

Visual Color Perception in Green Exercise: Positive Effects on Mood and Perceived Exertion

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ABSTRACT: Positive effects of green exercise on physical and psychological wellbeing have been found, yet little is known about the underlying cognitive mechanisms responsible for such effects. The purpose of this visual sensation study was to establish the extent to which the color green, as a primitive visual feature of many natural environments, contributes to the green exercise effect. Fourteen participants performed three moderate-intensity 5-min cycling tasks (50% peak power output) while watching video footage of a rural cycling course that simulated cycling through a real natural environment. The three randomly counter-balanced video conditions were unedited (V_{GREEN}), achromatic (V_{GRAY}) or red filter (V_{RED}). Lower total mood disturbance and ratings of perceived exertion were found during the V_{GREEN} compared to V_{GRAY} and V_{RED} . Feelings of anger were higher after V_{RED} compared to the other conditions. Feelings of tension, depression, fatigue, vigor, and confusion did not differ among conditions. This is the first study to show that the color green, as a primitive feature of visual sensation, has a contributory effect toward positive green exercise outcomes.



INTRODUCTION

The biophilia hypothesis describes the apparent innate attachment that humans have for nature and living systems.¹ Simple forms of exposure to nature, such as looking through windows, have furnished a variety of therapeutic effects including enhanced recovery from surgery,² improved feelings of wellbeing,³ and more positive mood.⁴ The potential positive mental health impact of interacting with natural environments has also been acknowledged in a variety of reviews and policy information reports.^{5–11}

During the past decade there has been growing interest in the idea that combining exercise with exposure to nature may render physical and psychological health benefits in addition to those usually achieved through exercise alone. The term “green exercise” was first used in 2003 to describe the act of performing physical activity in natural environments.¹² Empirical evidence for green exercise has generally been quite favorable with beneficial effects found for positive moods,^{13–19} negative moods,^{14–20} self-esteem,^{15–20} enjoyment,^{13,19–22} and motivation.^{13,19} A recent systematic review concluded that, while these green exercise findings are promising, most of the studies are hampered by weak methods, small sample sizes, and a failure to consider or measure long-term effects.²³ There are considerable methodological challenges associated with green exercise research such as being able to achieve the high standards of rigor and control expected of empirical studies while exposing participants to outdoor natural environments that, due to both regional and seasonal factors, are inherently varied and difficult to standardize.

Notwithstanding the methodological limitations of some studies,²³ there does appear to be some evidence that green exercise has a positive effect on various aspects of physical and

psychological wellbeing. Nevertheless, there have been very few attempts to explain why such green exercise effects occur, and no systematic studies to identify the underlying cognitive processes that are responsible. A possible contributing mechanism of green exercise is the direct effect it has upon the exteroceptive senses that perhaps give rise to an intrinsically harmonious, satisfying, and superior perceptual experience compared to non-natural environments. While green exercise probably acts on all of the senses,²⁴ there is some indication from previous studies that visual information alone about natural environments is sufficient to elicit therapeutic effects.^{2–4,25} What is not known is the extent to which positive natural environment effects are attributable to the primitive features of visual sensation, such as color and intensity, as opposed to the interpretation and meaningfulness of such environments. Previous studies have found that exposure to green and blue evokes lower feelings of anxiety²⁶ and greater feelings of calmness.²⁷ Therefore, an interesting question is whether the color green, as a primitive visual feature, has any significant contribution to the green exercise effect, especially since natural environments are not necessarily always green.

The purpose of this study was to establish the extent to which color, as a primitive visual feature, contributes to the green exercise effect. It was hypothesized that cycling while being exposed to video footage of a green natural environment would result in a more positive mood and a lower perception of effort compared to achromatic or red-filtered video footage.

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MATERIALS AND METHODS

Participants. Fourteen healthy male participants with normal color vision were recruited for this study (age 20.7 ± 1.5 years; body mass 76.4 ± 10.2 kg; stature 177 ± 6 cm) and all provided their written informed consent. The study and its associated procedures were approved by the University of Essex ethics committee.

