Color Psychology: Effects of Perceiving Color on Psychological Functioning in Humans

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Abstract

Color is a ubiquitous perceptual stimulus that is often considered in terms of aesthetics. Here we review theoretical and empirical work that looks beyond color aesthetics to the link between color and psychological functioning in humans. We begin by setting a historical context for research in this area, particularly highlighting methodological issues that hampered earlier empirical work. We proceed to overview theoretical and methodological advances during the past decade and conduct a review of emerging empirical findings. Our empirical review focuses especially on color in achievement and affiliation/attraction contexts, but it also covers work on consumer behavior as well as food and beverage evaluation and consumption. The review clearly shows that color can carry important meaning and can have an important impact on people's affect, cognition, and behavior. The literature remains at a nascent stage of development, however, and we note that considerable work on boundary conditions, moderators, and real-world generalizability is needed before strong conceptual statements and recommendations for application are warranted. We provide suggestions for future research and conclude by emphasizing the broad promise of research in this area.

Contents

INTRODUCTION

Humans encounter the world as a colorful place. Color is perceived on essentially every object that we view in daily life; it is even present in our dreams (Rechtschaffen & Buchignani 1992). Those with normal color vision experience a vast and rich chromatic palette, with estimates reaching up to 2.3 million discernable colors (Linhares et al. 2008) that may be seen together in an "almost infinite" number of possible combinations (Hård & Sivik 2001, p. 4). Color considerations emerge regularly in our decision making and conversation, as we choose which color clothes to wear, pick a color for our new car or computer, and comment on the color of our friend's skin, hair, or makeup. Popular opinions abound on the nature of color associations and on presumed influences of color on our feelings, aesthetic judgments, and beyond.

A considerable amount of scientific research has been conducted on many aspects of color. There are robust, well-developed literatures focused on the way that color is defined and modeled (i.e., color physics), on the way that the eye and brain process color stimuli (i.e., color physiology and neuroscience), on the way that color terms are represented in language (i.e., color linguistics and categorization), and on various practical issues such as color reproduction, color deficiency, and color appearance phenomena (e.g., illusions, synesthesia). Surprisingly, there is no comparably robust, well-developed literature on the effects of color perception on psychological functioning in humans. However, research activity in this area has surged in the past decade, and a number of noteworthy theoretical ideas and empirical findings have emerged. The time is right for a review of this research.

Several *Annual Review of Psychology* (ARP) articles have been written on color. Until 1989, each of these reviews was entitled "Color Vision" and focused on color physics and physiology. In 1989, an article entitled "Essay Concerning Color Constancy" was published in ARP, but here again the focus was on basic properties of color perception. The same is true for the two other

color-focused ARP articles that have appeared since 1989, the 1994 article "Color Appearance: On Seeing Red or Yellow or Green or Blue" and the 2008 article "Color in Complex Scenes." An article with "color psychology" in the title has yet to appear in ARP. Our focus in the present review is on a subset of color psychology, namely, the influence of perceiving color on psychological functioning in humans. Even this subset of color psychology is too broad for a single review; thus, we focus primarily on effects of color perception on downstream affective, cognitive, and behavioral responding in two fundamentally important domains of daily life: achievement contexts and affiliation/attraction contexts.

HISTORICAL CONTEXT (PRE-TWENTY-FIRST CENTURY)

Theoretical Work

Scholarly interest in the link between color and psychological functioning may be traced back to the German poet and polymath Johann Wolfgang von Goethe. In his classic work "Theory of Colors," Goethe (1810/1967) offered intuition-based speculation on the influence of color perception on emotional experience. Colors were categorized as "plus colors" or "minus colors." Plus colors, namely, yellow, red-yellow, and yellow-red, were thought to induce positive feelings such as lively, aspiring, and warm, whereas minus colors, namely blue, red-blue, and blue-red, were said to induce negative feelings such as restless, anxious, and cold.

Goethe's speculations were expanded on in the twentieth century by psychiatrist Kurt Goldstein. Goldstein (1942) integrated Goethe's ideas with his own clinical observations in proposing that color perception produces physiological reactions in the body that are overtly manifest in people's emotions, cognitive focus, and motor behavior. Red and yellow were posited to be stimulating, to prompt an outward focus, and to produce forceful action, whereas green and blue were posited to be relaxing, to encourage an inward focus, and to produce calm and stable action. Goldstein's ideas were vaguely formulated, and subsequent researchers have tended to read his ideas through the lens of wavelength and arousal. Specifically, longer wavelength colors such as red and orange are thought to be experienced as arousing or warm, whereas shorter wavelength colors such as green and blue are thought to be experienced as relaxing or cool (Nakashian 1964). The experiential states induced by wavelength are presumed to influence performance on achievement tasks, with longer, relative to shorter, wavelength colors inducing states that impair performance on complex tasks but facilitate performance on simple tasks (Stone & English 1998).

Similar to Goldstein, Ott (1979) proposed that color directly produces physical reactions in the body that are manifest in observable behavior. He posited that pink and orange light have an endocrine-based weakening effect on muscle functioning, whereas blue has an endocrine-based strengthening effect on muscle functioning. Others have offered theoretical statements focused on learned associations to color and their possible influence on affective, cognitive, and behavioral responding. For example, Frank & Gilovich (1988) proposed that black is associated with negative concepts such as evil and death and prompts people to behave more aggressively toward others, accordingly. In similar fashion, Soldat et al. (1997) proposed that red is associated with happiness and blue is associated with sadness, and that these colors lead to information processing and behavior consistent with these emotions. Finally, much of the pre-twenty-first-century writing on color and psychological functioning focused on applied questions per se (e.g., Does the color on an office wall influence worker productivity? What colors are most fashionable? What colors enhance the taste of food?), with little or no interest in or reliance on theoretical considerations.

Methodological Issues

Conducting scientific research on color requires attending to the fact that color varies on multiple attributes. In most experimental research, the most important of these attributes to attend to are hue, lightness, and chroma (Fairchild 2005). Hue is wavelength and is what most people think of when they hear the word "color." Lightness is similar to brightness and is essentially the white-to-black property of the color. Chroma is similar to saturation and is essentially the intensity or vividness of the color (Fairchild 2005). Each of these color attributes may have an influence on psychological functioning (Camgöz et al. 2004), so only one of them should be allowed to vary in a well-controlled experiment. Failure to control for nonfocal color attributes leads to a confounded design and results that are essentially impossible to interpret (Valdez & Mehrabian 1994). That is, if more than one color attribute varies at the same time, it is not possible to determine if an obtained result is due to the color attribute of central interest or to one or more of the other color attributes. In addition to varying on hue, lightness, and chroma, color also varies on perceived typicality—the degree to which a color is seen as a standard representation of its category. Although not as important as controlling for the multidimensionality of color stimuli, equating colors on perceived typicality bolsters the rigor of empirical work on color.

Unfortunately, the majority of the extant research on color and psychological functioning conducted pre-twenty-first century failed to systematically attend to the multidimensionality (and perceived typicality) of color stimuli. Many investigators likely selected colors that appeared (to their eyes) to be reasonable exemplars of color categories without pilot testing this assumption; others simply picked colors from unsystematic popular sets that were readily available (e.g., Milton Bradley color papers) or picked colors by visually matching (i.e., "eyeballing") them to systematic sets without independent verification. In addition to this critical flaw, many of the studies conducted during this time also contained other methodological problems such as failing to keep the experimenter blind to the hypothesis, failing to exclude color-deficient participants, and failing to present the color stimuli in a time-controlled manner. In light of these issues, it should come as little surprise that much of the research conducted in this era yielded inconsistent findings that were largely unsupportive of hypotheses. Also in light of these issues, we have refrained from reviewing the details of this literature herein, referring the reader instead to reviews by Whitfield & Wiltshire (1990), Valdez & Mehrabian (1994), and Elliot & Maier (2012). Given the centrality of the hypothesized relation between wavelength and arousal, however, we offer a brief summary statement on empirical work testing this relation. Simply put, many studies have been conducted, but they have primarily produced null results; this is particularly the case for experiments utilizing rigorous methods (Kaiser 1984, Suk & Irtel 2010, Valdez & Mehrabian 1994).

RECENT THEORETICAL ADVANCES AND METHODOLOGICAL CONSIDERATIONS

Theoretical Advances

In the past decade, the primary theoretical advances in the area of color and psychological functioning have shared a common feature: They have sought to ground color effects in biology, drawing on parallels between human and nonhuman responding to color stimuli. The germ of these ideas has been present for quite some time and noted by a number of different scholars (Darwin 1872, Ellis 1900, Humphrey 1976). However, these new theoretical frameworks contain additional insights and conceptual statements informed by contemporary knowledge from multiple disciplines and afford the generation of clear and precise hypotheses that can be put to direct

empirical test. These frameworks have focused primarily, but by no means exclusively, on the color red.

Hill & Barton (2005) highlighted the signal function of red in competitive interactions in human and nonhuman animals. In many animals, including primates, red coloration in aggressive encounters is a testosterone-based indictor of dominance in males; the alpha male shows the most prominent red. Likewise, in humans, testosterone surges in aggressive encounters produce visible reddening of the face, whereas fear produces pallor. This link between red and dominance may transfer from physiological processes to artificial stimuli such as sport jerseys (for analogs in the wild, see Healey et al. 2007, Pryke 2009). If so, wearing red in aggressive competitions such as boxing should function as a dominance signal and lead to enhanced performance attainment.

Other theorists have focused on the signal value of skin coloration in affiliative interaction and attraction in human and nonhuman animals. Changizi and colleagues (2006) argue that trichromatic color vision evolved to allow primates to detect subtle color changes on the skin based on underlying blood flow. These skin color modulations reflect the emotion, state, or condition of the perceived conspecific, and visual sensitivity to these modulations is thus extremely useful in interpersonal interaction. Our visual systems detect modulations in both the oxygenation of hemoglobin (along a red-green axis) and concentration of hemoglobin (along a blue-yellow axis), and these modulations are associated with specific shifts in coloration. Greater oxygenation produces more red and less green coloration, whereas greater concentration produces more blue and less yellow coloration. Thus, color vision enables perceivers to discern, among other things, when a date is becoming sexually aroused (more oxygenation-based redness) or an elderly parent is becoming sick (more concentration-based blueness). Likewise, Stephen and colleagues (2009b) draw parallels between human and nonhuman signal coloration in positing that facial skin coloration carries cues that perceivers use to judge the attractiveness, health, and dominance of conspecifics. They propose that the redness and yellowness of skin promote positive perceptions: Redness (due to blood oxygenation) is thought to reflect cardiovascular wellness, and yellowness (due to carotenoids) is thought to reflect fruit and vegetable consumption. Fink and colleagues (2006) contend that the homogeneity of skin color, beyond hue per se, influences perceptions of the attractiveness, health, and age of faces.

