For the use of circular data, modal responses for each subject and trait were calculated to ensure independence of data, resulting in a sample size of 100 data points per trait.

6.3.5.3 Statistical analysis of predictions 3-5

Data were analyzed using IBM SPSS version 20. For each participant we calculated how often they chose red for each trait and then used the non-parametric Mann-Whitney test to test for differences between the frequencies of male and female participants (predictions 3). Univariate ANOVAs were used to control for possible confounds (order) in the investigation of prediction 4. Prediction 5 is tested with independent *t*-tests.

6.4 Results

6.4.1 Test results prediction 1

We predicted that participants explicitly associate 'aggressive' and 'dominant' with the colour red. Table 14 provides an overview on how often each colour was associated with any of the six traits and Figure 27 compares the percentage of participants selecting for red T-shirts compared to the 11 other T-shirt colour categories. Red was clearly selected most frequently during the entire experiment, but even more so for the traits 'aggressive' and 'dominant'.

	Aggressive	Dominant	Generous	Punctual	Nervous	Ignorant	Total
Blue	120	256	53	209	77	42	**757**
Blue Magenta	75	69	78	46	98	86	**452**
Magenta	43	36	108	36	92	184	**499**
Red-Magenta	128	120	98	49	118	80	**593**
Red	814	686	62	86	415	37	**2100**
Orange	120	89	100	80	121	120	**630**
Yellow	71	44	144	111	211	387	**968**
Green-Yellow	23	28	160	85	86	141	**523**
Green	34	36	235	113	93	79	**590**
Green-Cyan	20	20	110	100	46	87	**383**
Cyan	19	31	237	291	91	196	**865**
Blue Cyan	33	85	115	294	52	61	**640**
Total	**1500**	**1500**	**1500**	**1500**	**1500**	**1500**	**9000**

Table 14: Frequency distributions for *all* traits and colours classified as described in figure 26 (90 responses per participant)

Looking at Figure 27 and the frequency table (Table 14) reveals that 54.27% of choices for 'aggressive' and 45.73% for 'dominant' fall into the 'red'-segment. Results reported in Table 15 support prediction 1 as only the mean vectors of participants' modal responses for 'aggressive' and 'dominant' are located in the red segment (Figure 28). None of the control variables' mean vectors fall into the red category.

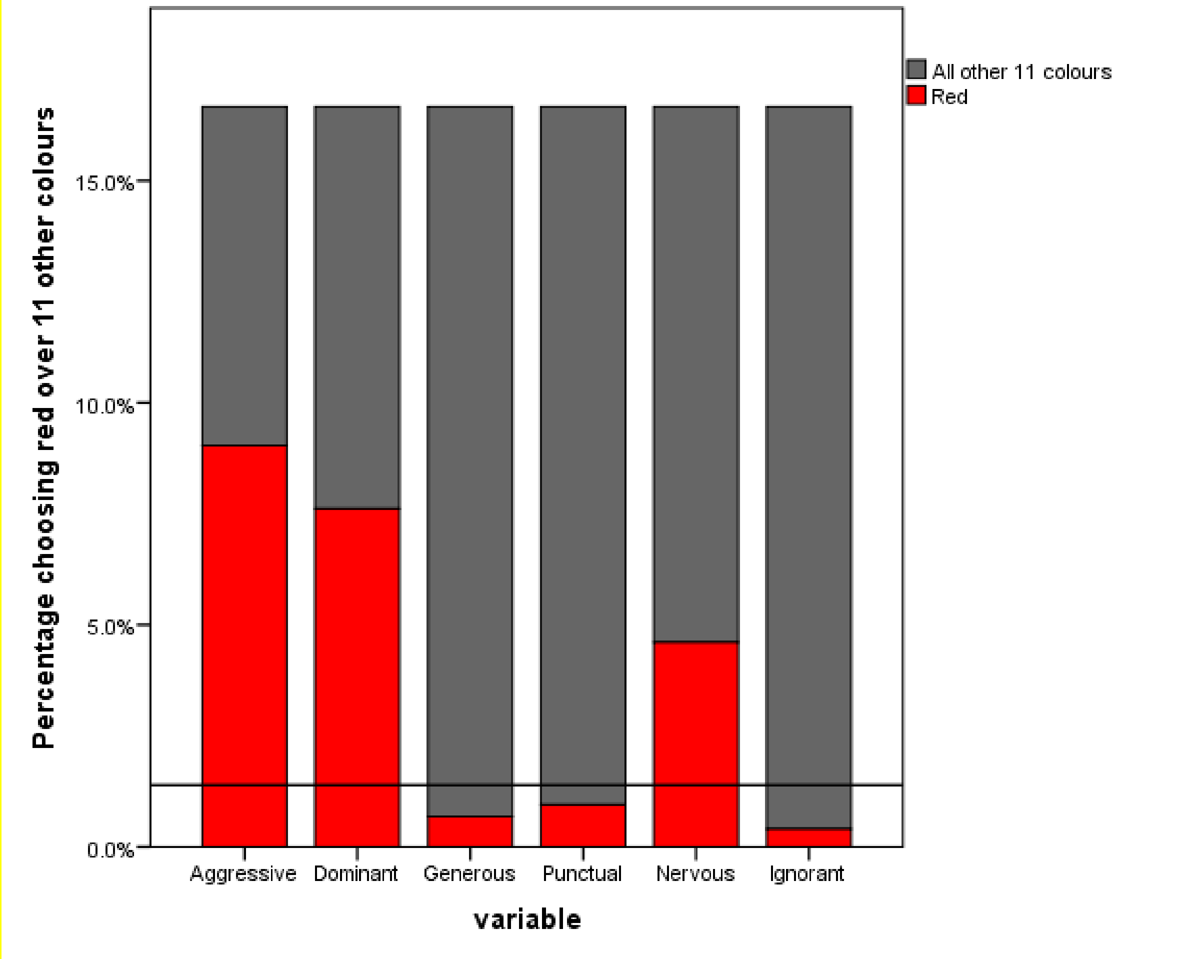


Figure 27: Percentage of participants (16.67% = all 100 participants) choosing red over 11 other T-shirt colours for the six different traits. Note that the reference line marks 1.39% which indicates the expected percentage of the colour red if all 12 colours were to be chosen equally often.

	Aggressive	Dominant	Generous	Punctual	Nervous	Ignorant
Mean vector	354.19°	343.0°	114.14°	157.13°	21.23°	61.01°
Colour category	Red	Red	Green	Green-Blue	Orange	Yellow
SD	4.64°	6.35°	12.08°	16.39°	7.42°	8.00°
Length (*R*)	0.72	0.58	0.33	0.25	0.51	0.48
Concentration (*k*)	2.14	1.42	0.69	0.51	1.18	1.09
Rayleigh test *Z*	51.36	33.08	10.63	5.93	25.74	22.59
Rayleigh test *p*	< .001	< .001	< .001	.003	< .001	< .001

Table 15: Overall results of tests applied in order to analyze the circular data for prediction 1 and 2

6.4.2 Test results prediction 2

Our prediction was that responses for 'aggressive' and 'dominant' are less dispersed than those for the control variables. Figure 29 demonstrates that the responses for the traits 'aggressive' and 'dominant' clearly peak in the red category. In comparison, frequencies for the traits 'generous', 'punctual', and 'nervous' are more equally dispersed around the mean with no obvious concentration of response frequencies. A peak within the yellow category is present for the trait 'ignorant'.

'Aggressive' attains the highest *Z*-value (Z = 51.) dominance the 2nd highest (Z = 33.08) which implies a greater concentration of the data around the mean, and thus less likelihood of the data being uniformly distributed. In comparison, *Z*-values for the control variables are between 5.93 (punctual) and 25.74 (nervous).

The Mardia-Watson-Wheeler test is highly significant (W = 134.03, p < .001), indicating that the distributions for the six traits are not identical. The same applies when distributions for male (W = 120.36, p < .001) and female participants (W = 134.03, p <.001) were analyzed separately.

The test result from the Wallraff test for the six traits is $H(5)$ = 17.43, p < .001. Thus, the test rejects the possibility of a common concentration, which means that values for all six traits are far from being equally distributed. The concentration parameter k is the second highest for the trait 'dominant' (k = 1.422). In sum, there is a chance less than 0.1% that the distributions of the six traits are the same. This is in support of prediction 2. Colour choices for the trait 'aggressive' are the most clustered as the resultant vector length is the closest to 1 amongst all traits, followed by 'dominant' (Table 18). The concentration parameter k is, for 'aggressive' the highest, indicating tight clustering of responses (Figure 28).

6.4.3 Test results prediction 3

We predicted sex differences and find that male and female participants differed in how often they appointed the colour red to the six different traits (Table 16, N_{women} = 961, N_{men} = 1139); Mann-Whitney U = 955.0, N_{women} = N_{men} = 50, p = .04). This supports prediction 3. However, looking at frequency-differences for each trait separately did not reveal any significant difference, neither for the predicted variables 'aggressive' and 'dominant', nor for any of the control variables (Mann-Whitney U's ≥ 1032.5, N_{women} = N_{men} = 50, *ps* ≥ .133). Thus, prediction 3 is not supported.

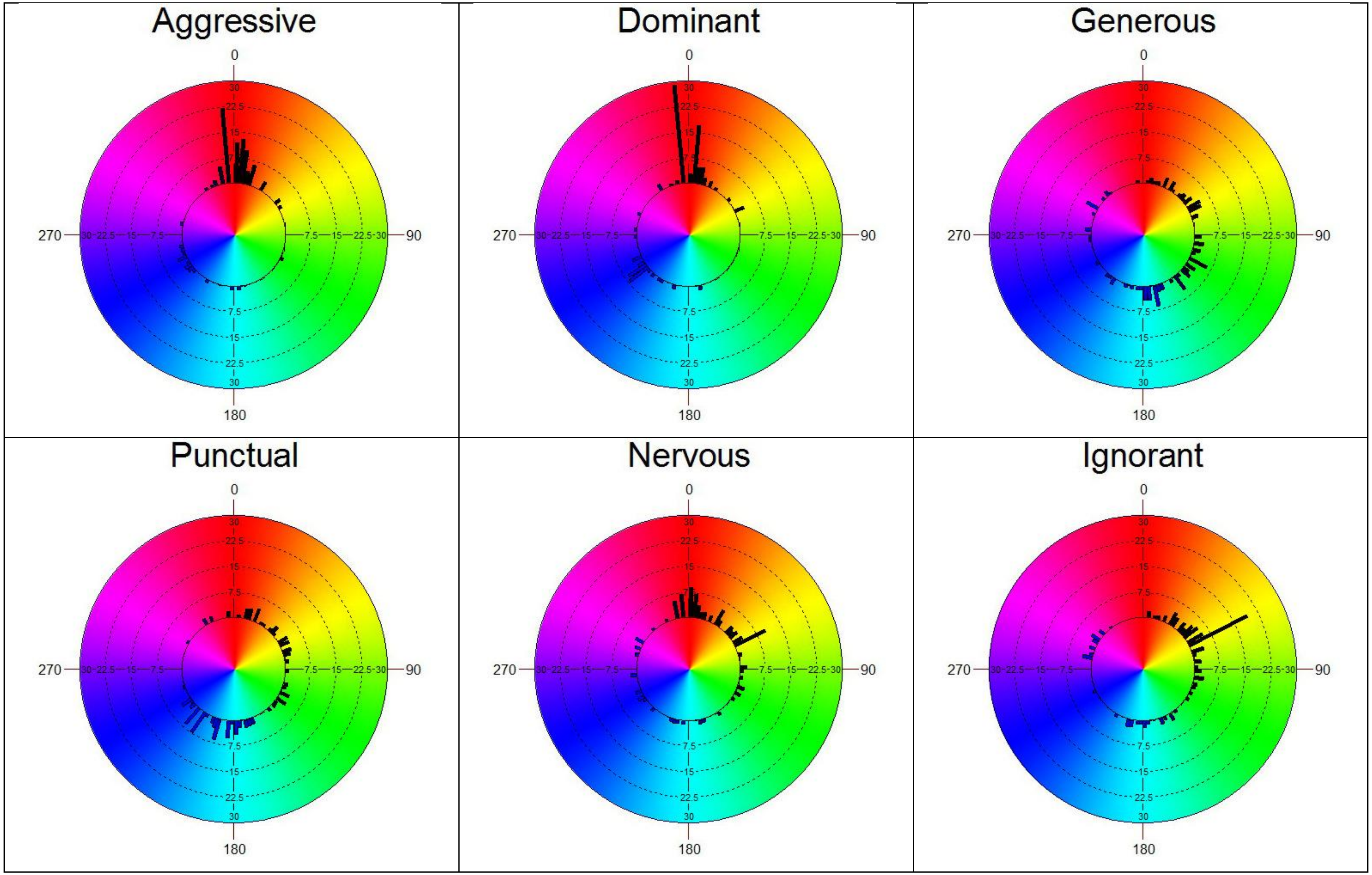


Figure 28: Rose diagrams depicting the modal responses of each participant (N = 100) for each trait, results for the questions "Make this person look as '...' as possible", each dotted grid line marks a frequency of 7.5 (frequency inner circle = 0, 3rd circle = 15, outer circle = 30)

	Aggressive		Dominant		Generous		Punctual		Nervous		Ignorant	
	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men
Red	373	**441**	322	**364**	**35**	27	27	**59**	185	**230**	**19**	18

Table 16: Frequencies of red colour distributions for men and women separately. Numbers in bold depict which colour has been chosen the most for each trait and sex.

Source	**Type III Sum of Squares**	**df**	**F**	**Sig.**
Order	25528.056	1	759.776	<.001
Colour	267.821	11	.725	.716
Sex	187.372	1	5.577	.018
Variable/Trait	318.670	5	1.897	.091
Colour X Sex	746.107	11	2.019	.023
Colours X Variable	3480.204	55	1.883	<.001
Sex X Variable	261.176	5	1.555	.169
Colour X Sex X Variable	3786.339	55	2.049	<.001
Error	297523.056	8855		
Total	821508.681	9000		
Corrected Total	335298.507	8999		

Table 17: Results of the between-subjects effect of an univariate ANOVA treating reaction time (in seconds) as dependant variable, colour (12 categories), sex (male or female) and trait (6) as a between-subjects factor

6.4.4 Test results predictions 5 and 6

We predicted that men will choose red T-shirts more rapidly than women do, specifically when the traits 'aggressive' and 'dominant' are assessed. An univariate ANOVA treating reaction time (in seconds) as DV, colour (12 categories), sex (male or female) and trait (6) as a between-subjects factor. A significant interaction between colour and trait and colour, sex and trait (see Table 17 for all results) was found Figures 29a and 29b depict this complex 3-way interaction.

The main effect for order implies that participants sped up as they progressed through the experiment (r = -.287, n = 100, $p \leq .001$). Regarding sex differences, post-hoc analysis (Bonferroni test for multiple comparison) showed that women were significantly faster to take a decision (M_{women} = 7.44 sec) than men were (M_{men} = 7.85 sec).

Trait and colour did not influence reaction time. However, a significant interaction occurred between colour and sex showing that male participants were 1.04 seconds faster to chose a red frame than women were (M_{Males} = 7.19 sec; $M_{Females}$ = 8.23 sec), thus, supporting prediction 5.

With regard to prediction 6, independent t-tests for sex and each trait separately revealed that participant's sex only had an influence on when red T-shirts were selected to develop dominance (F (1, 98) = 5.750, p = .017); male participants selected the colour red significantly faster (M_{males} = 6.26 seconds) than women (M_{women} = 7.20 seconds) did, $t(98)$ = 2.398, p = .017[14].

[14] In comparison, the same independent t-test for the trait 'dominant' including all non-red-stimuli revealed that men picked a colour significantly slower (M_{males} = 8.65 seconds) than women did (M_{women} = 7.27 seconds), $t(812)$ = -3.169, p = .002.

6.4.5 Summary Results

Prediction 1	Participants will explicitly associate 'aggressive' and 'dominant' with the colour red. We have no specific prediction whether or not any of the other traits will be associated with a particular colour, though we do not expect it to be red.	*Supported*
Prediction 2	We predict that the dispersion of the responses for 'aggressive' and 'dominant' will be less than for the control variables. In other words, participants' choice will be much more dense around the mean vector for the traits 'aggression' and 'dominance', whereas the frequency distributions for the other four traits will be much more spread out.	*Supported*
Prediction 3	Red should be chosen more often by males than females and this effect should be strongest for aggression and dominance.	*Not Supported*
Prediction 4	Men will chose red T-shirts more rapidly than women do.	*Supported*
Prediction 5	For the traits 'aggressive' and 'dominant', men will chose red T-shirts more rapidly than women do.	*Supported but only for the trait 'dominant'*

Table 18: Overview of predictions and results

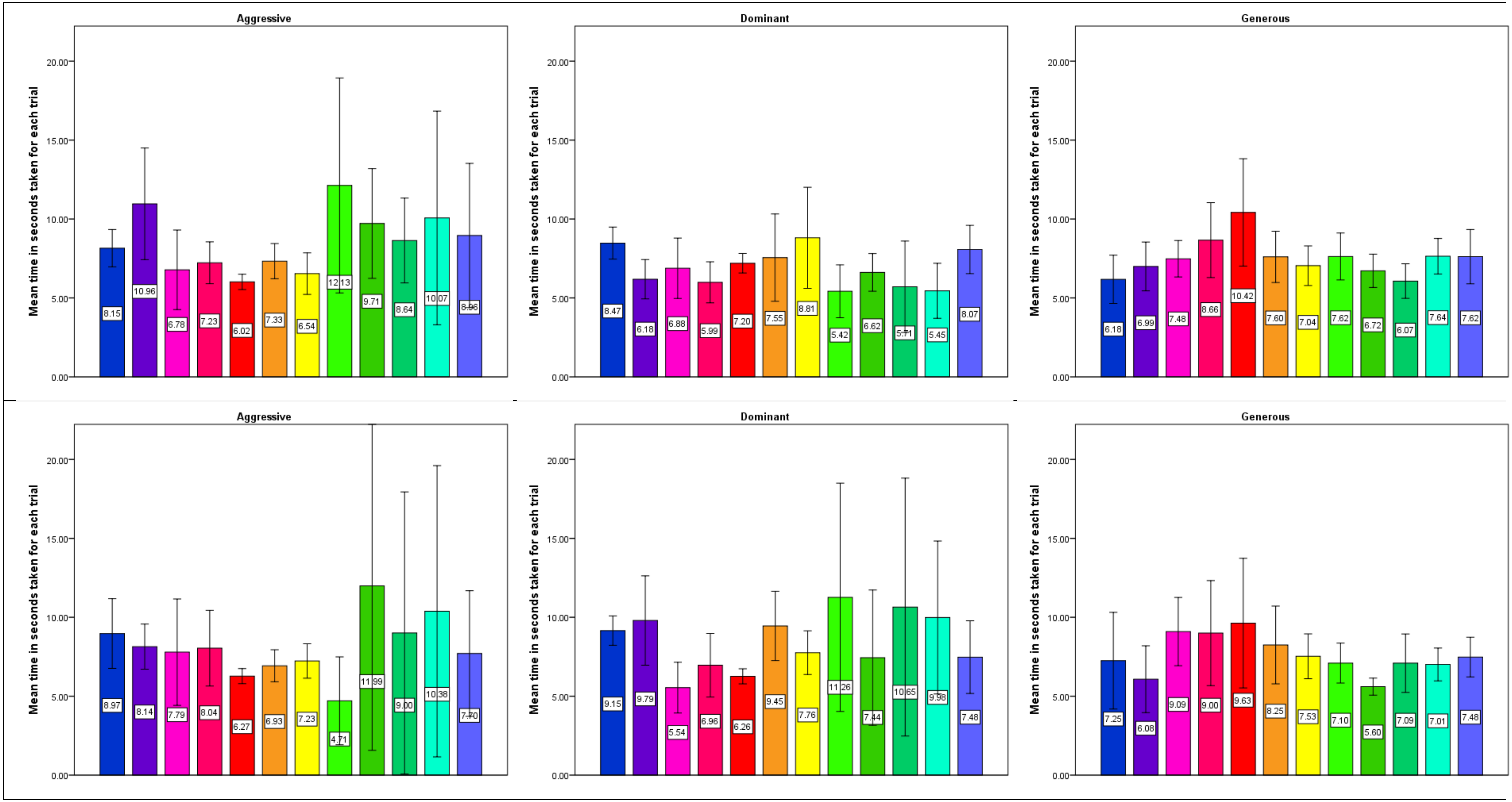


Figure 29a: Womens' (1st row) and mens' (2nd row) mean times to assign colour **(e**rror bars indicate 95% CIs) for choosing a T-shirt colour that represents a given target (N = 90) the best for aggression, dominance, and generosity.

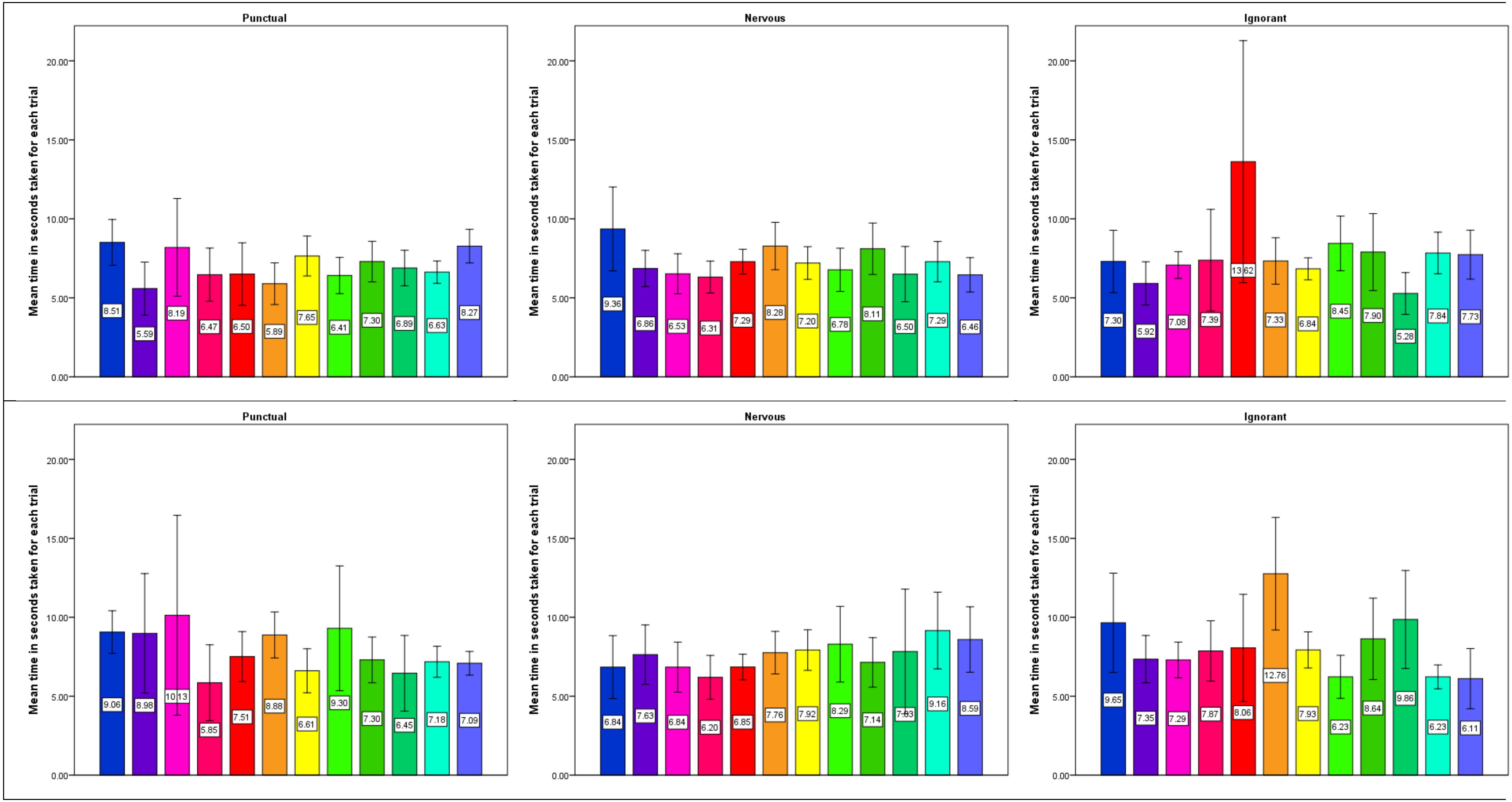


Figure 29b: Womens' (1st row) and mens' (2nd row) mean times to assign colour (+ error bars indicate 95% CIs) for choosing a T-shirt colour that represents a given target (N = 90) the best for punctuality, nervousness, and ignorance.

