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Original article

Perceiving red decreases motor performance over time: A pilot study

Percevoir rouge diminue la performance motrice au cours du temps : une étude pilote

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ABSTRACT

Introduction. – Colors may influence motor performance.
Objective. – The present study aimed to compare the effects of perception of red and green environments on physical (performance and heart rate) and psychological (perceived effort, anxiety and enjoyment) parameters during cycling trials.
Method. – Ten cyclists achieved two identical series of three randomized 7-minute trials on home trainers, during which they were continuously exposed to red, green, and gray environments. Covered distance and heart rate were recorded during each trial, after which participants answered items intended to assess perceived effort, anxiety, and enjoyment experienced during the trial.
Results. – Results showed that covered distance ($ps \leq .02$) and heart rate ($ps \leq .03$) were lower in the red environment than in the gray and green environments. Enjoyment was higher in the green environment than in the red environment ($p = .006$). The colored environments did not influence perceived effort and anxiety ($ps > .05$).
Conclusion. – This study is the first to show that perceiving red is detrimental for motor performance over an extended period of time.

Mots clés :
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RÉSUMÉ

Introduction. – Les couleurs peuvent influencer la performance motrice.
Objectif. – La présente étude avait pour but de comparer les effets de la perception des environnements rouge et vert sur des paramètres physiques (performance et fréquence cardiaque) et psychologiques (perception d'effort, anxiété et plaisir) durant des épreuves de cyclisme.
Méthode. – Dix cyclistes ont réalisé deux séries identiques de trois épreuves randomisées de 7 minutes sur *home trainer*, durant lesquelles ils étaient continuellement exposés à des environnements rouge, vert et gris. La distance parcourue et la fréquence cardiaque étaient enregistrées durant chaque épreuve, après quoi les participants ont répondu à des items de perception d'effort, d'anxiété et de plaisir ressentis durant l'épreuve.
Résultats. – Les résultats ont montré que la distance parcourue ($ps \leq .02$) et la fréquence cardiaque ($ps \leq .03$) étaient plus basses en environnement rouge qu'en environnements gris et vert. Le plaisir était plus élevé en environnement vert qu'en environnement rouge ($p = .006$). Les environnements colorés n'ont pas influencé la perception d'effort et l'anxiété ($ps > .05$).
Conclusion. – Cette étude est la première à montrer que percevoir rouge a des effets délétères sur la performance motrice au cours d'une période de temps étendue.

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Colored environments have visual properties that, once treated by the perceptual system, may develop meanings, depending on biology, context or learning, thereby leading to influence affects, perceptions and behaviors. Research on the effects of colors on human functioning gained its impetus since Hill and Barton (2005) provided evidence that wearing red has a powerful effect on competitive outcomes in sports. On the basis of archival data of outcomes in Olympic games, the authors have demonstrated that athletes who were wearing red had greater probability of winning contests than those who were wearing blue. Studies supported Hill and Barton's (2005) findings by showing that (virtual or real) achievers wearing red reported higher levels of sport or motor performance (e.g., Attrill, Gresty, Hill, & Barton, 2008; Dreiskaemper, Strauss, Hagemann, & Büsch, 2013; Ilie, Ioan, Zagrean, & Moldovan, 2008).

Some hypotheses have been proposed to explain the powerful effect of red on performance. Hill and Barton (2005) suggest that red is a testosterone-based cue that reflects dominance. However, the authors failed to clarify the origin of such an effect: Does this effect originate in actor or observer (e.g., referee, opponent)? Focused on gambling activity, Ten Velden, Baas, Shalvi, Preenen, and De Dreu (2012) reported that players who played with red poker chips took more betting risk than those who played with blue poker chips, suggesting that wearing red would develop a sense of competitiveness. Moreover, Hagemann, Strauss, and Leißing (2008) reported that tae kwon do referees made beneficial decisions toward the fighters wearing red than toward those wearing blue, suggesting that observing red would bias one's own judgments. In a recent study, Wiedemann, Burt, Hill, and Barton (2015) provided evidence that men wearing red were perceived to be more aggressive and dominant than those wearing blue or gray. This supports the hypothesis that red is a dominance-related cue (Hill & Barton, 2005).

