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“I've been thinking about it a lot....and I just am in love with the colour!” - How behavioural life sciences can help us understand consumer reactions to colour.

Abstract

In this article we will explore a novel approach to understand consumer responses to colour by integrating recent theories, data and methods developed in behavioural life sciences. We deliver an interdisciplinary literature review on natural colours that may be used for marketing purposes. Furthermore, we provide experimental data on how natural food colouration and the colouration of facial skin are perceived by humans. Additionally we show first evidence of a sex biased influence of naturally reddish colours on perceived quality in food or other humans. Based on our literature analysis we will discuss the limits and implications of our experimental results and the potential of integrating novel theories, data and methods developed in behavioural life sciences into marketing research on consumer reactions to colour.

Keywords

colour, red, vision, consumer behaviour, life sciences, selective attention, peak shift

Introduction

Humans communicate intensively via colours. Today, in marketing, colour is almost ubiquitous, to an extent where it is sometimes even the lack of colour that may help attract the consumer's attention (reviewed by Divard & Urien, 2001). However, because colour perception is very complex, research studies on consumer reactions to colour often deliver findings inconsistent with former colour psychological data (Divard & Urien, 2001). This is true despite the increasingly precise measurement of colour stimuli, their standardised presentation in experimental settings and their analysis in complex human colour perception spaces, such as Munsell or CIELab colour space. Ambiguities arise because researchers can effectively only test a limited number within over 2.3 million perceivable colours (Linhares, Pinto, & Nascimento, 2008) and not all of these colours are equally effective for communication. When working with colour, researchers and practitioners need to know more than just how to measure colour, they need to know how humans communicate via colour.

Human visual communication is inherently complex but like most behavioural patterns it is based on a limited set of innate reactions. These reactions have evolved in response to specific natural stimuli because they allowed ancestral humans and our primate ancestors to better survive and care for their offspring. To be evolutionary stable, these reactions should be limited to contexts in which they yield benefits. However, in visual perception research and especially in marketing research, scientists often observe individuals reacting to colours without any apparent benefit: What is the benefit for the consumer of becoming aroused by reddish colours in a sales place (reviewed in Dauce & Rieunier, 2002)□? Such reactions might arise through diverse cultural biases, however, recent studies throughout various disciplines support novel evolutionary theories that explain the underlying principles of such deceptive communication more parsimoniously.

According to a set of evolutionary models which Endler and Basolo (Endler & Basolo, 1998)□ merged into the so called *sensory drive model*, individuals can be naturally biased to react to a specific stimulus in various contexts as long as there is at least one context, in which the benefits of the reaction outweigh the losses in all other contexts. As such, Grant Allen (1879), a physiologist specialized in animal colouration, already postulated, that the humans' “love” for the colour red is a non-cultural universal, which evolved in ancestral humans and primates in response to the red colouration of valuable food resources, such as ripe fruit and young leaves. This general appraisal of red, Allen speculated, has been and still is exploited in “almost every object of human industry”: Food, fashion, cosmetics, product design, advertisement, packaging, and many more.

Customers might actually just “be in love” with the colour of a product, a packaging, a website, an advertisement, a brand logo, a service uniform or any other coloured object associated with a company, because it just happens to be a colour humans have evolved to “love” in an ancestral context. In this study we explore this new perspective on human behaviour to better understand consumers' appraisal of colour. To this end we conducted an interdisciplinary literature research in which we identified red in contrast to green as an important natural colour stimulus in humans and primates in the food and the mating context. We reviewed the interdisciplinary knowledge on basic reactions to red and explored its usage in recent marketing research on colour. In order to assess if a general appraisal of red is possible throughout different contexts, we first conducted experiments to make sure that it truly is the redness of fruit (food context) and human faces (mating context) which is associated with a given quality (ripeness and sexual attractiveness, respectively) and hence makes humans react. Second, in order to provide evidence that human reactions in both contexts are influenced by a common bias ("love") for red, we tested if colour preference in one context can be influenced by stimuli of the other context, something, that should not be possible if appraisal of redness had evolved independently for each context.

Our objective is to outline a novel strategic approach which allows marketing researchers and practitioners to choose colour in a straightforward process with clear predictions on consumer reactions. To this end, we first illustrate how to identify important natural colour stimuli, for example red, via an interdisciplinary literature research. Second we provide a comprehensive insight into the evolutionary *sensory drive model* which explains how natural stimuli can theoretically influence human reactions throughout various contexts. Third we present detailed information on our methodology including novel interactive optimization experiments coupled with eye-tracking experiments, which allowed us to collect sound data on human reactions to red in two natural contexts, food and mating. We deliver first empirical evidence of a context independent and sex specific bias to react to the colour red. We discuss our results and the limits of our experiments and finally outline implications for future marketing research as well as practical managerial implications.

2 Literature Review

2.1 Artificially created and natural colours

Natural colours differ from artificially created colours in their way of influencing humans. We react to colour codes in stores and fashion or to specific anthropomorphic signs like traffic lights and to the colours of social organisations like political parties, the police and the fire brigade, because we have individually learned to associate all of these items with the corresponding artificially created colours. It is important to stress, that human vision offers such a high colour resolution (Linhares et al., 2008), that we have the capacity not only to loosely associate any red with the fire brigade, but we can readily associate exactly the red of our home town fire brigade with it. As such, reactions to artificially created colours are highly influenced by our upbringing and cultural environment. Hence, it is a general belief that all reactions to colour vary individually. Still, colour psychologists have been trying to unravel universal reactions to various colours in humans for over a century, unfortunately, without consistent results (Whitfield & Wiltshire, 1990). Consequently, the few recent studies on the effect of colour in marketing based on colour psychological studies still encounter ambiguous or contradictory results (e.g. Cheng, Wu, & Yen, 2009, Lichtlé, 2007).

In contrast, more parsimonious approaches from evolutionary and developmental psychologists, looking only at colour preferences, have shown in the last 20 years, that there are universals to human reactions to colour: Humans appear to be born with a specific set of colour preferences, specifically preferring red over other colours (Adams, 1987; Franklin, Bevis, Ling, & Hurlbert, 2010). These innately attractive colours are most likely to have occurred in ancestral environments. Human and primate ancestors have evolved to react to these colours because they gained benefits from these innate reactions over generations. However, these studies on basic colour preferences also acknowledge that, as humans grow up, they may progressively adapt these preferences to contexts as they learn to appropriately associate the artificially created colours in their society. In essence, our current understanding of individual colour preferences is that there are underlying universal colour preferences, however, preferences might or might not be altered during individual development depending on the social environment and the context.