6.5 Discussion

Given a free choice across the whole colour spectrum, participants optimising aggression and dominance focused narrowly on red. This greatly extends previous research demonstrating that red wearing individuals are perceived as more dominant and aggressive (Wiedemann *et al.* 2015), even though the range of colours participants could chose from was up to 30 times higher than in previous studies. More importantly, our results suggest that wearing a red T-shirt does very well signal aggressiveness and dominance to others. In contrast, a red T-shirt is not associated with, for example, generosity, punctuality, or ignorance. We have also been able to demonstrate the strength of these associations. It is the strongest for red and aggression, then for red and dominance, whereas none of the control variables show such a strong association with any colour. This is, to our knowledge, the first experiment that is able to demonstrate a) with what colour(s) aggression and dominance are linked with, b) how strong this link is, c) with what colour(s) aggression and dominance are not associated with and d) in what way control variables are also linked to red or other colours and how strong these associations are.

Using a much wider range of colours is an advanced method that also allowed to investigate whether red is associated with traits other than 'aggressive' and 'dominant' and also with what colours the other traits are associated with. The use of directional data as a compliment of linear data is also a methodological innovation in this thesis and allows for a differentiated and, in terms of colour, better adapted approach of statistical analysis.

When participants were asked to make a person look as aggressive and as dominant as possible red T-shirts were chosen more frequently than any other colour (prediction 1) and frequency distributions were very dense around the mean vector within the red colour hues (prediction 2). 54.26% of all participants picked a red T-shirt to optimise 'aggression'. For the trait 'dominant', almost half of the participants showed a preference for red T-shirts. It can therefore be stated that there was a stronger association of red colouration for aggressiveness than for dominance, but frequency distributions for both traits still clustered in the red sector. And our results overall concert with a very recently published paper demonstrating a strong association between red colouring and the notions of arousal and dominance whereas colours such as green and blue were a lot less strongly related to these concepts (Briki and Hue 2016).

No control traits were expected to be associated with a particular colour, but we predicted that if colour preferences did exist for the control variables the responses would be less concentrated than those for 'aggressive' and 'dominant' would. Although 'ignorant' did show a peak for preferences associated with the colour yellow, control variables were generally not as clearly related to one particular colour as the red associations for 'aggressive' and 'dominant'. However, the fact that 27.67% of participants chose a red hue for the trait 'nervous' was unexpected. The webpage www.freedictionary.com describes 'nervous' in English as 'easily agitated or distressed; high-strung or jumpy; marked by or having a feeling of unease or apprehension'. In German, the same webpage describes a 'nervous' person as someone being 'stressed or agitated before going on stage (showing signs of stage fright)'. It is also often used in terms of the nervous system and describes someone as being neurasthenic, restless or headless. On several French websites (e.g., www.larousse.fr, www.linternaute.fr), similar explanations as in English and German are proposed but a nervous person is also described as 'strong', 'full of vigour' and 'vital force', 'violent', 'troubled', who can easily 'aggravate/annoy someone else'. The 'active' nature of this part of the French description could explain the red association by some participants. Even though back-translation is a common tool to ensure accuracy and linguistic validation (conceptual equivalence, content validity, and reliability), it is advised to use at least two native speakers from the target population (here: for example French professional translators) in order to identify correct terms or usage, review the existing translation, and point out possible misunderstandings (Wild *et al.* 2009). Future work should pay close attention to this issue when translations are needed for the experiments.

Many participants raised the question as to why they were not able to chose white, black, grey or brown as a colour on the slider. During the debriefing, it was explained to them that achromatic or composite colours did not exist in the colour spectrum on which the slider experiment was built on. Furthermore, since black and white do not exist in different nuances and are not "real" colours, they were not part of the slider experiment.

Aggressiveness seems generally most associated with red (see also Little and Hill 2007), whereas results are not as straightforward for the trait 'dominant', specifically when sex preferences are take into account. Little and Hill (2007), for example, found that female participants judged red as more dominant than male participants did and that darker shades are perceived as more dominant than lighter shades. Wiedemann *et al.* (2015) demonstrated that men were sensitive to red as a signal of dominance whereas women were not. The study presented here could not detect any general sex differences in associations of red with dominance, but we did find that men are significantly faster to choose a red T-shirt in order to make a person more dominant than women are (see section 6.5.1).

6.5.1 Reaction time

Generally, participants were not faster in taking a decision for one specific trait than compared to another. The colour red seems to elicit a faster reaction which concerts with Elliot and Aarts' finding (2011) that viewing red before or during a motor response increases an individual's velocity and strength, possibly due to the elicitation of fear caused by red (Elliot and Aarts 2011). Instead we found that colour, trait, and sex all three influence reaction time. Men are quicker than women to decide on red coloured T-shirts. Specifically, men were quicker to choose red for the trait 'dominant'. Red is associated with dominance in nonhuman primates (e.g., Setchell *et al.* 2005) and reddening of the skin due to increased blood flow is associated with anger in humans (Changizi *et al.* 2006, Fetterman *et al.* 2011). Therefore, sexual selection may have acted on the evolution of human response to red stimuli in competition (Ioan *et al.* 2007). Reacting quickly to a red stimulus may be of special importance for males who compete with individuals of the same sex over mates, status and territory. The association of red and dominance is therefore of great importance for the judgment of potential physical interactions with opponents. However, it is at this stage premature to conclude that males should always react quicker to red stimuli than women do, specifically since the context of this experiment here was free of male-male competition. However, future work would do well to further investigate how reaction times, colour stimuli and participant sex with regard to aggressiveness and dominance may interact.

6.5.2 "Optimal Red"

Wiedemann *et al.* (2015) called for further work to determine whether there is an "optimal red" related to dominance and aggressiveness. Across the whole colour spectrum, we observed a clear peak in frequencies for frame 50 (360°) for the trait 'aggressive' and frame 49 (356.4°) for the trait 'dominant' and this does not seem to be due to a mere random selection (see Figure 30). The study here was motivated by the idea that there is a theoretical optimum defined by the colour of oxygenated blood. Associations between facial skin redness and social dominance are found not only in nonhuman primates (Setchell and Dixson 2001, Setchell *et al.* 2008) but also among humans, e.g., the enhancement of apparent facial aggression and dominance with increased skin redness (Stephen *et al.* 2012). Skin redness in humans has been found to correlate with testosterone (Ferrucci *et al.* 2006) and fluctuates with emotional state in aggressive encounters; increasing with anger and decreasing with fear (Drummond and Quah 2001, Montoya *et al.* 2005, Changizi *et al.* 2006). Red therefore appears to carry specific biological signals in both humans and other animals. Artificial stimuli may also exploit these evolved responses to natural red signals and further research is encourage to investigate whether there is an "'optimal artificial red" that resembles to naturally occurring red shades.

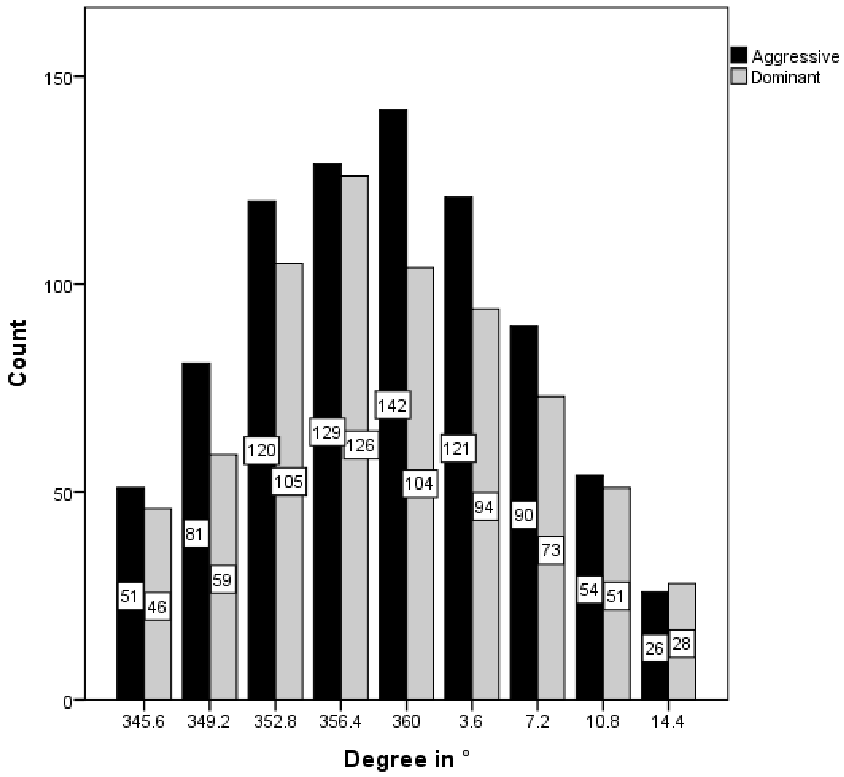


Figure 30: Frequency distribution of red shirts (331.2°-14.4°, frames 46-54) chosen out of 12 colour categories; traits: 'aggressive' and 'dominant'

Chapter 7

7 General Discussion

7.1 Introduction

This chapter synthesises the results presented in Chapters 2 to 6 and discusses methodological considerations and aspects of cultural differences. Results are reviewed only relatively briefly as they are discussed in detail within each of the previous chapters. The outcomes of this research work are then recapped, suggestions and recommendations for further research are put forward, and general conclusions drawn.

Many psychologists have minimised or even relegated colour to the study of preferences or aesthetics or downgraded it altogether as mere environmental "noise" (Fehrman and Fehrman 2004). In countering this the thesis joins the growing body of research demonstrating that colour should be more often and more strongly considered in the analysis of human perception and human behaviour (see Wiedemann *et al.* 2012, Elliot and Meier 2012, Elliot and Maier 2014, and Elliott 2015 for reviews). This thesis adds to a growing body of literature on psychological and perceptual effects of colour on human beings. However, this research also contributes to the broader psychological, anthropological, and biological literature, especially to a growing literature on context-specific research in social-personality psychology (e.g., Elliot and Maier 2012) but also comparative literature of nonhuman primates (e.g., Setchell and Wickings 2005), pointing to the signal value of red.

Colour is an important aspect of our visual perception. However, even though there is a large literature to be found on the physiology of colour processing, little is known about its psychological implications (Elliot and Maier 2014). The primary focus of the experiments presented here has been on whether exposure to red, in essentially neutral contexts, can bias social perceptions (Chapters 2-6) and self-perception (Chapters 3 and 5). The range of colours participants could choose from varied from very few (two to three colours, Chapters 2-5) to the whole colour spectrum (Chapter 6) and we made extensive use of strictly controlled laboratory settings (Chapters 2-4, 6), but also explored the pros and cons of web-based surveys (Chapter 5).

Results revealed a number of informative and interesting findings. For example, red T-shirts increase perceptions of aggression, dominance, and anger relative to blue or grey T-shirts in experiments on character ratings (Chapter 2). However, putting on a red T-shirt does not necessarily lead male wearers to feel more dominant (Chapter 3 and 4), though we found some evidence that they might act more dominantly given that they took more items from a reward box than blue-wearers did (Chapter 4).

We have also contributed to the research field in that we have tested a new methodology that allowed us to use a wider range of colours than what was previously used. This led to the result that aggression and dominance are still associated with red, and, more importantly, predominantly with red, even though participants could chose from 100 hues of which only 9 were red (Chapter 6). This specifically demonstrates that the association of red with aggression and dominance works in two ways. Once when participants act rather passively in that they simply rate displayed targets wearing red (versus other colours) for aggressiveness and dominance (Chapter 2 and 3) and once when participants actively chose a target's T-shirt colour (via a slider) to make him appear more aggressive and more dominant (Chapter 6). That means that individuals are not only *perceived* as being more aggressive/dominant when wearing red (Chapter 2 and 3), participants also actively *chose* a red T-shirt in order to enhance an unknown individual's aggressiveness and dominance (Chapter 6). This clearly relates to a *perceiver-effect*. However, we also conclude that simply putting on a red T-shirt does not immediately change one's self-perception and that it may need a certain amount of time but possibly also a more competitive context to trigger a *wearer-effect* (Chapters 3 and 4, see for example Dreiskaemper *et al.* 2013). Of course, failing to demonstrate a connection between T-shirt colour worn and self-perceived dominance does not mean that a wearer-effect does not exist. It is still possible that researchers who control for the limitations we identified in Chapters 3 and 4 (e.g., the necessity of longer exposure to colours) might find the effect even in contexts free of competition or perhaps when using different measures of self-perceived dominance or dominant behaviour. Nonetheless, until more data are available, the most appropriate conclusion from our findings seems to be that there is little evidence that putting on a plain red T-shirt causes an immediate change in self-perceived dominance.

7.2 Applicability to real-world scenarios

Despite efforts to recruit all age cohorts, the majority of our participants were young adults provided with limited or even falsified (Chapter 3) information who were then tested in highly controlled and standardized laboratory settings (with the exception of Chapter 5). These elements enabled us to carry out sensitive tests of the "red-effect" in neutral contexts, but open up questions regarding real-world applicability and ecological validity. For example, does red have such a strong effect (or any effect at all) on perceivers in real-world decisions and evaluations whilst many other verbal and non-verbal cues are present in the environment? A point of criticism could be that the "red-effect" or the association of red with aggression and dominance is constrained to situations and environments with static or minimal information or, more pessimistically, to situations in which the decision-making and evaluation are of no actual consequence. However, evidence from real-life sports competitions demonstrates that red sports attire might cause biases in sporting contests (Hill and Barton 2005, Attrill *et al.* 2008) and that judges and referees are biased in favour of red-wearers (Hagemann *et al.* 2008, Sorokowski and Szmajke 2014).

7.3 Biological Basis

Why could red-wearers have an advantage? Several possible mechanisms could be at play. This could be, for example, associative learning in context of exposure to red stimuli in threatening situations. Another possibility is that the emotional context alters the colour's impact on motor behaviour and attention (Kiniecki *et al.* 2015). Innate predispositions to learn certain associations could also be hormonally guided. Barton and Hill (2005) suggested that the impact of colour might operate through hormonal influences in that wearing red may elevate testosterone levels in the wearer and/or reduce them in the opponent. Androgens are hormones involved in human male competition, antisocial norm breaking, dominant and aggressive behaviour (Elias 1981, Mazur and Booth 1998, Susman *et al.* 1987). The androgen testosterone is a steroid hormone responsible for the development and maintenance of masculine features but it is also found, in lesser amounts (in most species), in females (e.g., Davison and Davis 2003). Various studies of nonhuman primates have shown that a male’s status and testosterone levels are linked: elevated testosterone levels are recorded when males achieve high rank or status, but decline again when status is lost (Eberhart *et al.* 1980, McGuire *et al.* 1986, Setchell *et al.* 2008). Similar effects can be found in human competitions as sporting winners gain more status than losers and have increased testosterone levels (Mazur and Lamb 1980, Mazur and Booth 1998). Higher testosterone levels have been associated with offensive behaviour such as attacks, fights, and threats in male judo competitors (Salvador *et al.* 1999) and winning tennis players have also been reported to have increased testosterone levels (Booth *et al.* 1989, Mazur and Lamb 1980). Male basketball players were found to have higher testosterone levels the more their individual contribution to the team outcome was (Gonzalez-Bono *et al.* 1999) suggesting that this is a highly consistent relationship. Whether colour of attire influences androgen levels in sporting contests is currently unknown.

So far only a small pilot study has been published investigating whether red-coloured apparel influences hormones in humans. Five black-wearing athletes competed for two minutes against five red-wearing athletes in a cycle ergometry exercise test (Hackney 2006). Blood samples were taken on three occasions: pre-exercise (REST), immediately after exhaustion (EXH) and after a 15 minute recovery period (REC). In both treatment groups, testosterone was observed to increase significantly in the EXH- and REC-samples as compared to REST. While the sample size was too small for statistical analysis, there was qualitative support for red athletes experiencing elevated testosterone levels (Hackney 2006 - but note that Hackney interpreted the non-significant result as contradicting the hypothesis rather than due to inadequate statistical power). Further research is clearly required to assess the psychological and hormonal effects of wearing red. We have tried to embark on a project investigating both psychological changes and changes in testosterone values of red- versus blue-wearing rowers in a staged competition between rowers of equal physical characteristics and abilities. Due to financial restrictions, we were not able to take the pilot project (see Appendix VIII) to a full and complete study with a decent number of participants. However, even though findings also only emerge from an imagined competitive task, Farrelly *et al.* (2013) showed that individuals who chose red as the colour of the symbol that represent themselves had higher testosterone levels, and rated their colour to be more aggressive and dominant, than did participants who chose blue. Again, individuals who actively chose a red symbol did not perform better in the multi-tasking framework. This demonstrates once more that individuals might have to be in direct competition with each other in order for the a red advantage effect to occur. However, the study still shows that testosterone levels are associated with red in competition, at least when the colour is actively chosen. We encourage future research to actively pursue hormonal mechanisms of the red advantage, if possible even in real-life sports competitions. It is also yet still unknown whether individuals with high testosterone levels were more likely to choose red because of an innate or because of a learned association of red with dominance/aggression. If the first was true then more research would be needed to reveal the link between elevated testosterone levels and natural (red) stimuli such as skin colour redness in humans.

7.4 Cultural influences

It should be stressed that the results presented here leave open the role of innate biases and cultural learning as determinants of colour associations. It is possible that individuals learn to associate red with anger or danger as a result of being repeatedly exposed to this kind of association. For example, language is potentially a very important factor in creating such associations, for example, “he got red with anger” and “seeing red” imply that an individual is angry, whereas sadness is often linked to blue (“feeling blue”). Biology possibly drives cultural uses of red and these colourful metaphors might reflect innate predispositions. The origin of colour associations may exist because of our genetic predisposition to receive, for example, a signalling function behind red colouration/red skin colouring. Cross-cultural consistency or universality in colour associations would tend to reinforce the idea of a biological component. For example, red is perceived as ‘active’ in 23 different cultures (Adams and Osgood 1973) and the association of red, but also black, with anger is cross-cultural (Hupka *et al.* (1997). It might be that individuals all over the world observe that excited, active, or angry people go red, and therefore learn the association because they are all exposed to it - biology, learning, and culture would then all be implicated. Future research is needed to test the here described colour effects cross-culturally.

Some researchers have focussed on cultural differences and social learning, which may reinforce an innate predisposition (Elliot *et al.* 2013), however, it is only recently that scientists have empirically tested this hypothesis in colour psychology. For example, a study of Chinese stockbrokers indicates that colour meanings may be reversible (Zhang and Han 2014). In the Chinese stock market, a rise is indicated with red numerals, a decrease with green. This positive connotation of red in the Chinese stock market might reverse the negative "red-effect" on IQ tests (Elliot *et al.* 2007, Lichtenfeld *et al.* 2009). This prediction was supported by Zhang and Han (2014). A red stimulus presented before an IQ test undermined performance of college students but enhanced performance among stockbrokers. Future research needs to address the extent to which experience can modify colour effects in contexts other than the achievement context.

7.4.1 Cultural influences in the romantic context

Cultural experience has also been demonstrated to play a role in colour-associations in a romantic context. As such, men from westernized cultures (U.S. and Europe) but also men from an isolated traditional small-scale society in Burkina Faso, rated women presented in a red coloured picture frame to be more attractive than those presented in blue. More importantly, the observed red-attraction link runs counter to explicit negative associations with red that exist in this culture (Elliot *et al.* 2013). Therefore, having been able to demonstrate the red-link in the Burkinabe sample, the researchers provided initial support for the argument that the "red-effect" may represent a human universal. According to the authors, this might be a psychological process that carries the same meaning and serves the same function across all human societies (Norenzayan and Heine 2005). Whether similar results are obtained for the link between red and aggression and dominance needs to be tested in traditional societies.

7.5 Methodological considerations

Colour studies require special caution. Colour is a function of the three properties chroma (saturation), value (or lightness), and hue (e.g., blue, red), and each of these dimensions may separately influence perception. Although experiments systematically varying all three of these parameters were beyond the scope of this study, they should be conducted in the future. For experiments carried out in laboratories, we ran all tests on calibrated computer monitors but did not use a spectrophotometer. A spectrophotometer is an apparatus that assesses colour at the spectral level and provides objective numeral values for chroma, lightness, and hue (or similar elements). It also takes into account observer viewing angles and the differences of study environments (i.e., white fluorescent lighting versus sunlight). Using a spectrophotometer, colour attributes of a given stimulus are assessed and then adjusted to select target values that differ on only one attribute. That way, colour can be assessed in a range of formats, be it presented on a computer screen, or printed, or even present on a physical object. This combination of flexibility and accuracy makes the spectrophotometer approach optimal. In the absence of such stimulus control, the stimulus parameters used in the experiments reported here must be considered approximate. Although it cannot control for individual differences in how a person perceives colour, this variation is like any other individual difference in that it merely adds unsystematic variance to the design that is randomly dispersed across conditions (Elliot and Meier 2014).

