Journal of Experimental Psychology: General
2007, Vol. 136, No. 1, 154–168

0096-3445/07/$12.00 DOI: 10.1037/0096-3445.136.1.154

Color and Psychological Functioning: The Effect of Red on Performance Attainment

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This research focuses on the relation between color and psychological functioning, specifically, that between red and performance attainment. Red is hypothesized to impair performance on achievement tasks, because red is associated with the danger of failure in achievement contexts and evokes avoidance motivation. Four experiments demonstrate that the brief perception of red prior to an important test (e.g., an IQ test) impairs performance, and this effect appears to take place outside of participants' conscious awareness. Two further experiments establish the link between red and avoidance motivation as indicated by behavioral (i.e., task choice) and psychophysiological (i.e., cortical activation) measures. The findings suggest that care must be taken in how red is used in achievement contexts and illustrate how color can act as a subtle environmental cue that has important influences on behavior.

Keywords: color, red, performance, avoidance, EEG

Color is ubiquitous in individuals' perceptual experience of the world. Daily encounters with people, objects, and environments are rife with color; color is even present in dreams. Given the ubiquity of color in people's lives, it is not surprising that a great deal of research has been conducted over the past century focusing on the physics, physiology, and psychology of color. What is surprising is the disproportional amount of research conducted on color physics and physiology relative to color psychology (Wright, 1998) and how little is known, at present, regarding the effect of color on psychological functioning (Fehrman & Fehrman, 2004; Whitfield & Wiltshire, 1990).

In the present work, we focus on the effect of color on one form of psychological functioning: performance in achievement contexts (i.e., contexts in which competence is evaluated). In the following, we begin by comprehensively reviewing the extant literature on the relation between color and performance; this review clearly highlights the need for further theoretical development and empirical exploration in this area. Next, we articulate a conceptualization of color and psychological functioning and apply this conceptualization to the color–performance relation. Specifically, we propose a set of hypotheses regarding the influence of the color red on performance and report the results of six experiments designed to test these hypotheses.

Color and Performance: The Extant Literature

Theoretical Work

A significant portion of the existing research on color and performance represents a direct attempt to discover which colors, if any, boost worker, student, or athlete performance or productivity (e.g., Hatta, Yoshida, Kawakami, & Okamoto, 2002; Isaacs, 1980; Pressey, 1921; Rosenstein, 1985). This research is not theoretically based but has emerged from applied concerns alone. Of the theoretically based research, most appears to have been loosely guided by Goldstein's (1942) conceptualization of color and psychological functioning.

On the basis of subjective reports of psychiatric patients and speculation by Goethe, Goldstein (1942) posited that the body has inherent physiological reactions to color that are reflected in psychological experience and functioning. He proposed that the colors red and (to a lesser degree) yellow are experienced as stimulating and disagreeable and focus individuals on the outward environment, whereas the colors green and (to a lesser degree) blue are experienced as quieting and agreeable and focus individuals inward. Accordingly, red (and yellow) relative to green (and blue) was posited to impair performance on activities in which exactness is required (Goldstein, 1942, p. 151). Goldstein's conceptualization was not clearly articulated, and researchers have tended to interpret his ideas through the lens of the Yerkes–Dodson law or variants thereof (see Kwallek, Woodson, Lewis, & Sales, 1997; Stone & English, 1998). That is, longer wavelength colors (red, orange) are viewed as arousing, whereas shorter wavelength colors (green, blue) are viewed as calming, and it is thought that longer

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This research was supported by a grant from the William T. Grant Foundation and a Friedrich Wilhelm Bessel Award from the Alexander von Humboldt Foundation to Andrew J. Elliot. We thank David Cohn and Mark Fairchild for their valuable contributions to the research presented herein.

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wavelength colors, relative to shorter wavelength colors, impair performance on complex tasks.

Aside from Goldstein's conceptualization and accompanying proposals, only a few hypotheses regarding the color–performance relationship have been proffered. Soldat, Sinclair, and Mark (1997) hypothesized that red is associated with happiness and evokes heuristic processing that undermines cognitive performance, whereas blue is associated with sadness and evokes systematic processing that facilitates cognitive performance. Hill and Barton (2005), however, hypothesized that red triggers dominance in contests and that wearing red in such situations therefore enhances performance relative to wearing blue. Ott (1979; see also Krieg, 1932) posited that light that is colored pink (or, to a lesser degree, orange) has an endocrine-based weakening effect on muscles that undermines performance on strength tasks, whereas blue-colored light has a parallel strengthening effect that facilitates performance on strength tasks.

Unfortunately, the basic premise of each of the aforementioned hypotheses is suspect. Although many in the popular, applied, and scientific literatures contend that longer wavelength colors (especially red) are more arousing than shorter wavelength colors (especially blue and green), the existing research, particularly that using well-crafted experimental designs, simply does not support this proposition (Fehrman & Fehrman, 2004; Kaiser, 1984; Wright, 1998). Furthermore, the utility of the general arousal construct and the validity of the arousal–performance relation posited in the Yerkes–Dodson law have been called into question by many theorists (see Matthews, 1985; Neiss, 1988). Likewise, the existing body of research on color and emotion does not support the notion that red is associated with happiness (Bellizzi & Hite, 1992; Valdez & Mehrabian, 1994). In addition, there is no existing evidence suggesting that red evokes heuristic processing, nor is there evidence suggesting that red triggers dominance in humans performing in contests. Finally, researchers have suggested that any effects of pink relative to blue light on strength performance would likely be due to gender-based demand characteristics rather than endocrine-based processes (Ingram & Lieberman, 1985; Smith, Bell, & Fusco, 1987).

Empirical Work

A majority of the research that has been conducted on color and performance has contrasted the effect of red versus blue (or, less often, white or green) on cognitive or psychomotor performance. No consistent effects have been found in this research. In nearly all studies, null results have been obtained for the color–performance relation (Ainsworth, Simpson, & Cassell, 1993; Goodfellow & Smith, 1973; Green et al., 1982; Hammes & Wiggins, 1962; Hatta et al., 2002; Isaacs, 1980; Kwallek & Lewis, 1990; Kwallek, Lewis, Lin-Hsiao, & Woodson, 1996; Kwallek, Lewis, & Robbins, 1988; Kwallek et al., 1997; Pierce & Weinland, 1934; Pressey, 1921; Profusek & Rainey, 1987; Rosenstein, 1985; Shick, 1975; Stone & English, 1998). A few studies have yielded data indicating worse performance under red conditions (James & Domingos, 1953; Nakashian, 1964; Sinclair, Soldat, & Mark, 1998; Soldat et al., 1997; Stone, 2001), but another study found the opposite pattern (Hill & Barton, 2005). Moreover, even with the studies that found an effect, in nearly every case the significant results have only been observed for some comparisons, or null results have been found for most indicators of performance.

Some extant color–performance research has focused on the effect of pink versus blue (or, less often, white or red) on performance on strength tasks. This research has also failed to yield any consistent effects. Although a few studies have found worse performance under pink conditions (Pellegrini & Schauss, 1980; Pellegrini, Schauss, & Birk, 1980), most have not (Gilliam, 1991; Gilliam & Unruh, 1988; Green et al., 1982; Ingram & Lieberman, 1985; Pellegrini, Schauss, Kerr, & Ah You, 1981; Profusek & Rainey, 1987).

In sum, in the literature at present, there is no clear evidence for a color effect on performance attainment. It is possible that this summary statement reflects the fact that color effects on performance attainment do not actually exist. However, it is also possible that color–performance relationships do exist but that weaknesses in the existing research have made them difficult to detect. Several important weaknesses may be noted. First, in most studies, researchers have manipulated color by using colored walls, colored partitions, or colored lights, often in simulated work environments. Colored walls or partitions cannot provide precise color manipulations because the amount of time participants actually view the colors is completely uncontrolled. In addition, colored lights create highly unusual work environments that likely alter participants' typical approach to task engagement. Furthermore, the long presentation time of many wall-, partition-, and light-based manipulations (up to 4 full work days; see Kwallek et al., 1997) raises the possibility that participants might habituate to or react against the manipulation in such instances. Second, colors vary in perceived typicality, saturation, and brightness, as well as hue. This variability is not taken into consideration in the existing research, despite the fact that each of these factors can influence participants' response to hue (Camgoz, Yener, & Guvenc, 2003; Valdez & Mehrabian, 1994). Indeed, not a single study on the color–performance relation has controlled for perceived typicality, nor have any of these studies controlled for both saturation and brightness (see Goodfellow & Smith, 1973, for the closest approximation). Some would argue that this renders the extant literature essentially uninterpretable (Valdez & Mehrabian, 1994; Whitfield & Wiltshire, 1990). Third, perhaps because of the strong applied focus of much of the literature, many of the existing studies have neglected to attend to basic experimental considerations such as ensuring the experimenter is blind to hypotheses and condition, limiting participation to noncolorblind persons, and so on. In addition, many studies have been published as brief reports (e.g., one or two pages) containing insufficient detail with which to evaluate methodological rigor. In sum, important weaknesses in the existing studies in the literature suggest that further research is needed before definitive statements regarding the color–performance relation are warranted.