In their color-in-context theory, Elliot & Maier (2012) focus on both biologically based and learned sources of color meanings and effects. Some color effects are thought to represent inherent tendencies to interpret and respond to color in a manner similar to that observed in our nonhuman primate relatives. Other color effects are thought to be rooted in the repeated pairing of color and particular concepts, messages, and experiences; over time, these pairings create strong and often implicit color associations such that the mere perception of the color evokes meaning-consistent affect, cognition, and behavior. Furthermore, it is likely that some color-meaning links, especially those that are observed across time and culture, are a product of the cognitive reinforcement and shaping (via social learning) of an initial biologically engrained predisposition. Such higher-order learning may be responsible for reinforcing and extending the applicability of color-meaning links beyond natural bodily processes (based in blood physiology) to objects in close proximity to the body (e.g., clothes) and even objects in the broader environment (e.g., signs and signals). Thus, a red dress may carry sexual meaning, much like the red of sexual excitation on the face and upper chest. Critically, color meanings and effects are posited to be context specific. The same color can have different and even opposite meanings and effects in different contexts. For example, red is hypothesized to have a negative meaning (failure) and aversive implications (avoidance motivation) in achievement contexts, but it is hypothesized to have a positive meaning (sexual receptivity or status) and appetitive implications (sexual desire) in mating contexts.

Methodological Considerations

As noted in the Methodological Issues section above, to avoid confounding hue, lightness, and chroma in an experiment, it is imperative to vary only one attribute at a time. In the past decade, researchers have begun to address this issue of color control with much greater regularity by implementing a variety of different techniques. These techniques vary considerably in their effectiveness, ease of use, and flexibility of application.

One approach that has been adopted quite frequently is to use a computer software program to select colors to be printed or displayed on a computer monitor. Many software programs such as Photoshop include a function that allows the user to insert numerical values for hue, lightness, and chroma (or similar attributes) based on the metric of a particular color model. Unfortunately, the software program, computer monitor, and printer are typically not calibrated and thus do not produce color in the same way. The upshot is that the resultant color output is typically discrepant from the color values entered into the computer program; this discrepancy can be trivial or considerable, but, importantly, its extent is unknown. Given this problem, this approach to color control is not a good option; it is certainly better than no control at all, but data obtained via this method must be interpreted cautiously.

A second approach that may be employed is to select pre-existing color samples within a well-validated model such as the Munsell color system or the Natural Color System. These systems provide arrays of color chips that are systematically arranged according to uniform perceptual spacing for hue, lightness, and chroma (or similar attributes). Color chips may be selected that vary on one attribute but are the same on the other two attributes. Although this approach affords tight experimental control, it is limited to the specific color combinations provided in the material sets of each system. In addition, and more importantly, the color chips themselves must be used as stimuli to fully exploit the rigor of the approach, and this greatly limits the ways in which color can be presented (e.g., it can't be presented on a monitor or superimposed onto a picture of an object for printing). Accordingly, this approach is not well suited to many types of research on color and psychological functioning.

A third approach is to use a spectrophotometer to create color stimuli. A spectrophotometer is a device that assesses color at the spectral level; it provides objective numeral values for hue, lightness, and chroma (or similar attributes) and does so taking into account different types of environments (e.g., direct sunlight or cool white fluorescent lighting) and observer viewing angles. Using a spectrophotometer, the color attributes of a given stimulus are assessed and then adjusted to select target values that vary on only one attribute. Color may be assessed in a range of formats, be it printed, presented on a computer monitor, or present on a physical object. This combination of accuracy and flexibility makes the spectrophotometer approach ideal.

The one limitation of the spectrophotometer approach is that it does not take into account variability in color perception across individuals. A technique commonly used in psychophysical research that does account for this variability is the minimally distinct border method. In this approach, two adjacent hues are presented on a computer monitor, and participants' task is to adjust the lightness or chroma of one of the hues until they become the same on this attribute. Although this approach allows tight experimental control, there are several limitations to employing this method in research on color and psychological functioning: It can only be used when presenting color on a computer monitor, it draws explicit attention to color stimuli (making research on implicit effects impossible), and it can only be used with participants who are able to complete the minimally distinct border task.

We think the use of a spectrophotometer is the optimal method for controlling color in research on color and psychological functioning. It is objective, flexible, and adaptable, and it yields data

that are sufficiently accurate for anything except, perhaps, psychophysical research. Although it does not control for individual differences in color perception, this variation is like any other individual difference in that it merely adds unsystematic variance to the design that is randomly dispersed across conditions.

In the following empirical review, we focus primarily on work that has used one of the aforementioned forms of color control, including a good deal of work that has utilized the spectrophotometer method. We think the move toward more rigorous control of color stimuli is an important factor contributing to the improved clarity and consistency of the empirical yield during the past decade and is an important reason for the current resurgence of research in this area.

One final methodological issue should be noted, and that concerns conducting color research on web platforms such as the popular Mechanical Turk (MTurk). Color presentation is device dependent. The color values selected and inputted by an investigator for use in an MTurk experiment will be presented to participants in myriad different ways because participants will be viewing the color stimuli on myriad different computer monitors. Given that color matching is impossible in this instance, it seems prudent to limit color research to one of two possibilities, accordingly: (*a*) comparison of one chromatic color to a white control condition (in which case color control is not possible anyway) or (*b*) use of color words rather than color stimuli. Even the former possibility must carry an important caution: Participants will view the presented color stimuli at myriad different angles, and perceived color can vary considerably as a function of viewing angle. For example, an experimenter-intended red may indeed look red when viewed by participants straight on, but may look washed out or even pinkish when viewed from even a moderate angle.

In the following, we review the empirical research on color and psychological functioning from the past decade, focusing primarily on work relevant to achievement and affiliation/attraction contexts. We limit our review to articles published in peer-reviewed journal articles and papers published in edited volumes or conference proceedings.

EMPIRICAL FINDINGS: COLOR EFFECTS ON PSYCHOLOGICAL FUNCTIONING

Color in Achievement Contexts

Competitive sport performance. Hill & Barton (2005) used data from four combat sports (e.g., boxing, tae kwon do) in the 2004 Olympics to test their proposal that red functions as a dominance cue in human competitions and enhances performance accordingly. Their results showed that competitors randomly assigned to red relative to blue sportswear were more likely to win the competition; this was particularly the case with male competitors (Barton & Hill 2005) and with competitors of relatively equal ability. Ilie et al. (2008) extended this finding to performance on a multiplayer first-person shooter video game, finding that red teams win more virtual matches than blue teams. Attrill et al. (2008) analyzed more than 50 years of archival data from elite English soccer leagues and found a performance advantage for teams wearing red relative to others colors. Subsequent research testing for a red advantage in soccer and rugby leagues in England and other countries has yielded mixed results. Piatti et al. (2012) found the red effect in the Australian National Rugby League but also found evidence that it was primarily driven by the top teams in the league. Allen & Jones (2013) found the red advantage in the English Premier League with more recent data than those examined by Attrill et al. (2008), but they also found that this effect did not hold for home games with team ability held constant. Red was not found to boost team performance in archival analyses of elite soccer leagues in Germany, Poland, and Spain (Garcia-Rubio et al.

2011, Kocher & Sutter 2008, Szmajke & Sorokowski 2006), and the National Hockey League in North America (Caldwell & Burger 2011). These data suggest that the red effect may be present in some countries but not others, perhaps as a function of culture-specific learned associations to red that run counter to, and weaken the influence of, any inherent meaning. Likewise, the strength of the red effect may vary as a function of team versus one-on-one competition (Kocher & Sutter 2008) or collaborative versus combat sport. For example, red may have a stronger effect in combat sports where direct physical dominance is the aim, and the red of blood, both spilled and drained from the face of a frightened opponent, is more visible and salient.

Although less studied, some evidence from one-on-one combat sports such as judo suggests that wearing blue may convey a performance advantage over wearing white (Matsumoto et al. 2007, Rowe et al. 2005). However, reanalyses of such data have revealed that this effect may be partially or entirely due to confounding factors (e.g., inclusion of repechage rounds; Dijkstra & Preenen 2008). Black and white have been examined as achromatic colors that have associations with aggression (black) or its absence (white), and that, accordingly, may influence either players' aggressiveness or referees' perceptions of aggressiveness in competitive sport. The data appear to be mixed, but the most recent, and perhaps methodologically strongest, research yielded supportive evidence (see Caldwell & Burger 2011, Tiryaki 2005, Webster et al. 2012).

The mechanism to account for the red effect posited by Hill & Barton (2005) is that wearing red enhances one's dominance, aggressiveness, and testosterone, which facilitates competitive outcomes. That the red effect has been found to be most prominent with males (Barton & Hill 2005) is consistent with this account, as are several studies linking wearing red or being affiliated with red (relative to chromatic or achromatic controls) to perceiving oneself as more dominant, intimidating, threatening, aggressive, and powerful (Feltman & Elliot 2011, Ten Velden et al. 2012) and exhibiting a higher heart rate, higher testosterone, and greater preperformance strength (Dreiskaemper et al. 2013, Farrelly et al. 2013; although see also Hackney 2006). Independent of the influence of wearing red, viewing red on an opponent may also exert an influence. A number of studies have yielded results that are ambiguous regarding this wearing/viewing distinction, showing that a target presented in red is perceived to be more dominant, aggressive, brave, competitive, and more likely to win a competition (Little & Hill 2007, Sorokowski & Szmajke 2007) or demonstrating a general association between red and anger or aggression (Bagchi & Cheema 2013; Fetterman et al. 2011, 2012; Guéguen et al. 2012; Tharangie et al. 2009, 2011; Young et al. 2013). Other research has clearly differentiated viewing red from wearing red and found that opponents wearing red are perceived to be more dominant, intimidating, competitive, and assertive (Feltman & Elliot 2011, Greenlees et al. 2008, Ten Velden et al. 2012; although see also Furley et al. 2012). In a particularly elegant series of studies, Ten Velden et al. (2012) showed that playing with red (relative to blue) poker chips increased participants' experienced dominance and led to increased betting behavior, whereas the opposite perceptions and behavior were observed for participants playing against an opponent using red (relative to blue) chips. Other explanations have also been offered for the red effect, namely that the influence of red is due to its greater visibility (for relevant findings, see Rowe et al. 2005) or to referee bias favoring those wearing red (for relevant findings, see Hagemann et al. 2008). It should be noted that all of these explanations may have merit and may be seen as complementary rather than conflicting.

Individual cognitive and motor performance. Elliot and colleagues (2007) proposed that viewing red in an achievement context can undermine performance on challenging tasks that require mental manipulation and flexibility. They posited that red is associated with failure and danger and evokes avoidance motivation in such contexts, which impedes performance attainment. Their experimental studies indicated that individuals who viewed red before or during

anagram, analogy, and math tasks performed worse than those who viewed green or achromatic control colors. Subsequent research has also observed this red effect using additional chromatic controls and additional types of challenging cognitive tasks (e.g., verbal reasoning, working memory, attentional interference, creativity, and language proficiency; Elliot et al. 2011, Gnambs et al. 2010, Ioan et al. 2007, Jung et al. 2011b, Lichtenfeld et al. 2009, Maier et al. 2008, Yamazaki & Eto 2011). Some experiments have found evidence that the red effect may be particularly or only present for males in some instances (Gnambs et al. 2010, Ioan et al. 2007), and others have not found the effect with some control conditions (Jung et al. 2011b, Lichtenfeld et al. 2012, Mehta & Zhu 2009, Yamazaki 2010) or with ambient color (i.e., color painted on an office wall; Küller et al. 2009). Some experiments have yielded evidence suggesting that viewing blue or green may be particularly beneficial for creative performance (Lichtenfeld et al. 2012, Mehta & Zhu 2009; cf. Küller et al. 2009) and that yellow may be detrimental for certain types of challenging cognitive tasks (Kumi et al. 2013, Yamazaki 2010), but these questions have received only a modicum of empirical attention. In a related vein, Akers et al. (2012) found that viewing green (relative to red or gray) during a cycling task led to less perceived exertion during the task.