Other aspects of the stimuli may also be important. The quality of the stimuli we used in the four data chapters including image presentation (Chapters 2, 3, 5, and 6) varied. Stimuli in Chapter 2 (see section 2.3.2) varied in the amount of manipulated colour being displayed, other colours than the manipulated one were present and the background differed as well. Some stimuli were based on images obtained from the internet, while others were obtained from our own photographs taken specifically for the purpose. Despite this diversity, we were able to detect a "red-effect" on perceptions of aggression and dominance. In Chapter 3, we included only these stimuli from Chapter 2 that displayed a single colour, even though the amount of manipulated colour and the background colour still varied. Yet, we found similar effects of red. Stimuli used in chapter 6 were of superior quality. With the help of a T-shirt mask to produce the stimuli, the background and the amount of colour in display was (at pixel-level) equal for every single stimulus. We recommend the use of a T-shirt mask for all future studies investigating the signaling function of red clothing colour.

7.6 Future directions

Future research is needed to begin to examine the ultimate source of the implicit red-aggression (red-dominance) link, possibly by creating novel colour-aggression associations in the laboratory and contrasting and comparing their properties with the focal red-aggression (red-dominance) association. We also encourage the integration of tests that lead to the observation of behavioural differences such as we tried in Chapter 4 when we investigated whether red-wearers behaved more dominantly than their blue-wearing opponents. Future work would also do well to examine other implicit associations to red that might be derived from the nonhuman primate, bird and fish literature such as red and status (Cuthill *et al.* 1997, Pryke 200, Wickings and Dixson 1992, Setchell and Dixson 2001, Setchell *et al.* 2008). For example, can results from Wiedemann *et al.* (2015) be reproduced with targets wearing differently coloured ties, similiar to the study of Maier *et al.* (2013). Contemporary literature states that colour effects and colour meanings are not only a function of psychological signaling and social learning, but also a function of biology. Researchers have drawn parallels between nonhuman and human animals' uses of, and responses to, colour, and findings have been published that are consistent with such parallels. A next step would be to translate that biological basis question to direct empirical testing. This could be done, for example, by testing whether and how colour effects emerge across culturally distinct countries around the world, also focusing on culturally isolated populations. Furthermore, women's sensitivity to red as a signal of aggression and/or dominance has not been investigated sufficiently. Whereas we only used male faces in our stimuli, including female stimuli would help to understand sex-differences with regard to perceptions of aggressiveness and dominance. Are men still sensitive to red stimuli when the target is a woman? How would the presentation of stimuli with female targets wearing differently coloured T-shirts influence the judgements of perceived personality attributes in men and women (outside of the romantic context, e.g., Elliot and Niesta 2008)? The broader relevance of determining this would help to distinguish between the psychological signalling that red has towards men (e.g., opponent evaluation) and women (e.g., partner evaluation). As anger and dominance are associated with red skin colouration (Drummond and Quah 2001), and submissiveness and fear with pale skin (Changizi *et al*. 2006), it would also be important to determine whether there are psychological benefits displaying reddened skin colouration and/or negative psychological effects on opponents in competitive scenarios. It could then be investigated how these effects are manifested hormonally through the influence of the colour red on the testosterone levels of the individual with reddened skin (or wearing red sports attire) and this individual's opponent.

Another focal interest in the future should be to determine the exact value of hue/chroma/lightness that gives an advantage to sportsmen, or the "optimal red" for making an individual seem stronger or superior. This could perhaps help to understand whether the link between red and aggression, and between red and dominance, is related to the colour of blood or oxygenated skin, which then would strengthen the notion that these links are rooted in an innate evolutionary-based predisposition.

7.7 General conclusion

This thesis has presented a variety of methodologies (e.g., lab- versus web-based studies) and techniques (e.g., questionnaires, behavioural observation, etc.) to investigate the effects and psychological influence of the colour red on human perception in a neutral context. Red has been shown to associate with perceptions of aggressiveness and dominance in male targets. The fact that red was shown to be linked with anger, aggressiveness, and dominance in neutral environment adds support to the proposition that red has a signaling function, already demonstrated in human sports competitions (Hill and Barton 2005).

Although his thesis provides a useful basis for further research in this area and represents the ending of an often necessarily and intensively exploratory investigation, it is important to keep in mind that existing empirical and theoretical work is still at an early stage of development and the literature needs time to mature. Colour research is a complex area of inquiry (Kuehni 2012, Fairchild 2013, Elliot 2015) that is only beginning to thrive and be recognized. There is considerable promise in field of colour research, but significantly more empirical and theoretical work needs to be put forward before the full extent of this promise can be accredited and, hopefully, fulfilled.

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Appendix I

IMAGE	BLUE	GREY	RED
ahcangf1	148	150	147
Aman1	128	134	124
andyangry	95	149	94
angrysuit	129	137	128
ATANGf1	131	133	131
jcangs2	134	137	134
jsangf1	129	133	127
paulangry	68	75	68
pbangs2	129	130	129
rwangf1	137	139	137
tdang	139	140	138
bjneuf1	104	118	103
football	109	115	103
gore	110	128	103
GSNEUF1	122	125	121
jdneuf1	130	131	129
jgneuf1	134	136	134
Nman1	122	132	125
small	134	140	132
cfneuf1	132	135	132

RGB-values

Durham University

Thank you very much for having agreed to your participation in this experiment!

You will be presented 60 pictures during the following experiment. Please rate each face towards specific character traits and attributes. A 7-rank-scale is provided for this purpose. Please use your computer mouse and click on the value that, in your opinion, represents the most appropriate value. There are no wrong or right answers. What matters is your personal opinion and view.

After the evaluation of each single picture, please click on **Next trial**

Please answer all questions truthfully and conscientiously. Falsified answers are detected through statistical methods and will be excluded from the data analyses. There is no time limit for answering the questions. You should, however, answer all questions quickly and come to a decision after brief consideration.

All your information will be kept confidential and will not be passed on to a third party. Your answers and details are anonymously assayed.

If you have any questions, please contact: diana.wiedemann@durham.ac.uk

Subject Number: …………… **Date: ………..…2010**

General Details

Note: Your information is kept confidential.

1.) Age

……… years old

2.) Gender

- ○ Female
- ○ Male

3.) Do you have any visual defects?

- ○ No
- ○ Yes

If yes, what visual do you have?

- ☐ Nearsightedness
- ☐ Long sightedness
- ☐ Colour blindness
- ☐ Miscellaneous: ………………

If yes, do you use any visual aids?

- ☐ Glasses
- ☐ Contact lenses
- ☐ None
- ☐ Miscellaneous: ………………

Subject Number: …………… **Date: ………..…2010**

The experiment is now finished. Thanks again for your participation!

Finally, please answer the following question:

What do you think was the purpose of the study?

____

____

____

____

Appendix II

Merci beaucoup d'avoir accepté de participer à cette expérimentation.

Le but de cette étude est de rechercher comment les différents tissus influences nos systèmes sensoriels (toucher, etc.) et dans quelles mesures ils pourraient jouer un rôle sur vos sensations et vos émotions ou sur celles des autres et comment ces émotions peuvent changer sur une courte durée.

Chaque participant portera soit un T-shirt en coton, en soie ou en laine. Comme cette étude se déroule de façon aléatoire, vous piocherez un papier qui vous indiquera quel tissu vous porterez lors de l'expérimentation.

Une fois que vous porterez le T-shirt, nous vous remettrons un court questionnaire qui atteste de vos sentiments et émotions personnelles. Ensuite, nous vous demanderons d'évaluer comment le tissu que vous portez influence vos sensations envers les autres.
Enfin vous devrez remplir un questionnaire portant sur vos propres émotions une deuxième fois.

Merci de répondre à chaque question le plus sérieusement et consciencieusement possible. Toutes réponses non rigoureuses sont détectées statistiquement et sont exclues de nos analyses.

Vos données personnelles resteront confidentielles et ne seront transmises à aucune tierce personne. Vos réponses seront analysées anonymement.

Si vous n'avez pas d'autre question, nous allons maintenant procéder à l'expérimentation.

Contact: diana.wiedemann@durham.ac.uk

Durham University

Je souhaite maintenant étudier comment le tissu que vous portez influence vos sentiments envers les autres.

Nous allons vous présenter 42 photos sur l'écran d'ordinateur. Chaque individu présent sur la photo apparaitra plusieurs fois. Une échelle mesurant le degré de domination (allant de 1 à 7) de chaque visage vous sera alors proposée.
Merci d'utiliser la souris d'ordinateur et de cliquer sur le chiffre qui, à votre avis, représente le mieux votre sentiment. Il n'y a pas de bonne ou de mauvaise réponse. Ce qui importe est votre opinion personnelle et votre avis.

Merci de répondre à chaque question le plus sérieusement et consciencieusement possible. Il n'y a pas de limite de temps pour répondre aux questions. Vous devez, toutefois, répondre aux questions rapidement et prendre une décision après une courte réflexion.

Si vous n'avez pas d'autre question, nous allons maintenant continuer.

Contact: diana.wiedemann@durham.ac.uk

QUESTIONNAIRE 1/2

Décrivez en quelques mots, quelles sensations le tissu que vos portez procure au contact de votre peau.

___

___

___

Si oui, comment le tissu que vous portez influence votre humeur?

___

___

___

		Pas du tout d'accord.	Pas d'accord	Ni en désaccord ni d'accord	D'accord	Tout à fait d'accord
1.	J'essaie de surpasser les autres.	①	②	③	④	⑤
2.	Je suis rapide pour corriger les autres.	①	②	③	④	⑤
3.	J'impose mes désires aux autres.	①	②	③	④	⑤
4.	Je demande des explications aux autres.	①	②	③	④	⑤
5.	Je veux contrôler la conversation.	①	②	③	④	⑤
6.	Je n'ai pas peur d'émettre des critiques.	①	②	③	④	⑤
7.	Je remets en cause le point de vu des autres.	①	②	③	④	⑤
8.	J'impose la loi aux autres.	①	②	③	④	⑤
9.	Je mets les gens sous pression.	①	②	③	④	⑤
10.	Je déteste paraitre insistant.	①	②	③	④	⑤

Appendix III

Merci beaucoup d'avoir accepté de participer à cette expérimentation !

Le but de cette étude est de rechercher comment les différentes méthodes d'enregistrements physiologiques et comportementaux fonctionnent. Cette étude a été approuvée par le comité d'éthique de l'université de Durham et inclut plusieurs parties :

1.) Une phase de compétition durant laquelle je vous demanderai de presser avec vos mains un dynamomètre mécanique le plus fort possible afin de battre le deuxième participant
2.) Deux courts questionnaires sur votre personnalité
3.) Un test sur la distance sociale
4.) Une photographie
5.) Un test sur votre odeur

Après avoir rempli le premier questionnaire, l'instructeur vous demandera de porter un T-shirt pour le reste de cette étude. Ce T-shirt servira au test sur l'odeur. Chaque T-shirt n'est utilisé qu'une seule fois et lavé ensuite.

Je souhaite prendre des photos de votre visage et le haut de votre torse. Avec votre autorisation, une de ces photos pourra être utilisée dans une étude ultérieure.

Vos données personnelles resteront confidentielles et ne seront transmises à aucune tierce personne. Vos réponses seront analysées anonymement.

Si vous n'avez pas d'autre question, nous allons maintenant procéder à l'expérimentation.

Sujet numéro: ________________ Date: __.__. 2012

Formulaire de consentement

Cher participant,

en signant ce papier, vous acceptez de participer bénévolement à une étude dirigée par l'Université de Durham.

Cochez les cases ci-dessous.

1. Je confirme avoir lu et compris les instructions de cette étude et d'avoir eu la possibilité de poser toutes questions. [ ]
2. Je comprends que la participation est volontaire et que j'ai le droit de quitter cette étude à tout moment et sans donner de raison. [ ]
3. J'ai été informé que les données recueillies seront gardées confidentielles. [ ]
4. Je n'ai aucune restriction médicale qui pourrait influencer ma performance. [ ]
5. J'accepte de participer bénévolement à cette étude. [ ]
6. J'accepte que l'on me photographie et comprends que l'image pourrait être utilisée dans une expérimentation ultérieure. [ ]

Pour toute question, n'hésitez pas à me contacter: diana.wiedemann@durham.ac.uk

____

Signature

QUESTIONNAIRE 1 + 2

Les questions suivantes concernent votre personnalité. Merci de répondre à chaque question le plus sérieusement et consciencieusement possible. Cochez la case correspondant à votre choix.

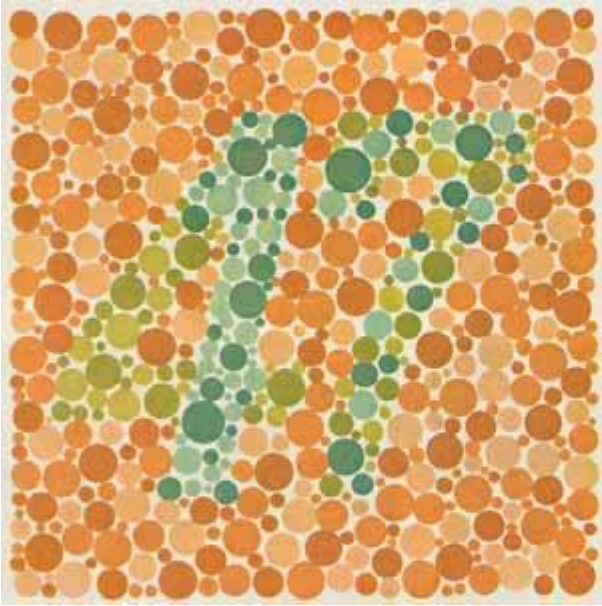
		Pas du tout d'accord.	Pas d'accord	Ni en désaccord ni d'accord	D'accord	Tout à fait d'accord
1	J'essaie de surpasser les réussites des autres.	①	②	③	④	⑤
2	Je n'essaie pas de surpasser les autres.	①	②	③	④	⑤
3	Je suis rapide pour corriger les autres.	①	②	③	④	⑤
4	Je n'impose pas mes désirs aux autres.	①	②	③	④	⑤
5	Je demande des explications aux autres.	①	②	③	④	⑤
6	Je ne veux pas contrôler la conversation.	①	②	③	④	⑤
7	Je n'ai pas peur d'émettre des critiques.	①	②	③	④	⑤
8	Je ne remets pas en cause le point de vue des autres.	①	②	③	④	⑤
9	J'impose ma loi aux autres.	①	②	③	④	⑤
10	Je ne mets pas les gens sous pression.	①	②	③	④	⑤
11	J'arrive à convaincre les autres que j'ai raison.	①	②	③	④	⑤
12	Je déteste paraître insistant.	①	②	③	④	⑤

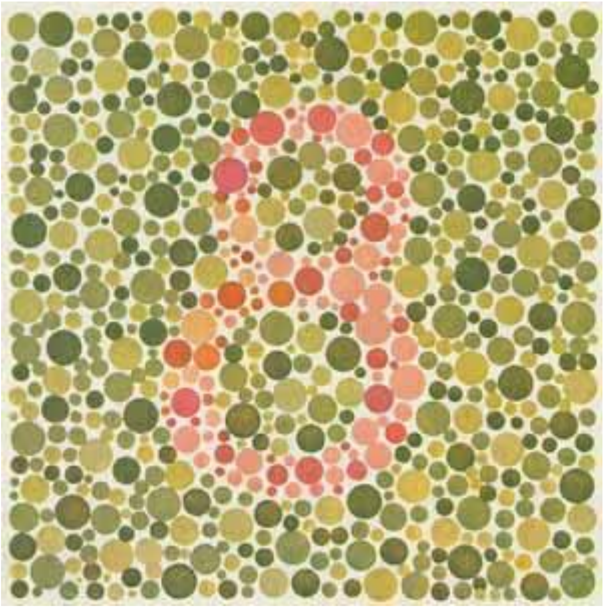
Sur une échelle de 1 à 7, pensez-vous être une personne dominante?
1 = pas du tout dominant et **7** = très dominant

1	2	3	4	5	6	7

Colour Blindness Test

http://www.augenarztonline.eu/index-Dateien/PatienteninformationenFarbe.htm





DONNEES PERSONNELLES

Notez: Ces informations seront gardées confidentielles. Mettez une croix dans les cases vous correspondant.

1.) Age: ______

Poids : _____ kg

Taille: _____ cm **O** Ne souhaite pas le dire

2.) À propos de l'autre participant

- A votre avis, quelle taille fait l'autre participant ? _____cm
- A votre avis, est-ce qu'il était :
  - plus fort que vous
  - moins fort que vous
  - pareil
- Connaissez-vous l'autre participant ?
  - ○ Oui, très bien
  - ○ Oui, un peu
  - ○ Non, pas du tout

3.) Pays de naissance: _____________

____

4.) Appartenance ethnique

- ○ Noir ou Afro Américain
- ○ Blanc
- ○ Asiatique
- ○ Métisse
- ○ Autre
- ○ Ne souhaite pas le dire

6.) Vous êtes :

- ○ Gaucher
- ○ Droitier
- ○ Ambidextre (les deux)

7.) A votre avis, quel était le but de cette étude ?

____

____

____

____

____

____

____

____

8.) Avez-vous des problèmes de vue ?

- ○ Non
- ○ Oui

Si oui, quel problème avez-vous?

- ☐ Myopie
- ☐ Presbytie
- ☐ Daltonisme
- ☐ Autre: ………………………………

Si oui, quelles aides visuelles avez-vous utilisées <u>pendant cette expérimentation</u>

- ☐ Lunettes
- ☐ Lentilles de contact
- ☐ Aucun
- ☐ Autre: ………………………………

9.) Quels chiffres voyez-vous dans les images ci-contre ?

Image 1: ______

Image 2: ______

Image 3: ______

10.) Souhaitez-vous connaître votre classement parmi les autres participants (environ 100 hommes au total) ?

O Non **O Oui** – si oui, l'instructeur va vous demander de noter votre adresse email sur le formulaire de consentement lequel sera gardé séparément de vos données personnelles afin de respecter votre anonymat.

Appendix IV

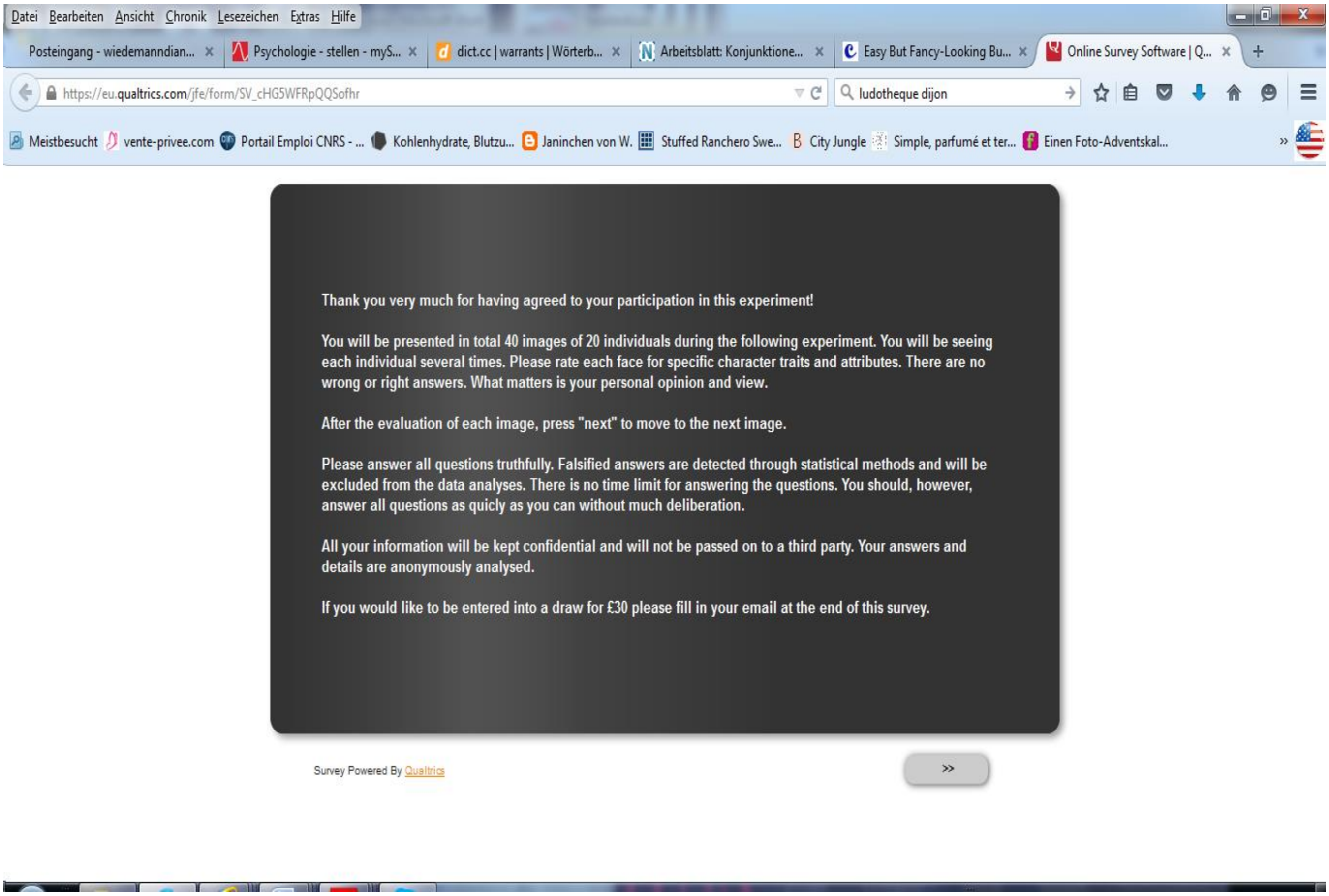
To all my English speaking friends/family-members/fbook-friends:

If you have a few spare minutes, I would really appreciate if you could help me by taking a little experiment/survey that I'm currently running.

The experiment takes about 10 minutes and every participant has the chance to win £30. All you have to do is to rate 40 images and fill in a short questionnaire.

*** IF YOU KNOW ANYTHING ABOUT MY HYPOTHESES OR IF YOU ARE NOT A NATIVE ENGLISH SPEAKER, PLEASE DO NOT PARTICIPATE***

Many, many thanks!
Diana
https://survey.qualtrics.com/SE/?SID=SV_cHG5WFRpQQSofhr
P.S.: Please forgive me for tagging you all but this is very urgent! I would also really appreciate if you could share this info with your friends and family.