A Conceptualization of Color and Psychological Functioning

Our contention is that color does influence performance and psychological functioning more generally and that it does so via learned associations that may be embedded in deeply ingrained predispositions. Color clearly has aesthetic value, but it can also carry specific meaning and convey specific information. From infancy onward, persons encounter both explicit and subtle pairings between colors and particular messages, concepts, and experiences in particular situations. With repetition, these pairings are posited to produce strong color associations, such that the mere perception of a color in a particular situation activates its paired associate and influences affect, cognition, and behavior accordingly (see Baldwin & Meunier's 1999 cued activation model for a conceptual parallel). It is important to note that the activation of the color association, as well as its influence on affect, cognition, and behavior, is viewed as occurring without the individual's conscious awareness or intention. That is, once a color association is in place, color is presumed to operate as a nonconscious prime and have an automatic influence on psychological functioning (see Bargh's 1990 auto-motive model for a conceptual parallel).

Some color associations are undoubtedly a product of learning alone, but color theorists suspect that many such associations emerge from evolutionarily ingrained predispositions to color stimuli (Jacobs, 1981; Mollon, 1989). Color vision evolved because it contributed to adaption and survival, and research indicates that color often serves a signal function for animals, facilitating fitness-relevant behavior (Byrne & Hilbert, 2003; Guilford & Rowe, 1996; Hutchings, 1997). If, as suspected, humans are prepared to respond to color stimuli in similar fashion, then at least some color associations may actually represent a cognitive reinforcing or shaping of biologically based response tendencies.

The popular, applied, and scientific literatures are replete with statements regarding the content of color associations. For any given color, these associations are multifarious and, at times, contradictory, making clear conclusions about color associations and their implications elusive (Levy, 1984; Stone, 1998; Valdez & Mehrabian, 1994). We believe that clarity on this issue may be gained by taking context into consideration. We posit that color carries different meanings in different contexts and, therefore, that color has different implications for feelings, thoughts, and behaviors in different contexts.

The Influence of Red on Performance in Achievement Contexts

In the present research, we examined the influence of the color red on performance in achievement contexts. Our hypothesis is that red impairs performance in such contexts and that it does so in nonconscious fashion. The rationale for this hypothesis is grounded in our conceptualization of color and psychological functioning as applied to the achievement context.

Achievement contexts are situations in which competence is evaluated and both positive outcomes (i.e., success) and negative outcomes (i.e., failure) are possible. We propose that in such contexts, red is associated with danger, specifically, the psychological danger of failure. This association is presumed to be the product of multiple sources. Most specifically and directly, the repeated pairing of red with mistakes and failures that is encountered by most children in the educational system (e.g., incorrect answers marked with red ink) teaches them to associate red with failure in achievement contexts. This association is bolstered and elaborated on over time by the link between red and danger in other contexts in which negative possibilities are salient, such as the red of stoplights, the red of fire alarms, and the red of warning signs. Furthermore, it is even possible that these learned associations emerge from a deeply ingrained predisposition across phylogeny to interpret red as a signal of danger in competition contexts (e.g., the superiority, aggressiveness, or attack readiness of an opponent; Pryke, Andersson, Lawes, & Piper, 2001; Setchell & Wickings, 2005). That is, the use of red to mark errors, warn of negative possibilities, and so on in society may emerge from a biologically based tendency to view red as a danger signal. Thus, through associative processes that may themselves be embedded in deeply ingrained proclivities, red comes to function as a danger cue in achievement contexts, signaling the possibility of failure.

Researchers have demonstrated that encountering a negative object, event, or possibility (including the dangerous possibility of failure) automatically evokes a motivational tendency to avoid that object, event, or possibility (for reviews, see Bargh & Chartrand, 1999; Cacioppo, Gardner, & Berntson, 1999). Furthermore, research in achievement contexts indicates that the motivational tendency to avoid failure negatively impacts performance by producing anxiety, task distraction, and a host of self-protective processes (e.g., disidentification, selection of easy tasks, self-handicapping; Birney, Burdick, & Teevan, 1969; Elliot & McGregor, 1999; for a review, see Elliot, 2005). Thus, the perception of red in achievement contexts is hypothesized to impair performance because it evokes a motivational tendency to avoid failure that, ironically, undermines performance. In accord with Bargh's (1990) auto-motive model, this inimical influence of red is posited to take place without individuals' awareness that avoidance motivation has been activated and is operative in the achievement context.

In sum, the present research is designed to examine a set of hypotheses regarding the influence of the color red on performance. Our foremost interest was in testing the hypothesis that red undermines performance on achievement tasks (Experiments 1–4); most of these experiments used an IQ test as the focal achievement task. We also sought to examine the degree to which individuals were conscious of the processes involved in the proposed inimical influence of red (Experiments 2–4). We anticipated that individuals' self-reported avoidance motivation, as well as their self-reported appraisals, perceptions, and moods, would be unrelated to the perception of red and, furthermore, that individuals would not be aware that perceiving red undermined their performance. Finally, we sought to move beyond self-report measures to examine the link between red and avoidance motivation with measures that do not require conscious access to activated motivational processes (Experiments 5–6). We hypothesized that the perception of red would evoke motivation to avoid failure, as indicated by both behavioral and psychophysiological markers of avoidance motivation.

Experiment 1

In Experiment 1, we examined the effect of the colors red, green, and black on anagram performance. Green was selected as the chromatic contrast to red, because red and green are considered opposite colors in several well-established color models (Fehrman & Fehrman, 2004). In addition, although green is not viewed as having any specific associations in achievement contexts per se, it does carry the approach-oriented meaning of "go" in contrast to the avoidance-oriented meaning of "stop" in traffic lights. There are three achromatic (i.e., neutral) colors—black, white, and gray—and, in this experiment, we used black as the neutral color.

Method

Participants

Seventy-one (18 male and 53 female) U.S. undergraduates participated in the experiment for extra course credit. Participation was restricted to individuals who were native English speakers, did not have a language-related disability, and were not red–green colorblind (these restrictions were uniform across all experiments—although, in Experiments 2–6, participation was restricted to native German speakers—and will not be repeated hereafter). The mean age of participants was 20.20 years old with a range of 18–44 years.

Design and Procedure

Participants were randomly assigned to one of three between-subjects experimental conditions: the red condition, the green condition, or the black (neutral) condition. Anagram performance served as the dependent measure. General ability (i.e., Scholastic Aptitude Test [SAT] scores), premanipulation anagram performance (i.e., scores on a practice test), and sex were used as covariates, because each of these variables has been found to influence performance in prior experimental work on achievement motivation (see Elliot, Shell, Henry, & Maier, 2005; Inzlicht & Ben-Zeev, 2003; Steele & Aronson, 1995). In this and all applicable experiments, the general ability information was provided by participants at the end of the experiment.

Participants were tested individually by an experimenter blind to participants' condition and the experimental hypotheses. The experimenters in this and all subsequent experiments were aware that color played a role in the experiment, but they remained unaware of the color hypotheses throughout the data collection process. All experiments were explicitly designed to ensure that the experimenter did not see the manipulated color at any time during the experiment.

On arrival for the experiment, participants were informed that the experiment involved solving anagrams. The experimenter then provided participants with a verbal description of the anagram task. The task involved solving 15 moderately difficult, five-letter, single-solution anagrams during a 5-min period. The anagrams were selected from a published list of over 200 anagrams (Gilhooly, 1978), complete with difficulty ratings. A set of 15 moderately difficult anagrams were selected for a practice test, and a set of 15 comparably difficult anagrams were selected for the "real" test (sample anagram: *NIDRK*; solution: *DRINK*).

After the description of the task, participants were provided with an envelope containing a practice test, which was a packet containing six pages with a staple in the upper left-hand corner. The first page of the packet was a cover page, followed by five pages containing three anagrams each. The experimenter started a stopwatch and left the lab while participants completed the practice test. When 5 min had elapsed, the experimenter reentered the lab, announced that the time had expired, and replaced the practice anagram test with the real anagram test. The experimenter informed participants that they would be receiving feedback on this test.

Excepting the color manipulation and a different set of items, the real anagram test was the same as the practice anagram test. The experimental conditions were instantiated by placing a colored participant number on the test. Specifically, prior to the experiment being conducted, a research assistant blind to the experimental hypotheses wrote a participant number (1/2 in. tall × 3/4 in. wide) in the upper right-hand corner of each page of the test (excepting the cover page) in red, green, or black ink with a Sanford medium-point pen. The anagram test was presented to participants in an envelope. Participants were told that their participant number was written on all but the cover page of the test, and they were asked to check to verify that this was indeed the case (ostensibly because the pages would be separated after the experiment). The experimenter remained blind to color condition by turning away from participants as they checked their participant number. Pilot testing with a separate sample of undergraduates documented that each color used in the manipulations (a) was recognized as the designated color, (b) was viewed as a typical representation of the color, and (c) did not differ in the extent to which it was viewed as a typical representation of the color.[1] After the manipulation, the experimenter started a stopwatch and left the lab while participants completed the test. When 5 min had elapsed, the experimenter reentered the lab, announced that the time had expired, picked up the test, and stated that feedback would be provided shortly. The experimenter left the lab, scored the anagrams, and returned with feedback. All participants were informed of the number of anagrams that they solved correctly and were told that this represented very good performance.