Design. A within-subjects experimental design was used during which participants first performed an incremental cycling test to volitional exhaustion to establish their peak power output (PPO). Participants then returned to the laboratory 14–18 days later to complete a 5-min warm up at 20% PPO followed by three randomly counterbalanced 5-min cycling trials at 50% PPO during which they were required to watch a video of (i) a “green outdoor environment” cycling course (V_{GREEN}), (ii) the same footage presented achromatically (V_{GRAY}), and (iii) the same footage using a red filter (V_{RED}). Participants were required to rest between video trials until their cardiorespiratory measures had returned to post warm-up levels. Heart rate, oxygen uptake, respiratory exchange ratio, and ratings of perceived exertion were recorded during the last 30 s of each 5-min cycling trial. Mood state was measured immediately after each cycling trial.

Cycling Ergometry. All cycling procedures were performed using a Lode Excalibur Sport electromagnetically braked ergometer (Lode, Groningen, Netherlands). Saddle height was adjusted so that, with the crank position at bottom dead center and the foot secured to the pedal with toe clips, the knee joint was almost in full extension (approximately $175\text{--}180^\circ$) and the sole of the foot was parallel to the ground. The handlebars were aligned according to the preference of each participant that best enabled them to see the projected video footage. Each participant’s ergometer settings were recorded and used in all subsequent cycling tests.

During the first laboratory attendance participants performed an incremental cycling test that began at an intensity of 50 W and increased at a rate of 0.5 W/sec^{-1} until volitional exhaustion. During the test participants were instructed to maintain a pedaling cadence of approximately $70 \text{ r}\cdot\text{min}^{-1}$. Toward the end of each incremental test, participants were given verbal encouragement by the experimenters to ensure maximum effort was given. Peak power output for each participant was calculated as the average power output during the final 60 s of each test, which was used as a reference value upon which the relative intensity of all further cycling tests was based. The purpose of doing this was to control for fitness variation among the participants by ensuring that cycle intensity was always set relative to each individual’s PPO. When participants performed the incremental cycling test, they were not aware that their peak power output would be used to set the intensity of subsequent tests.

During the second laboratory attendance, participants performed a light 5-min cycling warm up at 20% PPO followed by three 5-min moderate intensity cycling tests at 50% PPO during which they were instructed to maintain a cadence of $70 \text{ r}\cdot\text{min}^{-1}$. During each 50% PPO cycling test participants watched three different types of projected video footage. Between video trials, participants rested while remaining seated on the cycle ergometer until their heart rate and respiratory exchange measures had returned to post warm-up levels.

Simulated Green Exercise and Videographic Variations. During each 50% PPO cycling task participants watched

video footage of a real rural cycling course that was projected onto a large screen ($2.65 \times 1.47 \text{ m}$) in front of them to create the impression of cycling forward through a natural environment. Commercially available cycle-training video footage was used (Bike-o-Vision, California, USA) comprising a 5-min capture of a road ride through the Shenandoah National Park, Virginia, USA. This particular video was selected because of the high percentage of green foliage in the screen and because none of the participants would be familiar with or recognize the area. During the V_{GREEN} condition participants watched an unedited version of the video footage. During the V_{GRAY} and V_{RED} conditions participants watched exactly the same 5-min video footage that, respectively, had achromatic and red filters digitally applied using Nero version 9 video editing software (Nero Inc., California, USA). A red filter was chosen because of its previous association with negative mood change.²⁶ The achromatic video transformation was chosen because it has been found to have neutral effects on mood²⁶ and, because participants were familiar with viewing achromatic film, it is perhaps less susceptible to image novelty effects. We acknowledge that novelty effects were not directly measured in this study. All the videos were encoded at $25 \text{ frames}\cdot\text{sec}^{-1}$ and, regardless of the type of digital editing, were matched for brightness, contrast, and sharpness. Participants were randomly assigned to complete V_{GREEN} , V_{GRAY} , and V_{RED} conditions in a particular sequence that had been counterbalanced to control for order effects. An image of the laboratory setup and a still frame from each of the three video conditions is presented in Figure 1.