Avoidance motivation can facilitate performance on basic, detail-oriented cognitive tasks that require minimal mental manipulation or flexibility (Friedman & Förster 2010), and, accordingly, Mehta & Zhu (2009) offered and found evidence to support the proposal that red facilitates performance on such tasks (e.g., proofreading; cf. Küller et al. 2009). Other experiments have found that red can facilitate performance on an overlearned motor task (Larionescu & Pantelimona 2012), a target-shooting task (Sorokowski & Szmajke 2011), and an immediate-response basic strength task (Elliot & Aarts 2011); some have found that red can undermine performance on a goal-directed motor movement task (Williams et al. 2011) and a delayed-response basic strength task (Payen et al. 2011). Other factors, beyond task type, also warrant consideration as boundary conditions and moderators of the influence of red on cognitive performance. For example, the red effect may vary as a function of the difficulty level of the task, the degree to which ability evaluation is made salient or social in the achievement setting, and the extent to which the individual's ability level, sex, or culture make ability evaluation threatening. Moderately challenging tasks, moderately evaluative contexts, and moderately reactive individuals would seem most likely to exhibit the red effect, whereas ceiling or floor effects may weaken or eliminate the effect in other instances (for an illustration regarding sex moderation, see Gnambs et al. 2010). Furthermore, ambient color may not be sufficient to produce an effect, or prolonged exposure to color may lead to habituation over time (Küller et al. 2009).

In terms of the mechanism(s) responsible for the red effect on performance, several studies have demonstrated that red is implicitly associated with failure and danger in achievement situations (Mehta & Zhu 2009, Moller et al. 2009, Rutchick et al. 2010). For example, Rutchick et al. (2010) showed that participants are more likely to complete word stems with failure-relevant words (e.g., fai_ as "fail" rather than "fair") when using a red (relative to black) pen. Interestingly, teachers are evaluated more negatively when they grade students' work using red versus aqua ink (Dukes & Albanesi 2013). Some research suggests that red may even carry negative valence by default, as red has been linked to negative content and affective experience in situations where no ability evaluation or content is present (Chien 2011b, Diehl et al. 2011, Genschow et al. 2012, Gerend & Sias 2009, Magee 2012, Moller et al. 2009, Piotrowski & Armstrong 2012; although see Chien 2011a). Viewing red in achievement situations prior to or during task engagement has been shown to evoke avoidance motivation and behavior in a number of studies using a variety of different indicators: local relative to global processing, selecting easy rather than moderately difficult tasks, walking more slowly to an evaluative event, knocking fewer times on the door of a testing room, moving physically away from an ability test, less risky investment decision making, decreased

heart rate variability, and right relative to left frontal cortical activation (Elliot et al. 2007, 2009, 2011; Gillebaart et al. 2012; Kliger & Gilad 2012; Lichtenfeld et al. 2009; Maier et al. 2008; Meier et al. 2012; Mehta & Zhu 2009; Rutchick et al. 2010; Shavit et al. 2013; Tanaka & Tokuno 2011). Data supporting the role of avoidance motivation as a mediator of the link between red and performance have been reported in Lichtenfeld et al. (2009), Maier et al. (2008), and Mehta & Zhu (2009). Furthermore, Mehta & Zhu (2009) documented approach motivation, operationalized as focusing on speed over accuracy, as a mediator of their observed positive effect of blue on creative performance.

High school and college teachers sometimes print alternate forms of quizzes or exams on different colored paper to ensure that students receiving the same form do not sit in close proximity to each other during the evaluative event. Several studies have been conducted to determine the fairness of this procedure (i.e., whether color or lack of color conveys a performance advantage). The results are mixed. A few studies have found that students perform better on exams printed on standard white paper relative to primary colors; white versus pastel colors have tended to produce null results (Clary et al. 2007, Fordham & Hayes 2009, Meyer & Bagwell 2012, Skinner 2004, Tal et al. 2008). Colored exams are unusual, and the white advantage that sometimes emerges may be a function of distraction due to novelty (Skinner 2004). In interpreting these studies it is important to bear in mind that they have been driven primarily by applied concerns and have not attended to basic methodological issues such as experimenter blindness or controlling nonhue attributes. One additional applied question that has received attention is whether adding color (of any sort) to cognitive tasks helps children with learning disabilities such as attention deficit-hyperactivity disorder to concentrate and perform better. Imhof (2004) found support for this possibility (see also controversial research on colored overlays and reading behavior in children with disabilities, overviewed in Henderson et al. 2013 and Wilkins 2003).

Color in Affiliation/Attraction Contexts

Color on the skin. Stephen, Perrett, and colleagues have conducted a program of research designed to test their theoretical proposals (described in the section Recent Theoretical Advances and Methodological Considerations) regarding relations between various properties of facial skin color and perceived health and attractiveness. In their research, participants have either added color to faces to enhance a target characteristic or they have rated faces or made forced choices between faces with regard to a target characteristic. This research has revealed that faces that are redder (presumably due to blood perfusion), yellower (presumably due to carotenoids), and lighter are rated as healthier and more attractive (Coetzee et al. 2012; Re et al. 2011; Stephen & McKeegan 2010; Stephen et al. 2009a, 2011, 2012a,b; Whitehead et al. 2012). Some data suggest that these relations may be particularly strong for own-race judgments (Stephen et al. 2012b). The links between redness or lightness and these characteristics are occasionally not observed (Coetzee et al. 2012, Stephen et al. 2012b), and the links between yellow and health and between lightness and health seem particularly prominent for female faces (Stephen et al. 2009a,b).

An experiment by Stephen et al. (2012a) focused specifically on women viewing men's faces found that women put more red on men's faces to make them more aggressive, dominant, and attractive; the relation was stronger for aggressiveness than dominance than attractiveness, a pattern that may reflect a tradeoff between the costs of selecting an aggressive mate and the benefits of selecting a dominant and attractive mate. Stephen et al. (2009a) showed that perceivers not only view redder (i.e., blood colored) facial skin as more healthy, but they also consider oxygenated blood color (brighter red) relative to deoxygenated blood color (bluish red) as a sign of better health. Stephen & McKeegan (2010) examined color contrast of the lips, relative to the rest of the

face, and found that perceivers view greater redness, less blueness, and more lightness contrast to be more attractive; this was especially so for female targets for the redness and blueness contrasts (cf. Stephen et al. 2009a). Johns et al. (2012) tested whether the link between enhanced redness and attractiveness is present for women's genitalia; no significant effect was observed. Two studies have tested whether women's facial skin becomes redder during the most fertile phase of their ovulation cycle. One study found supportive evidence (Oberzaucher et al. 2012), whereas the other did not (Samson et al. 2011).

Given that the relations observed in this body of work are presumed to be due to mate preference and selection processes, it is surprising that perceiver sex by target sex interactions have not emerged when tested. Additional research on this lack of sex specificity is needed. It would also be interesting to see if location of facial coloration moderates the observed relations and whether dynamic displays of facial redness have a different influence than static displays. For example, perceiving a slight increase in facial redness may be particularly likely to increase health and attractiveness ratings relative to a slight decrease or a static, average, degree of red coloration. An added benefit of such research is that the color manipulations could be instantiated in extremely subtle fashion, without conscious awareness or knowledge that the experiment involved the manipulation of color.

Fink and colleagues have conducted a number of studies testing their proposal that homogeneous facial skin color distribution (i.e., more even skin color) negatively predicts perceptions of age and positively predicts perceptions of health and attractiveness. These studies have yielded supportive results (Coetzee et al. 2012, Fink et al. 2006, Fink & Matts 2007, Matts et al. 2007, Samson et al. 2010). Fink et al. (2008) even demonstrated that perceivers look more often and longer at a face with homogeneous skin color. Most of these studies have examined skin color distribution for female targets, but two recent experiments have found the same pattern for male targets as well—more homogeneous facial skin color leads to lower perceptions of age and higher perceptions of health and attractiveness (Fink et al. 2012a,b). More detailed analyses focusing independently on the homogeneity of specific chromophores have found that both homogeneous hemoglobin and homogeneous melanin negatively predict age and positively predict health and attractiveness (Fink et al. 2012a, Matts et al. 2007). It is in these more detailed analyses that a subtle sex difference emerges: For women targets, the homogeneity of melanin is a stronger predictor of perceived age, health, and attractiveness, whereas for male targets, the homogeneity of hemoglobin is a stronger predictor of these characteristics. A recent study by Oberzaucher et al. (2012) found that women's facial skin homogeneity was greater during the most fertile phase of their ovulation cycle. As with the research on skin color per se, the relations observed are presumed to be due to mate preference and selection processes, but perceiver sex effects have not emerged. Subsequent work would do well to explore this issue.

Extended color stimuli. Color may not only have an influence on attraction when displayed directly on the skin, but it may also impact attraction when seen in close proximity to a person of the opposite sex. Indeed, in a series of experiments, Elliot & Niesta (2008) found that men rate women as more attractive and sexually desirable when the women are viewed within a red picture border or in red clothing. Subsequent research has also found support for this extended red effect on perceived attractiveness or attraction (Elliot et al. 2013b; Guéguen 2012a; Jung et al. 2011a,b; Pazda et al. 2012, 2013; Roberts et al. 2010; Schwarz & Singer 2013), although a few experiments have not found the effect with some measures (Schwarz & Singer 2013), some control conditions (Jung et al. 2011b, Roberts et al. 2010), or at all (Purdy 2009). Several experiments have shown that the effect is not limited to perceptions but may be observed in actual behavior. Specifically, researchers, especially Guéguen and colleagues, have demonstrated that men are more likely to

contact a woman displaying red on a dating website (Guéguen & Jacob 2013b), tip waitresses in red more generously (Guéguen & Jacob 2012, 2013a), are more likely to approach a woman at a bar wearing red lipstick (Guéguen 2012c), are more likely to pick up a woman hitchhiker wearing red (Guéguen 2012b), ask more intimate questions of and sit closer to a woman in red (Niesta Kayser et al. 2010), and walk more quickly to an interview on dating conducted by a woman in red (Meier et al. 2012). Research on the sex-specificity of the red effect is equivocal with regard to perceptions of attractiveness (see Elliot & Niesta 2008, Roberts et al. 2010), but it seems clear that the effect is specific to men with regard to actual behavior (Guéguen 2012b; Guéguen & Jacob 2012, 2013a). Both men and women rate women wearing color cosmetics (which include red) as more attractive than those not so adorned (Etcoff et al. 2011, Guéguen & Jacob 2011, Huguet et al. 2004, Smith et al. 2006; for complementary behavioral findings with male perceivers, see Guéguen 2008, Guéguen & Jacob 2011, Jacob et al. 2009). Interestingly, Burtin et al. (2011) demonstrated that women rate themselves as more attractive when wearing red, relative to blue, perhaps reflecting women's knowledge of men's preferences. Black, like red, has been shown to facilitate perceptions of attractiveness (either directly or indirectly) for men viewing women in the few experiments that have examined this question (Pazda et al. 2013, Roberts et al. 2010); however, this black effect does not appear to translate to men's actual behavior toward women (Guéguen 2012b; Guéguen & Jacob 2013a,b).