Participants then completed a brief demographics questionnaire and received a verbal funnel debriefing that probed for awareness and suspicion (e.g., "What do you think we were trying to test?") and, if color was mentioned, queried for specifics (e.g., "Do you have any guesses about what the purpose of the color might have been in the study?"). Next, participants were asked to name the color of the participant number on their test and then were debriefed, given their extra credit, and dismissed.

Results and Discussion

Analyses on Anagram Performance

A unifactorial (color condition: red vs. green vs. black) between-subjects analysis of covariance (ANCOVA) was conducted on anagram performance (M = 5.36, SD = 0.31), with general ability (i.e., SAT scores; M = 1277.67, SD = 14.11), premanipulation anagram performance (M = 4.97, SD = 0.40), and sex as covariates. To examine our specific hypotheses in this and all subsequent experiments, we ran planned comparisons (Fisher's least significant difference tests) that followed the omnibus analysis. The analysis revealed an effect of general ability, $F(1, 65) = 5.66$, $p < .05$, $\eta_p^2 = .08$, and premanipulation anagram performance, $F(1, 65) = 60.31$, $p < .01$, $\eta_p^2 = .48$, on anagram performance, indicating that participants who had higher SAT scores and who performed better on the practice test did better on the anagram test. No effect of sex was observed, $F = 0.02$, $p > .88$. Most important, the analysis also revealed an effect of color condition on anagram performance, $F(2, 65) = 3.14$, $MSE = 3.52$, $p = .05$, $\eta_p^2 = .09$ (see Figure 1 for means by color condition).

[1] The pilot test for Experiment 1 was a between-subjects experiment conducted with 30 participants (18 male, 12 female), 10 per condition, who were of the same approximate age as participants in the main experiment. Participants were asked three questions to examine whether they recognized each color as the designated color: "To what degree is the color red?" "To what degree is the color green?" and "To what degree is the color black?" They responded on a 1 = *not at all* to 5 = *very much* scale. Separate omnibus analyses of variance for each question revealed that participants indeed made accurate color categorizations (all Fs ≥ 27.96, ps < .01); pairwise comparisons additionally confirmed the accuracy of these categorizations (all ts ≥ 6.53, $p < .01$). Participants were also queried, "To what degree is the color a typical example of that color?" and responded on a 1 = *not at all* to 5 = *very much* scale. The mean for each condition was at or above the midpoint of the scale, and the conditions did not differ in their degree of typicality, $F = 0.44$, $p = .56$.

Similar pilot testing was conducted for each experiment in this article. These pilot tests were conducted using the same design, the same number of participants per cell, the same type of participants (i.e., matched in age to the experimental participants), the same questions, and the same analyses as Experiment 1. All analyses yielded the same pattern of results as those observed for Experiment 1. For the designated color questions, all Fs ≥ 13.49, ps < .01, and all ts ≥ 3.15, ps < .01; for the typicality question, all means were at or above the midpoint of the scale, and all Fs ≤ 2.27, ps ≥ .12.

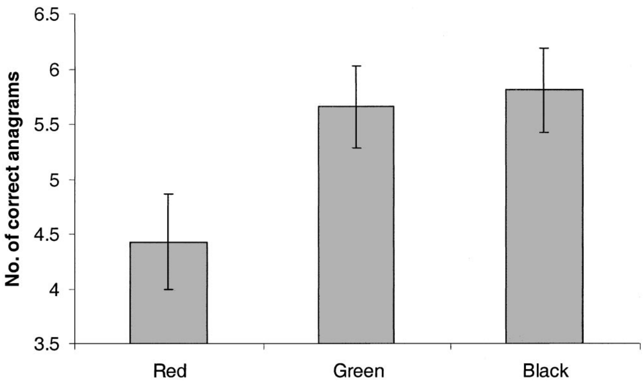

Figure 1. The effect of color on anagram test performance in Experiment 1: Mean number of correctly solved anagrams by color of participant number (means are adjusted for general ability, premanipulation anagram performance, and sex). Confidence intervals (95%) are indicated by vertical lines. Participants in the red condition ($n = 19$) performed significantly worse than participants in the green condition ($n = 27$) and the black condition ($n = 25$), who did not differ from each other. (A color version of this figure is available online.)

Planned comparisons revealed that participants in the red condition performed worse than those in the green condition, $t(44) = 2.11$, $p < .05$, $\eta_p^2 = .06$, and the black condition, $t(42) = 2.33$, $p < .05$, $\eta_p^2 = .08$. Participants in the green and black conditions displayed comparable levels of performance, $t = -0.24$, $p > .81$.

Awareness of Color and Purpose of Experiment

A chi-square test of independence was calculated to determine whether participants' color reports corresponded to their color condition. The analysis yielded a significant effect, $\chi^2(4, N = 70) = 88.87$, $p < .01$, indicating that participants were indeed cognizant of the color on the anagram test. In the funnel debriefing, however, not a single participant guessed that the experiment focused on color and performance.

In sum, the results from this experiment supported our hypotheses. Participants who viewed the color red prior to an anagram test performed worse on the test than those who viewed green or black; participants who viewed green performed comparably to those who viewed black. Participants were able to report the correct color on their anagram test but were unaware of the purpose of the study.

Experiment 2

In Experiment 2, we changed the neutral color from black to white, and we changed the color manipulation so that exposure to the color would be brief and completely separate from the performance period. We also changed the experimental task from a set of anagrams to a subscale of an IQ test, and we changed the location of the experiment from the United States to Germany. Finally, we included a variety of different process measures at the end of the experiment, and we asked participants to report their perceived competence after taking the test. We anticipated null effects on these process and perceived competence measures, given our contention that the influence of red on performance takes place without individuals being aware of this influence.

Method

Participants

Forty-six (4 male and 42 female) German undergraduates participated in the experiment for extra course credit. The mean age of participants was 21.67 years old with a range of 19–34 years.

Design and Procedure

Participants were randomly assigned to one of three between-subjects experimental conditions: the red condition, the green condition, or the white (neutral) condition. Analogy performance served as the dependent measure. As in the prior experiment, general ability (i.e., scores on the Arbitur, a standardized comprehensive exam taken at the end of high school by all students within the state), premanipulation analogy performance, and sex were used as covariates.

Participants were tested individually by an experimenter blind to participants' condition and the experimental hypotheses. On arrival for the experiment, participants were informed that the experiment involved solving analogies. The experimenter then provided participants with a verbal description of the analogy task. The task involved completing the 20-item analogy subtest of the Intelligence Structure Test (IST), a German IQ test (Amthauer, Brocke, Liepmann, & Beauducel, 1999), during a 5-min period. For each item on the test, a word pair is provided, along with the first word of a second pair (sample analogy: Expensive: Rarely = Cheap: __________); five response options are also provided, one of which best completes the pairing (the response options were Low-priced, Durable, Affordable, Ordinary, Frequent; the solution was Frequent). One form of the analogies subtest was used for the practice test, and a second parallel form was used for the "real" test.

After the description of the task, participants were provided with a practice test that was presented in a white two-ring binder. The first page within the binder was the cover page of the practice test, a piece of paper with the words *Practice Analogies* in black ink in 34-point font in the middle of the page. The following page contained the 20 practice analogies. The experimenter informed participants that the first page within the binder should contain the words *Practice Analogies* and then instructed them to open the binder to this page. The experimenter asked participants, "Do you see the words *Practice Analogies*?" When they replied in the affirmative, the experimenter told them to turn the page and begin the practice test. The experimenter started a stopwatch and retreated to the back of the lab while participants completed the practice test. When 5 min had elapsed, the experimenter announced that time had expired and replaced the practice analogy test with the real analogy test. The experimenter informed participants that they would be receiving feedback on this test.

Excepting the color manipulation and a different set of items, the procedure for the real analogy test was the same as that for the practice analogy test. The experimental conditions were instantiated by placing colored folio paper (or not) on the cover page of the analogy test. Thus, participants' exposure to the color manipulation was brief (approximately 5 s) and was restricted to the period immediately prior to the test. The experimenter remained blind to color condition by turning away from participants as they checked the cover page of the test. For the red and green conditions, the word *Analogies* was placed in black ink in 34-point font on a colored rectangle 5 in. long × 7 1/4 in. wide and positioned in the middle of the white page. For the white condition, the word *Analogies* was simply placed in black ink in 34-point font in the middle of the white page.

After the manipulation, the experimenter started a stopwatch and retreated to the back of the lab while participants completed the test. When 5 min had elapsed, the experimenter announced that time had expired and picked up the test. The experimenter then provided participants with a questionnaire containing process and perceived competence measures and asked participants to complete it during the scoring of the analogies. In this and all relevant experiments, the process measures included at least one measure of avoidance motivation (e.g., threat appraisal, avoidance goal regulation, vigilance) and at least one other measure of motivation, mood, or general arousal. The experimenter then left the lab, scored the analogies, and returned with feedback. All participants were informed of the number of analogies that they solved correctly and were told that this represented very good performance.

