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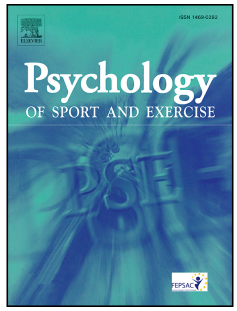

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The effects of facial expression and relaxation cues on movement economy, physiological, and perceptual responses during running.

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Abstract

Objectives: Previous research has supported the beneficial effects of relaxation training on running economy. However, no studies have compared the effects of brief contact instructions to alter facial expression or to relax on running economy or running performance. The primary aim of this study was to determine the effect of such attentional instructions on movement economy, physiological, and perceptual responses during running. *Method:* Using a repeated measures design, 24 trained runners completed four 6 min running blocks at 70% of velocity at VO_{2max} with 2 min rest between blocks. Condition order was randomized. Participants completed running blocks while smiling, frowning, consciously relaxing their hands and upper-body, or with a normal attentional focus (control). Cardiorespiratory responses were recorded continuously and participants reported perceived effort, affective valence, and activation after each condition. *Results:* Oxygen consumption was lower during smiling than frowning (d = -0.23) and control (d = -0.19) conditions. Fourteen participants were most economical when smiling in contrast with only one participant when consciously relaxing. Perceived effort was higher during frowning than smiling (d = 0.58) and relaxing (d = 0.49). Activation was higher during frowning than all other conditions (all $d \geq 0.59$). Heart rate, affective valence, and manipulation adherence did not differ between conditions. *Conclusion:* Periodic smiling may improve movement economy during vigorous intensity running. In contrast, frowning may increase both effort perception and activation. A conscious focus on relaxing was not more efficacious on any outcome. The findings have implications for applied practice to improve endurance performance.

Keywords: Smiling; relaxation; endurance activity; running economy; attentional focus

Introduction

Physiological factors related to prolonged endurance performance (e.g., marathon running) include the maximal amount of oxygen that can be utilized (VO_{2max}), lactate threshold (i.e., the intensity at which blood lactate first rises above baseline levels) and movement economy (e.g., Jones, 2006; Joyner, 1991). Running economy (RE) can be defined as the steady-state volume of oxygen consumed (VO_2) during a submaximal running intensity (Conley & Krahenbuhl, 1980) and can explain differences in performance between athletes otherwise matched in terms VO_{2max} and lactate threshold (e.g., Joyner, 1991; Moore, 2016). Improvements in RE are associated with chronic adaptations to both endurance (e.g., Barnes & Kilding, 2015) and strength (e.g., Barnes, Hopkins, McGuigan, Northuis, & Kilding, 2013) training, as well as manipulations to improve biomechanical and technical aspects of the running movement (e.g., Moore, 2016). To emphasize the importance of RE, long-term reductions in the oxygen cost of movement have been strongly associated with performance optimization in the most elite distance runners (Jones, 2006).

Psychological strategies are also important for endurance performance (e.g., Brick, MacIntyre, & Campbell, 2014) and can impact RE (e.g., Neumann & Piercy, 2013; Schücker, Schmeing, & Hagemann, 2016). Early research by Morgan and Pollock (1977) suggested that elite marathon runners typically used associative cognitive strategies (i.e., pay attention to sensory information and modulate pace accordingly), whereas non-elite performers tended to distract from sensations experienced during running (i.e., dissociate). One regulatory strategy was relaxation, whereby runners, ‘paid very close attention to bodily input… [and] constantly reminded or told themselves to “relax,” “stay loose,” and so forth’ (p. 390). Relaxation during running was considered responsible in part for a lower relative oxygen consumption amongst the elite marathoners in comparison with elite middle-distance runners. Subsequent research has supported the importance of relaxation to improved RE. Williams, Krahenbuhl, and

Morgan (1991) noted a positive relationship between lower tension (as a mood state) and improved RE, for example. In addition, Smith, Gill, Crews, Hopewell, and Morgan (1995) reported the most economical participants in their study used more relaxation during running.