2.2 Selective attention to natural stimuli

When working on visual communication it is important to acknowledge that individuals do not perceive everything they see. We use the term selective attention to describe the phenomenon that individuals only see what they want to see: Even the simplest environment delivers an almost unbearable amount of information encoded in visual stimuli so that most animals have evolved brain structures that filter the sensory input and unconsciously “decide” which visual information will be made available for cognitive processing, i.e. which information will be perceived (Haider et al., 2010). However, this decision is made based on the commands of other brain regions, such as the stem brain signalling the need for food or drink, and regions such as the cognitive centres where individuals decide to shop for red shoes and nothing else. As this phenomenon is quite difficult to observe, it has been discovered more or less concurrently in several psychological sub disciplines and is described as visual awareness, (sustained) inattentional blindness, change blindness, selective amnesia, attentional misdirection, spatial attention, covert attention, conscious vision, and others (for a review see Chun, Golomb, & Turk-Browne, 2011).

Despite it's utmost importance for understanding and especially for correctly measuring consumer behaviour, this phenomenon is still frequently ignored in marketing research with the exception of e-marketing: Website visitors want to perceive the information displayed on the site and hence selective attention manifests itself as banner blindness which marketers struggle to compensate, for example by actively forcing consumers to pay attention to the banners (e.g. Geisseler 2011). However, Lauri Nummenmaa et al. (Nummenmaa, Hietanen, Calvo, & Hyönä, 2011)□ a group of neuroscientists, have made most intriguing discoveries when studying the effect of natural versus artificially created objects on selective attention: First, natural food objects always attract more attention then artificial objects, such as cars. Second, when the scientists presented artificial objects that were similar to natural food objects in size, shape and colour, participants were also attracted to them. In essence, humans appear to be biased to naturally direct their selective attention to food objects or artificial objects that resemble food objects.

2.3 Known reactions to red

Colour is a ubiquitous phenomenon and a study subject for a large number of independent scientific disciplines. The first step of an evolutionary approach to colour in marketing is to identify colours that trigger similar reactions in humans throughout cultures. When screening the literature on human reactions to colour, there is one hue that has been of central interest in many studies throughout disciplines for its frequent usage and unique effects on human behaviour: Red. An overview of the existing literature allows us to categorise these reactions into three main natural contexts - foraging, mating and conflict – and a novel marketing context.

In the food context, we know that already primates show preferences for redness in fruit and leaves and use it as an indication for food quality (Lucas et al., 2003; Regan et al., 2001; Sumner & Mollon, 2000)□□. Indeed, it has been shown, that redness in fruit and leaves is correlated with nutritive value (e.g. He & Giusti, 2010)□. Food research in humans, assessing the colour preferences of customers in popular fruit such as apples, tomatoes, grapes etc., shows that we also prefer redder fruit over greener alternatives (e.g. Iglesias, Echeverria, & Soria, 2008)□. Even more intriguing is the fact that we do not only judge food and drinks according to their colour, but we also perceive their flavour differently: Red drinks for example are perceived as sweeter and more bitter than equally sweet or bitter drinks coloured differently (reviewed in Spence, Levitan, Shankar, & Zampini, 2010)□.

We also know from studies on primates, that skin redness is used to communicate fertility and fitness (Dubuc et al., 2009; Waitt, Gerald, Little, & Kraiselburd, 2006) and also humans have been shown to associate health with skin redness (Dubuc et al., 2009; Stephen, Coetzee, M. Law Smith, & Perrett, 2009; Stephen, M. J. Law Smith, Stirrat, & Perrett, 2009; Waitt et al., 2006). Physiological studies confirm that fertility, physical fitness and health with skin redness (Charkoudian, Stephens, Pirkle, Kosiba, & Johnson, 1999; Farage, Neill, & MacLean, 2009; Jablonski, 2004; Koos Slob, 1996; Stephen, Coetzee, et al., 2009). Congruent to the food context, the presence of red as a colour stimulus also biases the reactions of humans in the mating context: Recent psychological studies show that women and men wearing red clothes are perceived as more attractive compared to wearing other colours (Elliot & Niesta, 2008; Elliot et al., 2010). Furthermore, anthropologists and paleoanthropologists find that deceptive red ornaments and red body paint have been used since the dawn of humankind throughout cultures to attract mates (Knight, Power, & Watts, 2008).

In contrast to the mating context, we see in primates that redness of skin in a competition context effectively communicates the opponents arousal and willingness to fight (Bergman, Ho, & Beehner, 2009; Marty, Higham, Gadsby, & Ross, 2009; Setchell & Jean Wickings, 2005). Also in this context, physiological studies in humans confirm that flushed skin is correlated with arousal (Drummond & Quah, 2001). Psychological studies and statistical analysis of sporting events have shown, that also in humans, individuals experience a substantial decrease in physical and mental strength when confronted to red colouration in a competitive context such as an exam or in a sporting combat (Elliot, Maier, Binser, Friedman, & Pekrun, 2009; Elliot, Maier, Moller, Friedman, & Meinhardt, 2007; Hill & Barton, 2005).

In marketing, only few studies have actually tried to systematically approach consumer reactions to colour. For example, recent studies in France showed that the reaction to red in advertisements depends on the sex of the customer, the product type and the lightness of the red. As such, women prefer darker red over blue, whereas men do not differ between blue and red as long as they are both dark (M.-christine Lichtlé, 2005). Other studies show that the effect of red is more inert to variation of personal preferences than the effect of blue (M.-christine Lichtlé, 2007). Furthermore, complex variables such as appeal and pleasure that are linked to purchase decisions are likely to not to be influenced directly by colour but via moderating variables such as individual optimal stimulation levels. When focusing on associations of colour with brand personality, studies done in the United States showed that men and women found light red logos to appear most exiting, blue logos most competent, and

purple, pink and black logos most sophisticated (Labrecque & Milne, 2011).
It is important to stress, that we are currently still in the early stages of empirical research on colour in marketing. Hence, most studies have limited themselves to the four main hues (red, green, blue and yellow) and have focussed on the various effects that variation in saturation, lightness and contrast might produce, rather than which exact colour triggers a specific reaction. Consequently, with our growing knowledge on how colour parameters can have an impact on consumers and the ability to quantify colour in human perceptual colour space, we can now begin to empirically assess which of the more than 2.3 million perceivable colours (Linhares et al., 2008) might best serve a given marketing purpose. However, as in the natural contexts, in order to know which colours to test, we have to know why they might actually trigger a reaction.