Appendix V

Equation 1

$$\propto = \frac{2\pi x}{k}$$

Equation 2

$$\mu = \frac{(2 + 4 + 180 + 350 + 360)}{5} = 179.2$$

Equation 3

$$SD = \frac{(2 - 179.2)^2 + (4 - 179.2)^2 + (180 - 179.2)^2 + (350 - 179.2)^2 + (360 - 179.2)^2}{5} = 176.4$$

Equation 4

$$\mu = arctan\left(\frac{x}{y}\right)$$

with

$$x = \frac{1}{5}[sin(2) + sin(4) + sin(180) + sin(350) + sin(360)]$$

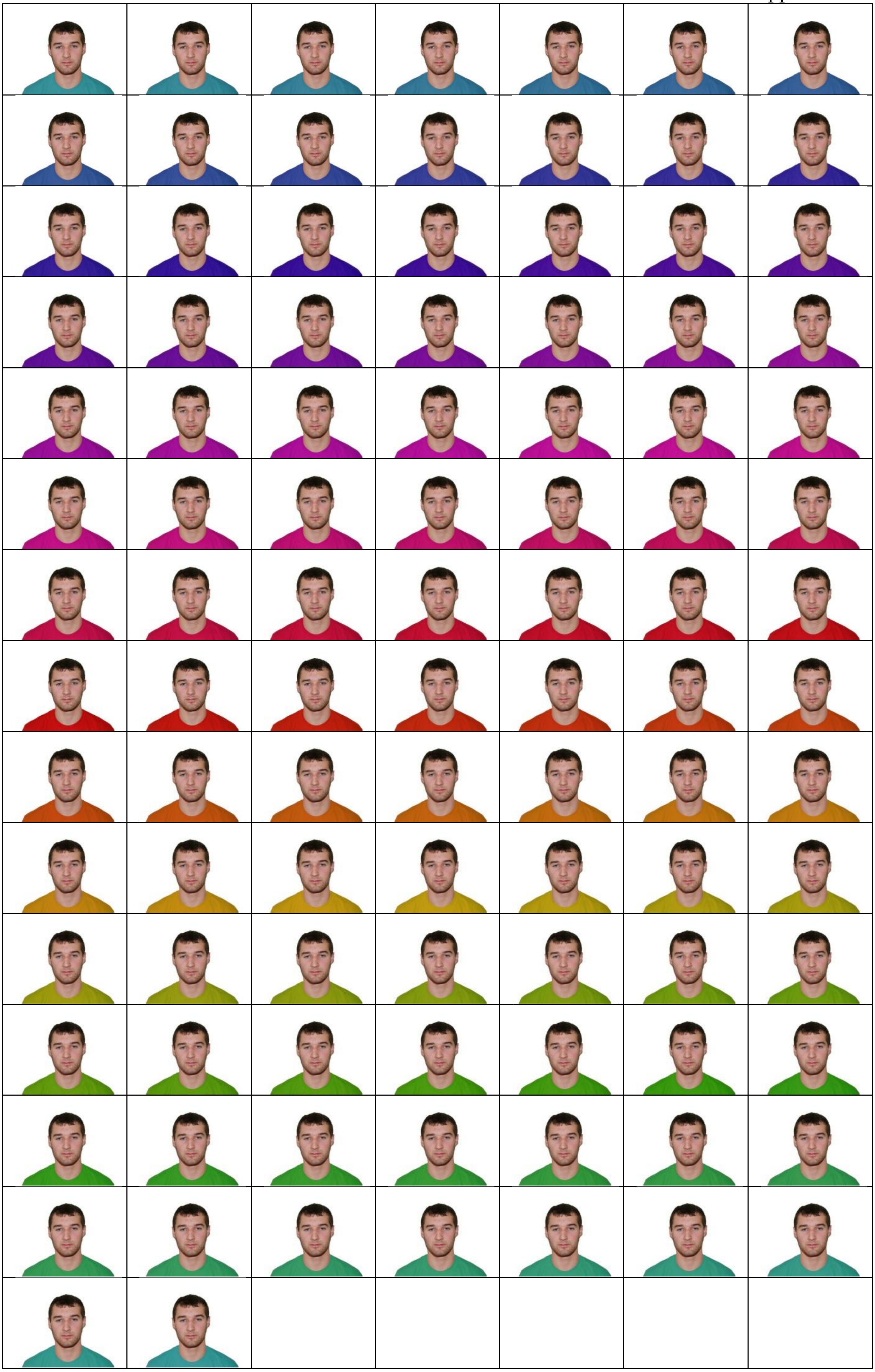
$$x = \frac{1}{5}[cos(2) + cos(4) + cos(180) + cos(350) + cos(360)]$$

Equation 5

$$SD = \sqrt{}-2ln(R)$$

$$R = \sqrt{}x^2 + y^2$$

Basic equations for circular statistics



Final question

At the end of the "slider experiment" we also asked an open question that allowed participants to chose from whatever colour came to their mind rather than restricting their choice to a small number of colour hues that might not always represent the colour of their personal choice. Furthermore, their choice may have also included colours that are not pure primary colours but composite colours (e.g., brown, bordeaux) or achromatic colours (white, grey and black). This is of special importance as these colours may also convey social judgements (e.g., 'black' and its association with aggressiveness in sports, Frank and Gilovich 1988) and these are all common colours of uniform or T-shirt fabrics. It is, thus, investigated which colours are associated with the six characteristics when free choice is given. Our initial hypothesis was that when participants can freely chose any colour (including composite colours and achromatic colours), they will show a clear preference for one colour to represent one of the six traits. The question we asked was whether they thought that there was a relationship between the traits previously presented in the slider experiment and colour. In a table in which the six traits/adjectives were listed, participants were asked to note down *one* single colour that came to their mind next to each trait. They were *not* provided with a list of possible colours.

The null hypothesis was that participants would note down the colour red equally often for each of the six traits. The alternative hypothesis was that more than 50% of participants (or at least the majority) will note down the colour red for 'aggressiveness' and 'dominance'. For the other four traits for which no a priori predictions were made, indications for red were not expected to attain 50%. We further predicted that, focusing only on cases where the colour red was written down, 'aggressive' and 'dominant' would have the highest frequencies.

Results attributions of colours to character traits

The frequency distribution of participants' choices are displayed in appendix Table 1. It was predicted that participants associated the colour red more often with 'aggressiveness' and 'dominance'.

The most common colour for each character trait/adjective was *red* for aggressive (80%), dominant (56%) and nervous (37%); *green* for generous (36%); *blue* for punctual (48%); and *yellow* for ignorant (32%). This is in concordance with the mean vectors depicted in the rose diagrams in section 6.4 (Figure 28, Table 15). This supports our first prediction.

The null hypothesis is that each colour was distributed equally across the six traits. Results of the Independent Sample Kruskal-Wallis test (appendix Table 2) show that the frequency distributions for the colours blue, pink, red, and yellow are not the same across the six traits (*ps* ≤ .001). Running the analysis separately for male and female participants, revealed the same results (*ps* ≤ .001).

Colour	Kruskal-Wallis Test	Sig.	Decision
Blue	110.234	<.001	Reject H_0
Violet	7.274	.201	Retain H_0
Pink	23.407	<.001	Reject H_0
Red	269.628	<.001	Reject H_0
Orange	9.204	.101	Retain H_0
Yellow	58.186	<.001	Reject H_0

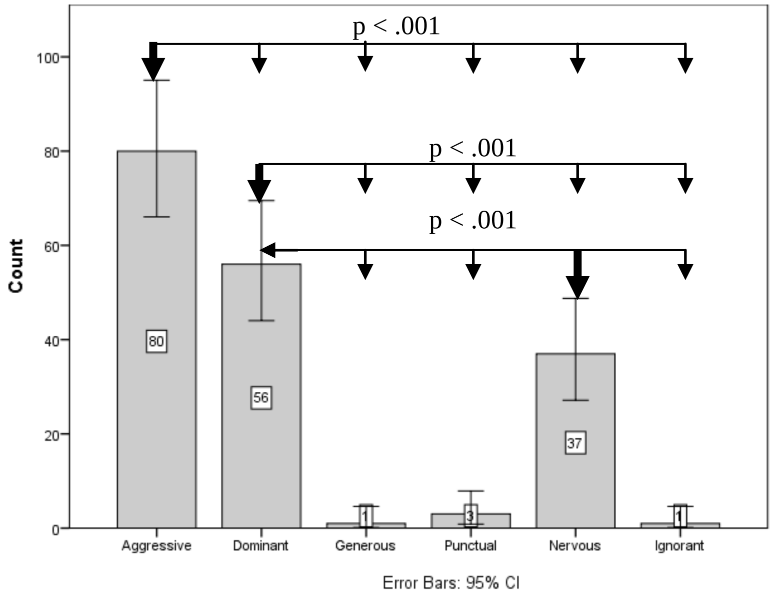
Appendix Table 1: Results of the Independent Kruskal-Wallis test for the six colour categories named at least once for each trait

Results attributions of the colour red to character traits

In order to test the 2nd prediction, the following analysis is narrowed down to the colour red only. Appendix figure 1 depicts how often 100 participants mentioned the colour red for each trait.

Results are in favour of our second prediction. More than half of the answers for each trait resulted in the colour red being named to represent 'aggressive' and 'dominant'.

Friedman's ANOVA statistical test for binomial distribution (red: yes/no) was performed and revealed that red was mentioned significantly more often for the trait 'aggressive' as compared to the other five traits (McNemar's $\chi^2(1, N_{pairs} = 6)$, $p < .001$), followed by the traits dominance and nervous. To compare the patterns of responses to two or more qualitative variables obtained from dependent samples (here: repeated-measures), Cochran's Q Test was applied and revealed that red was not mentioned equally often for each trait variable, Q(5) = 248.62, p < .001. This is true even when the analysis is run separately for female (Q(5) = 123.71, p < .001) and male participants (Q(5) = 126.58, p < .001).



Appendix Figure 1: Histogram of frequencies of the colour red being mentioned for each trait; larger arrows indicate the trait being compared to the other traits (smaller arrows) using McNemar Test for binomial distribution

In sum, regardless of sex, participants believed that the colour red represents the trait 'aggressive' the best (80 out of 100). Still more than half of participants (56 out of 100) assigned the colour red to 'dominant' and 37 out of 100 to 'nervous'.

These findings are mirrored in the results of the open question at the end of the experiment, in which participants were asked to name *any* colour that they thought stands in relation to the six traits. As predicted, more than half of the participants chose red for the traits 'aggressive' (80%) and 'dominant' (56%) whereas no such clear colour preference was found for any of the other traits. For all cases in which red was chosen, these two traits had the highest frequencies. For the trait 'dominant', 23% of all participants set the colour blue in relation to it. Despite two completely different methodologies, these results are similar to those from the slider experiment. Furthermore, many participants raised the question as to why they were not able to chose white, black, grey or brown as a colour on the slider. During the debriefing, it was explained to them that achromatic or composite colours did not exist in the colour spectrum on which the slider experiment was built on. Furthermore, since black and white do not exist in different nuances and are not "real" colours, they were not part of the slider experiment. Nevertheless, participants made very few use of these 'colours' in order to answer the open question. For example, in only 15 out of 600 occasions participants picked black or white. This is surprising, specifically in regard of the colour black, which has previously been found to influence perception of aggression in athletes (Frank and Gilovich 1988), and across cultures both black and red have been found to influence scoring of combat sport bouts

(Sorokowski and Szmajke 2014). It is, however, still possible that if black and white were included in the slider experiment, that participants may had made greater use of it, simply because its sudden appearance on the screen is extremely eye-catching. However, this would have required a dimension for saturation and luminescence which was not part of this study.

In sum, what we can take from this final, open question is that participants relate the colour red to aggressiveness and dominance even when they were not provided with a range of colours to chose from. Black seems to be a lot less associated to aggressiveness and dominance than red is. However, we decided to remove this part from the main analysis as participants were possibly too primed to not choose black and other colours because they were not in the slider experiment, which then could explain the results presented here in the appendix.

	Turquoise	Light Blue	Blue	Violet	Pink	Red	Orange	Yellow	Green	Dark Blue	Black	Grey	Brown	White	Fuchsia	Beige
Aggressive			3.0	6.0	1.0	80.0*	3.0	3.0		1.0	3.0					
Dominant		1.0	23.0	3.0	2.0	56.0*	4.0	2.0	2.0	1.0	5.0		1.0			
Generous		5.0	20.0	7.0	12.0	1.0	8.0	11.0	36.0*							
Punctual		9.0	48.0*	5.0	3.0	3.0	3.0	8.0	16.0		1.0	1.0	1.0	2.0		
Nervous		2.0	1.0	12.0	4.0	37.0*	11.0	17.0	12.0	1.0	2.0				1.0	
Ignorant	1.0	7.0	7.0	7.0	12.0	1.0	7.0	32.0*	19.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Appendix Table 2: Number of cases (100 cases for each row) in which each colour was written down when participants were asked to name a single colour that, in their opinion, might have a relationship with a specific character trait. Asterisks ***** mark the highest value for each trait. Grey marked colours are those named at least once for each trait. Columns with underlined colours depict that the distribution of this colour is not the same across the six traits (Kruskal-Wallis test, p < .005

Appendix V

Merci beaucoup d’avoir accepté de participer à cette expérimentation.

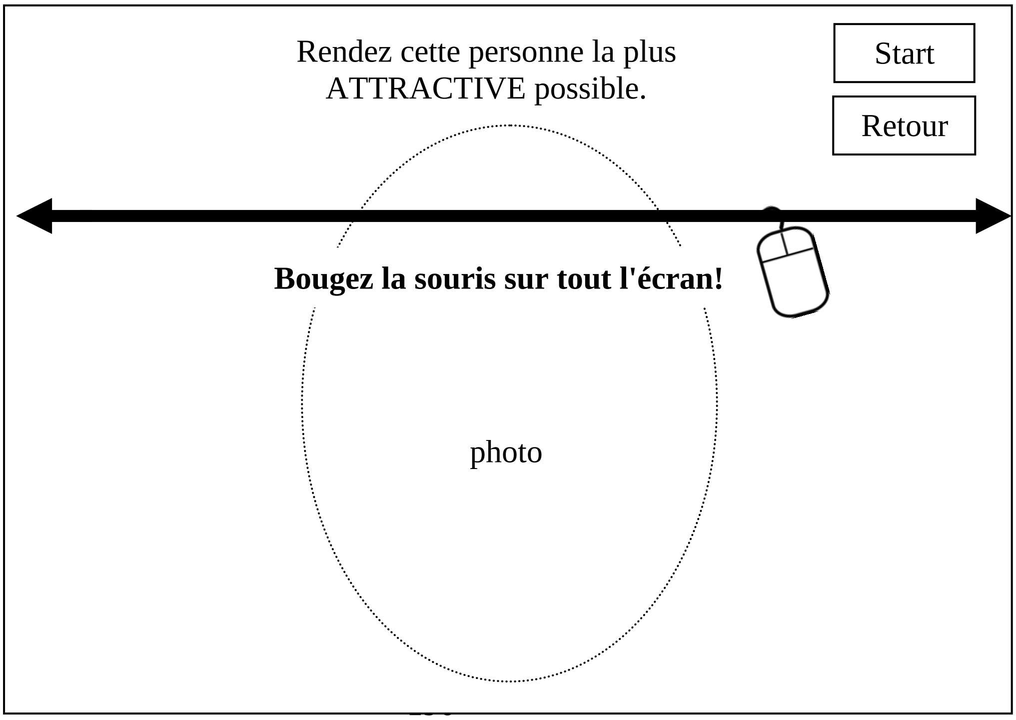
Le but de cette étude est de tester votre perception visuelle.

Je vais d'abord vous demander de remplir un court questionnaire concernant votre personnalité. Merci de répondre à chaque question le plus sérieusement et consciencieusement possible. Toutes réponses non rigoureuses sont détectées statistiquement et sont exclues de nos analyses.

Ensuite, je vais vous présenter 90 photos d' hommes sur l’écran d’ordinateur. En bougeant la souris vous allez voir que la couleur de T-shirt changera. C'est à vous de choisir la meilleure couleur et ainsi répondre au mieux à la question présentée avec cette photo. Il n’y a pas de bonne ou de mauvaise réponse. Ce qui importe est votre opinion personnelle et votre avis.

Vos données personnelles resteront confidentielles et ne seront transmises à aucune tierce personne. Vos réponses seront analysées anonymement.

Si vous n’avez pas d’autre question, nous allons maintenant procéder à l’expérimentation.



Sujet numéro: _______________ Date: __.02. 2015

Formulaire de consentement

Cher participant,

en signant ce papier, vous acceptez de participer bénévolement à une étude dirigée par l'Université de Durham.

Cochez les cases ci-dessous.

3. Je confirme avoir lu et compris les instructions de cette étude et d’avoir eu la possibilité de poser toutes questions. [ ]

4. Je comprends que la participation est volontaire et que j’ai le droit de quitter cette étude à tout moment et sans donner de raison. [ ]

3. J’ai été informé que les données recueillies seront gardées confidentielles. [ ]

4. J’accepte de participer bénévolement à cette étude. [ ]

Pour toute question, n'hésitez pas à me contacter: diana.wiedemann@durham.ac.uk

____
Signature

DONNEES PERSONNELLES

Notez: Ces informations seront gardées confidentielles. Mettez une croix dans les cases vous correspondant.

1.) Age: ___________ ans

2.) Avez-vous des problèmes de vue?

- ○ Non
- ○ Oui

Si oui, quel problème avez-vous?

- ☐ Myopie
- ☐ Presbytie
- ☐ Daltonisme
- ☐ Autre: ________________________ ________________________

Si oui, portez-vous des aides visuelles pendant l'étude sur l'ordinateur?

- ☐ Lunettes
- ☐ Lentilles de contact
- ☐ Aucun
- ☐ Autre: ________________________ ________________________

3.) Sexe

- ○ Femme
- ○ Homme

4.) Pays de naissance:

____

5.) Appartenance ethnique

- ○ Noir ou Afro Américain
- ○ Blanc
- ○ Asiatique
- ○ Métisse
- ○ Autre
- ○ Ne souhaite pas le dire

6.) Quels chiffres voyez-vous dans les images ci-contre ?

Image 1: ______

Image 2: ______

Image 3: ______

Appendix VI

Biology Letters

Diana Wiedemann[1], D. Michael Burt[2], Russell A. Hill[1], and Robert A. Barton[1]

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Red clothing increases perceived dominance, aggression and anger

Keywords: red, dominance, aggression

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ABSTRACT - The presence and intensity of red colouration correlates with male dominance and testosterone in a variety of animal species, and even artificial red stimuli can influence dominance interactions. In humans, red stimuli are perceived as more threatening and dominant than other colours, and wearing red increases the probability of winning sporting contests. We investigated whether red clothing biases the perception of aggression and dominance outside of competitive settings, and whether red influences decoding of emotional expressions. Participants rated digitally manipulated photos of men for aggression and dominance and categorized the emotional state of these stimuli. Men were rated as more aggressive and more dominant when presented in red than when presented in either blue or grey. The effect on perceived aggression was found for male and female raters, but only male raters were sensitive to red as a signal of dominance. In a categorization test, images were significantly more often categorized as "angry" when presented in the red condition, demonstrating that colour stimuli affect perceptions of emotions. This suggests that the colour red may be a cue used to predict propensity for dominance and aggression in human males.

INTRODUCTION

Red colouration is a sexually selected trait associated with dominance in many animal species (e.g., [1,2]) and appears to have similar associations in humans [3]. Skin redness in humans has been found to correlate with testosterone and fluctuates with emotional state; increasing with anger and decreasing with fear [4,5]. Red therefore appears to carry specific biological signals in both humans and other animals. Artificial stimuli may exploit these evolved responses to natural red signals. In birds, red leg bands enhance access to resources in male zebra finches [6], while rhesus macaques avoid red-wearing human experimenters [7]. In humans, several studies have shown that colour stimuli have similar effects on social perception [8,9] and behaviour such as the outcome of physical and virtual contests (see [10] for review). Being associated with or wearing red is also linked to higher heart rate, a greater pre-performance strength, and higher testosterone levels [11,12]. These effects may be explained by psychological associations of red colouration with dominance and aggression which boost red-wearers confidence and/or intimidate their opponents [13], although the effect may be restricted to males [14].

Targets presented in red are perceived as more aggressive, dominant, brave and also more likely to win a competition [15-17]. However, these experiments primed competitiveness or aggression in subjects by placing them in a competitive situation. To our knowledge, no study has yet investigated the effects of colour on social perceptions of dominance and aggressiveness in neutral settings. It is also unknown whether clothing colour influences attributions of emotional state: if colour is a cue to relative dominance in aggressive situations, red stimuli might be more likely to be categorised as angry. The present study explores how digitally manipulated T-shirt colour influences rapid social judgements of character traits in strangers. We predicted that people presented in a red shirt would be rated as being more aggressive and more dominant and also perceived more often as "angry" than when presented wearing blue or grey.

METHODS

Stimuli were selected from two sources, 14 images of males were taken from a previously published set [18] and six additional images were selected from the internet according to the criteria in that study. Clothing colour was first desaturated and luminance adjusted to mid grey (producing the grey stimulus) using *Micrografx Picture Publisher 10*; the hue and saturation were then adjusted to produce the red and blue coloured stimuli (see Supplementary Material). Previous studies have not considered achromatic stimuli, and the current study design thus allows a more robust assessment of how colour influences social perceptions.

Stimuli were presented under constant lighting conditions on a colour-calibrated computer screen. In a series of 60 randomly ordered trails, N = 100 participants (50 females, 50 males) were presented with the images of 20 males wearing either a red, blue or grey shirt and two 7 point scales: aggression (ranging from 1, extremely aggressive to 7, extremely friendly) and dominance (1, extremely submissive to 7, extremely dominant)[15]; and a selection of emotional states (angry, happy, frightened, or neutral). To facilitate data analysis, variables were coded so that high numbers represented high trait values (e.g., on the aggression scale, 7 = extremely aggressive, 1 = extremely friendly). Data were analyzed using repeated-measures ANOVA

[15] We also asked participants to rate stimuli for perceived "trustworthiness" and "confidence". Figure S3 in the Supplemental Material available online presents findings for these two variables.

with colour as a within-subjects variable. Greenhouse-Geisser correction was applied when sphericity could not be assumed (Mauchly's test for sphericity, $p < .05$).

Whilst previous research on colour perception and its effects in competitive situations has shown that an effect of red colour is more likely to occur amongst men [14], we also investigated whether the rater's sex influenced perceptions in our non-competitive task.

RESULTS

The analysis revealed a main effect of colour for aggression, $F(1.747, 172.934) = 12.101$, $p < .001$, $\eta_p^2 = .109$, and dominance, $F(2, 98) = 5.821$, $p = .004$, $\eta_p^2 = .106$. Bonferroni pairwise comparisons showed that raters judged targets wearing red as more aggressive than when wearing blue ($p = .005$) and grey ($p < .001$), and also more dominant in red than grey ($p = .003$). There was a trend for participants to rate red targets as more dominant than blue targets ($p = .063$). In contrast, there were no significant differences between blue and grey targets on ratings of aggression ($p = .519$) or dominance ($p = .704$). Female participants rated red-wearing targets to be more aggressive than grey-wearing targets ($p = .025$), while male participants judged red-wearing targets to be more aggressive than targets wearing blue ($p = .007$) or grey ($p = .003$, figure 1). For ratings of dominance, colour did not influence female raters' perception, $F(2, 48) = 1.425$, $p = 0.251$, $\eta_p^2 = .056$, but males' ratings were significantly influenced by colour, $F(2, 48) = 6.939$, $p = .002$, $\eta_p^2 = .224$, with targets wearing red being rated more dominant than targets wearing blue ($p = .010$) and grey ($p = .002$). Ratings for targets wearing blue did not differ from those wearing grey ($p > .999$).