Several potential mechanisms may explain why a relaxed state would improve RE. These include reduced autonomic sympathetic nervous system activity and a concomitant decrease in heart rate and muscle activation (i.e., the relaxation response; Benson, Dryer, & Hartley, 1978). In a running context, researchers have attempted to improve RE using brief contact relaxation interventions comprising advanced psychological methods. Hatfield et al. (1992), for example, had 12 trained runners complete a 36 min continuous run at an average intensity of 71% VO_{2max}. The run consisted of three randomized segments during which runners either 1) received concurrent biofeedback of minute ventilation (i.e., volume of air breathed per minute; V_E) and electromyography (EMG) data of forearm and trapezius muscles, 2) engaged in a distracting task, or 3) completed a control (no specific attentional focus) condition. Outcomes included a reduction in V_E and respiratory frequency during biofeedback, but no difference in VO_2 or EMG activity between conditions. The authors suggested participants may already have had a ‘relaxed running style’ (p. 223) and acute improvements RE may not have been possible (Hatfield et al., 1992).

The ability to improve RE with longer-term relaxation training has been demonstrated, however. Caird, McKenzie, and Sleivert (1999) reported a large reduction in VO_2 (d = 0.85), and a small-to-moderate reduction in heart rate (d = 0.35) at lactate threshold intensity following six weeks of biofeedback, progressive muscular relaxation (PMR), and centering training with seven trained distance runners. In addition, during the training period VO_2 data were recorded during control (no biofeedback or centering) and biofeedback conditions while running at an intensity equivalent to 70% of peak running velocity. Results indicated that RE progressively improved with relaxation training, ranging from trivial during the first trial (d = 0.03), to small-to-moderate during the sixth (d = 0.33), to moderate (d = 0.55) during the 12th intervention trial. Improvements in RE were independent of changes in other physiological markers of aerobic performance (e.g., VO_{2max}) over the study period.

The findings from these laboratory-based studies suggest that relaxation-induced improvements in RE may only be possible with longer-term training using sophisticated psychological methods. Furthermore, relaxation training (e.g., PMR, centering, or breathing techniques) as part of multimodal psychological skill interventions (i.e., also including self-talk, imagery, etc.) has improved performance during 1600m running (Patrick & Hrycaiko, 1998) and simulated triathlon events (e.g., Thelwell & Greenlees, 2003). These skills may be difficult to learn, however (e.g., Crews, 1992), and the specialist psychological support required is often unavailable to most runners (McCormick, Meijen, & Marcora, 2016). Consequently, whether relaxation cues can be effective as part of the brief contact interventions accessible to the majority of athletes (e.g., online, at pre-race events; Lane et al., 2016; Meijen, Day, & Hays, 2016) remains to be seen. Furthermore, which cues are most effective to induce relaxation is unknown. In this regard, a common instruction to relax runners' upper-body is to imagine 'holding a crisp [potato chip] between each thumb and forefinger, tight enough to hold it without crushing it,' or to hold the fingers in a 'relaxed clench position' (Murphy, 2009, p. 25). No research has determined the effects of these attentional cues on RE, physiological, or perceptual responses during running, however.

Some studies have experimentally demonstrated an impact of other attentional focus instructions on RE. Specifically, Schücker and colleagues evidenced a reduced RE when runners were instructed to focus attention on highly automated processes such as breathing or running movement in comparison with control conditions (e.g., Schücker, Knopf, Strauss, & Hagemann, 2014). Similar effects have been observed with both trained and inexperienced runners (Schücker et al., 2016). These findings further confound the use of relaxation during endurance performance. Specifically, it suggests that instruction to focus on breathing to relax during activity (e.g., Thelwell & Greenlees, 2003) may be counterproductive and, paradoxically, increase the oxygen cost of running (Schücker et al., 2014, 2016).

In addition, few studies have investigated the effects of facial expression (e.g., smiling, frowning) on physiological and perceptual responses during endurance activity. According to the facial feedback hypothesis (FFH), facial expression may influence one's emotional experience in a given situation (e.g., Tourangeau & Ellsworth, 1979). This concept embraces elements of embodied cognition; the notion that the body functions as a constituent of the mind and is directly involved in, and productive of, cognition (e.g., Shapiro, 2011). Specifically applied to emotional states (i.e., embodied emotion), manipulating the bodily expression of an emotion (e.g., facial expression) can influence how emotional information is processed and may be accompanied by self-reports of the corresponding emotion (e.g., Niedenthal, 2007; Niedenthal, Mermillod, Maringer, & Hess, 2010). Thus, simulated frowning may prime unpleasant feelings (e.g., Larsen, Kasimatis, & Frey, 1992) and, in contrast to relaxation, increase activation and muscle tension which may, in turn, reduce RE (e.g., Martin, Craib, & Mitchell, 1995). Furthermore, frowning muscle activity, termed the 'face of effort', has shown a moderate-to-strong positive relationship with effort perception during physical tasks (de Morree & Marcora, 2010). Encapsulating elements of embodiment concepts, de Morree and Marcora (2010) suggested this relationship may be bidirectional and exaggerated frowning – activated by contracting the corrugator supercilii muscles – may increase effort expended and/or perceived during a physical task.