The literature of color psychology clearly distinguishes studies focused on "wearing red" from those focused on "perceiving red". Research on the effect of perceiving red on performance revealed that red impaired performance on challenging intellectual tasks (Elliot, Moller, Friedman, Maier, & Meinhardt, 2007), and this would be due to the fact that red would be associated with anxiety and would evoke avoidance motivation in such contexts (Elliot & Maier, 2007; Elliot, Maier, Binser, Friedman, & Pekrun, 2009). In the context of motor performance, Elliot and Aarts (2011) examined whether perceiving red might influence maximal short-term performance (using pinchgrip and handgrip tasks), and found that red facilitated force and the velocity with which that force was developed. These findings led the authors to suggest that perceiving red increases force via the activation of the avoidance system that mobilizes energy for protective action.

Interestingly, drawing a parallel with studies focused on the effects of wearing red on performance (e.g., Attrill et al., 2008; Hill & Barton, 2005) that showed that competing against an opponent wearing red might precipitate negative outcomes, Elliot and Aarts (2011) suggested that "...Red may even prove deleterious for engagement in simple motor tasks over an extended period of time, as this requires sustained mental focus", and that "...Subsequent research would be welcomed on issues pertaining to the length of exposure to red and the duration of the red effect." (p. 448). Consistent with Elliot and Aarts' (2011) assumptions, the processing efficiency theory (e.g., Eysenck & Calvo, 1992; Eysenck, Derakshan, Santos, & Calvo, 2007) proposes that anxiety would increase the amount of effort during a short period of time by mobilizing cognitive capacity, while it would be responsible for decreasing performance over time once cognitive capacity is consumed. Therefore, the present study aimed to examine the effect of exposure to red on endurance performance.

Although the color red has received a particular attention from scientists, the color green has recently elicited their curiosity because green is considered as the primitive visual feature of nature (e.g., Akers et al., 2012; Barton, Griffin, & Pretty, 2012). Research has revealed that "green exercise", referring to performing physical activity in natural environments, fostered health-related outcomes, in terms of enjoyment, self-esteem (Barton et al., 2012) and well-being (Kaplan, 2001). In a noteworthy investigation, Akers et al. (2012) examined the effect of colored environments (green, red, or gray) on several feelings during moderate-intensity 5-minute cycling tasks, and found that the green environment decreased mood disturbance and perceived effort. The beneficial effect of viewing green while performing a motor task would be caused by a phylogeny-based association between the color green and the notion of fertility of natural environment (Wilson, 1984), thereby leading to activate an approach motivation (Elliot & Maier, 2007; Elliot et al., 2009). Although Akers et al. (2012) are the first to exhibit positive green exercise outcomes, they did not examine whether viewing green while performing a motor task might be beneficial for motor performance. Accordingly, the present study sought to *explore* whether green exercise might improve motor performance.

1. The present study

This study, conducted on a relatively small sample size, was a pilot study that aimed to explore the effect of prolonged exposure to red and green on physical and psychological parameters. Consistent with Elliot and Aarts' (2011) assumptions, it was expected that an exposure to red over an extended period of time would be deleterious for endurance performance. This means that we expected that perceiving red would be related to lower levels of endurance performance and heart rate. Additionally, because of the supposed links between red and avoidance motivation (e.g., Elliot & Maier, 2007), one can expect that perceiving red would be related to higher levels of anxiety (even if no strong prediction can be proposed since the literature did not reveal consistent findings; see Elliot et al., 2007; Zhang & Han, 2014). Furthermore, and consistent with studies on green exercise (e.g., Akers et al., 2012), it was expected that an exposure to green over an extended period of time would be beneficial for endurance performance. More specifically, it was expected that perceiving green would be related to higher levels of endurance performance and heart rate. Also, given the beneficial effects of green on enjoyment (Barton et al., 2012) and perceived effort (Akers et al., 2012), it was expected that perceiving green would be related to higher levels of enjoyment, and to lower levels of perceived effort.

Using an endurance task within colored environments represents a methodological challenge because "...ambient color may not be sufficient to produce an effect, or prolonged exposure to color may lead to habituation over time" (Elliot & Maier, 2014, p. 103). As a result, attempting to follow the Elliot and Maier's (2014) recommendations, we combined objective (i.e., excluding color deficient participants, and controlling hue, brightness, and intensity of colors) and subjective controls (i.e., controlling perceived typicality of colors).