Participants then completed a brief demographics questionnaire, received a verbal funnel debriefing, and were asked to name the color, if any, on the cover of the analogy test. After the color question, participants were debriefed, given extra credit, and dismissed.

Measures

Task appraisals. Task appraisals were assessed with Elliot and Reis's (2003) two-item threat (e.g., "I viewed this analogy task as a threat"; α = .97) and challenge (e.g., "I viewed this analogy task as a positive challenge"; α = .63) appraisal measures (scored on a scale of 1 = *not at all true of me* to 7 = *very true of me*).

Achievement goals. Achievement goals were assessed with task-specific versions of the three-item scales from Elliot and McGregor's (2001) Achievement Goal Questionnaire. Performance-avoidance goals (e.g., "While solving the analogies, my goal was to avoid performing worse than others on this task"; α = .95), mastery-avoidance goals (e.g., "While solving the analogies, my goal was to miss as few of the answers as I possibly could"; α = .87), performance-approach goals (e.g., "While solving the analogies, my goal was to perform better on this task than others"; α = .80), and mastery-approach goals (e.g., "While solving the analogies, my goal was to get as many answers right as I possibly could"; α = .70), were assessed (answered on a scale of 1 = *not at all true of me* to 7 = *very true of me*).

Affect. Negative affect was assessed with the 10-item Negative Affect subscale (e.g., "How irritable did you feel while solving the analogies?" α = .78) and positive affect was assessed with the 10-item positive affect subscale (e.g., "How inspired did you feel while solving the analogies?" α = .92) of Watson, Clark, and Tellegen's (1988) Positive and Negative Affect Schedule (answered on a scale of 1 = *not at all* to 5 = *very strongly*).

General arousal. General arousal was assessed with the five-item General Activation subscale (e.g., "How vigorous did you feel while solving the analogies?" α = .83) of Thayer's (1986) Activation–Deactivation Adjective Check List (answered on a scale of 1 = *not at all* to 5 = *very strongly*).

Perceived competence. Perceived competence was assessed with Elliot and Harackiewicz's (1996) single-item measure ("How do you think you did on the five minute analogy task today?" answered on a scale of 1 = *very poorly* to 7 = *very well*).

Results and Discussion

Analyses on Analogy Performance

A unifactorial (color condition: red vs. green vs. white) between-subjects ANCOVA was conducted on analogy performance (M = 12.15, SD = 2.51), with general ability (M = 2.30, SD = 0.46), premanipulation analogy performance (M = 12.13, SD = 2.86), and sex as covariates. The analysis revealed an effect of premanipulation analogy performance on analogy performance, $F(1, 40) = 10.09$, $p < .01$, $\eta_p^2 = .20$, indicating that participants who performed better on the practice test did better on the analogy test. No effects of general ability, $F = 0.20$, $p > .65$, or sex, $F = 1.61$, $p > .11$, were observed. Most important, the analysis also revealed an effect of color condition on analogy performance, $F(2, 40) = 8.51$, $MSE = 3.89$, $p < .01$, $\eta_p^2 = .30$ (see Figure 2 for means by color condition).

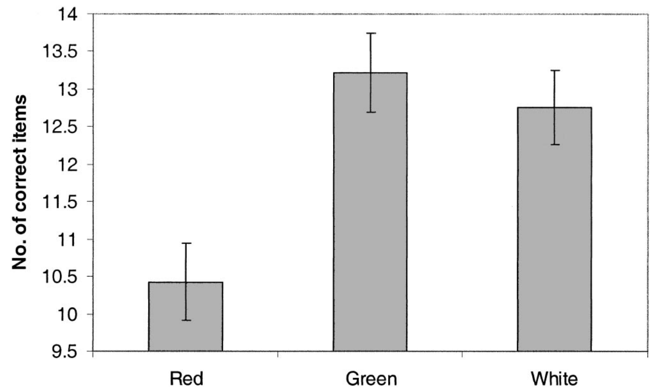

Figure 2. The effect of color on IQ test (analogy subtest) performance in Experiment 2: Mean number of correctly solved items by color on the cover of the test (means are adjusted for general ability, premanipulation analogy performance, and sex). Confidence intervals (95%) are indicated by vertical lines. Participants in the red condition (n = 15) performed significantly worse than participants in the green condition (n = 15) and the white condition (n = 16), who did not differ from each other. (A color version of this figure is available online.)

Planned comparisons revealed that participants in the red condition performed worse than those in the green condition, $t(28) = 3.78$, $p < .01$, $\eta_p^2 = .26$, and the white condition, $t(29) = 3.26$, $p < .01$, $\eta_p^2 = .21$. Participants in the green and white conditions displayed comparable levels of performance, $t = -0.62$, $p > .53$.

Analyses on Process Variables and Perceived Competence

Conducting an ANCOVA on each of the process variables—threat appraisal (M = 1.61, SD = 1.12), challenge appraisal (M = 5.07, SD = 1.06), performance-avoidance goals (M = 3.48, SD = 1.76), mastery-avoidance goals (M = 5.36, SD = 1.81), performance-approach goals (M = 2.84, SD = 1.37), mastery-approach goals (M = 5.46, SD = 1.26), negative affect (M = 1.73, SD = 0.60), positive affect (M = 3.02, SD = .48), and general arousal (M = 3.46, SD = .62)—failed to yield any significant effects of color condition (all Fs $\leq$ 1.10, ps $\geq$ .30). An ANCOVA on perceived competence (M = 3.59, SD = 0.98) also yielded a null effect, $F = 0.65$, $p = .53$.

Awareness of Color and Purpose of Experiment

A chi-square test of independence was calculated to determine whether participants' color reports corresponded to their color condition. The analysis yielded a significant effect, $\chi^2(4, N = 46) = 61.12$, $p < .01$, indicating that participants were indeed aware of the color on the test cover. In the funnel debriefing, however, not a single participant guessed that the experiment focused on color and performance.

In sum, the results from this experiment replicated those of Experiment 1 using a different neutral color, using a different color manipulation, using a different task, and using participants from a different country. In addition, the results suggest, as proposed, that the observed effects are not grounded in consciously accessible processes and that participants are not aware of the influence that color has on their performance. Participants could report the correct color on the analogy test but were unaware of the purpose of the study.

Experiment 3

In Experiment 3, we changed the neutral color from white to gray, we shortened the duration of the color exposure in the color manipulation, we explicitly identified the task as an IQ test, and we changed the venue of the experiment from a controlled laboratory setting to a real-world classroom setting. In addition, we shifted the assessment of process variables from the end of the experiment to after the manipulation but before the performance period.

Method

Participants

Thirty (5 male and 25 female) German high school students voluntarily participated in the experiment. The mean age of participants was 17.30 years old with a range of 15–20 years.

Design and Procedure

Participants were randomly assigned to one of three between-subjects experimental conditions: the red condition, the green condition, or the gray (neutral) condition. Analogy performance served as the dependent measure; as in the prior experiments, general ability (i.e., cumulative high school grade point average [GPA], which is highly correlated with Arbitur scores), premanipulation analogy performance, and sex were used as covariates.

Participants were tested in small groups in an actual high school classroom by an experimenter blind to participants' condition and the experimental hypotheses. At the beginning of the experiment, participants were informed that the study involved taking an IQ test. The experimental task was the analogy subtest of the IST used in Experiment 2.

The procedure for the rest of the experiment was the same as that of Experiment 2 with three exceptions. First, for both the practice and the real analogy tests, the experimenter simply instructed participants to open the binder to the cover page and then, after a 2-s pause, instructed them to turn the page. This procedure was not only more amenable to the group setting but also accentuated the brevity and subtlety of the color manipulation. Second, instead of completing the process items after the task, participants completed these items immediately after the color manipulation and prior to task performance. The process variable assessment was limited to two single-item measures (vigilance, an indicator of avoidance motivation, and eagerness, an indicator of approach motivation) to minimize interference with the manipulation. Thus, after the 2-s color manipulation, participants were instructed to turn the page, were given approximately 20 s to complete the process items, and then were instructed to turn the page and begin the test. Third, the group setting necessitated minor shifts in the funnel debriefing and feedback procedures. Regarding the funnel debriefing, participants wrote their answers rather than responding verbally, and the specific color questions were asked in contingent fashion (e.g., "If you mentioned color in your response to any of the above questions, do you have any guesses about what the purpose of the color might have been in the study?"). Regarding the feedback, after participants completed the experiment, they were informed that they would receive their feedback via e-mail.

Measures

Vigilance. Vigilance was assessed with Seibt and Förster's (2004) single-item measure ("How careful are you now?" answered on a scale of 1 = *not at all careful* to 9 = *very careful*).

Eagerness. Eagerness was assessed with Seibt and Förster's (2004) single-item measure ("How eager are you now?" answered on a scale of 1 = *not at all eager* to 9 = *very eager*).

Perceived competence. The same measure used in Experiment 2 was used in this experiment.