Some experiments have found that the red effect is limited to men rating younger (but not older) women (Schwarz & Singer 2013) and to culturally appropriate expressions of attraction (Elliot et al. 2013). Another possible moderator that warrants—but has yet to receive—attention is the attractiveness level of the female target. Red is unlikely to bolster the attractiveness of an already highly attractive woman due to a ceiling effect (a "10" is a "10" regardless), but the more interesting question is whether red facilitates attractiveness for unattractive females. One possibility is that men's immediate, subcortically driven response in this instance is appetitive but that this immediate response is overridden (perhaps even to the point of derogation) upon additional cortically driven appraisal. Type of clothing may also serve a moderating role, as a sexy dress might again produce a ceiling effect that minimizes or eliminates the influence of red; the strongest effect may be on more mundane apparel such as everyday shirts or dresses.

With regard to mediation of the red effect, Guéguen (2012a) and Pazda et al. (2012) posited that men perceive a woman in red to be more sexually receptive and that this in turn facilitates their perceptions of her attractiveness and sexual desirability. In support of this proposal, Guéguen (2012a) demonstrated that men rate women wearing red as more sexually receptive, and Pazda et al. (2012, 2013) showed that this influence of red on perceived sexual receptivity accounts for the effect of red on perceived attractiveness and sexual desirability. Pazda et al. (2013) also found that black (as well as red, unexpectedly; although see also Liang et al. 2010) enhances women's perceived fashionableness and showed that black (as well as red, again, unexpectedly) influences perceived attractiveness via its influence on perceived fashionableness.

In a series of experiments, Roberts et al. (2010) demonstrated that the red effect observed for men viewing women is also present for women viewing men. Specifically, they showed that women rate men wearing a red shirt (relative to white and several chromatic colors) as more attractive. Elliot et al. (2010) found this same effect of red (relative to white and several chromatic colors) on both perceived attractiveness and attraction, with color displayed on picture borders as well as shirts. Elliot & Maier (2013) also found evidence of this red effect in a pilot study and observed a supportive, but not quite significant, trend in a subsequent experiment. Meier et al. (2012) showed that women walk more quickly to an interview on dating conducted by a man wearing a red shirt. Research has yet to emerge on women's actual behavior when interacting with a man in red; such work is likely to require careful attention to social norms and conventions (that vary by country)

regarding the appropriateness of women taking the initiative in intersexual interactions. Research on the sex specificity of the red effect is equivocal, as some work suggests that it is specific to women viewing men, whereas other work suggests that it may generalize across sex (see Elliot et al. 2010, Roberts et al. 2010). In a set of experiments, Burtin et al. (2011) showed that men perceived themselves to be more attractive when wearing a red, relative to blue, shirt. Roberts et al. (2010) found that the faces of men photographed while wearing red are rated as more attractive, even when no color is made visible to the rater. Black (and sometimes blue), like red, has been shown to facilitate women's attractiveness to men in the few studies that have examined this relation (Roberts et al. 2010).

Other findings from the extant research point to possible moderators of this red effect. Wartenberg et al. (2011) found that women viewing a man in a red, relative to blue, shirt perceived him to be more attractive, but only if he was of the same race. Roberts et al. (2010) conducted an intriguing experiment in which they photographed men in a red or white shirt; they showed women both these original pictures and adjusted pictures, with red superimposed on the initial white picture and white superimposed on the initial red picture. They found the red effect overall but also found that the adjusted pictures had novel and potentially informative effects (e.g., men photographed in red but shown in white were viewed as particularly attractive, perhaps due to the juxtaposition of a confident red-induced facial expression and a humble white shirt). Women's cycle status is another possible moderator worthy of consideration, as women may be most attracted to men in red when they are most fertile (for relevant links between dominance cues and cycle status, see Penton-Voak et al. 1999). Furthermore, women may only find men in a particular type of red attractive: Intense, vivid red may cue aggression, and light, pinkish red may cue femininity, both to the detriment of women's attractiveness judgments and attraction. The optimal red for women may be one that is strong enough to evoke attraction without also cuing aggression (for discussion on women's preference for dominant but warm and trustworthy men, see Jensen-Campbell et al. 1995). The broader literature on sexuality indicates that the factors influencing women's attraction to men are much more complex and variegated than those influencing men's attraction to women (Buss 2008, Moore 2010), and this will likely prove true regarding women's perceptions of and responses to male red.

With regard to mediation of the red effect, Elliot et al. (2010) posited that women perceive a man in red to be higher in status and that this in turn facilitates their perceptions of his attractiveness and sexual desirability. Elliot et al. (2010) found support for the link between red and status perceptions (for a comparable finding, see Stephen et al. 2012a) and for status perceptions as a mediator of the red-attractiveness relation. Contrary to expectations, they did not find that status perceptions directly mediated the red–sexual desirability relation; instead, they found an indirect mediational process whereby perceived attractiveness mediates the link between perceived status and sexual desirability.

Use of color in sexual signaling. Research indicates that women convey sexual interest to men through a variety of overt and covert means, including flirtation, provocative body posturing, and wearing revealing clothing (Givens 1978, Grammer et al. 2005). Men tend to interpret red clothing on a woman as a sexual signal (Guéguen 2012a), but an independent question is whether women actually use red in this way or not. Elliot & Pazda (2012) found that women indeed use red clothing to signal sexual intent on dating websites. In one study, they showed that women who indicated an interest in casual sex on their web profile were more likely to display red (but not black, blue, or green) on their profile picture than women who did not indicate an interest in casual sex. In another study, they found that women on a website overtly dedicated to facilitating short-term sexual relations were more likely to display red (but not black, blue, or green) on their

profile picture than women on a website expressly dedicated to facilitating long-term relationships. Elliot et al. (2013a) showed that women expecting to converse with an attractive man (relative to an unattractive man, an attractive woman, or an average woman) were more likely to choose to wear red (relative to green or blue) for the conversation. They additionally found that women's choice of red was positively related to perceived attractiveness and status only when they expected to converse with an attractive man. Beall & Tracy (2013) found that women at peak fertility were more likely to wear red or pink clothing (but not other colored clothing) than women not at peak fertility. Guéguen (2012d) found that women wear more color cosmetics when near the midpoint of their cycle. Subsequent research would do well to explore the culture-based boundary conditions for women's use of red as a sexual signal. It is likely that in cultures with conservative norms or customs regarding women's assertiveness, only some women (e.g., those high in sociosexuality) may feel comfortable using red in this way or may constrain this use of red to particular settings (e.g., nightclubs) or relational contexts (e.g., preexisting intimate relationships). Research has yet to examine men's use of red in sexual signaling, and this too should be added to the empirical agenda.

BROAD CONCLUSIONS AND HIGHLIGHTS FROM OTHER RESEARCH AREAS

Broad Conclusions

The empirical work that we have reviewed clearly indicates that color can carry meaning and have an important influence on affect, cognition, and behavior in achievement and affiliation/attraction contexts. Red, especially, has been shown to be a critical color in this regard. This should come as no surprise, as red has long been identified as a unique, special color. Ellis (1900), for example, commenced his prescient essay "The Psychology of Red" with the following: "Among all colors, the most poignantly emotional tone undoubtedly belongs to red" (p. 365). Many things in biology, culture, and language point to the poignancy and prominence of red. Red is the color of blood and, therefore, the color of life and (when spilled) death. Dynamic variation in visible blood flow on the face and body of a conspecific communicates critical, adaptation-relevant information, from the pallor of fear, to the flush of sexual interest or arousal, to the florid crimson of anger and imminent aggression (Changizi 2009). More static individual differences in visible blood flow are indicative of cardiac health or illness (Stephen et al. 2011). Red is the color of ripe fruit, and vivid red (especially against a green background) allows such ripe fruit to be detected from afar (Regan et al. 2001). Red is the color of many aposematic (warning) signals conveyed on the bodies of poisonous insects and reptiles (Stevens & Ruxton 2012). Red is regarded by anthropologists to have been the first chromatic color used in symbolic fashion in interpersonal communication, and the use of red ochre in prehistoric cave painting is thought to be the first use of chromatic color in art (Henshilwood et al. 2009). Red is a term that appears in all or nearly all lexicons, and red is the first chromatic term to emerge in most of these languages (Kay & Maffi 1999). Given all of this, the contemporary use of red in signs (e.g., alarms, sirens), symbols (e.g., hearts, crosses), and sayings (e.g., "in the red," "roll out the red carpet") seems fitting, and the preponderance of red effects observed in the current literature is sensible.

Although red is clearly special and has garnered the majority of research attention, a few other colors have been examined in recent research as well. Conceptually, blue and green seem reasonable candidates for consideration, as they both have positive links in the natural realm (e.g., blue sky and water, green foliage and vegetation) and both have been shown to be associated with positive content [blue, e.g., openness, peace (Kaya & Epps 2004, Mehta & Zhu 2009); green, e.g.,

calmness, success (Clarke & Costall 2008, Moller et al. 2009)]. In the literature that we reviewed, a few studies have yielded preliminary evidence that one or both of these colors may have positive implications for performance or experience during task engagement in some instances. Yellow, like red, is linked to aposematism in insects and reptiles (Stevens & Ruxton 2012) and is commonly used to indicate caution in signage and brake lights. A few studies have hinted that yellow may have inimical implication for performance outcomes. Achromatic black and white tend to carry general negative and positive connotations, respectively (Lakens et al. 2012). The extant research suggests that black may be linked to greater, and white to lesser, aggression in competitive sport, and black may facilitate perceptions of fashionableness and attractiveness in the affiliation domain. Each of these nascent possibilities warrants further empirical consideration.

Another clear take-home message from the literature that we have reviewed is that color meanings and, therefore, color effects are context specific. The same color can have different meanings in different contexts, leading to different implications. For example, the extant literature shows that red carries negative, threatening meaning when seen on an opponent or test of ability and evokes avoidance-relevant affect, cognition, and behavior; but red carries positive, appetitive meaning when seen on a potential mate and facilitates approach-relevant responding. Importantly, context may be physical as well as psychological; color is typically viewed on an object as well as within a psychological context, and the object on which a color is viewed can influence its meaning and valence. Thus, red on a woman's T-shirt may be viewed as sexy and appealing, but the same red on the entirety of a woman's business suit may be seen as unfashionable and garish. When context cues are absent, it is possible that some colors have default associations, especially the most basic color terms in language (i.e., white, black, and red; Kay & Maffi 1999). For example, red may carry the meaning of danger (or potential danger) by default, with a clearly appetitive context (e.g., mating) needed to prompt positive associative content (see Genschow et al. 2012, Maier et al. 2013). Color and context, be it psychological or physical, are integrated together to produce meaning at an early, rudimentary stage of visual processing that requires no intention or awareness (Castelhano & Henderson 2008, Zachar et al. 2008). As such, color can act as an "implicit affective cue," influencing psychological functioning in a subtle, nonconscious fashion (Friedman & Förster 2010). Most work on color has neglected to attend to the issue of context moderation, and we believe that careful consideration of this issue holds great promise for advancing theory and research in this area.