2.4 The evolutionary basis of reacting to red

Mammals are generally limited in their colour perception to blue and yellow hues, only some primate species and humans share the ability to also distinguish between green and red hues (G. H. Jacobs, 2008). This ability arose due to a mutation in the colour receptor genes of ancestral primates some 35 million years ago. At that time, plants are thought to have already been exposing their ripe fruit to be eaten by birds which then dispersed the seeds (D Osorio & Vorobyev, 2008; Sumner & Mollon, 2000). The ability to perceive ripeness of fruit which are a valuable food source also for primates, was a considerable advantage which still today allows primates to effectively optimise their foraging (Lucas et al., 2003; Sumner & Mollon, 2000). However, it was only an advantage to those individuals that were also attracted to the reddish colouration, contrasting against unripe fruit and the leaves in the background. Hence, combining the ability to perceive red colouration and the attraction to reddish colours is supposed to be the reason why both traits quickly spread throughout ancestral populations and why it is still preserved today (Allen 1879; Fernandez & Morris, 2007).
It is probable that the successive loss of pelage on strategic parts of the body like the face, the chest and the genitalia in primates and then on the whole body in humans, was driven by the response of individuals to the reddening of unveiled skin (Fernandez & Morris, 2007). In addition, in the mating context, positive attraction similar to the one in the food context, is supposed to be beneficial as skin redness is physiologically coupled with fertility, physical fitness and health (Charkoudian et al., 1999; Stephen, Coetzee, et al., 2009). In this

perspective, the context of competition appears to be an exception where positive attraction would be detrimental, and therefore, secondarily, there has been selection pressure on evasive behaviour in this specific context.

The alternative hypothesis as to why old world primates and ultimately humans lost some of their pelage and body hair, is that primates benefit from the fact that others can detect health, physical fitness and even fertility via skin colouration (Changizi et al., 2006). Consequently, it has been proposed that today, specific selection for the ability to perceive fitness relevant cues via skin redness is the primary cause for human attraction to skin redness. However, as attraction to skin redness in the mating context has a high probability of not leading to offspring because of the various things that can go wrong between mating and birth, the basic attraction to skin redness might still be caused by an attraction-bias to red.

2.5 The sensory drive model

The fact that the reaction to red is similar throughout different contexts might not appear especially striking, especially not to marketers who witness this phenomenon on a regular basis. However, it is puzzling to evolutionary biologists and psychologists alike: How can humans react similarly in contexts with different selective pressures? Usually, if individuals show a reaction it must render benefits so it should necessarily be tied to one beneficial context. Furthermore, in some contexts, the reaction to a stimulus and the benefits from the reaction are so loosely connected that it is hardly possible to imagine any selective pressure to maintain this reaction. For example, as already mentioned, between the moment of being attracted to a certain amount of skin redness and the birth of offspring, there are an innumerable amount of things that can go wrong, so that the selective pressure on being attracted to reddish skin is expected to be very low.

However, theoretically, similar stimuli may trigger the same reaction in various contexts because the uncertainties or losses in some contexts might be buffered by at least one very beneficial context. This theory has already been outlined by Allen (1879) over one century ago but only recent studies on various species during the last two decades allowed scientists to build a comprehensive evolutionary model to explain this phenomenon, the *sensory dive model* (Endler & Basolo, 1998). In fact, some species like guppies gained scientific fame because researchers were able to manipulate females to be attracted to plain artificially coloured plastic discs that render no benefits whatsoever (Rodd, Hughes, Grether, & Baril, 2002). It turned out that guppies feed on orange fruit which are difficult to detect and to catch in rivers. Consequently, guppies appear to have evolved to be strongly attracted by orange colour stimuli. However, and fortunately for males, this attraction is not limited to the food context: Females are attracted to everything that is orange, even the experimenters' coloured plastic discs. Males exploit this bias for orange to attract females for mating by displaying orange spots on their fins. Even if reacting to such deceptive stimuli would be detrimental in the mating context, females apparently gain enough benefits from reacting to orange in the food context to be able to compensate for the deception.

What Allen (1879) proposed and Fernandez and Morris (2007) have supported via phylogenetic analysis is, that humans likewise exploit biases for specific natural colours in all types of coloured objects. As such, when humans need to attract attention, their most successful colour choices are red (e.g. fire brigade) and contrasting colourations of red against green (e.g. traffic light). Furthermore, whereas the guppies' colour spots may be costly to the males and hence actually promote their fitness, such as skin redness in humans does, humans do not display orange spots on their limbs nor do we display a lot of skin redness, humans and especially women use reddish ornaments such as clothes, jewellery, rouge and lipstick, all of which are truly deceptive and unrelated to fitness, if anything, they can cover up pale skin or divert attention from imperfections. Consequently, it seems plausible that such deceptive stimuli may work because of a general bias in humans for the colour red.

2.6 Peak shift phenomenon

The peak shift phenomenon offers the mechanistic explanation as to why humans react to exaggerated and potentially deceptive red colouration, for example red ornaments and body paint. In psychology and behavioural ecology, researcher consistently find that the preference of a stimulus shows some variation, its optimum being referred to as the peak preference (ten Cate & Rowe, 2007; Lynn, Cnaani, & Papaj, 2005). Many species show an innate or learned preference for a specific stimulus which lies on one end of a stimulus gradient, and at the same time, they show an aversion to another stimulus on the opposed end of a gradient. For example, on the colour gradient from green to red in fruit, primates show aversion towards green fruit and a preference for red fruit. The peak shift phenomenon manifests itself when individuals are presented with different stimuli along that gradient: The closer the original stimuli fall together on the gradient, e.g. the more alike unripe and ripe fruit are, the more individuals will prefer stimuli that are even stronger than the attractive original stimulus. For example, knowing the natural colour difference between unripe and ripe fruit, individuals may show a preference for fruit that is even redder than any kind of fruit they have ever seen before. This shift in peak preference has been intensively studied with learned stimuli on artificial gradients but it has also been shown to work with innate preferences along natural gradients (reviewed in ten Cate & Rowe, 2007). Consequently, humans that show shifted preference towards exaggerated red ornaments and body paint may have been born or they may have learned to prefer a specific skin redness over pale greenish skin. However, they may also show shifted preference to these deceptive stimuli because they generalize their peak shift behaviour from the food context, where red fruit is preferred over green fruit.

2.7 Review conclusion

Our literature review stressed the importance of natural colours in their ability to influence consumers' selective attention. Evolution has shaped human vision and behaviour such as to be able to optimally perceive and react to important natural colours and contrasts such as red against green. The evolutionary *sensory drive model* can give a theoretical explanation of the long standing hypothesis that human reactions to red in various contexts are due to a general appraisal of red throughout various contexts. Furthermore, the specific preference of exaggerated red stimuli can be explained by a shift in peak preference along the green-to-red colour gradient humans may have been born to or may have learned to associate with negative stimuli (green for unripe and unattractive) and positive stimuli (red for ripe and attractive). Based on these interdisciplinary findings we explored human reactions to redness in the food context and in the mating context in a comprehensive experimental setting which will be presented in detail in the following.