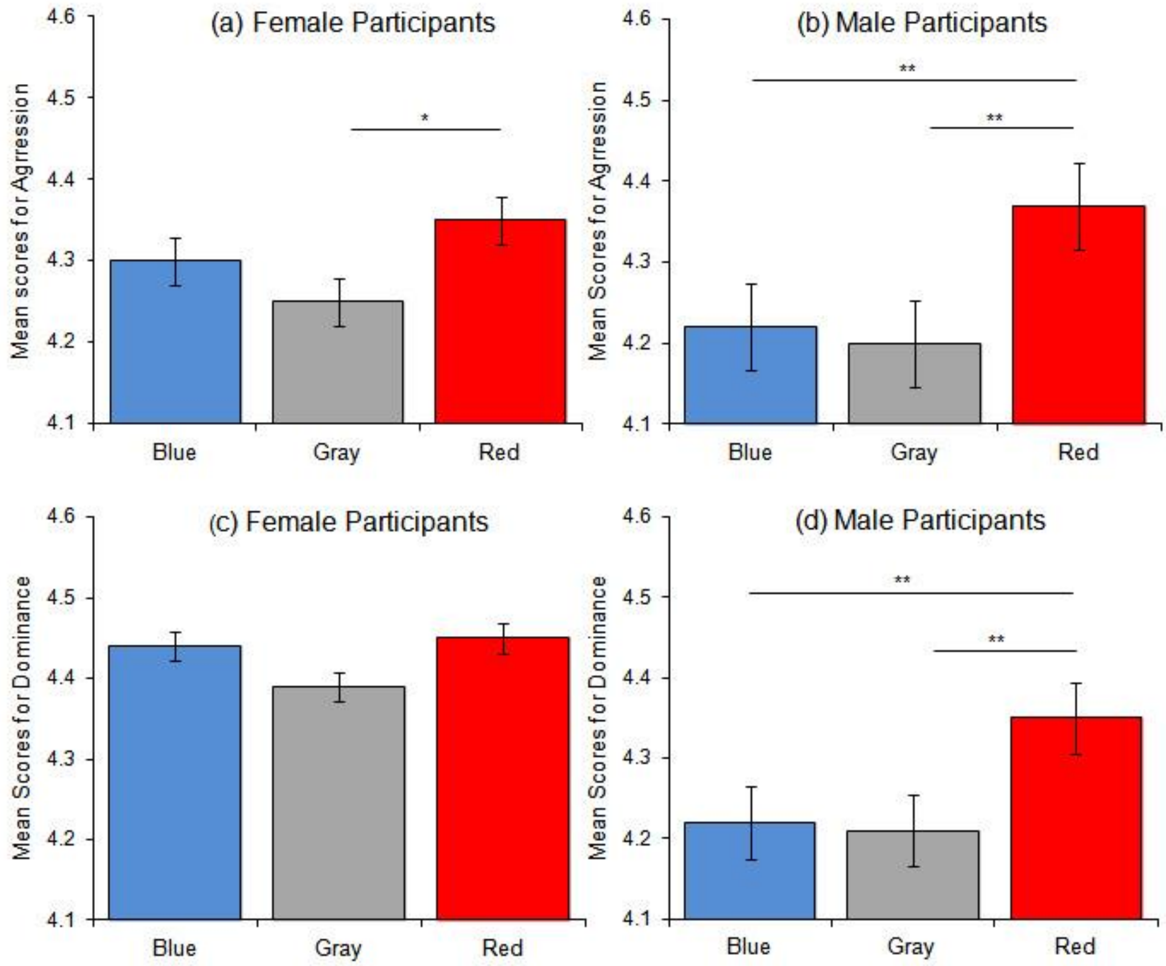

Fig. 1 Mean scores of women [(a)+(c)] and men [(b)+(d)] rating targets wearing three different colours for aggression [(a)+(b)] and dominance [(c)+(d)]; *$p \le .05$, **$p \le .01$. Error bars indicate 95% CIs (online version in colour).

Colour had a significant effect on how often a stimulus was categorized as “angry” (Friedman’s test $\chi^2 = 13.861$, df = 2, $p = .001$; figure 2) but not "happy", "neutral", or "frightened" (all *ps* > 0.25). Wilcoxon signed rank tests for pairwise comparisons showed that a target presented in a red shirt was more often categorized as “angry” than when presented in blue ($Z = -2.685$, $p = .007$) or grey ($Z = -2.896$, $p = .004$), but there was no difference between blue and grey ($p = .203$). Colour significantly affected the perceptions of anger in the stimuli both amongst female ($\chi^2 = 12.471$, df = 2, $p = .002$) and male raters ($\chi^2 = 10.812$, df = 2, $p = .004$).

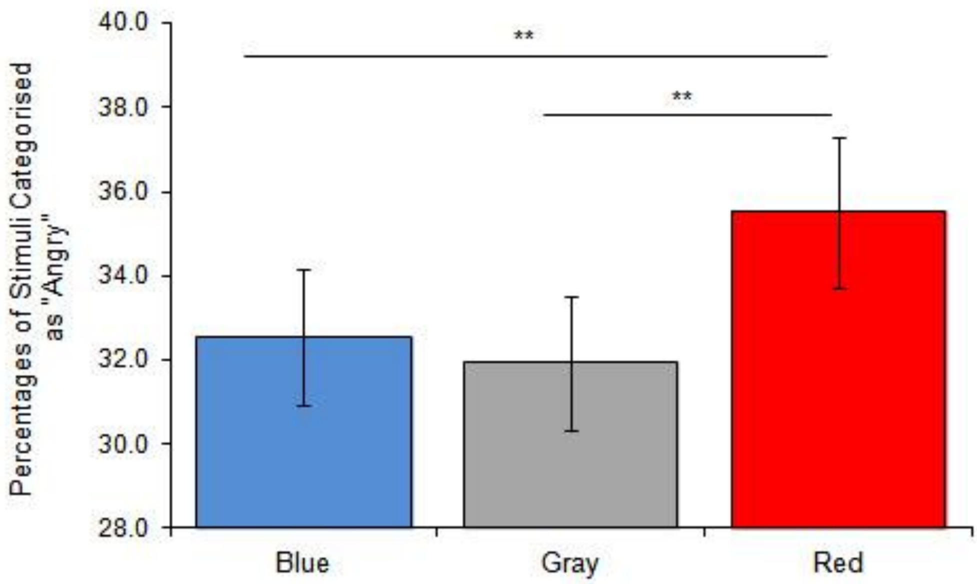

Fig. 2 Percentage of stimuli categorized by each subject as ”angry“ for three colour conditions, **p < .01. Error bars indicate 95% CIs (online version in colour).

DISCUSSION

We found that clothing colour biases the perception of aggression, dominance and anger in strangers, outside of competitive or achievements contexts. Men wearing red were rated as more aggressive and more dominant and were more often categorized as "angry" than targets wearing grey or blue. Clothing colour did not influence female participants’ perception of male dominance but did influence male participants’ perceptions. Whether or not this sex difference reflects different biases in social perceptions requires further investigation. For example, the colour red distorts time perception in men but not in women [19], and wearing red enhanced the probability of winning combat sport bouts in male, but not female, athletes [13,14].

Participants categorized targets significantly more often as “angry” when presented in the red condition. This indicates that colour influences the categorical judgment of emotional expression and, specifically, that red hue is associated with a bias towards angry judgments. Fetterman *et. al.* [20] showed that priming anger concepts (versus sadness) led participants to be more likely to perceive the colour red. Taken together, these findings suggest a clear association between the colour red and perceptions of anger possibly related to the role of facial reddening as a natural signal of anger [21].

While red images resulted in higher ratings for aggression and dominance, ratings for blue and grey images did not differ significantly. Hence, it seems to be specifically red that influences judgements of aggression and dominance. However, black has also been found to influence perception of aggression in athletes [22], and across cultures both black and red have been found to influence scoring of combat sport bouts [23]. In these studies, luminance and chroma were confounded, and it is known that these different dimensions have independent effects on social perceptions [16], and that skin darkness is sexually dimorphic and positively associated with testosterone [24]. Further work is needed to test for and separate out effects of hue and luminance, and to determine whether there is an 'optimal red' related to biological signalling of traits such as aggressiveness and dominance.

An important area for further enquiry is the cross-cultural consistency versus variability in biasing effects of colour. Culture may reflect, reinforce or modify innate biases, or it might be responsible for establishing biases in the first place through arbitrary or coincidental associations. The latter would predict considerable variability in biases. Indeed, cultural variation in colour-emotion associations exist [25]. However, there is also considerable cross-cultural consistency in associations between red and physical dominance [23], anger [25] and danger [26]. An attentional bias towards red versus other colours is present from early infancy, consistent with the idea that innate predispositions may play a role in establishing colour associations [27]. The ontogeny of colour biases in social perceptions would be an interesting area for further study.

Ethics Statement. This experimental protocol was approved by the Department of Anthropology Research Ethics sub-committee at Durham University (Wiedemann, March 2010). We obtained written consent from participants.

Data accessibility. An excel file is included as Electronic Supplementary Material (ESM).

Author Contributions. D.W., D.M.B., R.A.H. and R.A.B. designed the study; D.M.B. developed the stimuli; D.W. ran the study and performed data analysis and interpretation with R.A.H. and R.A.B. D.W, D.M.B, R.A.H and R.A.B wrote the manuscript; all authors approved the final version.

Conflict of interests. The authors declare no competing interests.

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Supplementary Material for

Red clothing increases perceived dominance, aggression and anger

Diana Wiedemann, D. Michael Burt, Russell A. Hill, and Robert A. Barton

Supplementary methods – presentation of stimuli

Each participant saw in random order the head and upper torso of a man wearing either blue, grey or red (see figure S1 for an example in which the target was presented in red and figure S2 for full colour sets of two stimuli). From the 20 stimuli, one half depicted an angry, the other half a neutral facial expression. Participants were asked to provide ratings of trustworthiness, aggression, dominance, and confidence, via mouse click, on a 7-point scale with each paired adjective being at either end of the scale. The paired adjectives which would accompany each individual stimulus were as follows:

(1) "trustworthiness" (1 = extremely trustworthy, 7 = extremely untrustworthy)

(2) "aggression" (1 = extremely aggressive, 7 = extremely friendly)

(3) "dominance" (1 = extremely submissive, 7 = extremely dominant)

(4) "confidence" (1 = extremely confident, 7 = extremely unconfident)

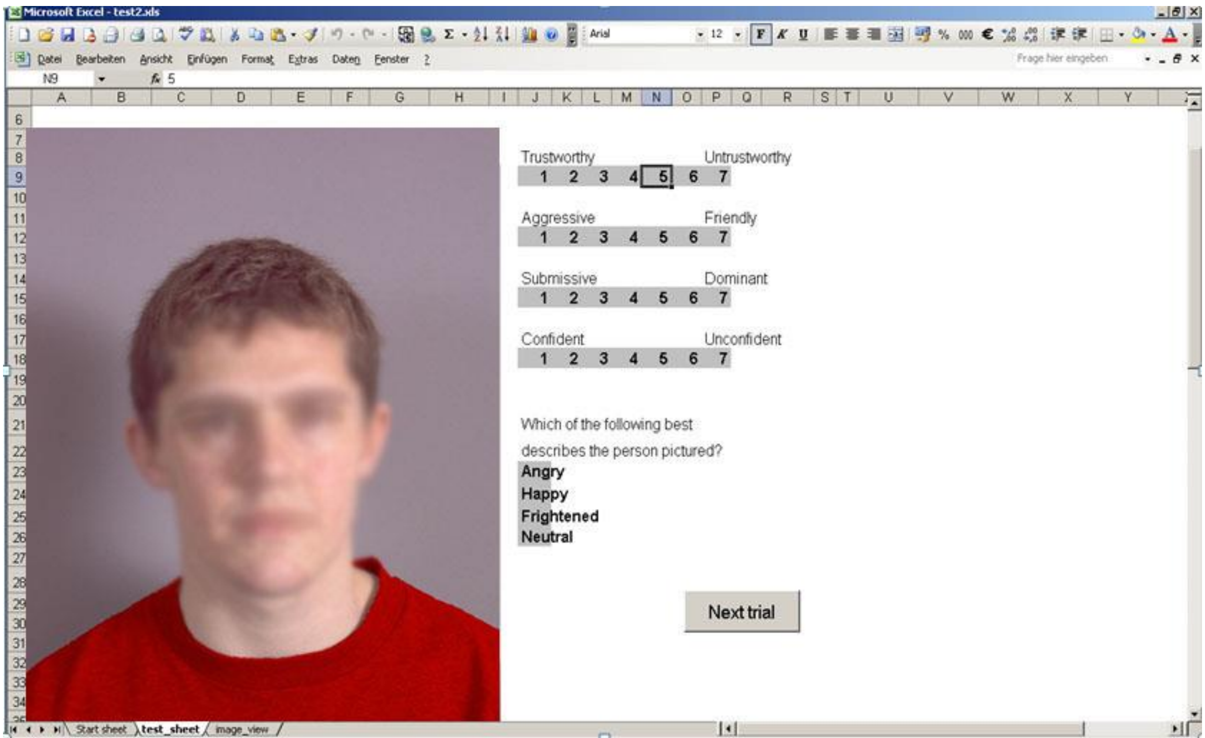

Fig. S1 Screenshot of the original experimental setting[1]

Fig. S2 Example set of two stimuli presented in blue, grey, and red[16]

Supplementary analyses 1: correlations

We calculated mean scores for dominance and aggression for each stimulus in each colour condition (3 sets of 20 ratings on each variable) and then computed bivariate correlations separately for each colour. The results can be found in Table T1. There is a strong correlation between ratings of dominance and aggression. Even though these are conceptually different constructs the correlation indicates that they are not entirely discrete. However, our results show that participants distinguish between these two constructs both across and with gender.

	r	**Sig.**	**N**
Blue	.749**	< .001	20
Grey	.745**	< .001	20
Red	.725**	< .001	20
**Correlation is significant at the 0.01 level (2-tailed).			

Tab. T1 Correlation analysis between scores of dominance and aggression.

[16] Consent has been obtained to publish the images in this Supplementary Material.

Supplementary analysis 2: Dominance scores for stimuli categorised as angry versus non-angry

Results from a one-way ANOVA show that stimuli classified as angry (*N* = 2185, $\tilde{x}$ = 5.27) were rated significantly more dominant than non-angry stimuli (*N* = 3815, $\tilde{x}$ = 3.82), (F (1, 5998) = 1850.6 p < .001). This holds true even if the analysis is carried out for each colour separately (all *F*'s (1, 1998) > 555.78, *ps* < .001). This means that no matter in what colour the targets were displayed, they were rated as more dominant when categorised as angry as when they were categorised as non-angry (neutral, frightened or happy).

Supplementary analyses 3: additional variables

We asked participants to rate stimuli for perceived confidence and trustworthiness, but restricted our main analysis to perceived aggression and dominance as they related directly to our primary research questions. While confidence is a variable quite similar to dominance, trustworthiness served as a control variable for us to investigate whether red colouration just randomly affects any sort of ratings or whether its impact is limited to traits of dominance/aggression.

Variables were coded so that high numbers represented high trait values (7 = extremely trustworthy/confident, 1 = extremely untrustworthy/unconfident). Mean scores awarded by each rater to the twenty images seen in blue, grey, and red were approximately normally distributed (skewness values ranging from -.213 to .096) allowing for parametric statistics.

The analysis revealed a main effect of colour for confidence, $F(2, 98) = 6.924$, $p = .002$, $\eta_p^2 = .124$ (Fig. S3). Pairwise comparisons showed that raters judged targets wearing red as more confident than when wearing grey (*p* = .001) but not when wearing blue (*p* = .208). Results between blue and grey-wearing targets revealed no significant difference for ratings of confidence (*p* = .077), consistent with the results in our paper. For the variable trustworthiness, which is unrelated to dominance, there was no main effect of colour $F(2, 98) = 1.095$, $p = .339$, $\eta_p^2 = .022$. Bonferroni pairwise comparison confirmed that red-wearers were not rated differently to blue-wearers (*p* = .664) or grey-wearers (*p* = .486), neither did ratings for blue and grey-wearers differ (p > .999).

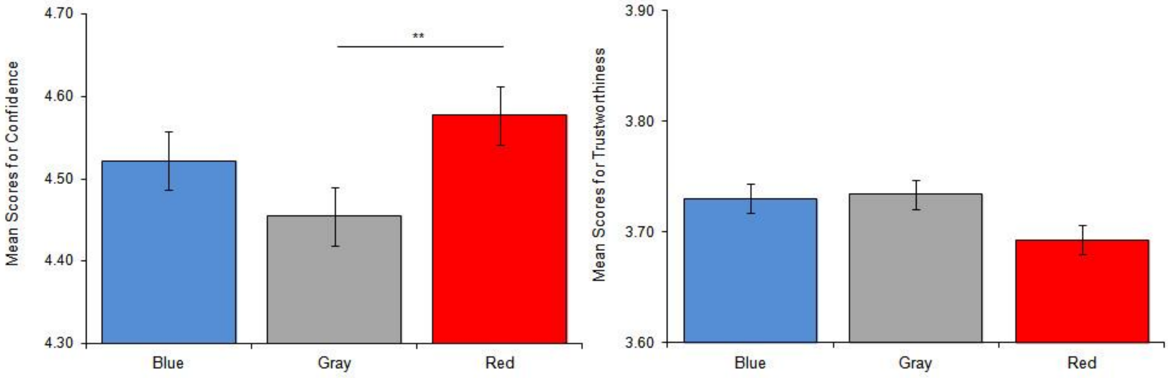

Fig. S3 Mean scores of judges rating targets wearing three different colours for confidence and trustworthiness, $**p \leq .01$. Error bars indicate 95% CIs.

Appendix VII –

Oxfor University Press Book Chapter:

Wiedemann, D., Barton, R.A. and Hill, R.A. (2012). Evolutionary approaches to sport. In: Roberts, S.C. (ed.) *Applied Evolutionary Psychology*. Oxford: Oxford University Press.

Evolutionary Perspectives on Sport and Competition

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Abstract:
"Evolutionary perspectives on sport and competition" examines the theoretical and empirical research into evolutionary aspects of four complex issues of human behaviour in sports. We highlight how evolutionary approaches have promoted our understanding of human sports and competition. To begin with, we describe the relationship between sports competitions and testosterone levels and elucidate how winning and losing leads to different, sometimes status-changing, endocrine responses. Secondly, we look at 'home advantage' and examine how hormonal and psychological research has aided our understanding of this well known phenomenon. The next section focuses on possible evolutionary explanations as to why left-handers may have an advantage in physical combat in both traditional and westernized societies. The final section examines colour influences on human behaviour in general and on sports competition in particular, focusing specifically on the significance of the colour red in human competitive interactions. These four themes serve to highlight the value of evolutionary approaches in enhancing and enriching our understanding of human sports competitions.

Key words: competition, testosterone, home advantage, handedness, aggression, red, dominance signalling, colour perception, performance, sports

Introduction

Sports are ubiquitous in human cultures and are valued as a form of physical competition (Chick and Loy 2001; Llaurens *et al.* 2009b). At the same time, watching sport is a pastime that captivates viewers across the world, with major sporting events such as the FIFA World Cup or Olympic Games attracting audiences of hundreds of millions, both as live spectators, and as television, internet and radio viewers or listeners. The worldwide appeal of sports such as football has led economists and psychologists to devote an increasing body of research to this global phenomenon (Kocher and Sutter 2010). Recently, there has also been a dramatic increase in research examining sport from an evolutionary perspective.

The aim of this chapter is to describe theoretical and empirical research into evolutionary aspects of human behaviour in sports to illustrate how evolutionary insights have been applied and enriched our understanding of human sports and competition, and to point to promising ideas for further study. We focus on four issues that have received recent attention. First, we describe the relationship between testosterone levels and sporting outcomes and how they play an important role in the phenomenon of home advantage. Second, we explore the issue of home advantage and its psychological and hormonal mediators in more detail. Third, we elucidate possible explanations for why left-handedness may be advantageous in physical combats in westernized but also traditional societies. Finally, we describe and assess influences of colour on human and animal agonistic behaviour.

Testosterone and Human Competition

Androgens are hormones involved in human male competition, antisocial norm breaking, dominant and aggressive behaviour (Elias 1981; Mazur and Booth 1998; Susman *et al.* 1987). The androgen testosterone is a steroid hormone responsible for the development and maintenance of masculine features but it is also found, in lesser amounts (in most species), in females. Various studies of nonhuman primates have shown that a male's status and testosterone levels are linked: elevated testosterone levels are recorded when males achieve high rank or status, but decline again when status is lost (Eberhardt *et al.* 1980; McGuire *et al.* 1986; Setchell *et al.* 2008). Similar effects can be found in human competitions as sporting winners gain more status than losers (Mazur and Booth 1998) and research suggests that males achieving high status are likely to have increased testosterone levels as a result (Mazur and Lamb 1980). Higher testosterone levels have been associated with offensive behaviour such as attacks, fights, and threats in male judo competitors (Salvador *et al.* 1999) and winning tennis players have also been reported to have increased testosterone levels (Booth *et al.* 1989; Mazur and Lamb 1980). Male basketball players were found to have higher testosterone levels the more their individual contribution to the team outcome (Gonzalez-Bono *et al.* 1999) suggesting that this is a highly consistent relationship. Nevertheless, establishing the direction of causality requires clarification.

Although the relationship between human aggression and testosterone levels is still under debate (Archer 1991), Mazur and Booth (1998) concluded that competitiveness and dominance in humans appear to be linked to testosterone and that testosterone encourages "behavior apparently intended to dominate – to enhance one's status over – other people". Intriguingly, if a sportsman anticipates a competitive event as being a real challenge, his testosterone levels rise directly before competition and if he wins, his testosterone rises after competition relative to the loser's testosterone level (Elias 1981; Mazur and Lamb 1980). The function of such changes in testosterone levels remains unclear, but Mazur and Booth (1998) suggested that high testosterone in winners may prepare them to engage in subsequent competitions and that the decrease in testosterone among losers may prevent them from injury as they withdraw from following challenges. Mehta and Joseph (2006) showed that a male's decision on whether to go back into a game having lost a one-on-one competition against another man can be predicted by the direction of change in his testosterone level. Although this was not a competitive sports setting, the same is likely to apply to physical competition. Indeed, Archer (2006) illustrated that sports competitions lead to larger increases in T than contrived competitions.

Animal studies give us some information about the function of testosterone. In his review of primate data, Dixson (1980) found that almost all studies linked testosterone to aggression. Mazur and Booth (1998) lay emphasis on the distinction between aggressive behaviour (the intention is to inflict physical injury) and dominant behaviour (the intention is to achieve/maintain high status). Mazur (1985) suggested regarding aggression as one form of dominance behaviour. Hence, the manifestation of aggressive behaviour might be motivated by dominance behaviour in animals as a result of the influence of testosterone, but humans may express aggressive behaviour due to the influence of testosterone on dominance in less obvious, more subtle, and also various ways.