Results and Discussion

Analyses on Analogy Performance

A unifactorial (color condition: red vs. green vs. gray) between-subjects ANCOVA was conducted on analogy performance (M = 11.77, SD = 2.54), with general ability (M = 2.50, SD = 0.64), premanipulation analogy performance (M = 12.12, SD = 2.17), and sex as covariates. The analysis revealed an effect of premanipulation analogy performance on analogy performance, $F(1, 24) = 14.80$, $p < .01$, $\eta_p^2 = .38$, indicating that participants who performed better on the practice test did better on the analogy test. No effects of general ability, $t = 2.73$, $p = .11$, or sex, $t = 0.02$, $p = .88$, were observed. Most important, the analysis also revealed an effect of color condition on analogy performance, $F(2, 24) = 11.81$, $MSE = 2.78$, $p < .01$, $\eta_p^2 = .50$ (see Figure 3 for means by color condition).

Planned comparisons revealed that participants in the red condition performed worse than those in the green condition, $t(20) = 4.81$, $p < .01$, $\eta_p^2 = .49$, and the gray condition, $t(16) = 3.29$, $p < .01$, $\eta_p^2 = .31$. Participants in the green and gray conditions displayed comparable levels of performance, $t = -1.51$, $p = .14$.

Analyses on Process Variables and Perceived Competence

Conducting an ANCOVA on each of the process variables—vigilance (M = 4.90, SD = 1.47) and eagerness (M = 6.23, SD = 1.57)—failed to yield any significant effects of color condition (Fs $\leq$ 1.08, ps $\geq$ .35). An ANCOVA on perceived competence (M = 3.80, SD = 0.92) also yielded a null effect, $F = 0.55$, $p = .53$.

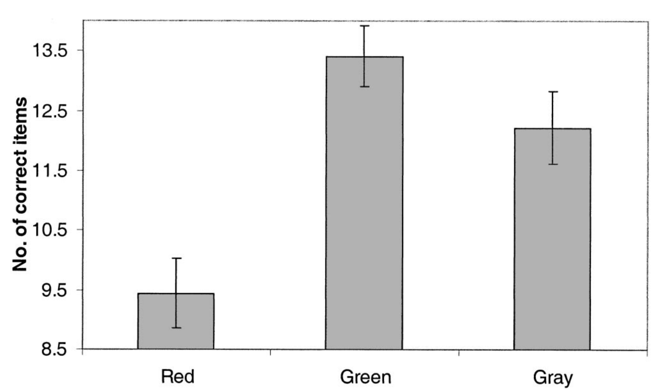

Figure 3. The effect of color on IQ test (analogy subtest) performance in Experiment 3: Mean number of correctly solved items by color on the cover of the test (means are adjusted for general ability, premanipulation analogy performance, and sex). Confidence intervals (95%) are indicated by vertical lines. Participants in the red condition (n = 10) performed significantly worse than participants in the green condition (n = 12) and the gray condition (n = 8), who did not differ from each other. (A color version of this figure is available online.)

Awareness of Color and Purpose of Experiment

A chi-square test of independence was calculated to determine whether participants' color reports corresponded to their color condition. The analysis yielded a significant effect, $\chi^2(4, N = 29) = 41.77$, $p < .01$, indicating that participants were indeed cognizant of the color on the test cover. In the funnel debriefing, however, not a single participant guessed that the experiment focused on color and performance.

In sum, the results from this experiment replicated those of Experiments 1 and 2 using a different neutral color, using a shortened exposure to the color manipulation, explicitly identifying the task as an IQ test, using a different set of process variables, and in a real-world achievement context. In addition, the results again appear to support our proposal that the observed effects are not grounded in consciously accessible processes and that participants are not aware of the influence that color has on their performance. Again, participants could report the correct color on the analogy test but were unaware of the purpose of the study.

Experiment 4

In Experiment 4, we selected colors for the color manipulations using a mathematical model of color. In addition, we changed the experimental task from a language-based task to a number-based task and changed the set of process variables.

Method

Participants

Fifty-seven (25 male and 32 female) German high school students voluntarily participated in the experiment. The mean age of participants was 17.88 years old with a range of 16–20 years.

Design and Procedure

Participants were randomly assigned to one of three between-subjects experimental conditions: the red condition, the green condition, or the gray condition. Numeric performance served as the dependent measure; as in the prior experiments, general ability (i.e., cumulative high school GPA), premanipulation numeric performance, and sex were covariates.

The procedure for the experiment was the same as that used in Experiment 3 with three exceptions. First, the experimental task involved completing 10 items from the numeric subtest of the IST. For each item on the test, a sequence of numbers is listed with a final number unspecified (sample item: *18, 16, 19, 15, 20, 14, 21, ?*); the task is to write down a number that completes the sequence (solution: *13*). Only one numeric subtest is available in the IST; therefore, the odd-numbered items were used for the practice test and the even-numbered items were used for the "real" test. Participants were given 5 min to solve each set of 10 items. Second, the colors in the color manipulation were selected using the HSV color model. This model defines a color space in terms of three parameters: hue, saturation, and value (similar to brightness; Fairchild, 2005). Using this model, the chromatic colors were equated on saturation and value (red: hsv[0, 87, 72], green: hsv[139, 87, 72]) and the achromatic color, which has no saturation, was equated on value (hsv[–, 0, 72]). The colors were printed in rectangular form (5 in. long × 7 1/4 in. wide) and were positioned in the middle of the white cover page; the word *Items* was placed in black ink in 34-point font in the middle of the colored rectangle. Third, a different set of process variables was assessed (performance-avoidance goals, general arousal, and mood) immediately after the color manipulation.

Measures

Performance-avoidance goals. Performance-avoidance goals were assessed with the item "I just want to avoid doing poorly at this task" (answered on a scale of 1 = *not at all* to 7 = *very much*). This item is the highest loader on the performance-avoidance goal measure in Elliot and McGregor's (2001) Achievement Goals Questionnaire.

General arousal. General arousal was assessed with the item "How energetic do you feel right now?" (answered on a scale of 1 = *not all energetic* to 4 = *very energetic*). This item is the highest loader on the General Activation subscale of Thayer's (1986) Activation–Deactivation Adjective Check List.

Mood. Mood was assessed with Seibt and Förster's (2001) single-item measure ("How do you feel right now?" answered on a scale of 1 = *very bad* to 9 = *very good*).

Perceived competence. The same measure used in Experiments 2 and 3 was used in this experiment.

Results and Discussion

Analyses on Math Performance

A unifactorial (color condition: red vs. green vs. gray) between-subjects ANCOVA was conducted on numeric performance ($M = 7.44$, $SD = 2.12$), with general ability ($M = 2.31$, $SD = 0.71$), premanipulation numeric performance ($M = 8.26$, $SD = 2.29$), and sex as covariates. The analysis revealed an effect of general ability, $F(1, 51) = 7.03$, $p < .05$, $\eta_p^2 = .12$, and premanipulation numeric performance, $F(1, 51) = 27.00$, $p < .01$, $\eta_p^2 = .35$, on numeric performance, indicating that participants who had a higher GPA and who performed better on the practice test did better on the numeric test. No effect of sex was observed, $t = 1.43$, $p = .24$. Most important, the analysis also revealed an effect of the color manipulation on numeric performance, $F(2, 51) = 3.17$, $MSE = 2.73$, $p < .05$, $\eta_p^2 = .11$ (see Figure 4 for means by color condition).

Planned comparisons revealed that participants in the red condition performed worse than those in the green condition, $t(38) = 2.20$, $p < .05$, $\eta_p^2 = .09$, and the gray condition, $t(33) =$

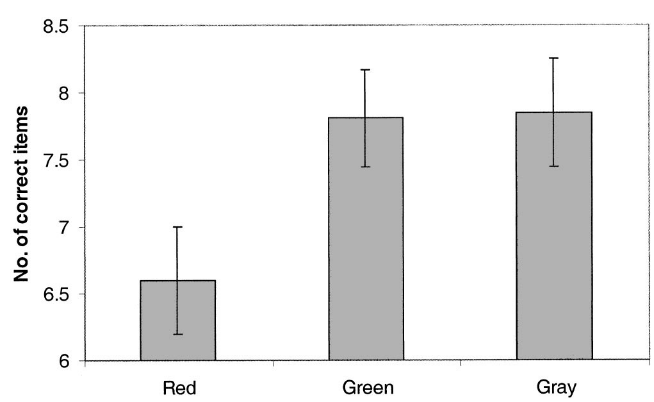

Figure 4. The effect of color on IQ test (numeric subtest) performance in Experiment 4: Mean number of correctly solved items by color on the cover of the test (means are adjusted for general ability, premanipulation numeric performance, and sex). Confidence intervals (95%) are indicated by vertical lines. Participants in the red condition ($n = 18$) performed significantly worse than participants in the green condition ($n = 22$) and the gray condition ($n = 17$), who did not differ from each other. (A color version of this figure is available online.)

2.21, $p < .05$, $\eta_p^2 = .09$. Participants in the green and gray conditions displayed comparable levels of performance, $t = 0.09$, $p = .93$.

Analyses on Process Variables and Perceived Competence

Conducting an ANCOVA on each of the process variables—performance-avoidance goals ($M = 4.37$, $SD = 1.72$), general arousal ($M = 2.44$, $SD = .71$), and mood ($M = 5.75$, $SD = 1.50$)—failed to yield any significant color effects (Fs $\leq .51$, ps $\geq .60$). An ANCOVA on perceived competence ($M = 4.74$, $SD = 1.59$) also yielded a null effect, $F = 0.18$, $p = .84$.

