Viewing red prior to a strength test inhibits motor output

Vincent Payen,a,* Andrew J. Elliot,b,1 Stephen A. Coombes,c,2 Aïna Chalabaevd,3 Jeanick Brisswaltere,4 François Curryf,5

a Laboratory Handibio EA 4322, University of Toulon-Var, France
b Department of Clinical and Social Sciences in Psychology, University of Rochester, Rochester, NY 14620, USA
c Department of Kinesiology and Nutrition, University of Illinois at Chicago, 60612, USA
d Laboratory of Human Motricity, Education, Sport and Health (LAMHESS), University of Nice Sophia Antipolis, France
e Laboratory of Human Motricity, Education, Sport and Health (LAMHESS), Department of Physiology, University of Nice Sophia Antipolis, France
f CNRS 6233 Human Movement Sciences Institute, University of Aix-Marseille II and University of Toulon-Var, France

Research in evolutionary biology and psychology indicates that color is not only an aesthetic stimulus, but also carries important meaning. Red is the color that has received the most research attention. In human and non-human primates alike, red is associated with threat and danger. For example, in mandrills, a testosterone-based flush of red on the face of an opponent is a signal of dominance and attack-readiness[46] (for examples in other species and vertebrates see Andersson and Iwasa[4] and Gerald [28]). In humans, red on the face of a competitor may likewise indicate testosterone-fueled anger or aggressiveness [10,18] and, furthermore, red is used in student evaluation to indicate mistakes, in language to represent negative situations (e.g. “in the red”), and in traffic signals, alarms, and sirens to indicate impending danger [21,42]. The clear parallels across phylogeny in the signal value of red suggest a biologically engrained link between red and danger in humans that is bolstered and broadened by societal learning [23].

Given the associative link between red and danger, it is not surprising that experiments have shown that red evokes avoidance motivation and behavior in human participants in achievement situations. Viewing red, relative to other chromatic and achromatic colors, prior to an achievement task produces an increase in right frontal cortical activation [23] and an increase in local perceptual focus [36], both indicative of avoidance motivation [15,16]. Perceiving red also leads to the selection of easy rather than moderately challenging test items [23], less knocking on the door of a room where a test will be taken [22], and subtle postural movement away from an anticipated test [22].

Avoidance motivation (and associated processes such as anxiety) is known to interfere with fluid and efficient cognitive processing and to undermine performance on tasks requiring complex mental operations [9,20,30]. Accordingly, as a danger cue that evokes avoidance motivation in achievement settings, red should undermine intellectual performance. This is precisely what has been observed in recent empirical work. Viewing red, relative to other chromatic and achromatic colors, prior to engaging in an achievement task has been found to undermine anagram, analogy, and math performance [23,34,36].
Recently, Elliot and Aarts [19] extended this research by examining the influence of red on performance on simple motor tasks. They found that participants who viewed red, relative to other chromatic and achromatic colors, while engaging in a pinchgrip or handgrip task produced greater strength output and did so more quickly (see [31] for a similar, but less systematic, observation). Elliot and Aarts [19] interpreted their findings in terms of the operation of a phylogenetically basic avoidance/defense system responsible for processing and responding to threat-relevant stimuli [17,38]. This avoidance/defense system is thought to be grounded in a network of largely subcortical structures (e.g. the amygdala and the basal ganglia) that detect threat stimuli and trigger autonomic activity required to support urgent and emphatic movement away from imminent danger [8,33]. Supportive research indicates that threatening pictorial images indeed activate the amygdala and basal ganglia [32,44], and produce voluntary motor behavior that is more forceful [11] and of greater velocity [12] than that produced by appetitive or neutral stimuli. The Elliot and Aarts [19] findings show that red operates as a threat stimulus in commensurate fashion.

In the Elliot and Aarts [19] research, participants engaged in the performance task immediately upon and during the presentation of the color stimulus. This is different than the “test cover” procedure, used in nearly all previous work on color and intellectual performance, in which the color stimulus is viewed several seconds prior to the onset of, but not during, task engagement (e.g. [23]). The immediate, urgent response to red seen in Elliot and Aarts [19] may be a subcortically based “call to arms” involving fear that facilitates efficient (rapid) and effective (forceful) motor action. On the other hand, the more distal, anticipatory response to red seen in research using the “test cover” procedure may draw on cortically based processing involving anxiety and concern about social evaluation that interferes with efficient and/or effective motor action. This distinction between fear-based and anxiety-based responding is consistent with threat models proffered in rodent research to explain differential responding as a function of the imminence of detected danger [7,26]. It is also consistent with findings from the human literature on threat stimuli and motor responding, in which threat stimuli presented conterminously with motor action have been shown to facilitate effective and efficient motor responding [11,12], whereas threat stimuli viewed prior to (but not during) motor action have been shown to decrease performance accuracy [14] and response speed in test anxious individuals [13].

In the present research, we made use of the “test cover” approach to color presentation to examine the influence of a prior, distal viewing of red, relative to other chromatic and achromatic colors, on performance on a simple motor task. In line with the above reasoning, we anticipated that the red stimulus viewed prior to the onset of motor action would produce slower and/or less forceful responding. Consistent with other research on red effects in achievement contexts (e.g. [23]), we anticipated that any observed effects would take place independent of general arousal and mood, and without participants being aware of the influence of color on their behavior. Critically, we conducted our research using precisely controlled color manipulations, and hues equated on lightness and (as applicable) chroma (see Elliot and Maier [21], for the importance of these factors). Evidence in support of our hypothesis not only would provide further evidence for the functional properties of the color red, but also would highlight the critical importance of attending to the temporal distance of threat cues in studying basic affective-motor processes (for calls for such work, see [11,48]).