In contrast to frowning, a facial expression of more positive emotions (e.g., smiling) may prime a more relaxed bodily state; reducing muscle activation, VO_2, and effort perceived. Smiling during stress-inducing tasks, for example, has been shown to lower heart rate during recovery to a greater extent than a neutral facial expression (e.g., Kraft &

Pressman, 2012). Such responses may be most pronounced when individuals produce 'real' or Duchenne smiles (Duchenne, 1990) that reflect positive emotions such as enjoyment (e.g., Niedenthal et al., 2010). Duchenne smiles differ from non-Duchenne smiles (e.g., false or insincere smiles), or smiles with alternative functions (e.g., social affiliative smiles or dominance smiles), by symmetrical activation of the zygomaticus major (mouth movement) *and* activation of the orbicularis oculi (eye and cheek movement) muscles (e.g., Niedenthal et al., 2010; Rychlowska et al., 2017). Both Philippen, Bakker, Oudejans, and Canal-Bruland (2012) and McCormick, Meijen, Pageaux, and Marcora (2016) have investigated the effects of facial expression during physical exercise. Philippen et al. (2012) indicated that smiling may reduce effort perception and increase affective valence during moderate-intensity cycling in comparison with frowning. However, this study did not include a control condition and did not report the physiological responses to each expression. In contrast, McCormick et al. (2016) reported that frowning did not influence heart rate, affective state, or perceived effort when compared with thumb contraction and no intervention control conditions during a time-to-exhaustion cycling task. Given these contrasting findings, and anecdotal accounts of the use of smiling by endurance athletes (e.g., Fitzgerald, 2014), further investigation of the physiological and perceptual responses to manipulated facial expressions is warranted.

Accordingly, the aims of this study were to compare the effects of attentional focus cues to a) smile, b) frown, c) consciously relax, and d) engage normal thoughts (control condition) on RE (i.e., VO_2), physiological (i.e., heart rate), and perceptual responses during running. Secondary respiratory variables (e.g., carbon dioxide produced (VCO_2), respiratory frequency, V_E) were also analyzed to gain a deeper insight into the physiological effects of the attentional focus cues. Three main hypotheses were proposed. First, it was hypothesized (H_1) that RE would be improved (i.e., lower VO_2) and heart rate reduced during smiling in comparison with frowning and control. Second, given that conscious relaxation may require a period of training (Caird et al., 1999) it was hypothesized (H_2) that VO_2 and heart rate would also be lower during smiling than relaxation. Thirdly, in line with the contentions of the FFH and embodied emotion, it was hypothesized (H_3) that effort perception and activation would be lower and affective valence more positive during smiling in comparison with frowning.

Methods

Participants

Research by Schücker and colleagues have reported moderate (η_p^2 = 0.099; Schücker et al., 2016) and large (η_p^2 = 0.29; Schücker et al., 2014) effect sizes for attentional focus manipulations on RE. For the present study, an a priori power analysis (Repeated Measures ANOVA, within factors) with a moderate effect size (f = 0.25), a power of 0.8, an alpha level of 0.05, a modest correlation between repeated measures (r = 0.5), and four measurements suggested a sample size of 24. This specific number allowed all possible randomized sequences of attentional focus cues (24 possible sequences) to be completed once during data collection. Consequently, 24 club-level endurance runners were recruited to participate. All participants were healthy, free from injury, were accustomed with treadmill running, and engaged in regular endurance running training. Specifically, all participants had previously completed a maximum race distance of at least one half-marathon (n = 7) or one marathon (n = 17), and currently ran on average 3.60 (SD = 0.86) days per week with a total running volume of 39.40 km (SD = 15.64) per week (see Table 1). Prior to recruitment all volunteers provided written informed consent and completed a medical history questionnaire to ensure no underlying medical conditions were present. The study was approved by the institutional research ethics committee and was conducted in accordance with the Declaration of Helsinki.