Awareness of Color and Purpose of Experiment

A chi-square test of independence was calculated to determine whether participants' color reports corresponded to their color condition. The analysis yielded a significant effect, $\chi^2(4, N = 57) = 96.58$, $p < .01$, indicating that participants were indeed aware of the color on the test cover. In the funnel debriefing, however, not a single participant guessed that the experiment focused on color and performance.

In sum, the results from this experiment replicated those of Experiments 1–3 using colors selected in objective fashion, using a different experimental task, and using different process variables. In addition, the results again appear to support our proposal that the observed effects are not grounded in consciously accessible processes and that participants are not aware of the influence that color has on their performance. Again, participants could report the correct color on the numeric test but were unaware of the purpose of the study.

Experiment 5

Consistent with our hypothesis that the influence of red on performance takes place outside of conscious awareness, Experiments 2–4 demonstrated that our color manipulation had no effect on either participants' self-reported avoidance motivation or any other self-reported state or perception. In this experiment, we examined the effect of our color manipulation on a well-established behavioral indicator of avoidance motivation grounded in task choice.

In his classic "risk-taking" model of achievement motivation, Atkinson (1957) posited that individuals motivated to avoid failure select themselves out of moderately challenging achievement situations when given the opportunity to do so (see also Birney, Burdick, & Teevan, 1969). This proposition has been empirically documented by many researchers using many different experimental procedures (for reviews, see Heckhausen, Schmalt, & Schneider, 1985; McClelland, 1985). In the present experiment, we used the choice of an easy rather than a moderately difficult task as our marker of motivation to avoid failure (see Atkinson & Litwin, 1960; Ceranski, Teevan, & Kalle, 1979; Strube & Roemmele, 1985). We hypothesized that participants exposed to red, relative to those exposed to green or gray, would demonstrate a preference for an easy rather than a moderately difficult task.

Method

Participants

Forty-eight (22 male and 26 female) German high school students voluntarily participated in the experiment. The mean age of participants was 17.65 years old with a range of 16–20 years.

Design and Procedure

Participants were randomly assigned to one of three between-subjects experimental conditions: the red condition, the green condition, or the gray condition. Task choice served as the dependent measure. Sex was used as a covariate, because sex differences in motivation to avoid failure have been observed in prior research (Birney et al., 1969; Rothblum, 1990). Given that performance was not used as a dependent variable in this experiment, neither general ability nor premanipulation performance data were acquired.

In the experimental session, participants were tested in small groups in an actual high school classroom by an experimenter blind to participants' condition and the experimental hypotheses. At the beginning of the experiment, participants were informed that the study involved taking an IQ test. The experimenter then provided participants with a white two-ring binder. Two sample analogy items from the analogy subtest of the IST were placed on a sheet of paper on top of the binder, and the experimenter provided participants with a verbal description of the task. Participants were told that they would be given 3.5 min to solve 10 analogies and that they would receive feedback on their performance.

Next, participants were informed that the first page in the binder was the cover page of the analogy test, and they were instructed to open to that page. The cover page was formatted as in Experiment 4 and contained the same color manipulations used in Experiment 4. After pausing for 2 s, the experimenter instructed participants to turn the page and to follow along as the task choice instructions were read aloud:

> There are several different versions of the 10 item analogy test included in your binder, and you can choose which one you would like to do. The different versions contain different numbers of easy and moderately difficult analogies. Easy analogies are ones that you will have about a 90% chance of getting right, and moderately difficult analogies are ones that you will have about a 50% chance of getting right. Please indicate the number of easy analogies and the number of moderately difficult analogies that you would like on your test: How many easy analogies?______; How many moderately difficult analogies? ______ (please make sure the numbers add up to 10). When you have made your choice, let the experimenter know that you are ready.

The number of easy analogies selected by participants represented the task choice variable.

When participants indicated that they had made their choice, they were informed that the experiment was over. Participants then completed a brief demographics questionnaire, received a funnel debriefing, and completed a manipulation check as in the prior experiments. After the manipulation check, participants were debriefed, given extra credit, and dismissed.

Results and Discussion

Analyses on Task Choice

A unifactorial (color condition: red vs. green vs. gray) between-subjects ANCOVA was conducted on task choice ($M = 4.81$, $SD = 1.33$), with sex as a covariate. The analysis revealed no effect of sex, $F = 1.14$, $p = .29$, but did reveal an effect of color condition on task choice, $F(2, 44) = 6.39$, $MSE = 1.43$, $p < .01$, $\eta_p^2 = .23$ (see Figure 5 for means by color condition).

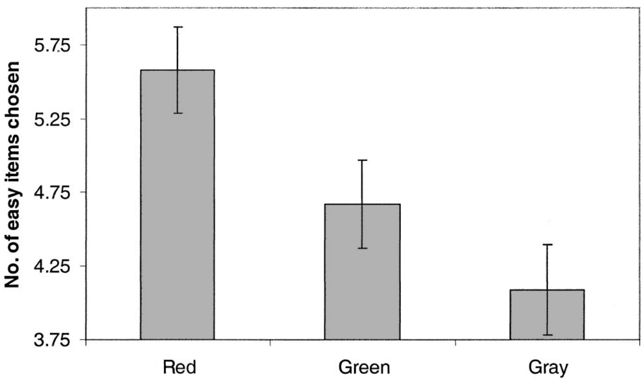

Figure 5. The effect of color on IQ test item choice in Experiment 5: Mean number of easy items chosen by color on the cover of the test (means are adjusted for sex). Confidence intervals (95%) are indicated by vertical lines. Participants in the red condition (n = 17) chose a greater number of easy items than participants in the green condition (n = 16) and the gray condition (n = 15), who did not differ from each other. (A color version of this figure is available online.)

Planned comparisons revealed that participants in the red condition chose a greater number of easy items than did those in the green condition, $t(31) = 2.19$, $p < .05$, $\eta_p^2 = .10$, and the gray condition, $t(29) = 3.53$, $p < .01$, $\eta_p^2 = .22$. Participants in the green and gray conditions displayed comparable levels of task choice, $t = -1.35$, $p = .18$.

Awareness of Color and Purpose of Experiment

A chi-square test of independence was calculated to determine whether participants' color reports corresponded to their color conditions. The analysis yielded a significant effect, $\chi^2(4, N = 47) = 94.00$, $p < .01$, indicating that participants were indeed aware of the color on the test cover. In the funnel debriefing, however, not a single participant guessed that the experiment focused on color and task choice.

In sum, the results from this experiment supported our hypotheses. Participants who viewed the color red prior to an (ostensible) analogy test selected a greater number of easy items than did those who viewed green or gray; participants who viewed green or gray selected a comparable number of easy items. Participants were not aware of the purpose of the study.

Experiment 6

In Experiment 5, we used a well-established behavioral indicator of motivation to avoid failure to demonstrate that red evokes avoidance motivation in achievement settings. In this experiment, we examined the effect of our color manipulation on a well-established psychophysiological indicator of avoidance motivation grounded in cortical activation.

Over two decades ago, Davidson and colleagues (Davidson, Schwartz, Saron, Bennett, & Goleman, 1979) posited a link between approach and avoidance motivational processes and asymmetrical activity in the frontal cortex measured using electroencephalography (EEG). To date, nearly 100 studies have validated this proposal, specifically linking avoidance motivation to greater right, relative to left, frontal cortical activation. In the present experiment, we used right, relative to left, frontal cortical activation as our marker of avoidance motivation (see Davidson et al., 1979; Harmon-Jones & Sigelman, 2001). We hypothesized that participants exposed to red, relative to those exposed to green or gray, would demonstrate greater relative right frontal activation. In addition, we posited that our color manipulation would not affect EEG asymmetry in other regions of the brain.

Method

Participants

Thirty (11 male and 19 female) German undergraduates participated in the experiment for extra course credit.[2] The mean age of participants was 22.55 years old with a range of 19–39 years.

Design and Procedure

Participants were randomly assigned to one of three between-subjects experimental conditions: the red condition, the green condition, or the gray condition. EEG asymmetry at various brain regions served as the dependent measures. Premanipulation EEG asymmetry corresponding to the focal postmanipulation EEG asymmetry variable was used as a covariate to control for baseline differences in cortical activation; sex was also used as a covariate, because sex differences in basic avoidance motivational tendencies have been observed in the literature (Buss, 1994; Costa, Terracciano, & McCrae, 2001). Given that performance was not used as a dependent variable in this experiment, neither general ability nor premanipulation performance data were acquired.

Participants were tested individually by an experimenter blind to participants' condition and the experimental hypotheses. On arrival for the experiment, participants were provided with a brief explanation of the EEG equipment, and then the electrodes were positioned and their proper functioning checked. Participants were informed that the experiment involved taking an IQ test and were instructed to look at the fixation cross on the computer screen until the test began. At this point, the experimenter exited the room and remained absent from the room throughout the experiment to remain blind to participants' color condition. Then 90 s elapsed, during which time premanipulation EEG activation was recorded.