Highlights from Other Research Areas

The literature on color psychology is vast. Indeed, the literature on the influence of color on psychological functioning is itself expansive, and this required us to conduct our review of the extant research in a selective fashion. There are many other interesting bodies of work emerging in this area, and in the following we briefly touch on a few highlights, focusing primarily on research in the areas of consumer behavior and food/beverage evaluation and consumption.

It is taken as an undeniable fact by marketers, advertisers, and graphic artists that color influences consumer behavior (Paul & Okan 2011). One line of research in this area focuses on atmospherics, addressing issues such as the influence of building, store, and website color on drawing consumers in, keeping them engaged, and enhancing their shopping experience. Blue appears to be a highly positive color in this regard, as blue stores and websites are rated as more relaxing, less crowded, and even more trustworthy (Alberts & van der Geest 2011, Gorn et al. 2004, Lee & Rao 2010, Yüksel 2009). Another focus in this area is on the role that color plays in company and brand identity and recognition. Color is often an integral aspect of logos and product packaging (e.g., Coca Cola red, IBM blue, Cadbury purple) and is presumed to be used in

shaping image/personality and facilitating reflexive purchasing behavior (Hynes 2009). The most commonly utilized color in logos of major companies is blue (Labrecque & Milne 2013), which has been linked to high perceptions of competence in this context (Labrecque & Milne 2012). Color norms have been shown to emerge for certain product categories, and deviations from these norms have been found to be beneficial in some categories (e.g., entertainment) but harmful when there is a dominant market leader (e.g., fast food; Labrecque & Milne 2013). A third line of research in this area focuses on the effect of color on consumers' evaluations of and purchasing intentions toward products. Consumers have been shown to prefer unusual color descriptions of products (e.g., Coke red, Kermit green; Miller & Kahn 2005), and male consumers have been shown to perceive greater savings when product prices are presented in red rather than black (Puccinelli et al. 2013). Consumers also desire that the color of a product match its intended use or purpose. Specifically, they prefer blue for products that are functional or associated with water, and prefer red for products that are luxury items or are associated with status, such as a sports car (Bottomley & Doyle 2006, Hanss et al. 2012, Ngo et al. 2012). On a general note, several researchers caution against making broad, global statements about color in the area of consumer behavior because consumer attitudes and behaviors are presumed to be influenced by context-free color preferences that vary by country, race, sex, and age (Aslam 2006, Chebat & Morrin 2007, Funk & Ndubisi 2006).

Another active area of research focuses on the influence of color on our experience and intake of food and drink. One line of work in this area focuses on the link between food/beverage color and flavor perception, with researchers drawing an important distinction between flavor identification and flavor intensity (Spence et al. 2010). Regarding identification, people have been found to have strong expectations regarding color-flavor links such that they expect, for example, red drinks to taste like strawberry or cherry and green drinks to taste like lime, mint, or apple (Shankar et al. 2010; Zampini et al. 2007, 2008). Violations of these expectations of "appropriate" color-flavor associations can lead to difficulty in taste discrimination. With regard to intensity, the empirical yield is more equivocal. Some experiments have found color effects consistent with color-flavor expectations (e.g., brown M&Ms are perceived to be more chocolaty than green; Hoegg & Alba 2007, Kappes et al. 2006, Shankar et al. 2009, Zellner & Durlach 2008), but many others have failed to find these types of effects (for reviews, see Shankar et al. 2010, Spence et al. 2010). Another line of research in this area focuses on the effect of tableware color on both flavor perception and food and beverage consumption. A few researchers have found red effects in this domain, showing, for example, that coffee is perceived to be warmer when served in a red cup (Guéguen & Jacob 2013c), that popcorn taken from a red bowl is perceived to be sweeter (Harrar et al. 2011), and that people eat less snack food from a red plate and drink less soda from a red-labeled cup (Genschow et al. 2012; see also Geier et al. 2012 for a related finding that could also be interpreted in terms of a red-stop association). Piqueras-Fiszman & Spence (2012) found that hot chocolate was rated as more chocolaty and better when consumed from orange- or dark-cream-colored cups, and Ross et al. (2009) found that red wine was perceived to have a better flavor when it was served in a blue glass. In Piqueras-Fiszman et al. (2012), people given strawberry mousse on a white (relative to black) plate rated it as sweeter, more intense, and tastier; Van Ittersum & Wansink (2011) found that people served themselves less food when putting red-sauced pasta on a white plate and white-sauced pasta on a red plate (relative to color-match conditions). These latter effects are likely due to a perceptual effect of color contrast, independent of color associations.

FUTURE DIRECTIONS

Throughout our empirical review we have made ongoing mention of specific issues in need of further research attention. Here we pull back from the specifics to offer broader suggestions

regarding directions for future research. We highlight three foci: the source of color effects, overlooked conceptual issues, and methodological considerations.

Color meanings, and therefore color effects on psychological functioning, are clearly a function of social learning (i.e., the repeated pairing of color and particular concepts, messages, and experiences over time and multiple repetition). The provocative proposal being advanced in the contemporary literature is that at least some color meanings and effects are also a function of biology. Theorists have drawn conceptual parallels between human and nonhuman animals' responses to and uses of color, and data have been acquired that are consistent with such parallels. An important next step for this literature, however, is to put this question of biological basis to more direct empirical test. Several methods are available to address this question; we briefly note three herein that have started to receive some research attention in this and related literatures. First, the degree to which the same color effect emerges across culturally distinct countries around the globe (including culturally isolated populations) may be examined (Norenzayan & Heine 2005). Convergence across countries/populations would suggest that the effect represents a human universal, likely grounded in biology (see Elliot et al. 2013). Second, for color effects involving women's sexuality, ovulation cycle effects may be examined (Gangestad & Thornhill 1998). To the extent that women naturally or behaviorally display more red mid-cycle, for example, it would suggest a biological basis for observed red effects in this domain (see Beall & Tracy 2013, Guéguen 2012d). Third, the degree of involvement of the two neural subsystems that underlie human color vision—L-M ("red-green") and S-(L+M) ("blue-yellow") cone-opponent processes—may be examined for a given effect (Hurlbert & Ling 2007). To the extent that variation in the two cone-opponent processes accounts for an affective, cognitive, or behavioral response, a biological basis is likely operative (for related work, see Taylor et al. 2013). It is important to reiterate that biological and environmentally based explanations of color effects are not mutually exclusive, and their interplay is complex. Any biological influence would take place in the context of highly impactful social learning histories and cultural norms that may support and extend, or may stifle or even countervail, inherent propensities (Elliot & Maier 2012).

Subsequent research on color and psychological functioning would do well to extend its reach to other, heretofore largely overlooked, content areas. One such area is that of color and emotion perception. Changizi et al. (2006) posit that a primary reason for the emergence of color vision in primates was the facilitation of emotional communication via color on the face. Research is needed to test implications of this provocative proposal. For example, from this perspective it seems reasonable to hypothesize that color-deficient individuals (typically male) would be less adept at navigating emotion-relevant social interactions. Another largely overlooked area is that of the influence of nonhue color attributes on psychological functioning. The vast majority of the research conducted to date has focused on hue, with a bit of attention paid to lightness in achromatic colors (Lakens et al. 2012, Meier et al. 2004, Sherman & Clore 2009). Lightness with regard to chromatic colors, as well as chroma, has been largely ignored (for exceptions, see Camgöz et al. 2004, Suk & Irtel 2010). A third overlooked area is the influence of psychological functioning on color perception. Again, nearly all of the research conducted to date has either focused on color-meaning associations or the influence of color on psychological functioning. The opposite direction of causality has been greatly understudied (although see Fetterman et al. 2011, Mitterer et al. 2009, Sherman et al. 2012).

From a methodological standpoint, the literature on color and psychological functioning has seen several improvements in the past decade, which are likely responsible for the current resurgence of interest and empirical activity. However, the need for improvement remains in several areas, three of which we briefly note. First, controlling for nonfocal color attributes is undoubtedly the most important of the recent methodological improvements, but implementation of this

advance remains inconsistent. Some continue to select color stimuli unsystematically, and many rely on computer software programs for color control which, as we detailed previously, is problematic. Controlling color attributes at the spectral level (using prematched stimuli or a spectrophotometer) is necessary to conduct truly rigorous color research. Second, much of the extant research on color and psychological functioning, like much of the research in experimental psychology in general, is underpowered. Greater rigor is needed with regard to statistical power, as more highly powered samples provide more stable and accurate estimates of population effect sizes. Third, the majority of research in this area has been conducted with university undergraduates (an attribute shared with much of the research in experimental psychology in general). Research utilizing samples with greater diversity in terms of age, education level, and socioeconomic status would be welcomed.

We close this section with a broader word on generalizability and application. The research that we have reviewed in this article has clearly demonstrated that color *can* have an influence on psychological functioning. However, the research remains at a nascent stage of development, and considerable work is needed to determine boundary conditions for and moderators of the observed effects before strong statements about robustness and real-world application are justified. Furthermore, most of the research to date has utilized tightly controlled laboratory experiments that present individuals with a single color on carefully prepared stimuli in a relatively distraction-free environment. The degree to which color effects are observed when individuals encounter a welter of colors on diverse stimuli in the bustle of everyday life remains a largely open question (for promising early returns, see Beall & Tracy 2013, Elliot & Pazda 2012, Guéguen 2012b). Color effects are provocative and media friendly, which can impel the urge to move quickly from initial empirical demonstration to conclusions about real-world implications. We think it best to resist this urge, opting instead to allow the evidence to accumulate and the literature to mature before definitive statements and real-world recommendations are offered.

CONCLUDING REMARKS

Color is a complex construct studied in multiple ways by scholars across multiple disciplines. Theory and empirical work linking color to psychological functioning have been relatively slow to emerge, but the past decade has seen considerable development. Our review herein has necessarily been selective, given the breadth of research in this area, but a clear take-home message is that color is about more than aesthetics—it can carry important information and can have an important influence on people's affect, cognition, and behavior. Research in this area holds promise not only to yield interesting and provocative findings regarding color per se, but also to produce important insights into the nature of attention and perception, interpersonal communication, and the biology-culture interface more generally.

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LITERATURE CITED

Akers A, Barton J, Cossey R, Gainsford P, Griffin M, Micklewright D. 2012. Visual color perception in green exercise: positive effects of mood on perceived exertion. *Environ. Sci. Technol.* 46:8661–66

Alberts W, van der Geest TM. 2011. Color matters: color as trustworthiness cue in Web sites. *Tech. Commun.* 58:149–60

Allen MS, Jones MV. 2013. The home advantage over the first 20 seasons of the English Premier League: effects of shirt colour, team ability, and time trends. *Int. J. Sport Exerc. Psychol.* In press

Aslam MM. 2006. Are you selling the right colour? A cross-cultural review of colour as a marketing cue. *J. Mark. Commun.* 12:15–30

Attrill MJ, Gresty KA, Hill RA, Barton RA. 2008. Red shirt colour is associated with long-term success in English football. *J. Sport Sci.* 26:577–82

Bagchi R, Cheema A. 2013. The effect of red background color on willingness-to-pay: the moderating role of selling mechanism. *J. Consum. Res.* 39:947–60

Barton RA, Hill RA. 2005. Reply. *Nature* 437:E10

Beall AT, Tracy JL. 2013. Women are more likely to wear red or pink at peak fertility. *Psychol. Sci.* 24:1837–41

Bottomley PA, Doyle JR. 2006. The interactive effects of colors and products on perceptions of brand logo appropriateness. *Mark. Theory* 6:63–83

Burtin L, Kaluza A, Klingenberg M, Straube J, Utecht C. 2011. *Red shirt, nice flirt! How red influences the perception of self-attractiveness*. Paper presented at Empiriepraktikumskongress, Univ. Jena, Ger.