Procedures

The study consisted of two sessions for each participant. Each session was completed at the same time of day (+/- 2 hours) and between 3-7 days apart to minimize fatigue. Participants were asked to maintain normal activity, sleep patterns, and diet, and to avoid strenuous exercise and excessive caffeine or alcohol consumption in the 24 hours before each session. Participants were also asked to drink 500 ml of water (to ensure adequate hydration) and avoid any food or caffeine consumption in the 2 hours before each session. Participants were naïve to the experimental aims and hypotheses. Only when all data collection was complete were participants fully debriefed on the nature and hypotheses of the study.

Session one. During session one, participants completed an incremental exercise test to volitional exhaustion on a treadmill (h/p/cosmos quasar; h/p/cosmos Sports & Medical GmbH, Traunstein, Germany) with continuous measurement of respiratory gas exchange using an online metabolic cart calibrated before each test (Quark C-PET, Cosmed Srl, Rome, Italy). Following a 5 min warm-up at a self-selected pace, participants began at a light intensity based on their ability, with the intention of reaching volitional exhaustion within 10-15 min. Stages during the test lasted 2 min, with 2 kph increments for each of the first three stages followed by 1 kph increments to volitional exhaustion. Heart rate was measured continuously by wireless telemetry (Polar RS400, Kempele, Finland). VO_{2max} was determined as the highest value for a 10-breath rolling average and velocity at VO_{2max} (vVO_{2max}) was determined as the lowest speed at which the plateau in VO_2 was evident (Hill & Rowell, 1996). The treadmill incline was maintained at 0% throughout. Mean data for all 24 participants indicated that volitional exhaustion was reached in 11.71 min (*SD* = 3.40).

During the last 30 seconds of each of the first three stages, participants were asked to indicate their perceived effort, affective valence, and activation (see subsection on *perceptual responses*). This served to familiarize participants with each scale. Participants were also informed that these were routine exercise laboratory measures. On completion of the VO_{2max}

test, participants were also asked to recount their attentional focus during the first three stages to indicate participants' 'normal' attentional focus during treadmill running in the laboratory environment (see *session two*). Thoughts were categorized using Brick et al.'s (2014) attentional focus categories. Specifically, these categories were *active self-regulation* (e.g., relaxing, running technique, etc.), *internal sensory monitoring* (e.g., effort sensations, breathing, thirst, etc.), *outward monitoring* (e.g., split times, distance information, etc.), and both *active* and *involuntary distraction* (e.g., irrelevant daydreams, reflective thoughts, etc.).

Session two. Following an experimental design pioneered by Schücker and colleagues (e.g., Schücker et al., 2016), session two consisted of four blocks of 6 min runs with a 2 min passive rest interval between blocks. Because both oxygen consumption and heart rate were outcome variables, each run was performed at 70% vVO_{2max}, on a 0% gradient, an intensity equivalent to that used previously to study the effects of relaxation on RE (Caird et al., 1999). Before beginning, participants were informed about the testing protocol and equipped with a heat rate monitor and the Cosmed Quark system as per session one. Prior pilot testing assured that wearing the breathing mask did not interfere with the ability to adopt and maintain the required facial expressions. Experimenters were positioned out of the direct eye-line of participants. Neither heart rate nor respiratory data were visible to participants and the treadmill interface displays were obscured during session two to avoid providing biofeedback or other information. Participants completed a 5 min warm-up comprising 3 min at 50% vVO_{2max} followed by 2 min at 70% vVO_{2max}. Following a 2 min passive rest post warm-up, participants then began their first 6 min block of running.

Running blocks were randomized (using a computer random number generator) and each participant completed one block either smiling, frowning, consciously relaxing, or with a normal (control) attentional focus. Condition instructions were read by the first author from a script. General instructions were based on those implemented by Smith et al. (1995).

Specific cues for the smiling condition were adopted from Philippen et al. (2012) to encourage a real (Duchenne) smile. Before the smiling condition participants were instructed, '*For this running block, please focusing on smiling. While several different types of smile exist, please focus on producing what you would consider a 'real' smile. Real smiles involve both one's mouth and one's eyes. Please monitor your facial expression and keep smiling'.*

Instructions during the frowning condition also incorporated cues from Philippen et al. (2012) and terminology from de Morree and Marcora (2010) (i.e., face of effort) to elicit each participant's facial expression of effortful running. Accordingly, prior to the frowning condition, participants were read the following, '*For this running block, please focus on frowning. A frown is produced when one brings the eyebrows together and down, and the eyes are narrowed to a slit. During running, you might consider this a face of intense effort. Please focus on producing what you would consider a 'real' frown or face of intense effort. Please monitor your facial expression and keep frowning*'.