An IQ test cover page was then presented on the computer screen for 2 s. This page was formatted as in Experiments 4 and 5 and contained the same type of color manipulations used in Experiments 4 and 5 (except that the color and the word *Items* were presented on a computer screen rather than on paper). The colors in the color manipulation were selected using the International Commission on Illumination LCh color model. This model defines a color space in terms of three parameters: lightness (similar to brightness), chroma (similar to saturation), and hue (Fairchild, 2005). Using this model, we equated the chromatic colors on lightness and chroma (red: LCh[36.56, 55.34, 32.53]; green: LCh[36.12, 52.08, 144.87]), and the achromatic color, which has no chroma, was equated on lightness (LCh[33.90, —, 250.66]); equated here means functionally equivalent (i.e., within five units on each relevant parameter; M. D. Fairchild, personal communication, June 9, 2005; Stokes, Fairchild, & Berns, 1992). The 2-s color presentation was followed by another 90 s for the postmanipulation EEG assessment, and the experiment was stopped after this second EEG assessment.

A stretch-lycra electrode cap was used to record EEG activation according to the International 10–20 Electrode Placement System. EEG activation was recorded from homologous sites at the frontal region (F7, F8; F3, F4) and, for comparison purposes, at homologous sites at the central (C3, C4), temporal (T3, T4), parietal (P3, P4), and occipital (O1, O2) regions as

[2] One participant was left-handed. All results reported in the text and footnote 3 are the same with this participant omitted from the sample.

well. A ground electrode was mounted in the cap near the frontal pole. EEG activation was recorded against Cz and rereferenced offline to the linked mastoids. Electrodes were also placed above and below the left eye and at the outer canthi of both eyes to monitor vertical and horizontal eye movements. The recordings were amplified using Neuroscan SynAmps (Compumedics, El Paso, TX), digitized at 500 Hz and bandpass filtered (0.1–40.0 Hz; 50-Hz notch filter). Impedances were under 5 kΩ and impedances at homologous sites were within 1 kΩ of each other.

The EEG data were segmented into epochs of 2,048 ms with 75% overlap (resulting in 173 epochs for 90 s). The epochs were scored for artifacts (e.g., eye movements, muscle movements), and epochs containing artifacts were omitted. Artifact-free epochs were extracted through a Hamming window and power spectra were calculated via fast Fourier transform. The alpha (8–13 Hz) power values were averaged across epochs separately for pre- and postmanipulation EEG and submitted to a natural log transformation for normalization. Asymmetry scores were computed (log right alpha power − log left alpha power) for each homologous pair (e.g., F8–F7). Alpha power (μV^2/Hz) is inversely related to cortical activation, so low values indicate greater right (relative to left) activation. The above procedures are fully in accord with those commonly used in the EEG asymmetry literature.

At the end of the experiment, participants completed a brief demographics questionnaire, received a funnel debriefing, and completed a manipulation check as in the prior experiments. After the manipulation check, participants were debriefed, given extra credit, and dismissed.

Results and Discussion

Primary Analyses on EEG Asymmetry

A unifactorial (color condition: red vs. green vs. gray) between-subjects ANCOVA was conducted on frontal asymmetry (M = .00, SD = .11), with premanipulation frontal asymmetry (M = −.02, SD = .12) and sex as covariates. The analysis revealed an effect of premanipulation frontal asymmetry, $F(1, 25) = 34.60$, $p < .01$, $\eta_p^2 = .58$, indicating that participants who had greater relative right frontal activation at baseline had greater relative right frontal activation after the manipulation. No effect of sex was observed, $t = 0.58$, $p = .45$. Most important, the analysis also revealed an effect of color condition on frontal asymmetry, $F(2, 25) = 6.17$, $MSE = .004$, $p < .01$, $\eta_p^2 = .58$ (see Figure 6 for means by color condition).

Planned comparisons revealed that participants in the red condition evidenced greater relative right frontal activation than those in the green condition $t(16) = 3.20$, $p < .01$, $\eta_p^2 = .29$, and the gray condition, $t(16) = 2.98$, $p < .01$, $\eta_p^2 = .26$; frontal asymmetry did not differ in the green and gray conditions, $t = 0.01$, $p = .99$.[3]

Additional Analyses on EEG Asymmetry

Unifactorial between-subjects ANCOVAs were also conducted on asymmetry in other brain regions: central (M = .06, SD = .20), temporal (M = .00, SD = .25), parietal (M = .07, SD = .16), and occipital (M = .03, SD = .22). Premanipulation asymmetry in the central (M = .05, SD = .19), temporal (M = −.01, SD = .22), parietal (M = .04, SD = .19), and occipital (M = −.05, SD = .21) regions were used as covariates when the corresponding postmanipulation asymmetry variable was examined; sex was used as a covariate in all analyses. These analyses yielded null results for color condition at each region: central, $F = 0.76$, $p = .48$; temporal, $F = 0.14$, $p = .87$; parietal, $F = 0.70$, $p = .51$; and occipital, $F = 0.51$, $p = .61$.

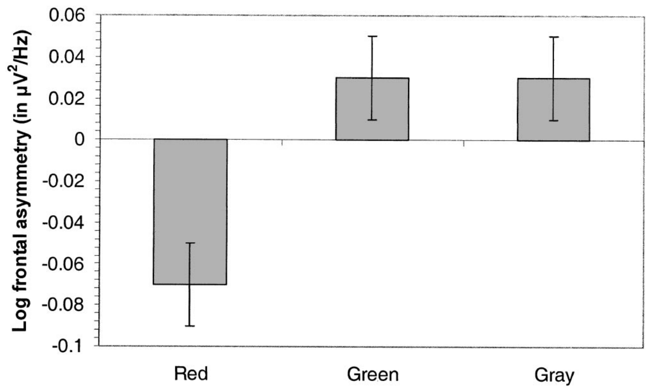

Figure 6. Effect of color on frontal cortical asymmetry (Experiment 6): Mean log-transformed frontal asymmetry (in μV2/Hz) by color on the cover of the IQ test (means are adjusted for premanipulation μV2/Hz and sex). Confidence intervals (95%) are indicated by vertical lines. Lower μV2/Hz values indicate greater right, relative to left, frontal activation. Participants in the red condition (n = 10) evidenced greater relative right frontal activation than participants in the green condition (n = 10) and the gray condition (n = 10), who did not differ from each other. (A color version of this figure is available online.)

Awareness of Color and Purpose of Experiment

A chi-square test of independence was calculated to determine whether participants' color reports corresponded to their color condition. The analysis yielded a significant effect, $\chi^2(4, N = 30) = 60.00$, $p < .01$, indicating that participants were indeed aware of the correct color on the test cover. In the funnel debriefing, however, not a single participant guessed that the experiment focused on color and brain activation.

In sum, the results from this experiment supported our hypotheses. Participants who viewed the color red prior to an (ostensible) IQ test evidenced greater relative right frontal activation than those who viewed green or gray; participants who viewed green or gray

[3] Examining the different frontal activation indices separately revealed that the effects were strongest for lateral frontal asymmetry (F8–F7). The omnibus analysis revealed an effect of premanipulation lateral frontal asymmetry, $F(1, 25) = 84.71$, $p < .01$, $\eta_p^2 = .77$, indicating that participants who had greater relative right lateral frontal activation at baseline had greater relative right lateral frontal activation after the manipulation. No effect of sex was observed ($t = 1.20$, $p = .24$). Most relevant, the analysis also revealed an effect of color condition on lateral frontal asymmetry, $F(2, 25) = 9.75$, $MSE = .006$, $p < .01$, $\eta_p^2 = .44$. Planned comparisons revealed that participants in the red condition (adjusted M = −.11, SE = .03) evidenced greater relative right lateral frontal activation than those in the green condition (adjusted M = .04, SE = .02), $t(16) = 4.39$, $p < .01$, $\eta_p^2 = .41$, and the gray condition (M = .03, SE = .03), $t(16) = 3.21$, $p < .01$, $\eta_p^2 = .34$. Lateral frontal activation did not differ in the green and gray conditions ($t = 0.35$, $p = .72$). The omnibus analysis for midfrontal asymmetry (F4–F3) revealed an effect of premanipulation midfrontal asymmetry, $F(1, 25) = 13.80$, $p < .01$, $\eta_p^2 = .36$, indicating that participants who had greater relative right midfrontal activation at baseline had greater relative right midfrontal activation after the manipulation. No effect of sex was observed ($t = 0.45$, $p = .66$). Most relevant, the analysis did not reveal a significant effect of color condition on midfrontal asymmetry, but it did evidence a trend consistent with the combined and lateral frontal asymmetry effects, $F(2, 25) = 1.24$, $p = .31$.

evidenced comparable levels of relative right frontal activation. The color manipulation did not affect EEG asymmetry in any other region of the brain. Participants were not aware of the purpose of the study.