Buss D. 2008. *Evolutionary Psychology: The New Science of the Mind*. Boston, MA: Allyn & Bacon. 3rd ed.

Caldwell DF, Burger JM. 2011. On thin ice: Does uniform color really affect aggression in professional hockey? *Soc. Psychol. Personal. Sci.* 2:306–10

Camgöz N, Yener C, Guvenc D. 2004. Effects of hue, saturation, and brightness: part 2. *Color Res. Appl.* 29:20–28

Castelhano MS, Henderson JM. 2008. The influence of color on the perception of scene gist. *J. Exp. Psychol: Learn. Mem. Cogn.* 34:660–75

Changizi M. 2009. *The Vision Revolution*. Dallas, TX: Benbella

Changizi MA, Zhang Q, Shimojo S. 2006. Bare skin, blood and the evolution of primate colour vision. *Biol. Lett.* 2:217–21

Chebat JC, Morrin M. 2007. Colors and cultures: exploring the effects of mall décor on consumer perceptions. *J. Bus. Res.* 60:189–96

Chien YH. 2011a. Message framing and color combination in the perception of medical information. *Psychol. Rep.* 108:667–72

Chien YH. 2011b. Use of message framing and color in vaccine information to increase willingness to be vaccinated. *Soc. Behav. Personal.* 39:1063–72

Clarke T, Costall A. 2008. The emotional connotations of color: a qualitative investigation. *Color Res. Appl.* 33:406–10

Clary R, Wandersee J, Schexnayder E. 2007. Does the color-coding of examination versions affect college science students' test performance? Counter claims of bias. *J. Coll. Sci. Teaching* 37:40–47

Coetzee V, Faerber SJ, Greeff JM, Lefevre CE, Re DE, Perrett DI. 2012. African perceptions of female attractiveness. *PLoS ONE* 7:e48116

Darwin C. 1872. *The Expression of the Emotions in Man and Animals*. London: John Murray

Diehl JJ, Wolf J, Herlihy L, Moller AC. 2011. Seeing red: color selection as an indicator of implicit social conceptions about the autism spectrum. *Disabil. Stud. Q.* 31:1–14

Dijkstra PD, Preenen PT. 2008. No effect of blue on winning contests in judo. *Proc. Biol. Sci.* 275:1157–62

Dreiskaemper D, Stauss B, Hagemann N, Buesch D. 2013. Influence of red jersey color on physical parameters in combat sports. *J. Sport Exerc. Psychol.* 35:44–49

Dukes RL, Albanesi H. 2013. Seeing red: quality of an essay, color of the grading pen, and student reactions to the grading process. *Soc. Sci. J.* 50:96–100

Elliot AJ, Aarts H. 2011. Perception of the color red enhances the force and velocity of motor output. *Emotion* 11:445–49

Elliot AJ, Greitemeyer T, Pazda AD. 2013a. Women's use of red clothing as a sexual signal in intersexual interaction. *J. Exp. Soc. Psychol.* 49:599–602

Elliot AJ, Maier MA. 2012. Color-in-context theory. *Adv. Exp. Soc. Psychol.* 45:61–126

Elliot AJ, Maier MA. 2013. The red-attractiveness effect, applying the Ioannidis and Trikalinos (2007a) test, and the broader scientific context: a reply to Francis 2013. *J. Exp. Soc. Psychol.: Gen.* 142:297–300

Elliot AJ, Maier MA, Binser MJ, Friedman R, Pekrun R. 2009. The effect of red on avoidance behavior in achievement contexts. *Personal. Soc. Psychol. Bull.* 35:365–75

Proposes and provides evidence for a social-emotional function to color vision.

Proposes and reviews research on a context-based theory of color and psychological functioning.

Elliot AJ, Maier MA, Moller AC, Friedman R, Meinhardt J. 2007. Color and psychological functioning: the effect of red on performance in achievement contexts. *J. Exp. Psychol.: Gen.* 136:154–68

Elliot AJ, Niesta D. 2008. Romantic red: Red enhances men's attraction to women. *J. Personal. Soc. Psychol.* 95:1150–64

Elliot AJ, Kayser DN, Greitemeyer T, Lichtenfeld S, Gramzow RH, et al. 2010. Red, rank, and romance in women viewing men. *J. Exp. Psychol.: Gen.* 139:399–417

Elliot AJ, Payen V, Brisswalter J, Cury F, Thayer J. 2011. A subtle threat cue, heart rate variability, and cognitive performance. *Psychophysiology* 48:1340–45

Elliot AJ, Pazda AD. 2012. Dressed for sex: red as a female sexual signal in humans. *PLoS ONE* 7:e34607

Elliot AJ, Tracy JL, Pazda AD, Beall A. 2013b. Red enhances women's attractiveness to men: first evidence suggesting universality. *J. Exp. Soc. Psychol.* 49:165–68

Ellis H. 1900. The psychology of red. *Pop. Sci. Mon.* 57:365–75

Etcoff NL, Stock S, Haley LE, Vickery SA, House DM. 2011. Cosmetics as a feature of the extended human phenotype: modulation of the perception of biologically important facial signals. *PLoS ONE* 6:e25656

Overviews basic principles of color science.

Fairchild MD. 2005. *Color Appearance Models*. New York: Wiley. 2nd ed.

Farrelly D, Slater R, Elliott H, Walden H, Wetherell M. 2013. Competitors who choose to be red have higher testosterone levels. *Psychol. Sci.* In press

Feltman R, Elliot AJ. 2011. The influence of red on perceptions of dominance and threat in a competitive context. *J. Sport Exerc. Psychol.* 33:308–14

Fetterman AK, Robinson MD, Gordon RD, Elliot AJ. 2011. Anger as seeing red: perceptual sources of evidence. *Soc. Psychol. Personal. Sci.* 2:311–16

Fetterman AK, Robinson MD, Meier BP. 2012. Anger as "seeing red": evidence for a perceptual association. *Cogn. Emot.* 26:1445–58

Fink B, Bunse PJ, Matts BJ, D'Emiliano D. 2012a. Visible skin colouration predicts perception of male facial age, health, and attractiveness. *Int. J. Cosmet. Sci.* 34:307–10

Links homogeneity of facial skin color distribution to evaluation of female targets.

Fink B, Grammer K, Matts PJ. 2006. Visible skin color distribution plays a role in the perception of age, attractiveness, and health in female faces. *Evol. Hum. Behav.* 27:433–42

Fink B, Matts PJ. 2007. The effects of skin colour distribution and topography cues on the perception of female age and health. *J. Eur. Acad. Dermatol.* 22:493–98

Fink B, Matts PJ, D'Emiliano D, Bunse L, Weege B, Röder S. 2012b. Colour homogeneity and visual perception of age, health, and attractiveness of male facial skin. *J. Eur. Acad. Dermatol.* 26:1486–92

Fink B, Matts PJ, Klingenberg H, Kuntze S, Weege B, Grammer K. 2008. Visual attention to variation in female facial skin color distribution. *J. Cosmet. Dermatol.* 7:155–61

Fordham DR, Hayes DC. 2009. Worth repeating: Paper color may have an effect on student performance. *Iss. Account. Educ.* 24:187–94

Frank MG, Gilovich T. 1988. The dark side of self- and social perception: black uniforms and aggression in professional sports. *J. Personal. Soc. Psychol.* 54:74–85

Friedman RS, Förster J. 2010. Implicit affective cues and attentional tuning: an integrative review. *Psychol. Bull.* 136:875–93

Funk D, Ndubisi NO. 2006. Colour and product choice: a study of gender roles. *Manag. Res. News* 29:41–52

Furley P, Dicks M, Memmert D. 2012. Nonverbal behavior in soccer: the influence of dominant and submissive body language on the impression formation and expectancy of success of soccer players. *J. Sport Exerc. Psychol.* 34:61–82

Gangestad SW, Thornhill R. 1998. Menstrual cycle variation in women's preference for the scent of symmetrical men. *Proc. Biol. Sci.* 265:927–33

Garcia-Rubio MA, Picazo-Tadeo AJ, González-Gómez. 2011. Does a red shirt improve sporting performance? Evidence from Spanish football. *Appl. Econ. Lett.* 18:1001–4

Geier A, Wansink B, Rozin P. 2012. Red potato chips: Segmentation cues can substantially decrease food intake. *Health Psychol.* 31:398–401

Genschow O, Reutner L, Wänke M. 2012. The color red reduces snack food and soft drink intake. *Appetite* 58:699–702

Gerend MA, Sias T. 2009. Message framing and color priming: how subtle threat cues affect persuasion. *J. Exp. Soc. Psychol.* 45:999–1002