Cardiorespiratory and Psychophysiological Measures. During all cycling procedures heart rate was continuously

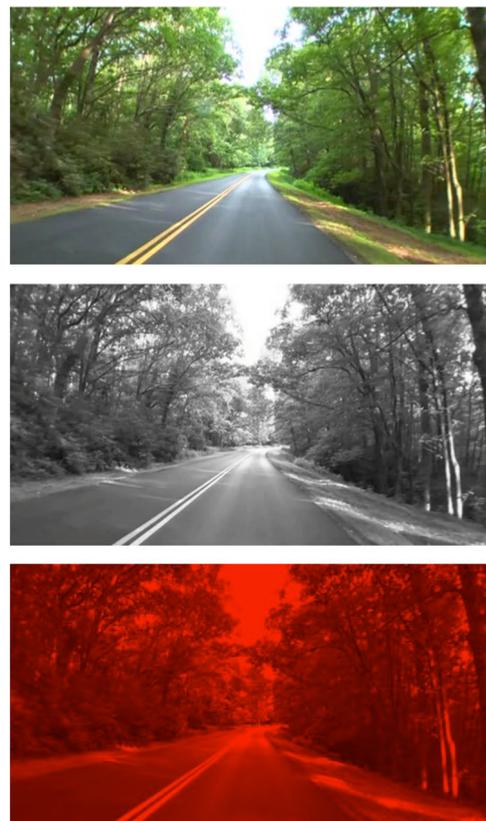


Figure 1. Still frames of the three video experimental conditions.

recorded using a Polar s610 heart rate monitor via a wireless chest strap (Polar Electro, Finland). Throughout each cycling test respiratory gas exchange measures were measured breath-by-breath using an online gas analyzer (Oxycon Pro, Jaeger, Germany) including rate of oxygen uptake (VO_2), rate of carbon dioxide elimination (VCO_2) and the respiratory exchange ratio VCO_2/VO_2 (RER). Immediately after the 20% PPO cycling warm-up heart rate and RER were recorded. At the end of each 5-min cycling test participants were required to rest until their heart rate and RER had returned to post warm-up values. Average VO_2 and RER values were subsequently calculated for the last 30-s period of each 5-min 50% PPO cycling test.

During the last 30 s of each 5-min 50% PPO cycling test participants were asked to state their perceived exertion using the Borg 6-20 fifteen-point rating of perceived exertion scale (RPE).²⁸ Each participant was familiarized with the RPE scale, which was administered in accordance with published standardized instructions.²⁹

Mood State Measurements. Mood state was measured immediately after each condition using the shortened “right now” version of the Profile of Mood States questionnaire (POMS).^{30,31} The POMS short form comprises 30 single-word mood descriptors, each with a 5-point Likert response scale, from which subscale scores for tension, depression, anger, vigor, fatigue, and confusion could be calculated. POMS raw scores for each subscale were converted into T-scores in accordance with McNair, Lorr, and Droppleman (p 36).³¹ POMS total mood disturbance score (TMD), which is a measure of overall feeling of mood, was calculated by subtracting the vigor subscale score from the sum of the tension, anger, depression, fatigue, and confusion subscale scores.^{30,31}

Statistical Analysis. POMS subscales were analyzed using a one-way within-subjects multivariate analysis of variance (MANOVA). Univariate ANOVAs and posthoc paired-samples *t* tests were used to identify subscale differences in mood and condition effects, respectively. Total mood disturbance scores, cardiorespiratory measures, and ratings of perceived exertion were all analyzed using one-way within-subjects ANOVAs and any differences were further investigated using posthoc paired-samples *t* tests. An alpha level of 0.05 was used to indicate statistical significance, and for the post hoc tests a Bonferroni corrected alpha level of 0.0167 was used. All values are presented as means \pm one standard deviation. Effect sizes for ANOVA outcomes are presented as partial eta-squared (η_p^2), and for *t* tests as eta-squared (η^2). In addition, standardized mean effect sizes are also presented as Cohen’s f^2 for all ANOVA outcomes where there were more than two conditions, and as Cohen’s *d* for all *t* tests.