3. Method

In our interdisciplinary literature review we have identified red as a colour of specific importance in three natural contexts: Foraging, mating and conflict. In two of these contexts, foraging and mating, humans show similar positive attraction to red. In two successive experiments we first empirically assessed if humans react to red in both natural contexts and second we tested if their preference for red colouration can be influenced by stimuli from distinct contexts. As we used novel interactive experiments and the human perceptual colour space CIEL*a*b* (reviewed in Judd, 1966), which is still rarely used in marketing research, we will present our methods in detail in this section.

3.1 Experimental setting

We conducted interactive optimisation experiments, in which participants could optimise the redness of a given image on an LCD screen. A total of 223 volunteers aged 18-30 years and with full colour vision were recruited for the experiments at the university campuses of the University of Göttingen, Germany, and the University of Freiburg, Germany.

In a first experiment, we assessed if redness of fruit or the face of a potential mate was associated with a given quality. To this end, groups of participants optimised the redness of a green apple for ripeness (13 men , 12 women) or a red apple for ripeness (13 men , 15 women) and unripeness (12 men , 12 women). The prediction for this experiment was, that participants would associate stronger redness with ripeness. Other groups optimised the redness of male or female faces for sexual attractiveness (26 men , 29 women) or sexual unattractiveness (24 men, 21 women). The prediction for this experiment was that participants would associate stronger facial redness with sexual attractiveness.

In a second experiment, we assessed if there was a common bias underlying the reaction to red in the food and in the mating context. To this end, we tested if the participants could be influenced in their skin colour preference of a potential mate by strong green or red colour stimuli that were emitted by objects from a non-mating context (here we used apples from the food context). Participants were presented with either a green apple (13 men , 13 women) or a red apple (13 men , 13 women) for two minutes before optimising the redness of the facial skin of a potential partner. The first prediction for the second experiment was, that if the there was pressure on humans to correctly assess fitness relevant cues via skin redness, they should not be influenced by other colour stimuli and always prefer the same facial redness which is associated with sexual attractiveness. In contrast, the alternative prediction for the experiment was that if humans were not under pressure to perceive fitness relevant cues via skin redness and their reaction to facial redness was influenced by an underlying bias, they would generalize their reactions to strong positive stimuli from the food to the mating context and consequently show a peak shift in preference towards more red when primed with a red stimulus.

3.2 Colour measurement

When measuring colour for research or for any practical use, it is important to acknowledge that there are crucial differences between the objective measurement of the colour of an object, the colour human colour receptors detect and finally the colour humans actually perceive. Objects reflect a very broad spectrum of electromagnetic waves, from far ultra violet to infra red heat waves. Colour receptors, however, are limited to a specific band of wavelengths, which is referred to as the visual spectrum (280 nm to 700 nm, Wald, 1945)□. Furthermore, the visual cortex does not process receptor signals as they arrive in the human eye, higher neuronal networks twist the signals around so as to enhance the colour resolution, which allows humans to almost optimally distinguish the vast majority of colours they encounter in their environments (Judd, 1966)□. Finally, these networks can compensate for variation in lighting conditions to some extent, so that colour perception does not change according to ambient lighting (e.g. Pretzel, 2008)□. Consequently, when scientists or practitioners need to know what colour is actually perceived after having gone through the receptors and the higher neuronal networks, they need to be able to translate the colour measured on an object under a specific ambient lighting into the truly perceived colour.

With the means of empirical experiments in which participants were asked to match various different colours, scientists have been able to approximate all colours humans can perceive and distinguish (reviewed in Judd, 1966, standard colorimetric observer; ISO 11664-1:2008(E)/CIE S 014-1/E:2006). Based on this data, the International Commission on Lighting (CIE) has been able to create the CIEL*a*b* colour space, a psychological colour space which accurately organises all distinguishable colours in a three-dimensional Cartesian coordinate system (ISO 11664-4:2008(E)/CIE S 014-4/E:2007). According to how colours are truly perceived, this colour space contains three dimensions, where L* is the dark-to-light axis, a* is the green-to-red axis, and b* is the yellow-to-blue axis. Each coordinate of this perceptual colour space represents a distinct colour. Furthermore, the CIE has published the algorithms through which it is possible to correct a measured colour spectrum for ambient light and then to translate this colour spectrum into the CIEL*a*b* colour space. In essence, each perceivable colour can be represented by three coordinates in the CIEL*a*b* colour space.

In our colour optimisation experiments, participants used Adobe Photoshop CS3 (Adobe Systems GmbH, München, Germany) to alter the redness of the food items or the faces along the green-to-red axis (a*) of the CIEL*a*b* colour space. However, computers represent colour coded in RGB (Red, Green, Blue) values that represent with which intensity those colours are emitted by each pixel of a screen. These colours are effectively what can be measured when working with computer screens. In order to be able to know what participants really perceived we used R (R 2.10.1, 2009 The R Foundation for Statistical Computing) to translated the RGB values of all the optimised pictures into CIEL*a*b* coordinates using the appropriate algorithms provided by the CIE.

3.3 Presentation of the stimuli

During the presentation of stimuli in an experiment, variations in ambient lighting and in the screens can alter the perception of the presented colours in a way that the measured RGB values will not correspond to the colours that were actually perceived. In order to make sure that the RGB values transformed into CIEL*a*b* will be the ones perceived, first, all pictures have to be taken under standardised ambient lighting with a calibrated camera, second, all screens must be calibrated to reproduce the standardised ambient lighting, and third, the ambient lighting during the experiment must be either standardised or turned off.

For our experiments, all pictures presented were taken with a calibrated digital camera (CANON EOS 20D, CANON Germany GmbH, Krefeld, Germany) under controlled lighting conditions in the photo-laboratory of the Evolutionary Psychology - Emmy Noether Research Group, University of Göttingen. All pictures were presented on calibrated wide gamut LCD screens (LaCie 324, LaCie GmbH, Weil am Rhein, Germany; QUATO Intelli Proof 240 excellence, Quatographic Technology GmbH, Braunschweig Germany) in original size and without ambient lighting. We used the European calibration standard D65 (ISO 10526:1999/CIE S005/E-1998) which corresponds to the ambient lighting of a moderately sunny day in central Europe.

3.4 Eye tracking

Selective attention of the participants is an important issue when measuring colour because it influences which areas of an object are fixated by the eyes. These areas are most important for colour assessment, as colour is mainly processed by the colour receptors in the *fovea centralis* of the humans eye, i.e. the region of the retina where the light coming from the fixated areas is focussed on (Hansen & Gegenfurtner, 2009). Light from surrounding areas is mostly processed as colourless light by peripheral parts of the retina. Consequently, in order to take only those colours into account that were decisive for the participants colour optimisation process, we conducted eye-tracking experiments to detect the fixations areas at the eye-tracking laboratory of the Evolutionary Psychology - Emmy Noether Research Group, University of Göttingen.