2. Materials and methods

2.1. Participants

Ten French males cyclists (age: 17.4 ± 1.1 years; height: 1.8 ± 6.6 m; body mass: 67.8 ± 5.7 kg), competing at regional level, volunteered to contribute to the present study. They provided their written consent. Written parental consent was also provided for those who were under 18 years. Participants were recruited from several clubs in Guadeloupe with the consent of their coaches. The coaches were contacted and queried as to whether cyclists would be interested in performing some physical trials on home trainer in a laboratory while also answering some questions about their psychological state experienced during the effort. Participants took part in this study because they reported that they had no current or recent medical issues (e.g., musculoskeletal injury, serious illness) and that they were not red-green color-blind.

2.2. Materials and experimental design

The experimental setup was permanently installed in the experimental room of the Sports Medicine Center of Guadeloupe. This setup included a laptop, a computer installed in the room (with a 48×27 cm computer screen), three lens glasses, a thoracic belt including a short-range telemetric system, and a home trainer bicycle. On the laptop, a program related to the home trainer was installed that allowed to display data of covered distance over time. Another program related to the thoracic belt allowed to display hear rate. The computer and lens glasses enabled participants to perceive their environments in green, red, and gray while performing the trials.

The protocol was designed to confront participants with six 7-minute cycling trials, during which they were exposed to all colored environment conditions. The order of the confrontations to the colored environments within the series was set up *randomly* in order to neutralize any order effect of the exposure to colors. More specifically, participants achieved two *identical* series of three trials, and this design aimed to neutralize any effect of fatigue that would be induced by the previous 7-minute trials. The experimental sessions were conducted in a neutral environmental climate (temperature, $M = 25.01\,°C$, $SD = 1.05\,°C$; relative humidity, $M = 39.73\%$, $SD = 4.46\%$).

Combining two sources of visual stimuli enabled to generate *perceived* colored environments. On the computer screen on which participants fixed their eyes during each effort, colors were created using the hue-saturation-value (hsv) color model (see Elliot & Maier, 2014), with red hsv (0°, 100%, 100%), green hsv (120°, 100%, 100%), and gray hsv (–, 0%, 50%). The hue of a color reflects its wavelength, the value its brightness, and the saturation its intensity or vividness. Additionally, to immerge participants in colored environments, participants wore red, green, or clear colored lens glasses during the effort.

2.3. Procedure

The experiment included an experimental session and a final debriefing. The Ethics Committees of the Sports Medicine Center of Guadeloupe (Ministry of Youth and Sports) and of the University of French West Indies (Ministry of Higher Education and Research) approved this experimental protocol.

2.3.1. Experimental session

Upon his arrival at the experimental room, the participant received instructions about the procedure from experimenters. Firstly, his was told that he was going to complete six 7-minute trials separated by a 4-minute rest period, and he was instructed that during each trial they had to perform as *best* he could. He received no information about the purposes of the present study until after all participants fully completed the experiment. Secondly, the participant was informed that during the rest period he was invited to answer items. The items and their scales were presented and explained him, and he was assured that his data would remain confidential. Thirdly, the participant was invited to wear colored lens glasses and to assess to what degree he *perceived* that each color corresponded to the typical representation of the color while seeing a colored computer screen. Fourthly, after a 13-minute warm-up, the participant was told that he had to wear lens glasses and to see the computer screen during the entire duration of each trial, and he was asked to begin the experimental task. When the experimental session was completed, the participant was asked to assess to which degree he believed that the color red, green, and gray could have influenced his performance. A sports doctor was available to intervene if needed, but no participant experienced physical problems during any of the sessions.

2.3.2. Final debriefing

When all experimental sessions were completed, participants were asked whether they really performed as best they could during each physical trial. All participants positively answered this question. Then, they were fully debriefed about the purposes of the study and were thanked for their participation.