RESULTS

Total Mood Disturbance. A one-way within-subjects ANOVA revealed a difference in POMS total mood disturbance between color-manipulated videography conditions ($F_{2,26} = 6.1$, $p = 0.007$, $\eta_p^2 = 0.321$, $f^2 = 0.473$). Posthoc paired-samples *t* tests revealed lower total mood disturbance scores during V_{GREEN} compared to V_{GRAY} (138.2 ± 16.2 vs 142.6 ± 18.5 , $t_{13} = -3.0$, $p = 0.005$, $\eta^2 = 0.409$, $d = 0.253$), and during V_{GREEN} compared to V_{RED} (138.2 ± 16.2 vs 145.2 ± 17.1 , $t_{13} = -3.1$, $p = 0.008$, $\eta^2 = 0.425$, $d = 0.420$). There was no difference in total mood disturbance between V_{GRAY} and V_{RED} (142.6 ± 18.5 vs 145.2 ± 17.1 , $t_{13} = 1.2$, $p = 0.132$, $\eta^2 = 0.100$, $d = 0.146$). Condition differences in POMS total mood disturbance are

presented in Figure 2A and means and standard deviations are given in Table 1.

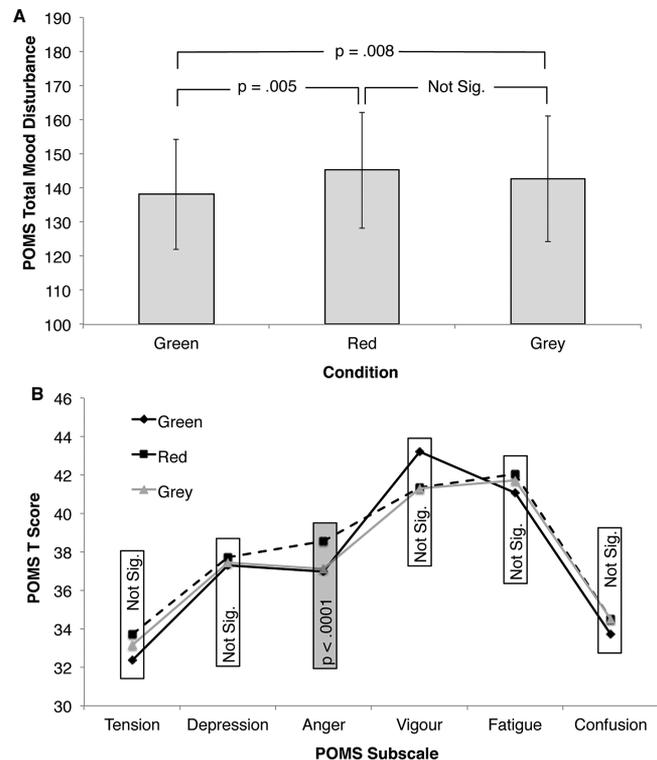


Figure 2. Condition differences in POMS total mood disturbance (A) and POMS subscales (B).

POMS Subscales. A one-way within-subjects MANOVA revealed a difference in POMS subscales between color-manipulated videography conditions ($F_{12,70} = 1.9$, $p = 0.046$, $\eta_p^2 = 0.248$, $f^2 = 0.330$). Univariate ANOVAs revealed a difference between conditions for the anger subscale ($F_{2,39} = 16.4$, $p < 0.0001$, $\eta_p^2 = 0.457$, $f^2 = 0.842$) but no differences in tension, depression, vigor, fatigue, or confusion. Posthoc paired-samples *t* tests revealed that anger was higher during V_{RED} compared to V_{GREEN} (38.6 ± 1.3 vs 37.0 ± 0.0 , $t_{13} = 4.6$, $p = 0.0005$, $\eta^2 = 0.619$, $d = 1.741$), and higher during V_{RED} compared to V_{GRAY} (38.6 ± 1.3 vs 37.1 ± 0.5 , $t_{13} = 4.0$, $p = 0.001$, $\eta^2 = 0.552$, $d = 1.523$). There was no difference in anger between V_{GREEN} and V_{GRAY} (37.0 ± 0.0 vs 37.1 ± 0.5 , $t_{13} = 1.0$, $p = 0.165$, $\eta^2 = 0.071$, $d = 0.283$). Condition differences in POMS subscales are presented in Figure 2B and means and standard deviations are given in Table 1.