We showed the same food items or faces they had previously manipulated to the participants and informed them, that they would see a change in colour balance similar to their own manipulation. We compensated for biases to the participants reactions that arise from the eye-tracking apparatus by limiting eye-tracking experiments to 30 seconds per picture. Furthermore, we only used the first 5 seconds to extract eye-tracking information to identify the regions of interest of each face and fruit for both sexes, respectively. In order to maximise the fixation resolution we sampled eye movements at 250 Hz and recorded fixations when the eyes fixated a point longer than 0,08 seconds.

The output of the eye-tracker contained fixation points as well as horizontal and vertical deviances due to eye movement. The mean deviances over all participants were taken to delimit the mean fixation area (FA). The probability with which a given pixel of the picture has been fixated by chance is the maximum number of fixations that could have been recorded (MNF) during the first 5 seconds, divided by the number of fixation areas on a given picture (NFA).

$$P=\frac{MNF}{NFA}$$

with

$$MNF=\frac{5s}{0{,}08\,s}=62{,}5$$

and

$$NFA=\frac{Numberofpixelofagivenpicture}{FA}$$

Using R (R 2.10.1, 2009 The R Foundation for Statistical Computing) we identified all the pixels that were looked at more often than expected by chance (P) via Binomal Tests for each face and fruit and both sexes, respectively.

The colours of the pixels within these regions were extracted from all pictures. Using R (R 2.10.1, 2009 The R Foundation for Statistical Computing) these colours were transposed into the CIEL*a*b* colour space and analysed. In order to assure reproducibility we used the D65 standard as ambient lighting spectrum for the transformation (ISO 10526:1999/CIE S005/E-1998).

4 Findings

4.1 Selective attention to specific areas of interest

The eye-tracking experiment showed the limited areas of our fruit pictures and our faces that were of interest to the participants when paying attention to change in redness. Whereas the areas where centrally located in fruit, the areas on the faces showed a T-shape along the eyes and the nose down to the lips (Fig. 1).

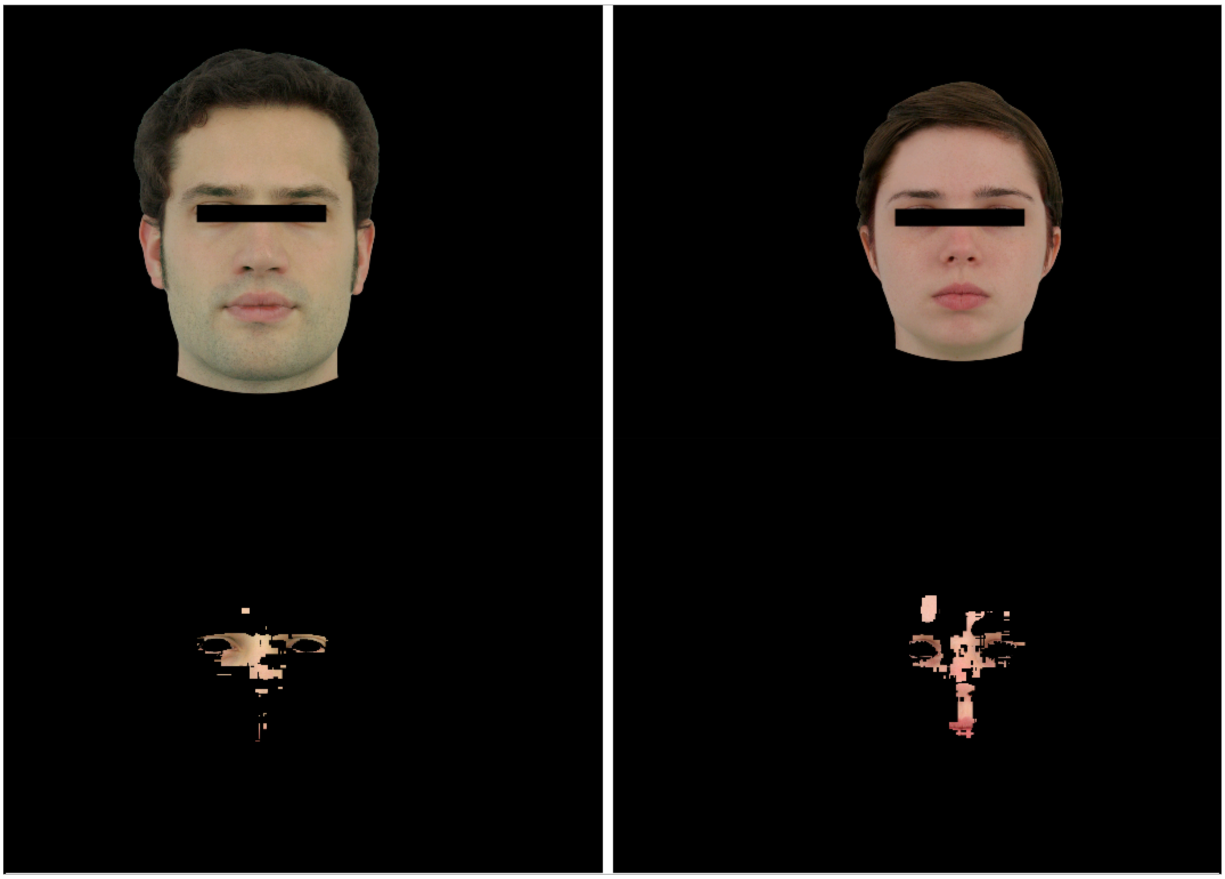

Figure 1: Top: Original male and female face as presented to the participants for the interactive optimisation experiment (censored for publication). Bottom: Areas of interest on the male face as seen by women (left), and on the female face as seen by men (right). Only the colours within these areas were extracted from all optimised faces and used for colour analysis.

4.2 Associating redness with quality

The results of our first experiment show that humans use redness of fruit and facial skin as cues for quality. Participants consistently associated redness with ripeness in apples (green apple: Binomial Test, men: n = 13, p < 0,001; women: n = 12, p < 0,001; red apple: Exact Wilcoxon Rank Sum Test, men: ripe n = 13, unripe n = 12, W = 146, p < 0,001; women: ripe n = 15, unripe n = 12, W = 173,5, p < 0,001). Remarkably, this is true for both our green and our red fruit items, even though the green apple was a Granny Smith, a strain which is green when ripe. However, the redness associated with ripeness shows strong variation, i.e. there is no evidence for the association of a precise amount of redness with optimal ripeness or unripeness.