Gillebaart M, Förster J, Rotteveel M. 2012. Mere exposure revisited: the influence of growth versus security cues on evaluations of novel and familiar stimuli. *J. Exp. Psychol.: Gen.* 141:699–714
Givens DB. 1978. The nonverbal basis of attraction: flirtation, courtship, and seduction. *Psychiatrie* 41:346–59
Gnambs T, Appel M, Batinic B. 2010. Color red in web-based knowledge testing. *Comput. Hum. Behav.* 26:1625–31
Goethe W. 1810/1967. *Theory of Colours*. London: Frank Cass
Goldstein K. 1942. Some experimental observations concerning the influence of colors on the function of the organism. *Occup. Ther. Rehabil.* 21:147–51
Gorn GJ, Chattopadhyay A, Sengupta J, Tripathi S. 2004. Waiting for the web: how screen color affects time perception. *J. Mark. Res.* 41:215–25
Grammer K, Renninger L, Fischer B. 2005. Disco clothing, female sexual motivation, and relationship status: Is she dressed to impress? *J. Sex Res.* 41:66–74
Greenlees I, Leyland A, Thelwell R, Filby W. 2008. Soccer penalty takers' uniform colour and pre-penalty kick gaze affect the impressions formed of them by opposing goalkeepers. *J. Sport Sci.* 26:569–76
Guéguen N. 2008. The effects of women's cosmetics on men's approach: an evaluation in a bar. *N. Am. J. Psychol.* 10:221–28
Guéguen N. 2012a. Color and women attractiveness: when red clothed women are perceived to have more intense sexual intent. *J. Soc. Psychol.* 152:261–65
Guéguen N. 2012b. Color and women hitchhikers' attractiveness: Gentlemen drivers prefer red. *Color Res. Appl.* 37:76–78
Guéguen N. 2012c. Does red lipstick really attract men? An evaluation in a bar. *Int. J. Psychol. Stud.* 4:206–9
Guéguen N. 2012d. Makeup and menstrual cycle: Near ovulation, women use more cosmetics. *Psychol. Rec.* 62:1–8
Guéguen N, Jacob C. 2011. Enhanced female attractiveness with use of cosmetics and male tipping behavior in restaurants. *J. Cosmet. Sci.* 62:283–90
Guéguen N, Jacob C. 2012. Lipstick and tipping behavior: when red lipstick enhances waitresses' tips. *Int. J. Hosp. Manag.* 31:1333–35
Guéguen N, Jacob C. 2013a. Clothing color and tipping: Gentlemen patrons give more tips to waitresses with red clothes. *J. Hosp. Tour. Res.* In press
Guéguen N, Jacob C. 2013b. Color and cyber-attractiveness: Red enhances men's attraction to women's internet personal ads. *Color Res. Appl.* 38:309–12
Guéguen N, Jacob C. 2013c. Coffee cup color and evaluation of a beverage's "warmth quality." *Color Res. Appl.* In press
Guéguen N, Jacob C, Lourel M, Pascual A. 2012. When drivers see red: car color frustrators and drivers' aggressiveness. *Aggress. Behav.* 38:166–69
Hackney AC. 2006. Testosterone and human performance: influence of the color red. *Eur. J. Appl. Physiol.* 96:330–33
Hagemann N, Strauss B, Leißing J. 2008. When the referee sees red. *Psychol. Sci.* 19:769–771
Hanss D, Böhm G, Pfister HR. 2012. Active red sports car and relaxed purple-blue van: Affective qualities predict color appropriateness for car types. *J. Consum. Behav.* 11:368–80
Hård A, Sivik L. 2001. A theory of colours in combination: a descriptive model related to the NCS colour-order system. *Color Res. Appl.* 26:4–28
Harrar V, Piqueras-Fiszman B, Spence C. 2011. There's more to taste in a coloured bowl. *Perception* 40:880–82
Healey M, Uller T, Olsson M. 2007. Seeing red: morph-specific contest success, and survival rates, in a colour-polymorphic agamid lizard. *Anim. Behav.* 73:337–41
Henderson LM, Tsogka N, Snowling MJ. 2013. Questioning the benefits that coloured overlays can have for reading in students with and without dyslexia. *J. Res. Spec. Educ. Needs* 13:57–65
Henshilwood C, d'Errico F, Watts I. 2009. Engraved ochres from the Middle Stone Age levels at Blombos Cave, South Africa. *J. Hum. Evol.* 57:27–47
Hill RA, Barton RA. 2005. Red enhances human performance in contests. *Nature* 435:293
Hoegg J, Alba JW. 2007. Taste perception: more than meets the tongue. *J. Consum. Res.* 33:490–98
Huguet P, Croizet J-C, Richetin J. 2004. Is "what has been cared for" necessarily good? Further evidence for the negative impact of cosmetics use on impression formation. *J. Appl. Soc. Psychol.* 34:1752–71

Early speculative theorizing on color and psychological functioning.

Links extended color displays to real-world behavioral responding.

Documents parallels between human and nonhuman response to color.

Humphrey N. 1976. The colour currency of nature. In *Colour for Architecture*, ed. T Porter, B Mikellides, pp. 95–98. London: Studio-Vista

Hurlbert AC, Ling Y. 2007. Biological components of sex differences in color preference. *Curr. Biol.* 17:R623–25

Hynes N. 2009. Colour and meaning in corporate logos: an empirical study. *Brand Manag.* 16:545–55

Ilie A, Ioan S, Zagrean L, Moldovan M. 2008. Better to be red than blue in virtual competition. *Cyberpsychol. Behav.* 11:375–77

Imhof M. 2004. Effects of color stimulation on handwriting performance of children with ADHD without and with additional learning disabilities. *Eur. Child Adolesc. Psychol.* 13:191–98

Ioan S, Sandulache M, Avramescu S, Ilie A, Neacsu A, et al. 2007. Red is a distractor for men in competition. *Evol. Hum. Behav.* 28:285–93

Jacob C, Guéguen N, Boulbry G, Ardicioni R. 2009. Waitresses' facial cosmetics and tipping: a field experiment. *Int. J. Cosmet. Sci.* 29:188–90

Jensen-Campbell LA, Graziano WG, West S. 1995. Dominance, prosocial orientation, and female preferences: Do nice guys really finish last? *J. Personal. Soc. Psychol.* 68:427–40

Johns SE, Hargrave LA, Newton-Fisher NE. 2012. Red is not a proxy signal for female genitalia in humans. *PLoS ONE* 7:e34669

Jung I, Kim M, Han K. 2011a. The influence of an attractive female model on male users' product ratings. *KHCI Conf. Proceed.*, Seoul, South Korea

Jung I, Kim M, Han K. 2011b. Red for romance, blue for memory. *HCI Int.: Posters Extended Abstr. Commun. Comput. Inf. Sci.* 173:284–88. Berlin: Springer

Kaiser PK. 1984. Psychological response to color: a cultural review. *Color Res. Appl.* 9:29–36

Kappes SM, Schmidt SJ, Lee SY. 2006. Color halo/horns and halo-attribute dumping effects within descriptive analysis of carbonated beverages. *J. Food Sci.* 71:S590–95

Kay P, Maffi L. 1999. Color appearance and the emergence and evolution of basic color lexicons. *Am. Anthropol.* 101:743–60

Kaya N, Epps HH. 2004. Relationship between color and emotion: a study of college students. *Coll. Stud. J.* 38:396–405

Kliger D, Gilad D. 2012. Red light, green light: color priming in financial decisions. *J. Sociol. Econ.* 41:738–45

Kocher MG, Sutter M. 2008. Shirt colour and team performance in football. In *Myths and Facts About Football: The Economics and Psychology of the World's Greatest Sport*, ed. P Andersson, P. Ayton, C Schmidt, pp. 125–130. Cambridge, UK: Cambridge Sch. Publ.

Küller R, Mikellides B, Janssens J. 2009. Color, arousal, and performance—a comparison of three experiments. *Color Res. Appl.* 34:141–52

Kumi R, Conway CM, Limayem M, Goyal S. 2013. Learning in color: how color and affect influence learning outcomes. *IEEE Trans. Prof. Commun.* 56:2–15

Labrecque LI, Milne GR. 2012. Exciting red and competent blue: the importance of color in marketing. *J. Acad. Mark. Sci.* 40:711–27

Labrecque LI, Milne GR. 2013. To be or not to be different: Exploration of norms and benefits of color differentiation in the marketplace. *Mark. Lett.* 24:165–76

Lakens D, Semin GR, Foroni F. 2012. But for the bad, there would not be good: grounding valence in brightness through shared relational structures. *J. Exp. Psychol.: Gen.* 141:584–94

Larionescu AM, Pantelimona M. 2012. The influence of colour on the efficacy of basketball throws. *Ann. Univ. Galaţi* 1452:82–85

Lee S, Rao VS. 2010. Color and store choice in electronic commerce: the explanatory role of trust. *J. Electr. Commer. Res.* 11:110–26

Liang CC, Chen K, Ho C. 2010. A study of color emotion for plastic eyewear. *New World Situat. New Dir. Concurr. Eng.* 3:147–62

Lichtenfeld S, Elliot AJ, Maier MA, Pekrun R. 2012. Fertile green: Green facilitates creative performance. *Personal. Soc. Psychol. Bull.* 38:784–97

Lichtenfeld S, Maier MA, Elliot AJ, Pekrun R. 2009. The semantic red effect: processing the word red undermines intellectual performance. *J. Exp. Soc. Psychol.* 45:1273–76

Linhares JM, Pinto PD, Nascimento SM. 2008. The number of discernable colors in natural scenes. *J. Opt. Soc. Am. A* 25:2918–24
Little AC, Hill R. 2007. Attribution to red suggests special role in dominance signaling. *J. Evol. Psychol.* 5:161–68
Magee RG. 2012. Impression formation online: how web page colors can interact with physical temperature. *J. Media Psychol.* 24:124–33
Maier MA, Elliot AJ, Lee B, Lichtenfeld S, Barchfeld P, et al. 2013. Red and impression formation in the job application context. *Motiv. Emot.* 37:389–401
Maier MA, Elliot AJ, Lichtenfeld S. 2008. Mediation of the negative effect of red on intellectual performance. *Personal. Soc. Psychol. Bull.* 34:1530–40
Matsumoto D, Konno J, Hata S, Takeuchi M. 2007. Blue judogis may bias competition outcomes. *Res. J. Budo* 39:1–7
Matts PJ, Fink B, Grammer K, Burquest M. 2007. Color homogeneity and visual perception of age, health, and attractiveness of female facial skin. *J. Am. Acad. Dermatol.* 57:977–84
Mehta R, Zhu RJ. 2009. Blue or red? Exploring the effect of color on cognitive task performance. *Science* 323:1226–29
Meier BP, D'Agostino PR, Elliot AJ, Maier MA, Wilkowski BM. 2012. Color in context: Psychological context moderates the influence of red on approach- and avoidance-motivated behavior. *PLoS ONE* 7:e40333
Meier BP, Robinson MD, Clore GL. 2004. Why good guys wear white. *Psychol. Sci.* 15:82–87
Meyer MJ, Bagwell J. 2012. The non-impact of paper color on exam performance. *Iss. Account. Educ.* 27:691–706
Miller EG, Kahn BE. 2005. Shades of meaning: the effect of color and flavor names on consumer choice. *J. Consum. Res.* 32:86–92
Mitterer H, Horschig JM, Müsseler J, Majid A. 2009. The influence of memory on perception: it's not what things look like, it's what you call them. *J. Exp. Psychol.: Learn. Mem. Cogn.* 35:1557–62
Moller AC, Elliot AJ, Maier MA. 2009. Basic hue-meaning associations. *Emotion* 9:898–902
Moore MM. 2010. Human nonverbal courtship behavior—a brief historical review. *J. Sex Res.* 47:171–80
Nakashian JS. 1964. The effects of red and green surroundings on behavior. *J. Gen. Psychol.* 70:143–62
Ngo MK, Piqueras-Fiszman B, Spence C. 2012. On the colour and shape of still and sparkling water: insights from online and laboratory-based testing. *Food Qual. Prefer.* 24:260–68
Niesta Kayser D, Elliot AJ, Feltman R. 2010. Red and romantic behavior in men viewing women. *Eur. J. Soc. Psychol.* 40:901–8
Norenzayan A, Heine SJ. 2005. Psychological universals: What are they and how can we know? *Psychol. Bull.* 135:763–84
Oberzaucher E, Katina S, Schmehl S, Holzleitner I, Mehu-Blantar I. 2012. The myth of hidden ovulation: shape and texture changes in the face during the menstrual cycle. *J. Evol. Psychol.* 10:163–75
Ott JW. 1979. The dual function of the eyes. *South. J. Optom.* 21:8–13
Paul S, Okan A. 2011. Response to color: literature review with cross-cultural marketing perspective. *Int. Bull. Bus. Adm.* 11:34–41
Payen V, Elliot AJ, Coombes SA, Chalabaev A, Brisswalter J, Cury F. 2011. Viewing red prior to a strength test inhibits motor output. *Neurosci. Lett.* 495:44–48
Pazda AD, Elliot AJ, Greitemeyer T. 2012. Sexy red: Perceived sexual receptivity mediates the red-attraction relation in men viewing women. *J. Exp. Soc. Psychol.* 48:787–90
Pazda AD, Elliot AJ, Greitemeyer T. 2013. Perceived sexual receptivity and fashionableness: separate paths linking red and black to perceived attractiveness. *Color Res. Appl.* In press
Penton-Voak IS, Perrett DI, Castles DL, Kobayashi T, Burt DM, et al. 1999. Menstrual cycle alters face preference. *Nature* 399:741–42
Piatti M, Savage DA, Torgler B. 2012. The red mist? Red shirts, success and team sports. *Sport Soc.* 15:1209–27
Piotrowski C, Armstrong T. 2012. Color red: implications for applied psychology and marketing. *Psychol. Educ. Interdisc. J.* 49:55–57
Piqueras-Fiszman B, Alcaide J, Roura E, Spence C. 2012. Is it the plate or is it the food? Assessing the influence of the color (black or white) and shape of the plate on the perception of food placed on it. *Food Qual. Prefer.* 24:205–8

Links multiple colors to psychological functioning and shows meditational processes.