Cardiorespiratory Measures and RPE. One-way within-subjects ANOVAs revealed no difference between color-manipulated videography conditions for heart rate ($F_{2,26} = 0.01$, $p = 0.99$, $\eta_p^2 = 0.001$, $f^2 = 0.001$), VO_2 ($F_{2,26} = 0.1$, $p = 0.92$, $\eta_p^2 = 0.016$, $f^2 = 0.016$), or respiratory exchange ratio ($F_{2,26} = 0.17$, $p = 0.848$, $\eta_p^2 = 0.013$, $f^2 = 0.013$). Cardiorespiratory measure outcomes are presented in Figure 3A–C and means and standard deviations are given in Table 1.

There was a difference in RPE between conditions ($F_{2,26} = 5.2$, $p = 0.007$, $\eta_p^2 = 0.285$, $f^2 = 0.399$), and posthoc paired-samples *t* tests revealed lower RPE during V_{GREEN} compared to V_{GRAY} (11.1 ± 1.6 vs 12.1 ± 1.6 , $t_{13} = -2.9$, $p = 0.007$, $\eta^2 = 0.393$, $d = 0.625$), and V_{GREEN} compared to V_{RED} (11.1 ± 1.6 vs 12.3 ± 1.6 , $t_{13} = -2.8$, $p = 0.008$, $\eta^2 = 0.376$, $d = 0.750$). There

Table 1. Condition Mean and SD Values for RPE, Mood, and Cardiorespiratory Measures

| | V_{GREEN} | | V_{RED} | | V_{GRAY} | |
|-------------------------------|-------------|------|-----------|------|------------|------|
| | mean | SD | mean | SD | mean | SD |
| ratings of perceived exertion | 11.1 | 1.6 | 12.3 | 1.6 | 12.1 | 1.6 |
| POMS total mood disturbance | 138.2 | 16.2 | 145.2 | 17.1 | 142.6 | 18.5 |
| POMS subscales | | | | | | |
| tension | 32.4 | 1.9 | 33.7 | 2.4 | 33.1 | 3.0 |
| depression | 37.3 | 0.7 | 37.7 | 0.9 | 37.4 | 0.9 |
| anger | 37.0 | 0.0 | 38.6 | 1.3 | 37.1 | 0.5 |
| vigor | 43.2 | 5.7 | 41.4 | 5.0 | 41.3 | 7.2 |
| fatigue | 41.1 | 7.4 | 42.1 | 7.6 | 41.7 | 7.1 |
| confusion | 33.7 | 3.5 | 34.5 | 4.1 | 34.5 | 4.4 |
| cardiorespiratory measures | | | | | | |
| heart rate | 137.3 | 12 | 137.5 | 14.3 | 137.1 | 12.3 |
| oxygen uptake | 28.1 | 3.4 | 28.0 | 4.6 | 27.9 | 3.7 |
| respiratory exchange ratio | 0.93 | 0.06 | 0.93 | 0.06 | 0.94 | 0.08 |