Men and women likewise unanimously associate facial redness with sexual attractiveness and a paler more greenish facial skin with sexual unattractiveness (Exact Wilcoxon Rank Sum Test, men: attractiveness n = 26, unattractiveness n = 24, W = 432.5 p = 0,018; women: attractiveness n = 29, unattractiveness n = 21, W = 518, p < 0,001). Notably women show less variance in the facial redness associated with sexual attractiveness then men, i.e. women were more consistent then men in their choice of optimal facial redness (F Test, women n = 26, men n = 29, F = 3.29, p < 0.001).

4.3 Assessment of a receiver bias for red

In our second experiment, we found a sex specific shift in the participants preference of facial redness when primed with a strong red stimulus. As such, when presented with a green apple, men and women both preferred the same amount of facial redness which was also associated with sexual attractiveness, i.e. neither men nor women were influenced by the green apple (Exact Wilcoxon Rank Sum Test, men: preference n = 13, attractiveness n = 26, W = 189, p = 0,558; women: preference n = 13, attractiveness n = 29, W = 180, p = 0,822). Congruently, when presented with a red apple, women also preferred an amount of facial redness which was associated with sexual attractiveness as well (Exact Wilcoxon Rank Sum Test, preference n = 13, attractiveness n = 29, W = 118, p = 0,051). However, the nearly significant result suggests, that there might be a trend in women for being influenced by the red apple. In contrast, men showed a clear preference for an amount of facial redness which was stronger than the one associated with sexual attractiveness after having been subjected to a red apple (Exact Wilcoxon Rank Sum Test, preference n = 13, attractiveness n = 26, W = 88,5, p = 0,015).

5. Discussion

Human reactions to colour are diverse to say the least. Our experiments are meant as a first step to explore a novel evolutionary approach to understand how consumers react to colour in marketing contexts by identifying and testing colours that trigger similar reactions in distinct natural contexts. In natural communication systems, red appears to trigger similar reactions in the food and in the mating context. We tested to what extent redness communicates quality in both contexts and to what extent the preference of redness in the mating context is additionally influenced by a bias for red in humans. In this section we discuss the results of our experiments as well as novel methodological aspects.

5.1 Selective attention to specific areas

Humans are known to show strong selective attention depending on psychological, physiological and environmental parameters (Chun et al., 2011)□. In experimental settings it has been shown that the selective attention of the participants can be directed by the experimenter (Balcetis & Dunning, 2006)□. By cueing our participants to the change in redness they would perceive during the eye-tracking experiment, we made sure to direct their selective attention to the areas on the presented food items and faces that were decisive for the assessment of redness. The eye tracker records these areas as the areas surrounding the fixation points. Our results confirm the importance of this method by showing that the areas of interest are not equally distributed over all the surface of the items or faces or even the screen, on the contrary, the areas of interest show specific concentrations in the centre of the fruit items and along facial structures such as the eyes and the nose. These results are in line with similar eye-tracking studies on the perception of human faces (Hsiao & Cottrell, 2008)□. As colour is processed mainly by the receptors in the *fovea centralis* (Hansen & Gegenfurtner, 2009)□, the measured colours around the fixations points were most likely the perceived colours.

5.2 Redness stands for quality

Humans may associate colour with quality because they are born or because they have learned to do so. Consumers are subjected to various colour codes and artificial colourations and may learn to associate red with the strength of a drug or a specific type of soda (reviewed by

Divard & Urien, 2001). However, even natural colourations may be learned, for example apples from the Granny Smith strain never become red during the ripening process. Some humans may have even learned to associate the lack of redness with the gustatory characteristics of those green apples and may prefer them over red apples. In our experiments, however, we show that redness is consistently associated with ripeness despite variation in personal preferences and experience. This association is also made by related primate species (Lucas et al., 2003; Sumner & Mollon, 2000) and appears to be a common universal in catarrhine primates and humans. From primatological studies we know that natural fruit show a large variance in colouration and there is no one colouration that could be associated with optimal ripeness or unripeness. Consequently, our participants also showed large variation in the redness associated with ripeness. This means on the other hand, that a wide range of similar colours will trigger a reaction in humans or translated into a practical context: In order to trigger the wanted reaction, the food item must not only display one single colour but a variation of colours.

Despite the intensive usage of human models for all kinds of marketing purposes, only some companies in the beauty industry, which are directly involved with facial attractiveness, have initiated specific scientific research on the influence of facial redness in humans (Fink, Grammer, & Matts, 2006; Fink & Grammer, 2001). However, recent studies mainly concerned with evolutionary aspects of human communication have shown that humans can infer fitness relevant cues such as health and fertility via facial skin redness (Stephen, Coetzee, et al., 2009; Stephen, Law Smith, et al., 2009). Our results fall in line with these studies and show that humans also associate sexual attractiveness with a certain amount of skin redness. Furthermore, we show for the first time that women are more precise in their assessment of sexual attractiveness via skin redness than men. This result may suggest that women are under stronger pressure than men to correctly assess fitness via skin redness.

5.3 Biased to react to red

Red is known to be an influential colour which has been used since the dawn of human kind for body painting and arts (Knight et al., 2008). Grant Allen (1879) suggested over a century ago, that humans may be universally biased to be positively attracted to red colouration but it has only been in recent years that strategic approaches in evolutionary biology and psychology have provided empirical evidence of such a bias in humans (Elliot &

Niesta, 2008; Elliot et al., 2010). However, these few existing studies focus on the bias to react to red within a single context, for example men and women are more attracted to potential mates wearing red instead of another artificially coloured shirt. Consequently, the results of these studies do not allow us to assess if the observed preference peak shifts are based on learned associations of skin redness with quality (the shirt being unconsciously perceived as red skin), or if these reactions might be still influenced by an underlying bias for red.

In our study we predicted that the participants either would or would not be influenced after being primed with a strong green or red stimulus. Conform to the first prediction, women were not influenced by the priming with the green apple and showed only a trend of being influenced by priming with the red apple. It appears plausible that women are under more pressure to correctly assess the fitness of a potential mate via skin redness, as for women, mating with a suboptimal mate is more costly than for men. However, conform to the alternative prediction, men were strongly influenced by priming with a red stimulus. It is not entirely clear why men should be less selected for assessing fitness via skin redness, as mentioned above, one plausible reason is the weak selective pressure on mating due to the loose connection to the actual birth of offspring. It remains the question why men would then react to red in the first place. As the red stimulus was presented on an object from a non-mating context, we can conclude that men, and to a lesser extent women, generalize their reaction to red over distinct contexts, which, in turn, can be explained by a sex specific receiver bias for the colour red.