Thirty-nine male undergraduates voluntarily participated in the study (age range: 18–37, M = 23.21; SD = 4.05). All participants gave informed consent. To avoid muscle fatigue that could lead to biased torques, participants were instructed to refrain from participating in any physical activity during the 24 h preceding the experimental session. Participants were randomly assigned to one of the three between-participants color conditions (n = 13 per condition): red, blue, or gray. Participants were required to make two isometric maximal voluntary contractions of the thigh, and the color manipulation was presented between these two contractions. Isometric voluntary contraction of the thigh was deemed an optimal task for the experiment, because measurement techniques in this area are well-developed and reliable. Aside from the color manipulation, all participants completed the same experimental procedure.

Motor performance was assessed via (1) maximal voluntary contraction (MVC) and (2) rate of force development (RFD). The MVC (Nm) is the peak of force reached after more than 300 ms during a strong muscle contraction [1]. A Biodex System 3 dynamometer (Biodex, Shirley, NY) with a 110° hip angle and a 90° knee angle (0° as full leg extension) was used to measure maximal voluntary isometric torque of the right knee extensor muscles [37]. To avoid hip motion during the contractions, straps were applied across the chest and pelvis. Arms were folded and placed on the chest to avoid any pulling from the arm rests of the chair. The knee axis was aligned with the dynamometer axis, and the ankle was attached to the biodex knee attachment extending from the transducer. The highest peak torques at Time 1 (T1) and Time 2 (T2) were, respectively, defined as MVC values.

The RFD assesses explosive muscle strength and is a determinant of the maximal force and velocity that can be produced during the initial phase of contraction (<250 ms; [1]). RFD is influenced by the level of neural activation and by intrinsic muscle properties (e.g. muscle size and fiber-type [2,3]). RFD (Nm/s) was defined as the slope of the torque–time curve (i.e., Δtorque/Δtime) in 25 incrementing time periods of 0–10, 0–20, up to 0–250 ms from the onset of contraction. The RFD score reflected the peak slope during the first 250 ms of the contraction.

In addition to measures of motor performance, we collected self-report measures of general arousal and mood. General arousal was assessed with the item “How energetic do you feel right now?” on a 1 (not at all energetic) to 5 (very energetic) scale. This item is the highest loader on the General Activation subscale of Thayer’s [49] Activation–Deactivation Adjective Check List. Mood was assessed with Seibt and Forster’s [45] single-item measure “How do you feel right now?” using a 1 (very bad) to 9 (very good) scale.

Upon arrival at the laboratory, participants were informed that the experiment involved assessing the strength of the right thigh. They were tested individually by an experimenter who was blind to hypotheses and experimental condition. Participants performed two 5 s quadriceps maximal isometric contractions (at T1 and T2). Contractions were separated by a 90 s rest period. The color manipulation was presented between T1 and T2 using the test cover procedure [23]. Participants were handed a white binder with two pages in it. The first page contained the color manipulation, which was a piece of Epson Enhanced Matte white paper containing a 18 cm × 12.68 cm colored rectangle with the words “strength test” printed in black ink in 34 point font in the middle of the rectangle. Adobe Photoshop was used to put color on the rectangle, and the colors for the manipulation were selected using the CIELCh color model and a GretagMacBeth Eye-One Pro spectrophotometer. A trial and error process was used to find standard red, blue, and gray hues that were equal on lightness and (for the chromatic colors) chroma. The parameters for the printed colors were: red LCh(49.9, 50.9, 27.0), blue LCh(49.6, 50.4, 271.0), and gray LCh(50.1, –, 270.9). The experimenter instructed participants to open the binder to the first page containing the words “strength test”; after 2 s had elapsed, the experimenter told participants to turn the page to complete a brief questionnaire comprised of the general arousal and mood items. Participants were then instructed to close the binder and give it back to the experimenter. At the end of the rest period, participants performed their second MVC trial. At the end of the experiment, participants received a verbal funeral debriefing that
The present study provides clear support for a link between red and basic motor functioning in humans. Viewing red as opposed to blue or gray prior to a simple strength test inhibited the rate of force development, but did not influence the peak amplitude of force production. These findings were obtained with color stimuli equated on lightness and chroma, thereby allowing hue to be unequivocally identified as the color property responsible for the observed effect. Null results were obtained for self-report measures and not a single participant was able to discern the purpose of the experiment; this suggests that the influence of color on motor behavior took place without participants’ conscious awareness.

The present research extends and compliments recent research by Elliot and Aarts [19], and the clearest picture of the link between red and motor functioning may be obtained by juxtaposing the two sets of findings. In the present research, participants viewed red several seconds prior to, but not during, task performance, and these individuals exhibited less efficient motor output. In the Elliot and Aarts [19] research, on the other hand, participants viewed red immediately before and during task performance, and these individuals exhibited more efficient and more effective motor output.
importance for the ability to rapidly regain balance during sudden postural perturbations, thereby potentially reducing the risk of falls’ [1, p. 1325]. Thus, ironically, an older person who is anxious about slipping may be putting him or herself at greater risk of suffering this exact fate.

In conclusion, red is a threat cue in achievement contexts that influences strength performance, as well as intellectual performance. The impact of red is subtle, yet powerful, and, as seen in emerging empirical work in both the achievement domain and (far) beyond [24,25,35], appears to be as pervasive as it is provocative.

References