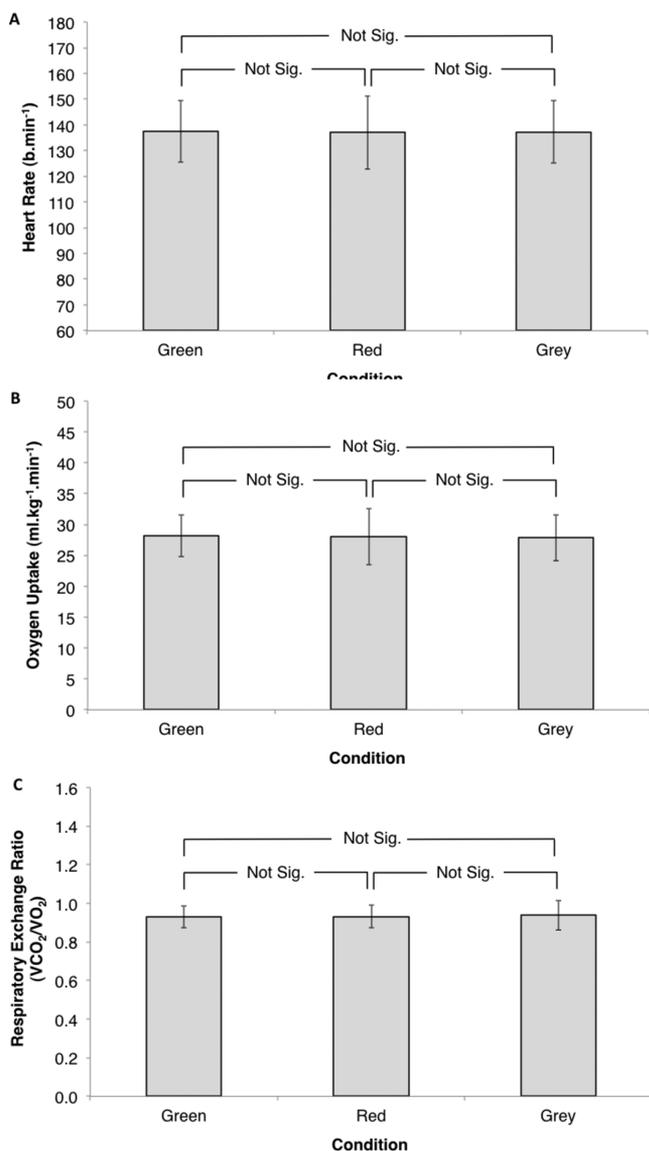


Figure 3. Heart rate and gas exchange responses to conditions.

was no difference in RPE between V_{GRAY} and V_{RED} (12.1 ± 1.6 vs 12.3 ± 1.6 , $t_{13} = -0.5$, $p = 0.310$, $\eta^2 = 0.019$, $d = 0.125$).

Condition differences in RPE are presented in Figure 4 and means and standard deviations are given in Table 1.

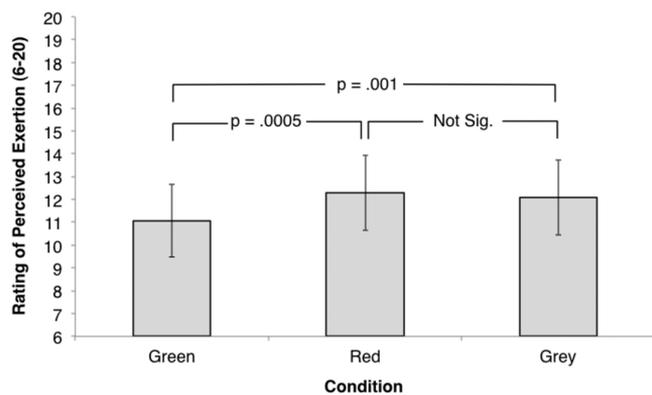


Figure 4. Condition differences in ratings of perceived exertion.

DISCUSSION

The main finding of this study is that total mood disturbance and perceived exertion were lower during simulated green exercise in the V_{GREEN} condition compared to V_{GRAY} and V_{RED} . The only difference in POMS subscales was higher anger during V_{RED} . This is the first study to show that the color green, as a primitive feature of visual sensation, has a contributory effect toward positive green exercise outcomes albeit among a relatively small sample of participants.

Color Perception and Mood during Green Exercise.

The lower total mood disturbance during the V_{GREEN} condition is consistent with previous studies where positive change in mood has been reported following green exercise.^{13–19,25} The lower total mood observed in V_{GREEN} indicates positive global affect which appears to be the product of small positive changes spread across all of the POMS subscales rather than a large change to an individual subscale. This is different from previous green exercise studies that have generally found reduced tension.^{15,20} It should be noted that, unlike most previous work,^{13–22} natural environments were incorporated into all of the conditions of our study albeit presented in different color formats. The improved total mood is therefore a product of the increased “greenness” in addition to any contextual effects of the natural environment effects that was present in all other conditions. What we are unable to determine from our study is

the extent to which greenness effects on mood are context dependent and one avenue of future investigation would be to examine the effect of the color green when presented independently of a natural environment. We are confident that our results are attributable to “greenness” rather than “familiarity” effects because mood was still more positive than V_{GRAY} , a nongreen condition that we intentionally included to ameliorate any novelty effects.