6. Limitations

The most obvious limitation in research on colour perception is visual impairment of the participants. When working with colour it is important to consider the fact that nearly 7 to 10% of men show on of two forms of red-green blindness. These men are insensitive to differences between red and green hues and are thus for example unable to differ between apple strains and are unable to see another person blush. In our experiments we selected for participants with full colour vision, consequently, our results do not apply to colour blind individuals. Colour blindness is an important marketing aspect considering that, on the one hand, up to 10% of the male consumers may be blind to the chosen colours and that, on the other hand, colours specifically chosen for colour blind consumers may attract the whole colour blind segment.

In our study we have been concerned with the association of quality with colour and colour preference. However, we have not assessed the influence of these variables on the purchase decisions in a specific marketing context. Marketing contexts show various parameters that are likely to equally influence consumer behaviour and need to be considered. For example, recent marketing studies have correctly pointed out that consumers will always perceive colours in the context of their own experiences (M.-christine Lichtlé, 2007). Consumers have learned to associate specific colours or colour codes with products, ingredients, services etc. Leading brands play an important role in shaping these associations, such as the association of red with soda thanks to Coca Cola (L. Jacobs, Keown, Worthley, & Ghymn, 1991). Consequently, when practitioners aim at attracting consumers by conspicuous colours, they have to be conscious that for example natural colours and shapes may universally attract a lot of attention, but they may be perceived as incongruous or inappropriate for the product, the service or the brand. It is still of utmost importance to assess how appropriate consumers consider a given colouration in a given context, not only the general attraction, and to test the influence on all variables that will eventually influence a purchase decision.

We sampled our participants randomly at two German university campuses, so our results should be interpreted considering this sampling method. We tried to minimize the influence of cultural implications or personal preferences, for example by asking the participants to optimise an apple not according to their personal preference but so as to appear optimally ripe. However, it is conceivable that some cultural or personal traits may impair the objectivity of the participants' judgements and we need to be conscious that despite random sampling, given the sample size of each group, single individuals may still have had an impact on our results.

7 Further research

7.1 Theoretical implications for future colour research

The omnipresence of colour in marketing emphasises its managerial importance. Colouration plays a central role in as little as a one time print advertisement up to as much as in being a central part of brand content and being used throughout a company for stores, sales uniforms, logos, signs, websites, packaging, product design and advertisement. However, the complexity of human reactions to colour makes the choice of adequate colour a difficult task: Marketers have to make their choice amongst over 2.3 million perceivable colours (Linhares et al., 2008)□ each of which may trigger different reactions of varying intensity depending on the individual psyche and physiology of a consumer, selective attention, context, culture, environment etc. Furthermore, marketers have to account for conflicting parameters such as ambient lighting, selective attention, cultural biases etc. It is our belief that it is only through directed empirical marketing research that researchers will be able to deliver sound data and straightforward methods for practitioners to enable them to successfully work with colour.

Colour psychological data has already proven to lead to ambiguous results despite precise colour measurement (reviewed by Divard & Urien, 2001)□. Based on our study we suggest that sensible choice of colour should start with considering how humans react to colour in natural communication systems. According to the sensory drive model, if specific colour stimuli are observed in different natural communication systems, there is a good chance that humans generalize their reactions to these stimuli throughout different natural contexts and that these reaction will also be triggered by similar stimuli in a marketing contexts. Future research will thus have to test natural stimuli in specific marketing contexts, such as product and web design, packaging, advertising etc.

7.2 Methodological implications for future research

Colour research in marketing has adapted means of standardizing colour measurement that increase reproducibility. The CIEL*a*b* colour space is easily accessible for researchers and practitioners, as professional colour manipulation software such as Adobe Photoshop allows colour manipulation in the CIEL*a*b* dimensions and many data analysis programs such as R offer pre-constructed algorithms which allow the transformation of RGB values into CIEL*a*b* coordinates (Ihaka et al. 2011). Furthermore, open source software such as ColourSpace (http://www.couleur.org) allow researchers and practitioners to easily visualise colours in CIEL*a*b* with different ambient lightings.

Working in the CIEL*a*b* colour space allows researchers to quantify colour as well as colour contrast. Future research can focus on assessing which colours are emitted by given objects and what the exact differences are between the colours of given objects. However, printed colours or colours presented on computers screens are limited and unevenly distributed in the human perceptual colour space which itself shows various distortions. For example humans are much less sensitive to saturation differences in blue hues and, additionally, computer screens tend to have a very limited resolution of blue hues. Consequently, visualising colour in CIEL*a*b* or similar colour spaces, is a crucial step for future research. With respect to saturation, visualising colour in CIEL*a*b* allows to account for the fact that merely increasing saturation may cause only very little perceptual changes, for instance in blue hues, or may lead to tremendous perceptual changes, for instance in red hues. Similarly, blue hues can maintain high saturation much longer while becoming lighter, whereas red hues loose saturation when becoming lighter.

For our experiments we chose a novel interactive optimisation method in which participants could manipulate colour of given objects until they perceived them as optimal according to a given quality. This type of experiment is very brief and easy to do for participants. Furthermore, it renders more accurate results as forced choice experiments because the presented objects are not biased by the experimenter and the active manipulation process allows participants to change the objects until they are satisfied.

Using standardised ambient lighting when taking the pictures, when presenting the objects on calibrated screens and when transforming RGB data into CIEL*a*b*, researchers and practitioners can make sure that the colours in the analysis are the ones that have been perceived and that their results can be reproduced. Most importantly, the use of a common ambient lighting standard (e.g. D65) throughout visual research disciplines, future researchers will be able to reproduce existing results, combine their data and compare their findings.

Our eye-tracking experiment has shown, that humans selective attention leads to the visual fixation of only a limited number of areas on a given object. When working with colour, it is important for researchers and practitioners to assess which areas of an object are of interest to consumers and will be fixated because colours are mainly perceived by the receptors on the *fovea centralis* (Hansen & Gegenfurtner, 2009) and peripheral colours may be ignored. Future research will have to account for this restriction, however, researcher may also refer to existing eye-tracking studies from other disciplines to learn which areas of an object might be fixated, such as the eyes and the nose rather than the cheeks on human faces.

In order to assess if the reaction to red was positively biased in the food and in the mating context, we conducted simple priming experiments where participants were primed with strong stimuli from another context before an optimisation experiment. Future research can readily use priming when participants are predicted to react with a peak shift in preference. If a peak shift is observed even when primed with objects from distinct contexts, there is substantial evidence that humans generalize their reaction to the stimulus throughout distinct contexts. Once a context independent stimulus is identified and tested, researchers can test the influence of the stimulus in marketing context using the prediction that consumers will react according to the reactions observed in the natural context.