2.4. Measures

2.4.1. Physical parameters

A specific program related to the home trainer (Tacx T-2020 I-Genius Multiplayer) enabled to display performance, as reflected by covered distance (in meters). A portable telemetry unit (Suunto Memory Belt) included in the thoracic belt worn by participants enabled to display heart rate. These physical parameters were recorded each minute during the sessions, thereby providing seven discrete measures (i.e., T_1, T_2, T_3, T_4, T_5, T_6, and T_7).

2.4.2. Psychological parameters

After completing a trial, each participant answered items to assess perceived effort, anxiety, and enjoyment he experienced while performing the trial. These items were randomly presented each time. To assess perceived effort, we used the 9-point scale of Stamford and Noble's scale (Stamford & Noble, 1974), with the points "*not at all hard*" ("2") and "*very, very hard*" ("8"). A single item of anxiety, from the cognitive anxiety subscale of the Competitive State Anxiety Inventory-2 Revised (Martinent, Ferrand, Guillet, & Gautheur, 2010), was measured: "While I was doing the trial, I was worried about performing poorly". To assess enjoyment (or intrinsic motivation), a single item from the enjoyment subscale of the Enjoyment Inventory (Ryan, 1982) was used: "While I was doing the trial, I was thinking about how much I enjoyed it". The items were rated on a 7-point scale, from "not at all" ("1") to "very much so" ("7"). Single items were used to facilitate the assessment of feelings.

Because participants achieved two series of several trials, where each trial was connected with a specific color condition, an overall assessment of each dependent variable was derived from the scores averaged across the both series for each color condition.

2.5. Analysis

To examine our hypotheses regarding the effect of perceived colored environments on covered distance, heart rate, and feelings, repeated measures ANOVAs were conducted using Statistica (v. 7.1). Follow-up post-hoc comparisons (LSD Fisher tests) were also computed when appropriate. However, before computing such analyses, two kinds of preliminary analysis were conducted: the assessment of perceived typicality of colors and the check of color-related beliefs. For all analyses, the significance level was set at $p < 0.05$.

3. Results

3.1. Preliminary analyses

Prior to the beginning of the experimental session, participants were asked to answer a question designed to control perceived typicality of each color because "...equating colors on perceived

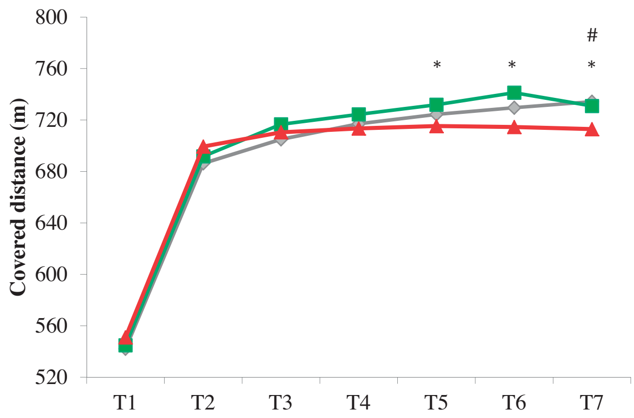

Fig. 1. Covered distance as a function of color and time. *: means the existence of a significant difference between the red and green conditions. #: means the existence of a significant difference between the red and gray conditions.

typicality bolsters the rigor of empirical work on color" (Elliot & Maier, 2014, p. 98); this procedure has been used in some previous studies (e.g., see Elliot et al., 2007). The question was the following: "To what degree is the color red (or green or gray) of your environment a typical example of that color?" on a 5-point scale ("1" = "not at all"; "5" = "very much so"). A repeated measures ANOVA (Color [Red vs. Green vs. Gray]) revealed no significant effect for perceived typicality of colors, $p > .05$ (red: $M = 4.50$, $SD = 0.71$; green: $M = 4.70$, $SD = 0.67$; gray: $M = 4.30$, $SD = 0.82$).

At the end of the experimental session, participants also answered a question that measured their beliefs about the impact of colors on their performance: "To what extent do you think having been immerged in a red (or green or gray) environment has influenced your performance?" on a 7-point Likert-type scale ranging from "1" ("...has decreased your performance") to "7" ("...has increased your performance"), with a midpoint "4" ("...did not influence your performance"). A repeated measures ANOVA revealed no significant effect of Color on participants' beliefs, $p > .05$ (red: $M = 4.40$, $SD = 1.17$; green: $M = 4.80$, $SD = 1.40$; gray, $M = 4.90$, $SD = 1.29$).