The positive effect of green on mood in our study is in fact consistent with more general findings about the effect that perceiving color for even short periods of time can have upon psychological functions such as affect and cognition.^{32,33} It has long been proposed that being exposed to colors with longer wavelengths such as red and yellow is stimulating and arousing, whereas shorter wavelength colors, such as green and blue, tend to evoke feelings of calmness and tranquility.²⁷ This idea is supported in a more recent study that found individuals are less anxious when exposed to green and blue compared to when they were exposed to red and yellow.²⁶ However, other studies have found an association between bright red and positive mood,^{34,35} suggesting that the brightness of the color also affects mood. Since we matched the brightness of the video in all three conditions of our study we are confident that the mood effects we observed are due to the “greenness” and were not confounded by variations in brightness.

It has been suggested that the origins of color vision among primates stems from the advantage it confers in being able to identify targets such as food against dappled or variegated backgrounds.³⁶ The color green may have a special connotation in terms of human evolution due to its correspondence with fertile natural surroundings where factors such as a temperate climate and the availability of food were more conducive to survival. Humans have tended to migrate toward and settle in green fertile geographic regions of the world and therefore, as predicted by the biophilia hypothesis,¹ perhaps the propensity to experience positive moods in natural surroundings is an innate instinct in which greenness has a particular significance. Our study certainly provides important preliminary evidence that the greenness of exercise environments appears to contribute to positive psychological outcomes. We nevertheless acknowledge that the way people respond to certain colors may vary from culture to culture,^{37,38} although in our study a homogeneous sample of UK national participants was used.

An interesting finding of our study was the increased feelings of anger reported by participants after cycling in the V_{RED} condition. A similar association between red and negative affect was reported in some studies^{26,39–41} but in others bright red was found to evoke positive moods.^{34,35} As well as the direct perceptual effects of red, the greater feelings of anger during V_{RED} in our study may have been due to the incongruence between the context of the video images and its red filtered projection. The outcomes of the V_{RED} condition highlight the need to differentiate between the contextual and color perception components of green exercise. One limitation of our study that we wish to highlight is that we did not take pre- and post-intervention measurements of mood but rather compared differences in mood measured at a single point immediately after exposure to each condition.

Color Perception and Perceived Exertion during Green Exercise. We are the first to report lower perceptions of exertion during green exercise, a measure which has been reported in one previous study.¹³ Interestingly, various measures of physiological stress did not differ among the

conditions (Figure 3A–C), indicating that, similar to the previously reported mood effects, the lower RPE was attributable to the greenness of the video stimulus. The participants in our study were asked to cycle while continually watching video footage that simulated forward movement through a natural environment. The simulated sensation of forward movement, known asvection,⁴² is affected by varying the colors used in the visual displays. Compared to green, the use of red in such studies was found to inhibitvection^{43–45} that might have been one of the factors responsible for the lower perceived exertion that we observed during V_{GREEN} . Ifvection was inhibited during V_{RED} , given that cycling intensity was identical between conditions, the apparent slower progress per unit of work might perceptually feel more difficult. Nevertheless, the apparent lower perception of exertion during “green” exercise may be related to the apparent positive effects on mood and perhaps participants’ motivations to engage in future episodes of green exercise. There is clearly a need elucidate some of the complex interactions among perception, affect, motivation, and engagement associated with green exercise. In particular, future studies should distinguish between the sensory effects and the exercise effects on mood and wellbeing, perhaps by making comparisons among a visual-only condition, an exercise-only condition, and a combined visual and exercise condition.

This study is the first to show a special significance of the color green in green exercise that resulted in a more positive total mood and lower perceptions of exertion. The color perception processes responsible for positive mood and RPE during green exercise are not well understood, in particular the extent to which the context of various color stimuli is important. Greater insights about the cognitive mechanisms of green exercise are needed in order to better understand its therapeutic potential.

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Notes

The authors declare no competing financial interest.

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