Studies on hormones and competition in humans have mostly focused on male athletes. Limited evidence suggests that women are generally unresponsive to the effect of competition on testosterone (Booth and Dabbs 1995; Mazur *et al.* 1995). However, Bateup *et al.* (2002) indicated that women's testosterone levels are as responsive to competition as those of men. DeBoer (2004) argues that the motivation for competition differs with gender: women are motivated to express themselves and men are motivated to prove themselves. More evidence is required, but provisionally it appears that the relationship between testosterone and aggression is different in men and women (Archer 2006).

Other factors, such as a competitor's mood (Booth *et al.* 1989), coping strategies, and state and trait psychological factors (Filaire *et al.* 2001) may also be important and should not be neglected when endocrine responses of competitors are studied. Similarly, behaviour influences hormones as well as the other way around, so causal inferences cannot easily be made from correlations (Kivlighan *et al.* 2005). Studying hormones in humans is also challenging as ethical limitations make it difficult to manipulate hormones and measure aggressive behaviour. Overall, therefore, while it is clear that hormonal responses have an important role to play in sporting contests the situation is complex and psychological, biological and anthropological elements must all be taken into account when assessing the role of endocrine responses in competition.

Home Advantage

It is common knowledge that teams have a greater chance of winning whenever the match takes place at their home venue, and this general perception is supported by statistical analyses (Pollard and Gomez, 2009). The received wisdom suggests that the home fans are tantamount to an extra player on the field, with the visitors having to cope with the home fans' hostility and inimical shouting, chanting and singing. The visiting team may also have made a long journey to reach the venue, possibly with a night in an unfamiliar hotel, while the hosts remain at home and follow their familiar routines. The combined effect is thought to give the home team the edge in the game.

The fact that game location affects sports success is a well documented phenomenon and the consistently better performance by teams playing at home is referred to as the 'home advantage' (Neave and Wolfson 2003; Pollard and Gomez 2009). Nevertheless, despite being a robust phenomenon, home advantage varies season by season, from region to region, across divisions, and from sport to sport. Indeed, levels of home advantage appear highest in the early years of each league's existence in all sports (Pollard and Pollard 2005b; Pollard and Gomez, 2009). Interestingly, declines in home advantage have been reported over the last two decades in, ice-hockey and basketball, as well as a large drop from 67% to 60% in English football after the Second World War (Pollard and Pollard 2005b).

Crowd support, in both team sports (Nevill *et al.* 1996; Schwartz and Barsky 1977) and individual sports (Balmer *et al.* 2005), travel fatigue and geographical distance (Clarke and Norman 1995; Pollard 2006b), familiarity with the pitch (Pollard 2002) and referee bias (Dawson *et al.* 2007; Nevill *et al.* 2002) are clearly all fruitful explanations for the robust home advantage phenomenon. However, none of them has been proved to have a very strong effect alone. Indeed, in their review of home advantage in football, Pollard and Pollard (2005a) proposed a model demonstrating that the interacting effects of various psychological factors and tactics, rather than any single cause, led to home advantage. In the same study, Pollard and Pollard (2005a) noted that levels of home advantage were very variable across European domestic football leagues, with Balkan nations (78.95%) showing a much higher home advantage than elsewhere. The authors suggested that the territoriality principle of Neave and Wolfson (2003) was likely to be a good reason for high home advantage numbers in regions like the Balkans where considerable conflict is part of each country's recent history.

Neave and Wolfson (2003) explored the relationship between testosterone, dominance, and territoriality in human competitive encounters. The authors define territoriality as 'the protective response to an invasion of one's perceived territory', which is also prevalent in various animal species giving a resident animal a "home advantage" when its territory is threatened or attacked (Alcock 1998). Intruders trigger territorial aggression and a rise in circulating levels of testosterone in occupying animals (Wingield and Wada 1989). Intriguingly, similar effects are found in humans: a footballer's salivary testosterone concentration is significantly higher when playing at home than before away games, and this effect is further increased when the opponent was an ‘extreme’ rival (Figure 1) (Neave and Wolfson 2003). Strikers (specialist goal-scorers) had the highest testosterone levels, while goalkeepers had the highest testosterone concentrations when playing against a bitter rival despite having the lowest levels in training sessions. Even though samples size were small and further investigation is required, Neave and Wolfson (2003) argued that goalkeepers, as the last defending line in a team, might be particularly inclined to testosterone changes when facing an important opponent. They conclude that their results suggest that testosterone, a hormone associated with aggression and territoriality in humans (Mazur and Booth 1998) and nonhuman animals (Nelson 2001), plays a mediating role in the differential performances of teams when playing away or at home. Nevertheless, the ways in which testosterone is able to improve home player performance remain obscure although likely explanations relate to increases in motivation, confidence, reaction times, information processing, and physiological potential (Neave and O’Connor 2009).

Knowledge of the potential hormonal basis of home advantage offers up a series of avenues for future research. Pollard (2006a) states that the direct analysis of hormone concentrations in players from Balkan countries could deliver fruitful insights into the high levels of home advantage it this region. Neave and O’Connor (2009) highlight the need to determine “how individual differences in testosterone might relate to performance during a game, and whether it is possible to (legally) manipulate testosterone to improve team performance when playing away”. Additionally, it would be interesting to test for “leader effects”, since a team’s captain or coach may also show additional testosterone changes; indeed winning has been shown to lead to increased testosterone levels even in fans (Bernhardt *et al.* 1998). Conversely, it might be possible to discover ways of mitigating loser effects mediated by testosterone reductions. Cortisol levels (which measure stress responses: Sapolsky *et al*. 2000) could also be a promising avenue for further research on territoriality with both male and female athletes. Overall, examining the endocrine responses associated with home advantage has opened up an exciting range of opportunities for future research that could greatly enhance our understanding of the complex inter-relationships of factors explaining home advantage and success in sports.

While the precise hormonally-mediated mechanisms remain elusive, home advantage is nevertheless a robust phenomenon. Knowing that home advantage can have such a major influence on sports outcomes, it is crucial for sports teams, their coaches and psychologists to prepare for, minimize and in the best case counteract these effects when walking into an unfamiliar stadium. Wolfson and Neave (2004) discuss potential strategies, emphasizing the importance of discipline, concentration, mental preparation and the establishment of rituals. At the same time, future research may identify 'legal' ways of raising testosterone levels through behavioural means (Neave and O'Connor 2010). As a consequence, while home advantage remains a robust and widespread phenomenon, its effects seem far from insurmountable. Recent decades have seen a decline in the magnitude of home advantage across a range of sports (Pollard and Pollard 2005b) and future research has the potential to increase the speed of this downwards trajectory.

Handedness

The list of famous left-handers extends to all walks of life, including leading scientists such as Albert Einstein, Marie Curie and Isaac Newton, artists such as Michelangelo and Leonardo da Vinci, and politicians such as David Cameron, Winston Churchill, Barack Obama, Bill Clinton and Benjamin Franklin; indeed five of the last seven US presidents are reported to be left handed. It is amongst sportswomen and sportsmen, however, that left-handedness appears especially common, with a high representation amongst athletes considered amongst the greatest ever in their sport: baseball: Babe Ruth; cricket: Garfield Sobers; football: Pelé, Diego Maradona, Johan Cruyff; swimming: Mark Spitz; and tennis: John McEnroe, Martina Navratilova. To what extent is such anecdotal evidence supported by more systematic analysis?

Though frequencies of sinistrality (left-handedness) vary across human cultures and can range between 3.3% and 26.9% (Faurie *et al.* 2005b), a consistent minority (10-13%) of individuals in all human populations is left-handed (Raymond *et al.* 1996; Raymond and Pontier 2004). Such frequencies have a long history, and have existed since at least the Upper Palaeolithic (Faurie and Raymond 2004), and similar patterns are also reported for chimpanzees (Hopkins 1993, McGrew and Marchant 1999). It has therefore been suggested that some sort of evolutionary mechanism must be involved in the persistence of this polymorphism (Llaurens *et al.* 2009a).

While left-handers are overrepresented in interactive forms of sports such as fencing (50%), table tennis (32%), badminton (23%), cricket (18.5%), and tennis (15%) (Aggleton and Wood 1990, Bisiacchi *et al.* 1985; Coren 1993; Goldstein and Young 1996; Raymond *et al.* 1996), sports without dual confrontations or direct opponents such as swimming (Raymond *et al.* 1996), skiing, cycling or gymnastics (Grouios *et al.* 2000) show no such bias (Figure 2). Furthermore, the smaller the physical distance between opponents (such as in combat sports like karate and judo), the higher the frequency of left-handed individuals (Grouios *et al.* 2000). For many sports, the advantages of left-handedness have been long recognised (Hagemann 2009; Harris 2010), and in some sports left-handed players are thought to hit with greater power (cricket: Brooks *et al.* 2004; baseball: Grondin *et al.* 1999). These effects are not confined to elite athletes; expert, intermediate and novice tennis players all find it more difficult to predict the direction of strokes by left-handers than those of non-left-handers (Hagemann 2009). Being left-handed, therefore, appears to be advantageous in interactive sports.

The role of left-handedness and laterality in sports has attracted interest from researchers from sports psychology, neuropsychology, kinesiology, as well as evolutionary psychology, biology, and anthropology (Aggleton and Wood 1990; Annett 1985; Faurie *et al.* 2005b, Porac and Coren 1981). In the context of sport, a simple reason why the minority of left-handers have an advantage has been termed the surprise-effect (Coren 1993; Faurie and Raymond 2005). Since the majority of sportspeople are right-handed, right-handers are more accustomed to competing against opponents favouring the same side. As a consequence, when they encounter a left-handed opponent, who already has the advantage of being practiced to compete in a mostly right-handed world, right-handers find themselves at a disadvantage. Left-handers thus have a frequency-dependant advantage (Goldstein and Young 1996; Brooks *et al.* 2004).

Such effects are not restricted to ritualised Western sports, and left-handers are more frequent in most warlike and violent societies (Raymond *et al.* 1996, Faurie and Raymond 2005). Indeed, the “fighting hypothesis” (Raymond *et al.* 1996, Faurie and Raymond 2005) suggests that left-handers thrive in traditional societies with high levels of violence because of the inherent advantages of left-handedness in these aggressive interactions. Across a range of societies, the frequency of left-handedness correlates positively with homicide rates (Figure 3). For instance, in the Dioula population of Burkina Faso, murder rates are as low as 0.013

murders per 1,000 residents per year, and there are only 3.4% left-handers within the population. In contrast, 27% of the Eipo of Irian Jaya are left handed and three out of 1,000 inhabitants are murdered each year in this society. One possible interpretation is that, in confrontations where death and injuries are likely, left-handedness confers a competitive advantage. It is not, however, currently possible to exclude alternative hypotheses, such as a causal relationship between androgens and both handedness (e.g., Sperling *et al.* 2010; Mathews *et al.*, 2004) and homicide rates (Dabbs *et al*. 2001).

Various environmental and developmental components have been identified to play a role in hand preference determinism (reviewed by Llaurens *et al.* 2009a), while genetics may also play a substantial role (Annett 1985; McManus 1991; Sicotte 1999; Francks *et al.* 2002). Left-handedness may be triggered by various factors associated with the in utero environment, pre-natal androgens, maternal age, birth weight, birth stress or birth trauma (see review Llaurens *et al.* 2009a).

In order to understand left-handedness, it is sensible to investigate why a predominance of right-handedness may have evolved in humans. Various evolutionary hypotheses have been put forward, such as the development of language in the left hemisphere (Annett 1985). It has been suggested that an 'impairment' of the right hemisphere (thus, a possible negative influence on skilled performances such as fast reactions, fine control with both hands, and visuo-spatial thinking) may in some cases result in the left hemisphere language specialization that can be found in nearly all right-handers (Annett, 1985). Right-handedness is also suggested to have evolved in association with the one-handed throwing ability and its associated cognitive, motor and postural demands as a possible pre-adaptation for the emergence of left hemisphere specialization in language and motor skills (Calvin 1982; Hopkins *et al.* 2005). Furthermore, infant handling on the left side permitting a caregiver to move freely on the right side for other purposes is another theory (Hopkins *et al.* 1993) as to why right-handedness has evolved. However, Raymond *et al.* (1996) and Grouios *et al.* (2000) emphasize that none of these hypotheses has been advanced to explain the ongoing existence and persistence of left-handers.

Outside of sports and competition, left-handedness is often reported to correlate with advantages, in cognitive tasks and socio-economic status (see review Faurie *et al.* 2008), creativity (Coren 1995; Newland 1981) or in the existence of a larger *corpus callosum*

(Witelson 1985). Better spatial and visual skills due to relatively larger right hemispheric brain regions are another suggestion as to why left-handers might have an advantage (Geschwind and Galaburda 1985). Cherubin and Brinkman (2006) asked participants to spot matching letters across their left and right visual fields and results show that extreme left-handed subjects were up to 43 milliseconds faster. It seems that left-handers are more bicerebral and that the transfer time between hemispheres is faster in left-handed than in right-handed persons (Cherbuin and Brinkman 2006).

If left-handers have a fitness advantage in a variety of situations, why are they not more common? What are the costs that maintain left-handedness at low frequencies within most populations? Left-handedness is associated with several fitness costs including a lower height in adulthood, a lower weight, a higher age at puberty, a lower life expectancy, diverse immune and neurological disorders, and an elevated accident risk (Aggleton *et al.* 1993; Coren 1989b, Coren and Halpern 1991; Gangestad and Yeo 1997; McManus and Bryden 1991; Olivier 1978), though some contradictory evidence exists specifically for reduced longevity (e.g., Wood 1988). Smaller size and weight (Olivier 1978) have obvious potential fitness costs for left-handers, particularly in relation to a male's reproductive value (Mueller and Mazur 2001; Pawlowski *et al.* 2000). Right-handers also have advantages for some life-history traits, such as number of offspring, which is lower in left-handers (Faurie *et al.* 2006; Gangestad and Yeo 1994). The fitness costs of left-handedness thus appear to limit its frequency in most societies, and provide strong support for adopting an evolutionary approach in addressing the role of laterality in sporting contexts.

Evolutionary accounts also help to explain the higher prevalence rates of left-handers found amongst men (Annett 1985). Following from the fighting hypothesis (Raymond *et al.* 1996, Faurie and Raymond 2005), the importance that survival in violent fights has on men's reproductive value and social status (Hill 1984; Chagnon 1988) may directly increase the winners own fecundity. The Yanomamö offer one such example as warfare involves kidnapping females (Gibbons 1993) and left-handers may gain an advantage as their surviving offspring would pass on their genes. Interestingly, however, a child is more likely to become left-handed when its mother is left-handed (McManus 1991; Porac and Coren 1981). One explanation for the maintenance of left-handed women in human populations is that they may benefit indirectly from their left-handed sons (Billard *et al*. 2005). Indeed, both male and female student athletes have been found to have more sexual partners than their non-sportive counterparts, and this effect is further elevated in high performance athletes (Faurie *et al.* 2004). Given the disproportionate prevalence of left-handed athletes, their sexual success may help to maintain the handedness polymorphism in contemporary societies, although this remains to be tested.

Left-handers are more frequent in traditional societies with high levels of violence and warfare due to the inherent advantages of left-handedness in these aggressive interactions. Similar arguments provide a compelling evidence for the advantage of left-handed athletes in interactive sports, with the frequency-dependent benefits of sinistrality leading to elevated frequency of left-handers in many sports. Although quantifying the costs and benefits of laterality remains challenging, it is clear that an evolutionary perspective offers unique insights into the role of handedness in sporting competition. Nevertheless, the evolutionary perspective offers few solutions to right-handed athletes; as long as left-handers remain comparatively rare they will retain their frequency-dependant advantage in competitive and sporting interactions.

Colour Influences in Sports

Having won 15 German Cups and 22 German Championships, F.C. Bayern Munich is by far the most successful German football club. Liverpool and Manchester United dominate the roll call of English domestic honours, while Ajax is the Netherlands' most decorated team. These successful teams are also united by a second characteristic; all have red as the primary colour on their signature football strip. Although this could easily be construed as pure coincidence, recent evidence suggests that clothing colour may play an important role in deciding sporting contests.

Two decades ago, Frank and Gilovich (1988) analysed penalty records of the National Hockey League (NHL) and the National Football League (NFL) and showed a bias in the referee's judgement of black sports attire. In both sports, teams playing in non-black uniforms were penalized significantly less often than their opponents in black uniforms. The data also revealed that a team's switch from non-black to black sportswear was followed by a rise in penalties; whereas the change of a team's colour from, for example, blue-and-gold to red-and-green uniforms did not coincide with an increase in penalty minutes in the NHL. Although, the authors could not find any difference in the likelihood of winning or losing a game when playing in black versus non-black uniforms, the study did indicate that the colour of attire can influence sporting contests.

The first evidence that colour might influence the outcome of sporting events was provided by Hill and Barton (2005) based on an analysis of four combat sports (boxing, taekwondo, freestyle wrestling and Graeco-Roman wrestling) at the 2004 Olympic Games in Athens, Greece. During this competition, red or blue uniforms were randomly assigned to competitors, providing a natural experiment. If colour had no effect on outcomes, an equal number of red and blue winners would be anticipated. Instead, Hill and Barton (2005) found that wearing red was associated with a significantly increased probability of winning with 55% of all bouts won by competitors in red (Figure 4a). Wearing red appeared to tip the balance between winning and losing in close contests: significant effects were found when competitors were closely matched (60% red winners), but not in more asymmetric encounters (Figure 4b). Interestingly, no such winning bias due to colour effects was found in judo contests when opponents were dressed in either blue or white (Dijkstra and Preenen 2008). This suggests that while factors such as skill and ability will inevitably have the greatest say in determining sporting outcomes, the subtle effects of red colouration may decide contests where competitors are evenly matched.

Recently, a series of studies have provided substantial support for the role of colour in determining sporting outcomes. A review of English football data found an association between teams wearing red shirts and long-term success (Attrill *et al.* 2008). Since the Second World War, red teams have provided more champions and averaged higher finishing league positions than teams in other colours. Most significantly, within cities with more than one team, red teams have significantly outperformed their non-red neighbours over the 55 year period (Attrill *et al*. 2008). Similar findings by Hill and Barton (2005) showed that teams at the Euro 2004 appeared to have significantly better results when they were playing in their red shirts. Greenlees *et al.* (2010) found that penalty takers were the least successful when they were opposed to a goalkeeper wearing red, supporting Greenlees *et al.*'s (2008) earlier finding that penalty takers in red shirts are perceived to possess character traits such as confidence, assertiveness and composure to a greater extent than those in white shirts. A growing body of evidence thus suggests that the colour red may play a significant role in deciding sporting contests, although these relationships may be confined to male competitors (Barton and Hill 2005).

Such effects also appear to operate in virtual contests. Ilie *et. al* (2008) examined advanced and experienced players in a first-person-shooter online computer game. Despite reflecting competition in an artificial computer-generated environment their results showed striking parallels to Hill and Barton (2005). Within the game individuals joined either the red or blue team, and despite better players showing no preference for either colour the red teams triumphed in significantly more (55%) of all matches.

Why should wearing red enhance performance in human contests? One possibility relates to the biological and cultural associations between red and anger, aggression and danger. On one hand, red’s signalling presence in traffic lights and stop signs reminds us to halt. On the other hand, red hearts and lingerie stand for romantic, passionate attraction and can even signal sexual opportunities, such as in red-light districts (Mahnke 1996; Kaya and Epps 2004). It is thus not surprising that women regard men as being sexually desirable and more attractive when they were presented in red clothing or on a red background (Elliot *et al.* 2010). Emotional states associated to red identify it as the colour of aggression, passion, anger, energy and danger (Greenfield 2005). Encountering red in various ways causes ambiguous feelings in humans as positive and negative emotions are associated with the colour red. As humans, we get impressions like red being intense and bloody, but also warm and passionate (Kaya and Epps, 2004). Compared to that, black seems to be very definite and relates to death, badness and evil in almost all cultures (Williams and McMurty, 1970). Still, one would assume that different colours have various meanings in different societies and cultures. Surprisingly, despite cross-cultural differences in colour meanings, similarities in emotional states associated to colours were found. Adams and Osgood (1973) carried out survey in 23 different cultures and postulated an affective salience of the colour red. Mostly, red is perceived as active and black as passive. However, both colours are considered to be strong. This could explain why athletes’ performances are impaired as an opponent dressed in red may be perceived as particularly active. It could, however, also mean that just the simple fact of being dressed in red creates some sort of higher motivation/more activity in the wearer.

Darwin (1876) noticed that primate males use colouration for attracting females and displaying dominance. Subsequent studies of primates provide support for the significance of red. Recent evidence has found an adaptive link between primate trichromatic vision and their ability to distinguish mood differences due to redness in skin flushing (Changizi *et al.* 2006). The intensity of red colouration in rhesus macaques (*Macaca mulatta*) and mandrills (*Mandrillus sphinx*) offers a cue to male quality and status (Waitt *et al.* 2003; Setchell and Dixson 2001b) and female rhesus macaques looked longer at images of redder males (Waitt *et al.* 2003). However, it is in male-male competition that the role of red is most pronounced. In mandrills, male red colouration on rump, face and genitalia depends on their testosterone-levels (Setchell and Dixson 2001b) and Setchell and Wickings (2005) concluded that mandrills assess a rival's fighting ability and dominance rank based on their brightness of the rival’s red colouration. In fact, red colouration is associated with dominance and aggression in a wide range of taxa and may be a signal of intimidation to rivals (Tinbergen 1955; Pryke 2009).

In humans, skin redness is not such a pronounced signal. However, males tend to be redder than females (Edwards and Duntley 1939, in Ioan *et al.* 2007), and facial redness correlates with testosterone levels (Edwards *et al.*, 1941), so may indicate high status and thus dominance. Redness due to oxygenated (redder) blood is a signal of increased aerobic fitness (Armstrong and Welsman 2001, in Stephen *et al.* 2009a; 2009b), whereas paler skin (reduced redness), can signal anaemia (Jeghers 1944) and can be caused by reduced levels of testosterone (Ferrucci *et al.*, 2006). While blushing is a sign of social discomfort in situations of shame or embarrassment (Drummond and Quah 2001; Montoya *et al.* 2005), red skin colouration is also associated with anger and dominance (Drummond and Quah 2001) whereas blanching is associated with submissiveness, fright and fear (Montoya *et al.* 2005; Changizi *et al.* 2006). Indeed, humans interpret skin blood colouration as an honest cue to underlying health (Stephen *et al.* 2009a) and a “ruddy” face is often associated with healthiness. The perception of redder skin as healthier has been found cross-culturally in both Caucasians and black South Africans (Stephen *et al.* 2009a).

Hence, there is evidence for both humans and nonhuman species, that red colouration signals both biological traits (health, testosterone and dominance) and emotional states (anger/arousal). It is also known that, in animals, artificial colours can exploit innate responses to natural stimuli. Cuthill *et al.* (1997) found that, when red and green leg bands were placed on the legs of male zebra finches (a species in which beak redness signals condition), red-banded males dominated green-banded males. Possibly, then, the effects of clothing colour in sporting contests in humans reflects a similar response based on the biological significance of natural skin redness.