General Discussion

The results of the present experiments provide strong support for our hypothesized effect of red on performance. Experiments 1–4 demonstrated that the perception of red prior to an achievement task impairs performance relative to the perception of green or an achromatic color. This effect was documented in two different countries (the United States and Germany), with two different age groups (high school and undergraduate), in two different experimental settings (laboratory and classroom), using two different types of color presentation (participant number and test cover), using four different variants of red and green hues, using all three achromatic colors (black, white, and gray), and using both language-based and number-based achievement tasks. Evidence from funnel debriefing data, self-report process data, and perceived competence data supports our premise that this undermining effect of red takes place outside of individuals' conscious awareness. In our fifth and sixth experiments, we moved beyond self-report data to examine the link between red and avoidance motivation with behavioral and psychophysiological measures. These experiments demonstrated that the perception of red prior to an achievement task, relative to the perception of green or an achromatic color, indeed evokes avoidance motivation, as indicated by participants' choice of easy relative to difficult tasks (Experiment 5) and greater right, relative to left, frontal cortical activation (Experiment 6).

The present findings represent the first demonstration of a direct, replicable effect of color on performance using rigorous experimental methods. Earlier, we overviewed several weaknesses in existing work on color and performance and suggested that these weaknesses have made color–performance relations, if they exist, difficult to empirically document. Our research was explicitly designed to address these weaknesses, and our (a) use of tightly controlled color presentations, (b) use of colors perceived to be typical and matched on saturation and brightness, and (c) adherence to basic methodological considerations (such as keeping the experimenter blind to the hypotheses and color conditions) allowed us to clearly and emphatically document a relation between red and performance.

The finding that a brief glimpse of red impairs performance is provocative in and of itself, but it is particularly striking that red impairs performance on IQ tests. IQ and other standardized tests (e.g., SAT, the Medical College Admission Test) are used as selection and filtering devices in society, channeling individuals into different educational tracks, achievement trajectories, and, ultimately, careers and social statuses (Jencks & Phillips, 1998). The administration of such tests is strictly uniform regarding item difficulty and time allotment, but factors such as the color of the clothing worn by test proctors and the color of the pencil used to indicate answers are allowed to vary. Our finding that a seemingly inconsequential factor such as the color of an IQ test cover has an important impact on performance raises the question of whether these other factors are indeed inconsequential and suggests that more strictly controlled procedures in these important assessment contexts may be needed.

More broadly, our research raises the possibility that red may have extensive effects across achievement contexts and achievement outcomes. Red is encountered by students, employees, and athletes in myriad manifestations on a daily basis and may not only negatively influence intellectual performance, as demonstrated herein, but also physical performance and other important outcomes such as persistence, aspiration levels, and intrinsic motivation. Given the subtlety of red's influence, it is easy to imagine red producing widespread consequences that nevertheless remain undetected. However, it is also important to consider that many real-world achievement settings contain a host of subtle and explicit cues of motivational relevance, and it is unclear how these cues interfere with or promote each other. Our results from Experiments 3 and 4, conducted in actual classroom settings, indicate that the message communicated by red is powerful enough to carry through this noise in at least some instances, but it is possible that this message gets drowned out in others. In addition, our results were obtained using brief, controlled color presentations placed directly on the achievement task, and the generality of the effect beyond these parameters needs to be tested. Clearly, testing the strength and breadth of red effects in real-world achievement contexts should be a central part of the future research agenda.

A study recently published in *Nature* reported that red enhances performance (Hill & Barton, 2005), whereas our experiments indicate that red impairs performance. How can these seemingly contradictory findings be reconciled? We think our research reveals the need to reexamine the prior study. The study found that Olympic athletes who wore red in face-to-face competitions (e.g., wrestling matches) performed better than those who wore blue, and from this finding it was concluded that wearing red enhances performance. However, wearing color and viewing color were completely confounded in this study, and it may have been that viewing red impaired performance, not that wearing red enhanced performance. Furthermore, the directionality of the finding could not be determined given the absence of an achromatic control condition and, it is important to note, the colors examined were neither rated on typicality nor equated on saturation and brightness. The designs and procedures used in our research enabled us to clearly document that viewing red impairs performance, not only relative to another chromatic color but also relative to all three achromatic colors. Questions regarding the influence of wearing red on performance would appear to remain open, much like questions regarding the generalizability of our findings to one-on-one competitions and to physical tasks.

An important aspect of our research is that it demonstrates the ease and subtlety with which avoidance motivation can be activated. This was shown most directly in Experiments 5 and 6, in that a 2-s background (i.e., ground, as opposed to figure) presentation of red led to the selection of easy rather than moderately challenging tasks and to greater right, relative to left, frontal cortical activation. These measures are well-established markers of avoidance motivation in their respective literatures, and the fact that the red effect was found with these very different measures represents strong support for the veracity of our hypotheses.

The efficacy of our subtle color manipulations likely reflects a general principle regarding information processing, namely, that our cognitive and motivational systems are highly attuned and responsive to negatively valenced stimuli (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Cacioppo, Gardner, & Berntson, 1997). This negativity bias was clearly adaptive in humans' evolutionary past and certainly has some enduring benefits in the present (Lang, Davis, & Ohman, 2000; Pratto & John, 1991), but, as with many physical and psychological adaptations (Cosmides & Tooby, 2000; Durrant & Ellis, 2003), it likely has some residual maladaptive consequences as well. Our research appears to illustrate one such consequence, in that the brief, background presentation of a negatively valenced stimulus activated avoidance motivation in a situation where it was neither needed by nor beneficial to the individual.

Our research shows not only that avoidance motivation can be activated subtly but that it can operate subtly as well. Participants neither expressed (in funnel debriefing) nor exhibited (on process and perceived competence measures) any conscious awareness of the influence of color on their motivation or performance. Perhaps most notably, direct self-reports of avoidance motivation in Experiments 2–4 yielded null results despite clear behavioral and psychophysiological evidence in Experiments 5 and 6 (respectively) that avoidance motivation was indeed operative. Admittedly, our assessment of self-report process variables was not exhaustive, but it is important to note that we did examine the most plausible variables from established theory and research on avoidance motivation (Elliot & Harackiewicz, 1996; Seibt & Förster, 2004), as well as several additional variables, such as mood and general arousal.

Both our theorizing and our empirical findings fit nicely with and may be viewed as fully supportive of Bargh's (1990) auto-motive model of motivation. In accord with the auto-motive model and consistent with a growing body of experimental work (for reviews, see Dijksterhuis, Chartrand, & Aarts, in press; Moskowitz, Li, & Kirk, 2004), our research suggests that a subtle prime can influence motivation in an automatic fashion. Our research also extends the existing work in two important ways. First, prior work has demonstrated that lexical (Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trötschel, 2001; Chartrand & Bargh, 1996), contextual (Aarts & Dijksterhuis, 2003), and relational (Fitzsimons & Bargh, 2003; Shah, 2003) stimuli can exert an influence on motivation without one's conscious awareness. Our research indicates that a seemingly benign background feature of the environment, color, can also influence motivation without one's conscious awareness. Second, prior work has documented nonconscious effects involving approach motivation. For example, Bargh et al. (2001) had participants complete a word-search puzzle containing success-relevant words and showed that this led to positive achievement outcomes without participants being aware of the influence of the priming. Our research suggests that such effects may be observed with regard to avoidance motivation, as well as approach motivation. In short, our research adds to an ever-increasing and ever-provocative body of work highlighting the nonconscious nature of human motivation and behavior.

Although our research is grounded in the premise that red carries the meaning of danger and evokes avoidance motivation in achievement contexts, we do not think that red carries this meaning and has this impact in all contexts. The relational context may be used to illustrate this point. In relational contexts, red is commonly linked to love and romance (e.g., red hearts on Valentine's Day), attraction and passion (e.g., red lipstick and rouge, red lingerie), and even sexual opportunity (e.g., red-light districts; Kaya & Epps, 2004; Mahnke, 1996). It is interesting that these red associations in the mating game may be deeply rooted in biology, as red coloration is used by many species of animals to signal sexual readiness and availability (Hutchings, 1997; Mollon, 1989). Thus, red seems to carry different meanings and evoke different responses in different contexts. Indeed, red would appear to carry opposite meanings and evoke opposite motivational responses in achievement and social contexts (danger and/or avoidance vs. attraction and/or approach, respectively). We are currently exploring this possibility in several different lines of research.

Another issue worthy of exploration is the degree to which the present findings generalize to other cultures. Cross-cultural work may be particularly useful in determining the necessary and sufficient cause(s) of the effects observed herein. For example, such work may help to determine whether a specific red–danger (i.e., failure) association generated by teachers' grading practices is necessary to produce the observed effects or whether the biologically based predisposition to interpret red as a danger signal in competitive contexts is sufficient in and of itself. If the specific association is necessary, the effects should only be observed in cultures where teachers mark mistakes in red; if the biologically based predisposition is sufficient, the effects should be observed across cultures, regardless of the presence or absence of any learned associations.

Individuals encounter a kaleidoscope of color in navigating daily life. Surprisingly, almost nothing is known at present regarding how the different colors that people perceive impact their affect, cognition, and behavior. We suspect that the influence of color on psychological functioning is as pervasive as it is subtle and provocative, and we urge other researchers to join us in adding color, literally and figuratively, to the scientific literature.

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Received February 9, 2006
Revision received July 21, 2006
Accepted August 1, 2006 ■