Piqueras-Fiszman B, Spence C. 2012. The influence of the color of the cup on consumers' perceptions of a hot beverage. *J. Sens. Stud.* 27:324–31

Pryke SR. 2009. Is red an innate or learned signal of aggression and intimidation? *Anim. Behav.* 78:393–98

Puccinelli NM, Chandrashekaran R, Grewal D, Suri R. 2013. Are men seduced by red? The effect of red versus black prices on price perceptions. *J. Retail.* 89:115–25

Purdy MA. 2009. The influence of the amygdala and color on judgments of attractiveness. *UNC-Ashville J.* (Dec.)

Re DE, Whitehead RD, Xiao D, Perrett DI. 2011. Oxygenated-blood colour change thresholds for perceived facial redness, health, and attractiveness. *PLoS ONE* 6:e17859

Rechtschaffen A, Buchignani C. 1992. The visual appearance of dreams. In *The Europsychology of Sleep and Dreaming*, ed. J Antrobus, M Bertini, pp. 143–55. Hillsdale, NJ: Erlbaum

Regan BC, Julliot C, Simmen B, Viénot F, Charles-Dominique P, Mollon JD. 2001. Fruits, foliage, and the evolution of primate colour vision. *Phil. Trans. R. Soc. Lond. B* 356:220–83

Roberts SC, Owen RC, Havlicek J. 2010. Distinguishing between perceiver and wearer effects in clothing color-associated attributions. *Evol. Psychol.* 8:350–64

Ross CF, Bohischeid J, Weller K. 2008. Influence of visual masking technique on the assessment of 2 red wines by trained and consumer assessors. *J. Food Sci.* 73:S279–85

Rowe C, Harris JM, Roberts SC. 2005. Seeing red? Putting sportswear in context. *Nature* 437:E10

Rutchick AM, Slepian ML, Ferris BD. 2010. The pen is mightier than the word: object priming of evaluative standards. *Eur. J. Soc. Psychol.* 40:704–8

Samson N, Fink B, Matts PJ. 2010. Interaction of skin color distribution and skin surface topography cues in the perception of female facial age and health. *J. Cosmet. Dermatol.* 10:78–84

Samson N, Fink B, Matts PJ. 2011. Does a woman's skin color indicate her fertility level? *Swiss J. Psychol.* 70:199–202

Schwarz S, Singer M. 2013. Romantic red revisited: Red enhances men's attraction to young, but not menopausal women. *J. Exp. Soc. Psychol.* 49:161–64

Scott IML, Pound N, Stephen ID, Clark AP, Penton-Voak IS. 2010. Does masculinity matter? The contribution of masculine face shape to male attractiveness in humans. *PLoS ONE* 5:e13585

Shankar MU, Levitan CA, Prescott J, Spence C. 2009. The influence of color and label information on flavor perception. *Chem. Percept.* 2:53–58

Shankar MU, Levitan CA, Spence C. 2010. Grape expectations: the role of cognitive influences in color-flavor interactions. *Conscious. Cogn.* 19:380–90

Shavit T, Rosenboim M, Cohen C. 2013. Does the color of feedback affect investment decisions? *Int. J. Appl. Behav. Econ.* 2:15–26

Sherman GD, Clore GL. 2009. White and black are perceptual symbols of moral purity and pollution. *Psychol. Sci.* 20:1019–25

Sherman GD, Haidt J, Clore GL. 2012. The faintest speck of dirt: Disgust enhances the detection of impurity. *Psychol. Sci.* 23:1506–14

Skinner NF. 2004. Differential test performance from differently colored paper: White paper works best. *Teach. Psychol.* 31:111–13

Smith MJ, Perrett DI, Jones BC, Cornwell RE, Moore FR, et al. 2006. Facial appearance is a cue to estrogen levels in women. *Proc. Biol. Sci.* 273:135–40

Soldat AS, Sinclair RC, Mark MM. 1997. Color as an environmental processing cue: External affective cues can directly affect processing strategy without affecting mood. *Soc. Cogn.* 15:55–71

Sorokowski P, Szmajke A. 2007. How does the "red win" effect work? The role of sportswear colour during sports competitions. *Pol. J. Appl. Psychol.* 5:71–79

Sorokowski P, Szmajke A. 2011. The influence of the "red win" effect in sports: a hypothesis of erroneous perception of opponents dressed in red—preliminary test. *Hum. Mov.* 12:367–73

Spence C, Levitan CA, Shankar MU, Zampini M. 2010. Does food color influence taste and flavor perception in humans?*Chem. Percept.* 3:68–84

Stephen ID, Coetzee V, Law Smith M, Perrett DI. 2009a. Skin blood perfusion and oxygenation colour affect perceived human health. *PLoS ONE* 4:e5083

Stephen ID, Coetzee V, Perrett DI. 2011. Carotenoid and melanin pigment coloration affect perceived human health. *Evol. Hum. Behav.* 32:216–27

Stephen ID, Law Smith MJ, Stirrat MR, Perrett DI. 2009b. Facial skin coloration affects perceived health of human faces. *Int. J. Primatol.* 30:845–57

Stephen ID, McKeegan AM. 2010. Lip colour affects perceived sex typicality and attractiveness of human faces. *Perception* 39:1104–10

Stephen ID, Oldham FH, Perrett DI, Barton RA. 2012a. Redness enhances perceived aggression, dominance and attractiveness in men's faces. *Evol. Psychol.* 10:562–72

Stephen ID, Scott IML, Coetzee V, Pound N, Perrett DI, Penton-Voak IS. 2012b. Cross-cultural effects of color, but not morphological masculinity, on perceived attractiveness of men's faces. *Evol. Hum. Behav.* 33:260–67

Stevens M, Ruxton GD. 2012. Linking the evolution and form of warning coloration in nature. *Proc. Biol. Sci.* 279:417–26

Stone NJ, English AJ. 1998. Task type, posters, and workspace color on mood, satisfaction, and performance. *J. Environ. Psychol.* 18:175–85

Suk HJ, Irtel H. 2010. Emotional response to color across media. *Color Res. Appl.* 35:64–77

Szmajke A, Sorokowski P. 2006. Permitted support in sport: the influence of sportsmen's outfit colour on competitions in sport. *Med. Sport* 10:119–22

Tal IR, Akers KG, Hodge GK. 2008. Effect of paper color and question order on exam performance. *Teach. Psychol.* 35:26–28

Tanaka A, Tokuno Y. 2011. The effect of the color red on avoidance motivation. *Soc. Behav. Personal.* 39:287–88

Taylor C, Clifford A, Franklin A. 2013. Color preferences are not universal. *J. Exp. Psychol.: Gen.* In press

Ten Velden FS, Baas M, Shalvi S, Preenen PTY, De Dreu CKW. 2012. In competitive interaction, displays of red increase actors' competitive approach and perceivers' withdrawal. *J. Exp. Soc. Psychol.* 48:1205–8

Tharangie KGD, Althaff Irfan CM, Yamada K, Marasinghe A. 2011. Appraisal and guideline to utilize colours in interactive learning environments based on Kansei engineering. *Int. J. Biometrics* 3:285–99

Tharangie KGD, Althaff Irfan CM, Young IM, Nomura S, Yamada K, Marasinghe A. 2009. Colour interaction, psychological functioning and Kansei measurement method. *J. Med. Inform. Technol.* 13:223–28

Tiryaki ME. 2005. Assessing whether black uniforms affect the decisions of Turkish soccer referees: Is finding of Frank and Gilovich's study valid for Turkish culture? *Percept. Mot. Skills* 100:51–57

Valdez P, Mehrabian A. 1994. Effects of color on emotions. *J. Exp. Psychol.: Gen.* 123:394–409

Van Ittersum K, Wansink B. 2011. Plate size and color suggestibility: the Delboeuf illusion's bias on serving and eating behavior. *J. Consum. Res.* 39:215–28

Wartenberg W, Höpfner T, Potthast P, Mirau A. 2011. If you wear red on a date, you will please your mate. *Proc. Empiriepraktikumskongress, 6th*, Aug. 7, pp. 26–27. Univ. Jena, Ger.

Webster DG, Urland GR, Correll J. 2012. Can uniform color cause aggression? Quasi-experimental evidence from professional ice hockey. *Soc. Psychol. Personal. Sci.* 3:274–81

Whitehead RD, Ozakinci G, Perrett DI. 2012. Attractive skin coloration: harnessing sexual selection to improve diet and health. *Evol. Psychol.* 10:842–54

Whitfield TW, Wiltshire TJ. 1990. Color psychology: a critical review. *Genet. Soc. Gen. Psychol. Monogr.* 116:385–411

Wilkins A. 2003. *Reading Through Colour*. Chichester, UK: Wiley

Williams CK, Grierson LE, Carnahan H. 2011. Colour-induced relationship between affect and reaching kinematics during a goal-directed aiming task. *Exp. Brain Res.* 212:555–61

Yamazaki AK. 2010. An analysis of background-color effects on the scores of a computer-based English test. *Lect. Notes Comput. Sci.* 6277:630–36

Yamazaki AK, Eto K. 2011. A preliminary examination of background-color effects on scores of computer-based English grammar testing using near-infrared spectroscopy. *Lect. Notes Comput. Sci.* 6883:31–39

Young SG, Elliot AJ, Feltman R, Ambady N. 2013. Red enhances the processing of facial expressions of anger. *Emotion* 13:380–84

Yüksel A. 2009. Exterior color and perceived retail crowding: effects on tourists' shopping quality inferences and approach behaviors. *J. Qual. Assur. Hosp. Tour.* 10:233–54

Links facial skin coloration to evaluation of male and female targets.

Highlights the importance of controlling for nonfocal color attributes in color research.

Zachar G, Schrott A, Kabai P. 2008. Context-dependent prey avoidance in chicks persists following complete telencephalectomy. *Brain Res. Bull.* 76:289–92

Zampini M, Sanabria D, Phillips N, Spence C. 2007. The multisensory perception of flavor: assessing the influence of color cues on flavor discrimination responses. *Food Qual. Prefer.* 18:975–84

Zampini M, Wantling E, Phillips N, Spence C. 2008. Multisensory flavor perception: assessing the influence of fruit acids and color cues on the perception of fruit-flavored beverages. *Food Qual. Prefer.* 19:335–43

Zellner DA, Durlach P. 2008. Effect of color on expected and experienced refreshment, intensity, and liking of beverages. *Am. J. Psychol.* 116:633–47

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