What are the underlying mechanisms of these effects? Barton and Hill (2005) suggested the impact of colour might operate through hormonal influences such that wearing red may elevate testosterone levels in the wearer and/or reduce them in the opponent. So far only a small pilot study has examined this possibility and while the sample size was too small for rigorous statistical analysis, there was qualitative support for red athletes experiencing elevated testosterone levels (Hackney 2006 – but note that Hackney interpreted the non-significant result as contradicting the hypothesis rather than due to lower statistical power). Further research is clearly required to assess the psychological and hormonal effects of wearing red, although a growing body of evidence is showing pronounced effects on the receivers of the stimulus.

Negative effects of perceiving (as opposed to wearing) red, are now well documented. In an ingenious experiment, Hagemann *et al.* (2008) noted a perceptual bias in decisions taken by professional taekwondo referees in response to competitor colour. Hagemann *et al.* (2008) digitally manipulated video footage to reverse the competitor colours and found that the referees evaluated the identical performances of the taekwondo competitors differentially according to whether they were wearing blue or red protective gear. In the original video footage, the red competitors scored more points, but with the colours reversed, the original blue competitor, now shown is red, was scored more highly. The results provide compelling support for the association between red and dominance influencing perceptions of sporting success.

Sportsmen could thus be distracted by a "threatening stimuli" such as the colour red, even if they are not aware of this fact (Elliot and Niesta 2008). Ioan *et al.* (2007) found that "seeing red" was a particular distractor for men in competitive situations; specifically, men seemed to experience more interferences than women when they were asked to name the colour red in the Stroop test (e.g., reading the word "blue" written in red). These findings support Hill and Barton's (2005) view that red colour may act as a distractor for men through a psychological effect that evolved in response to sexual competition. Similar results were reported by Little and Hill (2007) who showed that, in a study of perceptions of abstract shapes, red dominated the colour blue but the social perception of these colours again differed with gender. Mehta and Zhu (2009) also reported a significant difference in avoidance motivation of red compared with blue conditions in cognitive tasks but, at the same time, red enhanced performance in detail-oriented tasks. Elliot *et al.* (2007) and others (Kwallek *et al.*, 1997; Stone and English, 1998) showed that longer wavelengths in colours, such as red and orange degraded task performance and appeared to arouse, while short presentations of red have been found to significantly reduce motivation (Elliot *et al.* 2010). This reduced motivation can even go so far that participants would knock fewer times on a door when briefly shown a red cover sheet for a test relative to participants shown a green one (Elliot *et al.* 2010). The subtle effects of colour on performance may this be significant.

Colour thus appear to play a small but significant role in deciding sporting contests, with an increasing number of studies reporting the red advantage across a range of data sets. The results appear to reflect the evolutionary and cultural associations of red with dominance and aggression and raise a number of significant implications. In particular, one repercussion of these findings is that colour represents a significant obstacle to ensuring a level playing field in sport and suggest that governing bodies should play close attention to the colour of sporting attire. Recent analyses (Dijkstra and Preenen 2008) have shown that in judo, where competitors are assigned either blue or white outfits for each bout, there are no systematic colour biases in sporting outcomes. These results provide an easy solution to the influence of colour in many combat sports where a simple change of colours could reinstate the level playing field. The situation is more challenging in team sports, however, since signature shirt colours often have a long history as well as enormous commercial value. Nevertheless, provided sporting associations are aware of the potential significance of colour in determining sporting success then individual teams can make their own informed assessments of the relative importance of sporting and commercial success. While this may inevitably bias things to those teams already using red as their signature colour, the opportunity at least exists for other teams to exploit this advantage.

Conclusion

Evolutionary approaches have significantly increased our understanding of the factors influencing the outcome of human sporting competitions. Across a range of sports an evolutionary approach helps to explain phenomena such as home advantage, the high frequency of left-handedness and the ‘red advantage’ in human competitive interactions. The evolutionary approach has also opened up new questions and areas of research and suggests that alongside traditional studies of sporting behaviour may offer novel avenues for improving sporting performance.

The significance of testosterone levels has been a recurrent theme throughout the chapter, as endocrine responses appear to play a mediating role in territoriality, aggressive and dominance behaviour. Clearly, humans and animals differ in the way they express aggressive or dominant behaviour, and yet the relationships between rank, aggression and testosterone levels appear remarkably consistent. Further research is still clearly required, not least into gender differences in endocrine responses, but endocrine responses appear to underlie widespread phenomenon such as home advantage as well as recent investigations into the more subtle effects of colour stimuli. Given the significance of these effects for determining sporting outcomes, such evolutionary explanations increase the potential for further sporting enhancements, not least through investigations into how testosterone levels might be ‘legally’ manipulated before sporting encounters. Such investigations could adapt existing approaches or build on recent developments in evolutionary approaches to colour psychology, but either way the next few years offer exciting opportunities for research into factors underpinning sporting success in humans.

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Figure 1: Mean testosterone level in 19 soccer players playing against moderate and extreme rivals before home and away games, with mean level before neutral training sessions included for comparison. (from Neave and Wolfson 2003)

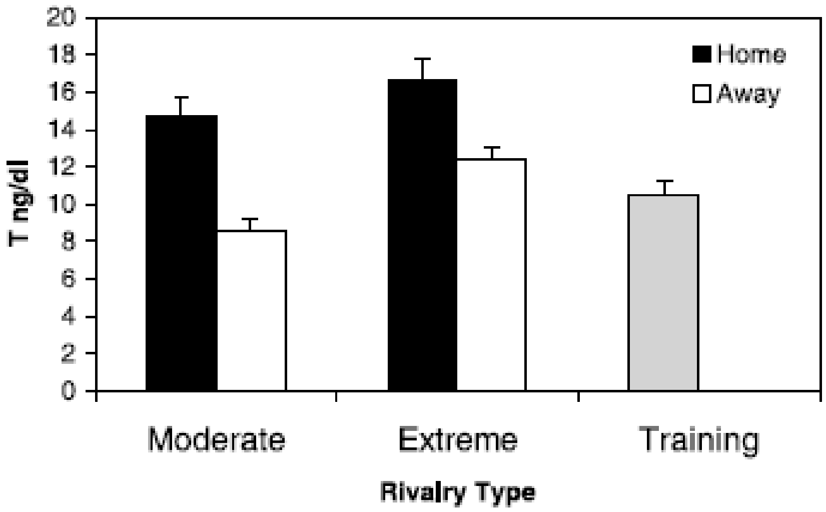


Figure 2: Frequency of left-handedness based on level of level of physical interaction between competitors in sport (based on data from Grouios *et al*. 2000).

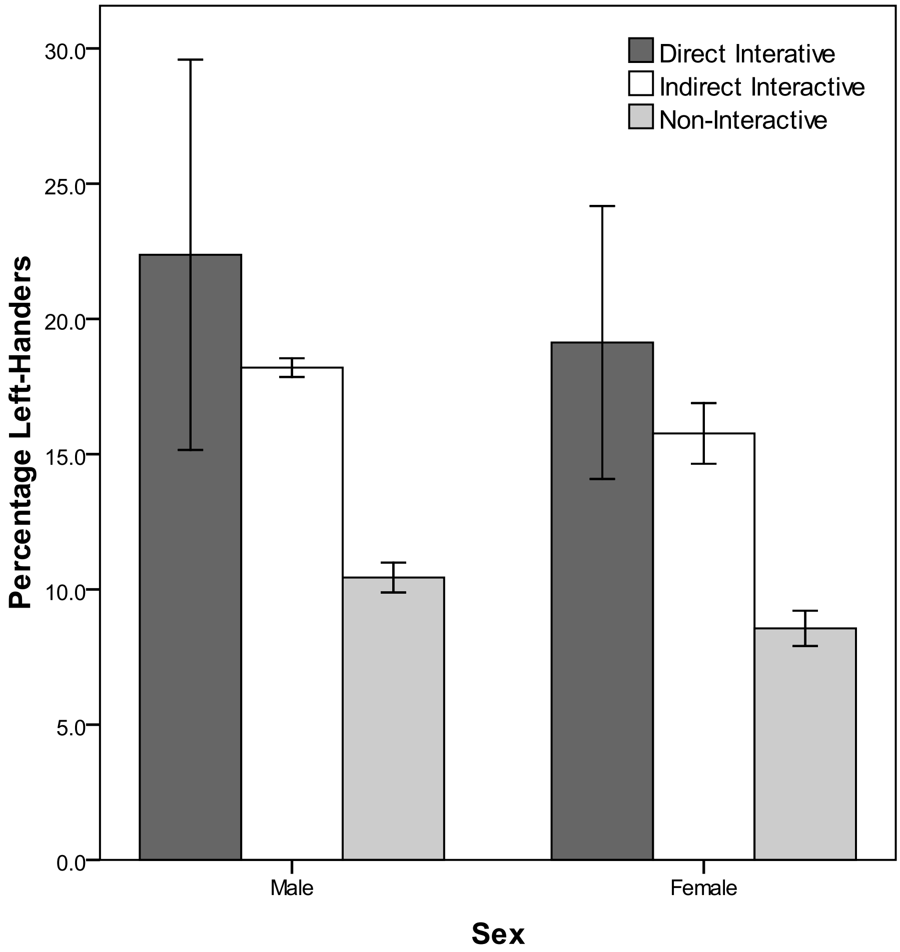


Figure 3: Percentage of left-handers and homicide rate in traditional/sub-traditional cultures. Handedness refers to had preference for machete use (Kreyol, Ntumu, Dioula, Baka), knife use (Inuit, Eipo) and (Yanomamö, Jimi Valley). Homicide rate was computed as the number of homicides per 1000 individuals per year (from Faurie and Raymond 2005).

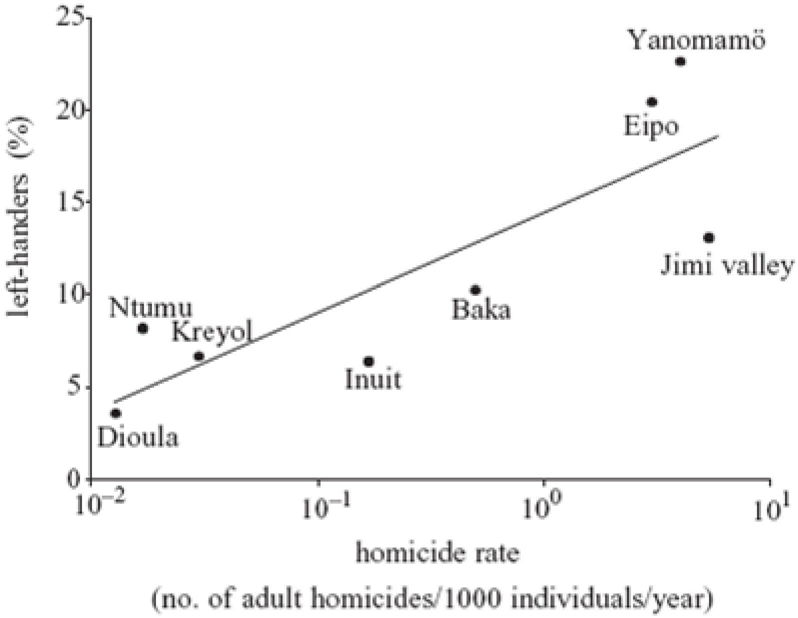
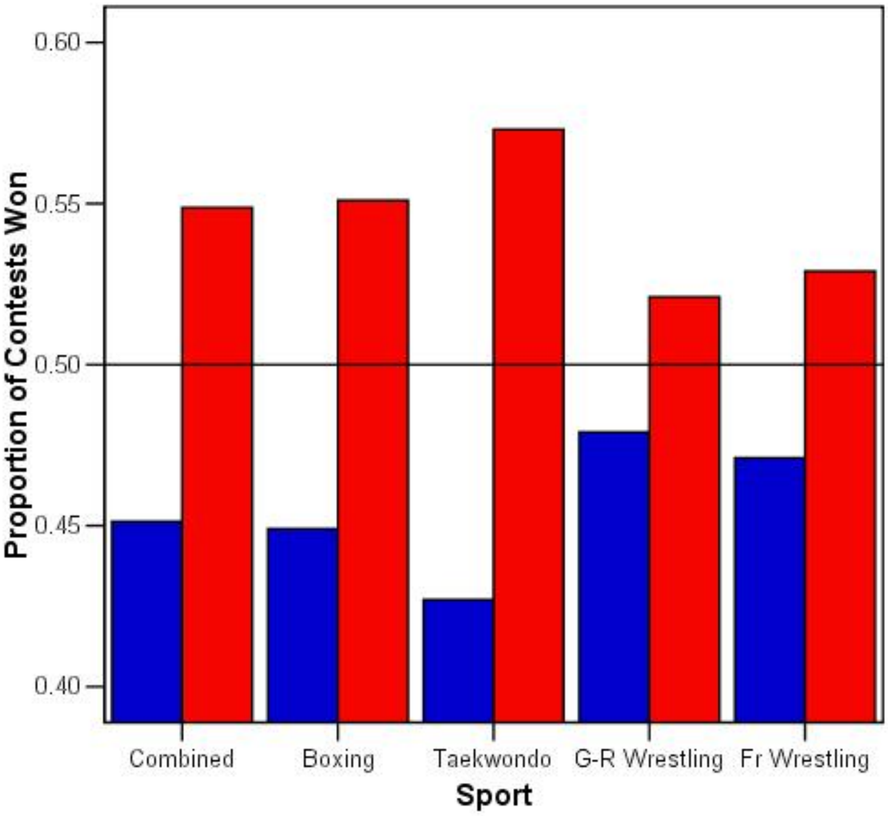
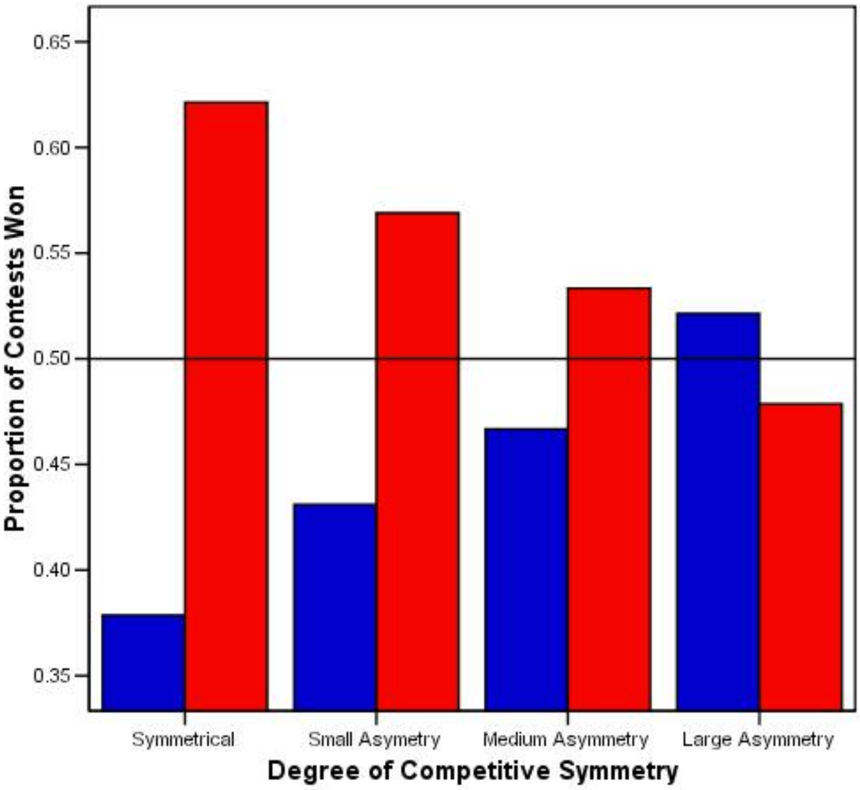


Figure 4: Influence of colour of sporting attire on the outcome of competitive sports. **a**, Proportion of contests in Olympic combat sports won by competitors wearing red or blue outfits for all sports combined and for the individual sports of boxing, tae kwon do, Greco-Roman (G–R) wrestling and freestyle (Fr) wrestling. **b**, Proportion of contests won by competitors wearing red or blue given different degrees of relative ability (asymmetry) in the two competitors in each bout. Black lines at 0.5 indicate the expected proportion of wins by red or blue under the null hypothesis that colour has no effect on contest outcomes. Redrawn from Hill and Barton (2005).

a)



b)


0.65
0.60
0.55
0.50
0.45
0.40
0.35
Proportion of Contests Won
Symmetrical
Small Asymetry
Medium Asymmetry
Large Asymmetry
Degree of Competitive Symmetry

Appendix VIII

Rowing-pilot/Hormone analysis

Key questions

(1) Are there psychological benefits to wearing red colours and/or negative psychological effects on opponents in competitive scenarios? In particular, does self-confidence differ between treatment groups?

(2) Is the mere exposure to the colour red (either as red wearer or as red perceiver) enough to elevate testosterone levels in either the red wearer or its opponent?

(3) Are testosterone levels more elevated in red- than in blue-wearing competitors?

(4) Do participants of both treatment groups show elevated cortisol levels?

(5) Are cortisol levels more elevated in blue- than in red-wearing opponents?

(6) Is the probability of winning a sports contest higher in sportsmen wearing red attires?

(7) Does the colour of sporting apparel influence testosterone levels?

(8) Does the colour of sporting apparel influence cortisol levels?

Pilot

In order to check the feasibility of the project and whether the research design needed improvement, a preliminary study (pilot study) with the Durham University rowing team was carried out in June 2010. Between one and four tests were run on three subsequent days in Maiden Castle (Durham) with each pair arriving at the study site with a time delay of 30 minutes. All tests were run between 15-17 h to control for possible circadian fluctuations of testosterone and cortisol levels. 16 male rowers (8 pairs), matched for height, weight and rowing experience, participated in the study. One experiment had to be terminated prematurely as one subject was unable to provide the required 1ml of saliva. Hence, seven pairs (14 participants) were included in the pilot. During the 5:00 minute race, the total distance rowed was measured on an 'Ergo' rowing machine. One race was won by a "red" participant, four by "blue" participants. Two races resulted in a tie (the two opponents rowed exactly the same distance). The longest duration of an experiment was 95 minutes, the shortest 45 minutes.

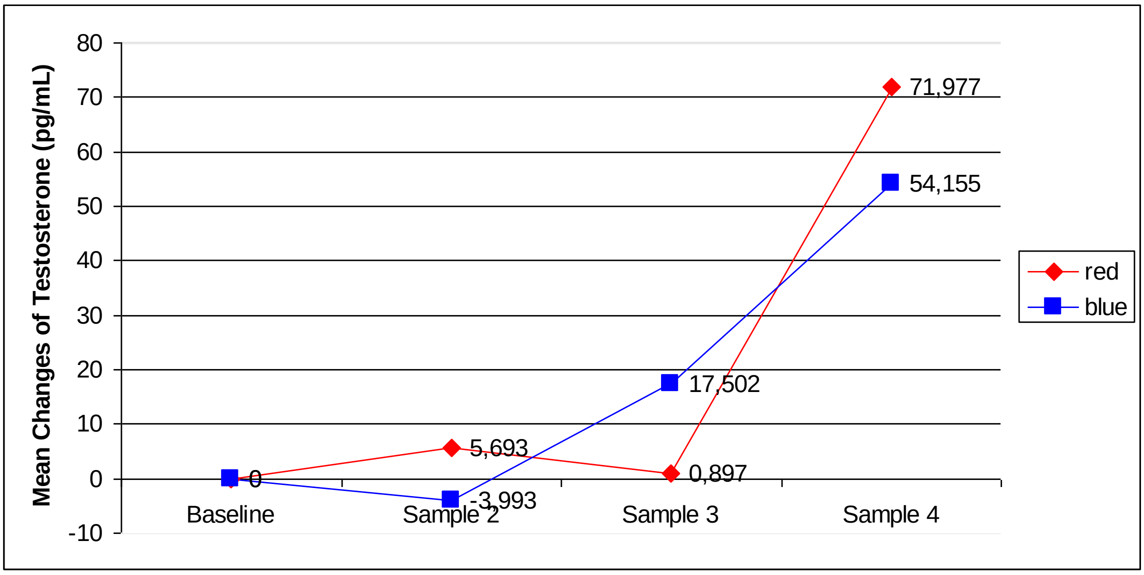
Design of pilot study:

1. Upon arrival, participants read the instruction (*Appendix VIII.A*) and filled in the informed consent (*Appendix VIII.B*) and a general questionnaire (*Appendix VIII.C*) ("Reception Room").
2. 1st saliva sample taken as a baseline ("Study Room").
3. Participants changed into the T-shirts (blue/red) that were randomly given out ("Study Room").
4. Participants then filled in a self-confidence questionnaires (20 questions, *Appendix VIII.D)* while already being exposed to their own and their opponent's T-shirt colour ("Study Room").
5. 2nd saliva sample ("Study Room").
6. 20-minute warm-up ("Warm-up Room").
7. 3rd saliva sample ("Study Room").
8. 5:00 race ("Race Room").
9. 4th saliva sample
10. Participants then filled in a last, short (6 questions, *Appendix VIII.E*) questionnaire ("Study Room").
11. End of the experiment.

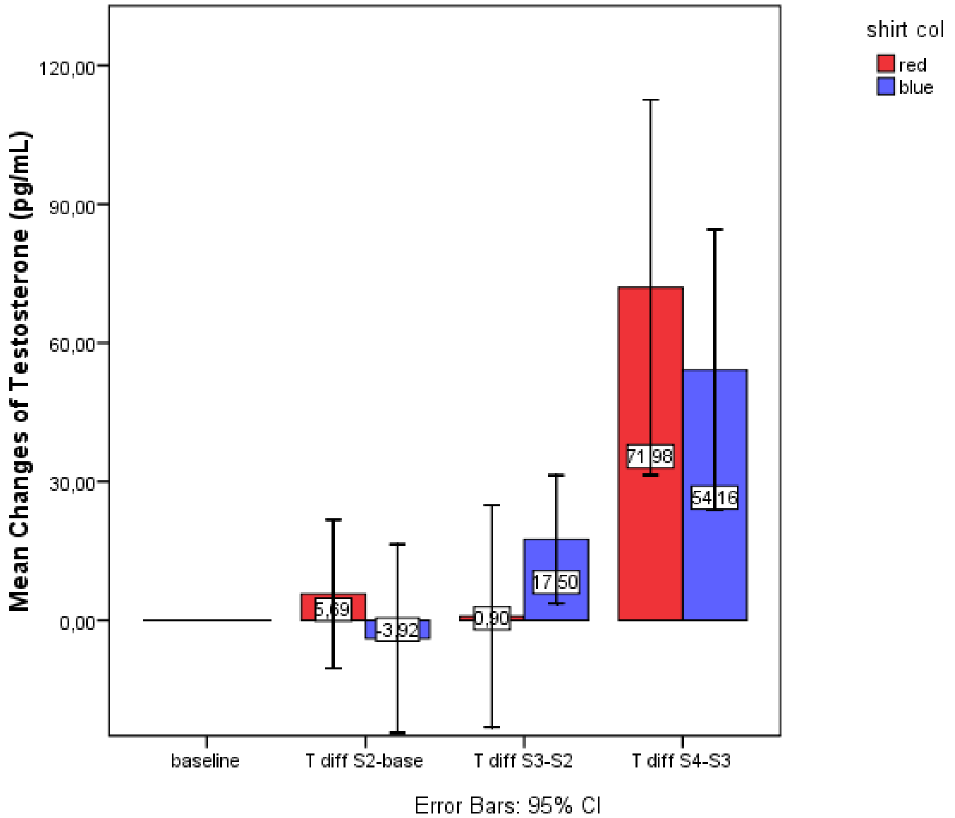
Preliminary results

Salivary samples. Due to financial restrictions, salivary samples were only assayed for testosterone levels, not for cortisol. However, all samples are archived at -80 °C and could still be assayed if sufficient funding becomes available.
The values in appendix figure 2 and appendix figure 3 depict the difference between one sample and its preceding sample (i.e., the average value across participants in sample 2 subtracted from the average value across participants in value sample 3 = Testosterone diff S3-S2). What can be seen from appendix figure 2 is that testosterone values always increased when the rower was dressed in red whereas they decreased in one occasion in blue opponents (sample 2 compared with baseline). Red wearing rowers experienced a light rise (5.69 pg/mL) in testosterone after they had put the red shirt on whereas their blue counterparts' testosterone levels decreased (-3.92 pg/mL) slightly. After both opponents warmed up for 20 minutes, blue opponents' testosterone levels increased (17.50 pg/mL) more than in red opponents (0.90 pg/mL). Both opponents had an obvious increase in testosterone levels right after the 5:00

minute race with red opponents' testosterone levels (71.98 pg/mL) overtaking blue opponents' testosterone levels (54.16 pg/mL).