In sum, color typicality perception and color-related beliefs were not affected by the color conditions, suggesting that any findings on the variables of interest would more likely be attributable to the color manipulation than to any other factors.

3.2. *Main analyses*

3.2.1. *Physical parameters*

To examine whether perceiving color while performing cycling trials influences covered distance and heart rate, 3 × 7 analyses of variance (color [red vs. green vs. gray] × time [ranging from T_1 to T_7]) with repeated measures on the two factors were computed. A correlation analysis revealed that covered distance and heart rate were positively correlated ($r = .38$, $p < .001$).

3.2.2. *Performance*

The analyses revealed a significant Color × Time interaction for covered distance, $F(12, 96) = 2.04$, $p = .03$. Subsequent post-hoc comparisons, as depicted in the Fig. 1, revealed that covered distance was significantly lower: (a) in the red condition, $M = 712.86$, $SD = 112.61$, than in the gray condition, $M = 734.20$, $SD = 101.01$, at T_7 ($p = .006$), and (b) in the red condition than in the green condition at T_5 (red: $M = 715.25$, $SD = 104.41$; green: $M = 731.86$, $SD = 99.62$; $p = .02$), T_6 (red: $M = 714.51$, $SD = 112.16$; green: $M = 741.25$, $SD = 98.63$; $p < .001$), and T_7 (red: $M = 712.86$, $SD = 112.61$; green: $M = 730.89$, $SD = 110.10$; $p = .02$). No significant main effect of color was found for covered distance ($p > .05$).

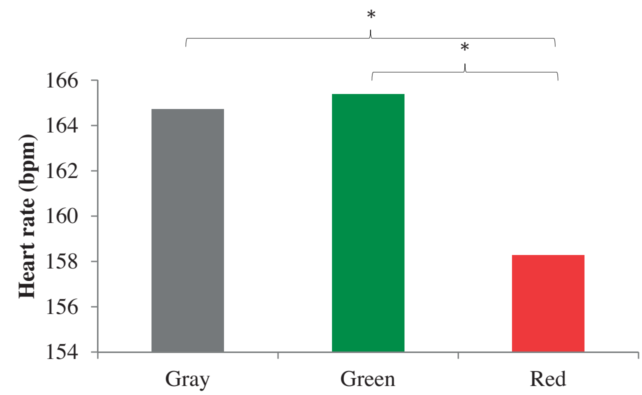

Fig. 2. Heart rate as a function of color. *: means the existence of a significant difference.

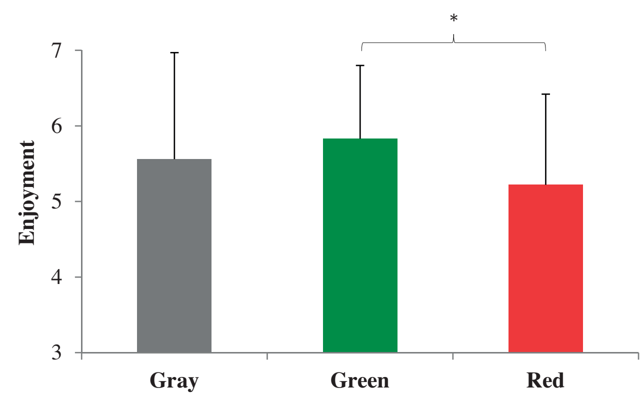

Fig. 3. Enjoyment as a function of color. The response scale for the item ranged from 1 ("not at all") to 7 ("very much so"). *: means the existence of a significant difference between the green condition and the red condition.

3.2.3. *Heart rate*

The analyses revealed a significant main effect of color for heart rate, $F(2, 16) = 4.22$, $p = .03$. Subsequent post-hoc comparisons, as depicted in the Fig. 2, revealed that heart rate was lower: (a) in the red condition, $M = 156.40$, $SD = 25.81$, than in the gray condition, $M = 164.54$, $SD = 20.18$, $p = .02$, and (b) in the red condition than in the green condition, $M = 165.86$, $SD = 20.90$, $p = .03$. No significant color × time interaction was found for heart rate ($p > .05$).