8 Managerial implications

8.1 Two approaches for working with colour

Marketers may have to work with colours throughout all aspects of the mix, the primary goal of colour as a marketing tool being to trigger a reaction in a consumer. In practice, there are two basic situations in which the practitioner has to deal with colour: First, when a novel colour has to be chosen in order to influence consumers, and second, when the colour has already been chosen and the context needs to be adapted so as to influence consumers. Our study suggests two distinct approaches to these situations:

1) If a novel colour has to be chosen for a product, a packaging, a website, a store, an advertisement, a sales uniform, a brand logo etc., practitioners may first assess which reaction should be triggered in consumers via the colour stimulus. Second, practitioners may research which colours trigger the wanted reaction in natural communication systems. Third, they may experimentally assess if the reactions to the natural colours are similar in distinct contexts. Finally, practitioners can readily test the prediction, that the consumers' reactions to the colour will be similar in the natural and the marketing context.
2) If a colour has already been chosen, practitioners may first assess which reaction should be triggered in consumers via the colour stimulus. Second, practitioners may research in which natural communication systems the given colour triggers the wanted reaction. Third, practitioners may experimentally assess if the reactions to the natural colours are similar in all known contexts or if they are only similar in a certain type of context. Finally, practitioners can readily test the prediction, that the consumers' reactions to colour in a natural context will be similar to a marketing context, which has been adapted to resemble the natural contexts triggering the reaction.

8.2 Adapting to the global market

The global marketplace poses tremendous challenges for practitioners trying to market products and services throughout most diverse cultures. Colour has proven to be a sensitive subject as cultural biases may lead to a great demand in one society and to categorical rejection in another (reviewed in Divard & Urien, 2001). Practitioners facing either the choice of a new colour or the necessity to work with an existing colour, must make a strategic decision on how to approach the colour issue. We have presented two practical approaches for the work with novel or existing colours. In both approaches, practitioners need to identify natural communication systems in which humans show the reactions that should be triggered in consumers. Because these reactions have evolved in human and primate ancestors, they are likely to be universal in modern humans. Consequently, when facing global markets, practitioners can start with the straightforward prediction that humans will react to the colour stimuli according to the reactions observed in natural contexts.

In general, consumers around the world should comply to this prediction, however, some will most certainly not. On the basis of the predicted reactions, practitioners can hence readily measure deviances and use them to identify cultural biases which in turn allow for thorough segmentation. In essence, instead of an erratic trial and error approach based on inconsistent colour psychological data or subjective suggestions from independent organisations such as the *Color Marketing Group*, our study suggests a well directed strategic approach with clear predictions based on universal human reactions to colour stimuli in natural communication systems.

8.3 Specific implications for the choice of colour for products and packaging

Colour choice is important throughout the mix, however it is of central interest for product design and packaging. Here, practitioners face the dilemma of being required to conform to given colour codes while being required to create conspicuous colourations in order to attract the consumers' attention. Hence, it is crucial for practitioners to consider the category of the product before choosing colour, as the category decides in which store the product will be sold, in which section of the store it will be presented and which colour code competing products and packagings will display. The consumers' selective attention will be directed to the colour code of the product type allowing them to easily find the correct shelves in a store. There, colours in line with the colour code may render the product or packaging cryptic. On the other hand, extreme nonconformist colouration of the product and packaging may be unintentionally ignored by consumers who are focussed on the colour code. From our study we can extrapolate two strategies that may allow practitioners to attract more attention despite selective attention to an existing colour code.

First, colouration can exploit the peak shift phenomenon if there are differences in colouring within the colour code, which consumers have learned to associate with different qualities. For example, if weak drugs show light blue and strong drugs show light red colouration, then customers searching for strong drugs are likely to show a peak shift and prefer a packaging with a stronger red. Inversely, if detergents that contain a lot of ingredients that wash very well but might harm the environment generally show a lot of saturated colours whereas detergents that are less harmful to the environment show a little less colourful packaging, customers searching for environmentally friendly detergents might show a peak shift towards very subtle and even more poorly saturated colouration.

Second, natural colours, if possible combined with natural shapes, may also attract attention to colours inconsistent with the colour code just because humans have evolved to react to these colours. For example, we can again extrapolate from our study that packagings showing fruit sized reddish shapes will automatically attract attention. This effect can be even stronger if the colour code shows the same gradient as the natural stimuli such as to allow the natural colours to use a peak shift in preference. For example, if red labels are shown on milk bottles with non-organic milk and green labels are shown on bottles with organic milk, consumers might generally be more attracted to the bottles showing reddish rounded shapes with a saturated red, however, consumers searching for non-organic milk are likely to additionally show a peak shift and prefer even stronger reddish colouration.

8.4 Specific implications for the choice of colour for brands

The colour scheme of a brand bears specific importance as it is a central part of brand identity and personality. The brand's colour is used almost everywhere, from service uniforms to logos, from packing to the band name itself, as nicely illustrated by the French *Orange* and the German *Blau.de*. Colour is a central aspect of how consumers perceive the brand (Labrecque & Milne 2011). How well the virtues of a brand are perceived is a result of how well the brand colour matches the colour which consumers associate with the qualities they are looking for. Practitioners thus have to optimise the colour scheme of a brand so as to fit to consumers' expectations.

From our study, we can distinguish at least three different factors, that shape consumers' perception of quality via colour. First, famous brands dictate the colour scheme of a specific type of company, which consumers have learned to associate with the quality of this leading brand. For instance, red in soda drinks is associated with the quality delivered by *CocaCola* (reviewed in Labrecque & Milne 2011). Consequently, practitioners have to adapt their brand colour to the leading brand's colour in order to avoid inattentional blindness or negative associations.

Second, consumers may show a general bias to react to specific colours which they have been born to or which they have learned to associate with specific qualities in a given context. For example, if consumers generalize their association of the redness with ripeness in fruit (i.e. high nutritive value and sugar content), brands producing sweets such as *Kinder* may profit from consumers that generalize this association to various types of food. If consumers are found to generalize their quality associations, practitioners can exploit these reactions by offering brand colours according to the consumers learned or innate associations of quality with colour.

Third, quality can be correlated with colour along a consistent colour gradient. In this case there is an optimal quality, that is associated with a specific colour. Brands showing a colour with a stronger or weaker saturation or lightness, as compared to the colour of optimal quality, may be associated with an even better quality. For example, if darker brown is associated with a higher amount of cacao in chocolate, a brand with an extremely dark brand logo may be associated with having even more cacao. Practitioners may use this peak shift in association to optimise the association of quality with their brand whilst staying within the given colour scheme or colour code.

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