Appendix figure 2 – Changes in Testosterone (pg/mL) over four trials between red- and blue-wearing opponents



Appendix figure 3 – Changes in Testosterone (pg/mL) compared to preceeding trial

It would be premature to state a difference between rowers wearing red or blue T-Shirts as the sample size is very small. However, what is important to take from the pilot study, is that the methods used lead to an increase of testosterone levels in each of the red samples.

Questionnaires. The first psychological questionnaire (*Appendix VIII.D*) was a reliable measure of self-confidence. However, having used a different questionnaire to measure self-confidence post-performance, made a comparison impossible. Furthermore, the smaller end-questionnaire (*Appendix VIII.E*) was not found to be a reliable measurement of self-perceived performance.

Appendix VIII.A: Instructions Rowing Pilot

Durham University

INSTRUCTIONS

Thank you very much for coming to Maiden Castle today! Your participation in today's experiment is vital for my research questions as to how male hormones are influenced by specific sports performances. A detailed information sheet about my research question and a T-shirt will be given to you after the last experiment has finished (mid-June, please keep you subject number in mind).

After having read these instructions, you will be asked to sign an agreement (informed consent) that says you are willing to participate in today's study. Following that, you will be asked to answer some general questions. You will also have the chance to ask me any questions if anything is unclear.
A first saliva sample will then be taken in another room. In fact, all 4 saliva samples will be taken in the same room. Please try to extract about 1ml of saliva using a straw. If you find it hard to collect enough saliva, please think of some food you like and gently rub your tongue. After having donated your 1st saliva sample, you will be given a T-shirt that you will wear during the whole experiment. The reason why you are wearing this shirt is that I want to keep open whether or not I will test sweat particles later on. Please do not hesitate to ask if you have any questions or let me or the research assistant know if you feel uncomfortable with this procedure. All T-shirts will be cleaned and given to you later on.

The rest of the experiment goes as follows:

12. Please fill in a questionnaire (20 questions) you are given [room: glass cube]
13. 2nd saliva sample [squash court]
14. 20-minute warm-up [warm-up-room]
15. 3rd saliva sample [squash court]
16. 5:00 race [2nd squash court]
17. 4th saliva sample [squash court]
18. Please fill in a last, short questionnaire (6 questions)
19. end of the test

Please keep in mind that it is important not to:
- talk to your opponent during the entire experiment.
- drink any water immediately before donating saliva.
- eat anything or drink Gatorade (sports drinks) before you have donated your last saliva sample.
- take off the T-shirt you are given.
- try and force your saliva collection. Please avoid triggering any blood!
- apply any deodorant or perfume.

All your information will be kept confidential and will not be passed on to a third party. Your answers, your saliva and all other details are anonymously stored and assayed.

If you have any further questions, please contact: diana.wiedemann@durham.ac.uk

Appendix VIII.B: Consent Form Pilot

Subject Number: …………… **Date: ………..…2010**

CONSENT FORM

ERGO-rowing competition and Saliva Donation

Please tick the first six boxes and sign below.

5. I confirm that I have seen and understood the information sheet for the study and have had an opportunity to ask questions about the study. [ ]

6. I confirm that I have not had any food or caffeine for 2 hours, nor any alcohol or tobacco for 24 hours. [ ]

7. I understand that taking part is voluntary and that I am free to withdraw at any time, without giving any reason. [ ]

4. I have been informed that my data is kept confidential. [ ]

5. I do not have any critical health issues that could affect my rowing abilities. [ ]

6. I agree to take part in the study at Maiden Castle and I feel well enough to do so. [ ]

Signature____

If you have any further questions, please do not hesitate to contact:
diana.wiedemann@durham.ac.uk.

Appendix VIII.C: General Questionnaire Pilot

General Details

Note: Your information is kept confidential.

1. Age: ____
2. Weight: _____
3. Height: _____
4. What time did you wake up today? _____
5. How many hours of sleep did you have in total last night? ______h
6. When did you last eat? ________________
7. When did you have your last *non-alcoholic* drink other than water (day/time)?

   ____
8. When did you have your last *alcoholic* drink (day/time)? _______________________
9. Do you smoke? YES/ NO → If yes, when did you have your last cigarette?

   ____
10. Do you take any prescribed medicines or drugs? YES/NO

    If yes, which? _____________________ When did you last take them?

    ____
11. Do you have any known health issues (i.e., asthma or diabetes)?

    ____
12. Do you have any known endocrine disorders (I.e., thyroid problems)? YES/NO

    If yes, what kind of disorder do you have?

    ____
13. Do your teeth or tissues often bleed after brushing your teeth? YES/NO
14. Do you currently have a cold? YES/ NO → If yes, for how many days?

    ____
15. Do you feel well enough to exercise today? YES/ NO
16. Do you currently have any open sores in your mouth? YES/NO
17. How many hours a week do you exercise? _______h
18. When did you last exercise (day, end time)? ___________________
19. How was this last exercise (circle what applies)? LIGHT/MODERATE/VERY HARD
20. Have you used any deodorant or perfume today? YES/NO → If yes, what time?

    ____

Appendix VIII.D: Self-confidence questionnaire

Subject Number: …………… **Date: ………..…2010**

QUESTIONNAIRE I

Below are listed a number of statements that reflect common feeling, attitudes, and behaviours. Please read each statement carefully and think about whether you agree or disagree that it applies to you. Try to respond *honestly* and *accurately*; however, it is not necessary to spend much time deliberating about each item. Think about how the item has applied to you during the **last 2 months** unless some other time period is specified. Indicate your degree of agreement with each statement by circling the appropriate number.

1=strongly agree **7=strongly disagree**

Sport is an area in which I excel.	1 2 3 4 5 6 7
If I were more self-confident, my life would be better.	1 2 3 4 5 6 7
I wish I could change my physical appearance.	1 2 3 4 5 6 7
I am happier right now than I have been in weeks.	1 2 3 4 5 6 7
I lack some important capabilities that may keep me from being successful.	1 2 3 4 5 6 7
Several times in the last few days, I have gotten down on myself.	1 2 3 4 5 6 7
I am pleased with my physical appearance.	1 2 3 4 5 6 7
I often feel unsure of myself, even in situations I have successfully dealt with in the past.	1 2 3 4 5 6 7

	1=strongly agree						7=strongly disagree
I sometimes avoid taking part in formal and informal sports activities because I don't think I am good enough at them.	1	2	3	4	5	6	7
It bothers me that I am not better looking.	1	2	3	4	5	6	7
Much of the time I don't feel comfortable at parties or other social gatherings.	1	2	3	4	5	6	7
I am less sure of myself today than I usually am.	1	2	3	4	5	6	7
I have more confidence in myself than most people I know.	1	2	3	4	5	6	7
I am a better athlete than most people of my age and sex.	1	2	3	4	5	6	7
I am more uncertain about my abilities today than I usually am.	1	2	3	4	5	6	7
Attracting a desirable boyfriend/girlfriend has never been a problem for me.	1	2	3	4	5	6	7
I feel more confident about myself today than I usually do.	1	2	3	4	5	6	7
When things are going poorly, I am usually confident that I can successfully deal with them.	1	2	3	4	5	6	7
When I think about playing most sports, I am enthusiastic and eager, rather than apprehensive and anxious.	1	2	3	4	5	6	7
Right now I am feeling more optimistic and positive than usual.	1	2	3	4	5	6	7

Appendix VIII.E: Performance questionnaire

Subject Number: …………… **Date: ………..…2010**

QUESTIONNAIRE II

Below are listed five statements that reflect common feeling, attitudes, and behaviours. Please read each statement carefully and think about whether you agree or disagree that it applies to you. Try to respond *honestl*y and *accurately*, however it is not necessary to spend much time deliberating about each item. Think about how the item applies to you regarding the **competition in which you have just participated in**. Indicate your degree of agreement with each statement by circling the appropriate number.

1=strongly agree

7=strongly disagree

I did better than I initially thought I would.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
I was less motivated than I usually am.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
I am pleased with my performance.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Overall, I could have done better.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
My opponent was a real challenge.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
I tried much harder than I usually do.	**1**	**2**	**3**	**4**	**5**	**6**	**7**

Do you have any idea what the purpose of the study was?

____

____

____

____

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Cite this article: Wiedemann D, Burt DM, Hill RA, Barton RA. 2015 Red clothing increases perceived dominance, aggression and anger. *Biol. Lett.* **11**: 20150166.
http://dx.doi.org/10.1098/rsbl.2015.0166

Received: 3 March 2015
Accepted: 19 April 2015

Subject Areas:
behaviour, evolution

Keywords:
red, dominance, aggression

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Electronic supplementary material is available at http://dx.doi.org/10.1098/rsbl.2015.0166 or via http://rsbl.royalsocietypublishing.org.

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Animal behaviour

Red clothing increases perceived dominance, aggression and anger

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The presence and intensity of red coloration correlate with male dominance and testosterone in a variety of animal species, and even artificial red stimuli can influence dominance interactions. In humans, red stimuli are perceived as more threatening and dominant than other colours, and wearing red increases the probability of winning sporting contests. We investigated whether red clothing biases the perception of aggression and dominance outside of competitive settings, and whether red influences decoding of emotional expressions. Participants rated digitally manipulated images of men for aggression and dominance and categorized the emotional state of these stimuli. Men were rated as more aggressive and more dominant when presented in red than when presented in either blue or grey. The effect on perceived aggression was found for male and female raters, but only male raters were sensitive to red as a signal of dominance. In a categorization test, images were significantly more often categorized as 'angry' when presented in the red condition, demonstrating that colour stimuli affect perceptions of emotions. This suggests that the colour red may be a cue used to predict propensity for dominance and aggression in human males.

1. Introduction

Red coloration is a sexually selected trait associated with dominance in many animal species (e.g. [1,2]) and appears to have similar associations in humans [3]. Skin redness in humans has been found to correlate with testosterone and fluctuates with emotional state, increasing with anger and decreasing with fear [4,5]. Red therefore appears to carry specific biological signals in both humans and other animals. Artificial stimuli may exploit these evolved responses to natural red signals. In birds, red leg bands enhance access to resources in male zebra finches [6], while rhesus macaques avoid red-wearing human experimenters [7]. In humans, several studies have shown that colour stimuli have similar effects on social perception [8,9] and behaviour such as the outcome of physical and virtual contests (see [10] for review). Being associated with or wearing red are also linked to higher heart rate, a greater pre-performance strength and higher testosterone levels [11,12]. These effects may be explained by psychological associations of red coloration with dominance and aggression that boost red-wearers' confidence and/or intimidate their opponents [13], although the effect may be restricted to males [14].

Targets presented in red are perceived as more aggressive, dominant, brave and also more likely to win a competition [15–17]. However, these experiments primed competitiveness or aggression in subjects by placing them in a competitive situation. To our knowledge, no study has yet investigated the effects of colour on social perceptions of dominance and aggressiveness in neutral settings. It is also unknown whether clothing colour influences attributions of emotional state: if colour is a cue to relative dominance in aggressive situations, red stimuli might be more likely to be categorized as angry. This study explores how digitally manipulated T-shirt colour influences rapid social judgements of character traits in strangers. We predicted that people presented in a red shirt would be rated as

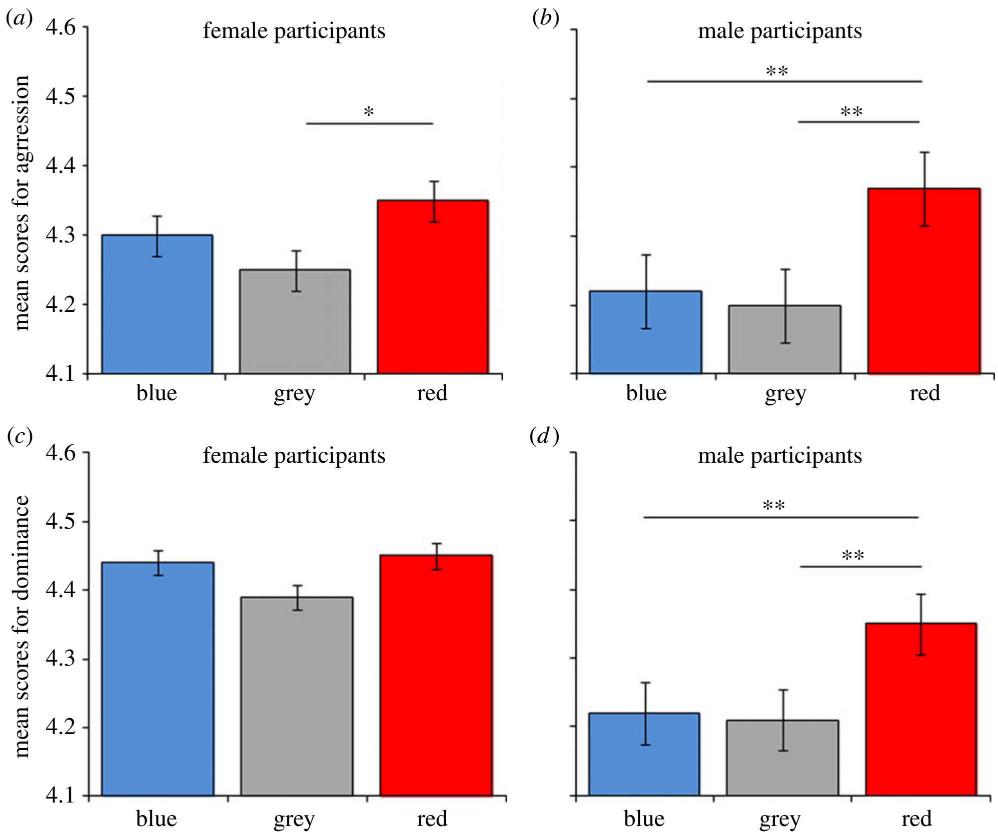

Figure 1. Mean scores of women (*a*,*c*) and men (*b*,*d*) rating targets wearing three different colours for aggression (*a*,*b*) and dominance (*c*,*d*); $*p \leq 0.05$, $**p \leq 0.01$. Error bars indicate 95% CIs. (Online version in colour.)

being more aggressive and more dominant and also perceived more often as 'angry' than when presented wearing blue or grey.

2. Material and methods

Stimuli were selected from two sources. Fourteen images of males were taken from a previously published set [18] and six additional images were selected from the Internet according to the criteria in that study. Clothing colour was first desaturated and luminance adjusted to mid-grey (producing the grey stimulus) using MICROGRAFXPICTUREPUBLISHER v. 10; the hue and saturation were then adjusted to produce the red and blue coloured stimuli (see the electronic supplementary material). Previous studies have not considered achromatic stimuli, and this study design thus allows a more robust assessment of how colour influences social perceptions.

Stimuli were presented under constant lighting conditions on a colour-calibrated computer screen. In a series of 60 randomly ordered trails, $N = 100$ participants (50 females and 50 males) were presented with images of 20 males wearing either a red, blue or grey shirt and two 7-point scales: aggression (ranging from 1, extremely aggressive to 7, extremely friendly) and dominance (1, extremely submissive to 7, extremely dominant)[1]; and a selection of emotional states (angry, happy, frightened or neutral). To facilitate data analysis, variables were coded so that high numbers represented high trait values (e.g. on the aggression scale, 7 = extremely aggressive, 1 = extremely friendly). Data were analysed using repeated-measures ANOVA with colour as a within-subjects variable. Greenhouse–Geisser correction was applied when sphericity could not be assumed (Mauchly's test for sphericity, $p < 0.05$).

While previous research on colour perception and its effects in competitive situations has shown that an effect of red colour is more likely to occur among men [14], we also investigated whether the rater's sex influenced perceptions in our non-competitive task.

3. Results

The analysis revealed a main effect of colour for aggression ($F_{1.747,\ 172.934} = 12.101$, $p < 0.001$, $\eta_p^2 = 0.109$) and dominance ($F_{2,98} = 5.821$, $p = 0.004$, $\eta_p^2 = 0.106$). Bonferroni pairwise comparisons showed that raters judged targets wearing red as more aggressive than when wearing blue ($p = 0.005$) and grey ($p < 0.001$), and also more dominant in red than grey ($p = 0.003$). There was a trend for participants to rate red targets as more dominant than blue targets ($p = 0.063$). By contrast, there were no significant differences between blue and grey targets on ratings of aggression ($p = 0.519$) or dominance ($p = 0.704$). Female participants rated red-wearing targets to be more aggressive than grey-wearing targets ($p = 0.025$), whereas male participants judged red-wearing targets to be more aggressive than targets wearing blue ($p = 0.007$) or grey ($p = 0.003$, figure 1). For ratings of dominance, colour did not influence female raters' perception, $F_{2,48} = 1.425$, $p = 0.251$, $\eta_p^2 = 0.056$, but males' ratings were significantly influenced by colour, $F_{2,48} = 6.939$, $p = 0.002$, $\eta_p^2 = 0.224$, with targets wearing red being rated more dominant than targets wearing blue ($p = 0.010$) and grey ($p = 0.002$). Ratings for targets wearing blue did not differ from those wearing grey ($p > 0.999$).

Colour had a significant effect on how often a stimulus was categorized as 'angry' (Friedman's test $\chi^2 = 13.861$, d.f. = 2, $p = 0.001$; figure 2) but not 'happy', 'neutral' or 'frightened' (all $p > 0.25$). Wilcoxon signed-rank tests for pairwise comparisons showed that a target presented in a red

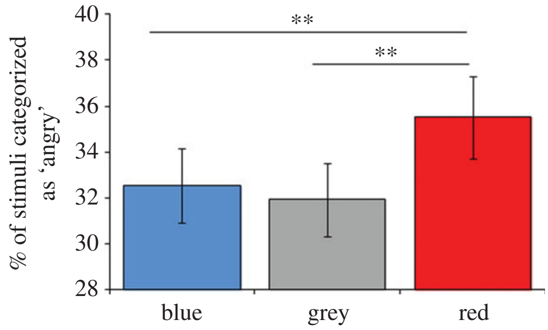

Figure 2. Percentage of stimuli categorized by each subject as 'angry' for three colour conditions, $**p < 0.01$. Error bars indicate 95% CIs. (Online version in colour.)

shirt was more often categorized as 'angry' than when presented in blue ($Z = -2.685$, $p = 0.007$) or grey ($Z = -2.896$, $p = 0.004$), but there was no difference between blue and grey ($p = 0.203$). Colour significantly affected the perceptions of anger in the stimuli both among female ($\chi^2 = 12.471$, d.f. $= 2$, $p = 0.002$) and male raters ($\chi^2 = 10.812$, d.f. $= 2$, $p = 0.004$).

4. Discussion

We found that clothing colour biases the perception of aggression, dominance and anger in strangers, outside of competitive or achievements contexts. Men wearing red were rated as more aggressive and more dominant and were more often categorized as 'angry' than targets wearing grey or blue. Clothing colour did not influence female participants' perception of male dominance but did influence male participants' perceptions. Whether or not this sex difference reflects different biases in social perceptions requires further investigation. For example, the colour red distorts time perception in men but not in women [19], and wearing red enhanced the probability of winning combat sport bouts in male, but not female, athletes [13,14].

Participants categorized targets significantly more often as 'angry' when presented in the red condition. This indicates that colour influences the categorical judgement of emotional expression and, specifically, that red hue is associated with a bias towards angry judgements. Fetterman *et al.* [20] showed that priming anger concepts (versus sadness) led participants to be more likely to perceive the colour red. Taken together, these findings suggest a clear association between the colour red and perceptions of anger, possibly related to the role of facial reddening as a natural signal of anger [21].

While red images resulted in higher ratings for aggression and dominance, ratings for blue and grey images did not differ significantly. Hence, it seems to be specifically red that influences judgements of aggression and dominance. However, black has also been found to influence perception of aggression in athletes [22], and across cultures both black and red have been found to influence scoring of combat sport bouts [23]. In these studies, luminance and chroma were confounded, and it is known that these different dimensions have independent effects on social perceptions [16] and that skin darkness is sexually dimorphic and positively associated with testosterone [24]. Further work is needed to test for and separate out effects of hue and luminance and to determine whether there is an 'optimal red' related to biological signalling of traits such as aggressiveness and dominance.

An important area for further enquiry is the cross-cultural consistency versus variability in biasing effects of colour. Culture may reflect, reinforce or modify innate biases, or it might be responsible for establishing biases in the first place through arbitrary or coincidental associations. The latter would predict considerable variability in biases. Indeed, cultural variation in colour–emotion associations exist [25]. However, there is also considerable cross-cultural consistency in associations between red and physical dominance [23], anger [25] and danger [26]. An attentional bias towards red versus other colours is present from early infancy, consistent with the idea that innate predispositions may play a role in establishing colour associations [27]. The ontogeny of colour biases in social perceptions would be an interesting area for further study.

Ethics statement. This experimental protocol was approved by the Department of Anthropology Research Ethics sub-committee at Durham University (Wiedemann, March 2010). We obtained written consent from participants.

Data accessibility. An Excel file is included as electronic supplementary material.

Authors' contributions. D.W., D.M.B., R.A.H. and R.A.B. designed the study; D.M.B. developed the stimuli; D.W. ran the study and performed data analysis and interpretation with R.A.H., D.M.B. and R.A.B.; D.W, D.M.B, R.A.H and R.A.B wrote the manuscript; all authors approved the final version.

Conflict of interests. The authors declare no competing interests.

Endnote

[1]We also asked participants to rate stimuli for perceived 'trustworthiness' and 'confidence'. Electronic supplementary material, figure S3, presents findings for these two variables.

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