3.2.4. *Psychological parameters*

To examine whether perceived effort, anxiety, and enjoyment were influenced by colors, one-way ANOVAs were conducted. The means and standard deviations of these variables for each color condition are presented in Table 1. The analyses revealed a main of effect of Color for enjoyment, $F(2, 16) = 5.09$, $p = .02$. Post-hoc comparisons, as depicted in the Fig. 3, revealed that enjoyment was higher in the green condition, $M = 5.83$, $SD = 0.97$, than in the red condition, $M = 5.22$, $SD = 1.20$, $p = .006$. No significant effects of Color were found for anxiety and perceived effort, $ps > .05$.

4. Discussion

This pilot study attempted to examine the effects of perceiving red and green on physical and psychological parameters in cyclists who performed repeated 7-minute trials. It was predicted that perceiving a red environment would decrease endurance performance and heart rate, and would increase anxiety. It was also predicted that perceiving a green environment would increase

Table 1
Descriptive statistics for psychological variables according to the color conditions.

Variables	Gray condition M (SD)	Green condition M (SD)	Red condition M (SD)	*p*-value
Perceived effort	5.61 (1.41)	5.58 (1.26)	5.72 (0.71)	0.83
Cognitive anxiety	3.78 (1.72)	3.94 (1.84)	4.17 (1.27)	0.47
Enjoyment	5.56 (1.18)	5.83 (0.97)[a]	5.22 (1.20)	0.02

The response scale for the item of perceived effort ranged from 1 to 9, with 2 ("not at all hard") and 8 ("very, very hard"). The response scale for the items of enjoyment and anxiety ranged from 1 ("not at all") to 7 ("very much so").
[a] Means the existence of a significant difference between the green condition and the red condition.

endurance performance, heart rate, and enjoyment, and would decrease perceived effort.

With regard to our first prediction, the results revealed a significant color × time interaction for covered distance, where covered distance appeared to be lower in the red environment than in the gray environment at the end of the cycling trial (i.e., at T_7) (see Fig. 1). It was also found that covered distance was lower in the red environment than in the green environment from T_5 to T_7 of the trial (see Fig. 1). Furthermore, heart rate was found to be lower in the red environment than in the gray and green environments (see Fig. 2). Take together, these findings indicate that perceiving red lowered participants' engagement in the cycling trials, and support the Elliot and Aart's (2011) view that perceiving red may have deleterious consequences on motor performance over an extended period of time. This negative effect would be due to the fact that perceiving red would activate avoidance motivation, which would be beneficial for explosive action only. Moreover, the analyses revealed that anxiety was not influenced by the color conditions.

With regard to our second prediction, the analyses revealed that perceiving green did not influence endurance performance, heart rate, and perceived effort. However, the analyses revealed higher levels of self-reported enjoyment in the green environment than in the red environment (see Fig. 3), supporting previous studies that have shown that green exercise was associated with higher levels of agreeable feelings (e.g., Barton et al., 2012). More generally, this supports the general view that the color green reflects an appetitive cue and evokes approach motivation (e.g., Elliot & Maier, 2007; Elliot et al., 2009). Interestingly, the set of our findings reveals that cyclists not only performed better in the green environment than in the red environment, but also experienced more agreeable feelings. As a result, from an applied standpoint, perhaps coaches could suggest their athletes to employ green lenses to deal with prolonged and intense effort.

In all, the most provocative result revealed in the present pilot study is that perceiving red debilitates motor performance over an extended period of time. However, this study has some limitations. Firstly, it was based on a relatively small sample, and thus our findings should be considered as tentative, at present, until examined further in subsequent work. Secondly, we failed to objectively control colors characteristics resulting from the combined effect of the both sources of colors (i.e., computer and lens), and thus further studies should employ a spectrophotometer. Finally, this study strongly incites to pursue the examination of the effects of perceived colored environments on affective, cognitive and behavioral spheres using a time-based approach. Interestingly, Elliot and Maier (2014) supposed that the prolonged exposure to color would entail a habituation phenomenon leading to remove any effect of color. Thus, further studies should use a larger temporal window than we used and examine whether the deleterious effect of red on motor performance would be removed over time.

Disclosure of interest

The authors declare that they have no competing interest.

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