Attentional instructions for the relaxation condition were based on cues to induce relaxation in the hands and upper-body (e.g., Murphy, 2009). Specifically, participants were instructed, '*For this running block, please focus on your hands and upper-body, keeping your hands and upper-body as relaxed as possible while running with your normal gait. One cue might be to focus on touching your thumb and index finger together as lightly as possible as if you were holding a crisp and trying not to break it, or to hold your fingers in a relaxed position. Please monitor your hands and upper-body and keep them relaxed.*'

Finally, prior to the control condition participants were asked to focus on their 'normal' thoughts during running. Because of the context (i.e., laboratory-based), participants were reminded of the thoughts they self-reported during session one. Participants were instructed, '*For this running block, please focus on those thoughts you would normally focus on during running. For example, during your* VO_{2max} *test you said you focused on* [inserted each participant's most frequent thoughts during session one] *during the start and middle parts of that run. Please monitor your thoughts and focus on your normal thoughts during running*.' The data collected during session one suggested that the most frequent foci in each category were relaxing (58.33% of participants) and improving technique (45.83%) (*active self-regulation*), breathing (75%) and body movement/form (54.17%) (*internal sensory monitoring*), the treadmill (e.g., speed; 50%) and breathing apparatus (41.67%) (*outward monitoring*), and reflective thoughts (29.17%) and daydreaming (20.83%) (*distraction*).

During all conditions, a brief manipulation reminder (final sentence of each instruction) was read to all participants after every 60 seconds of running.

Data Collection

Respiratory variables and heart rate. Respiratory exchange variables (VO_2, VCO_2), respiratory frequency, tidal volume, minute ventilation (V_E), respiratory quotient (ratio of VCO_2:VO_2), and heart rate were measured continuously throughout session two.

Perceptual responses. Immediately following completion of each block, participants were asked to rate their perceived effort (RPE 6-20 scale; Borg, 1982). Specifically, runners were asked to rate how hard, heavy, or strenuous they perceived each 6 min run to be (Pageaux, 2016). Points of reference were exercise-anchored for session two and participants were instructed that 'no exertion' (i.e., point 6) reflected no physical activity, and 'maximal exertion' (i.e., point 20) corresponded to the point of volitional exhaustion during the VO_{2max} test. As a measure of affective valence, participants were asked to report how good or bad they felt during each block using Hardy and Rejeski's (1989) 11-point Feeling Scale. Verbal anchors for positive affect are feeling *fairly good* (+1), *good* (+3), and *very good* (+5). Finally, for perceived activation, participants were asked to indicate how aroused or 'worked up' they felt using the 6-point Felt Arousal Scale (Svebak & Murgatroyd, 1985). This scale ranges from *low arousal* (+1) to *high arousal* (+6). Each scale was projected on a screen 3.5 m in front of the treadmill and removed once participants responded.

Manipulation check and attentional focus. As a manipulation check, participants rated their ability to maintain each attentional cue during each block. Participants responded subjectively on a Likert-type scale with verbal anchors at 0% (*none of the time*), 50% (*half of the time*), and 100% (*all of the time*). Finally, on completion of all blocks, participants were asked to recount specific thoughts engaged during each block during a brief interview.

Statistical Analyses

Repeated Measures Analyses of Variance (RM-ANOVA) were conducted for each of the primary dependent variables (VO_2, heart rate, perceived effort, affective valence, and activation), for secondary respiratory variables, and for the manipulation check. Mean data for minutes 4 – 6 (i.e., last 3 min of each condition) were averaged for cardiorespiratory variables to ensure steady-state data only were analyzed. If assumptions of sphericity were violated, the Greenhouse-Geisser correction was used to report analyses. Follow up analyses were conducted using the Holm-Bonferroni sequential adjustment (Holm, 1979) where significant F ratios were observed. Statistical significance was accepted as $p \leq .05$ (two-tailed). To indicate the magnitude of differences between pairs of conditions, Cohen's d (Cohen, 1988) effect sizes are reported where relevant. Effect sizes for RM-ANOVA outcomes (partial η^2) are reported in Table 2. All analyses were conducted using the Statistical Package for the Social Sciences (IBM Statistics 23.0; SPSS Inc., Chicago, IL).

Results

Mean and standard deviation (*SD*) data for all outcomes are presented in Table 2. During running blocks (at 70% vVO_{2max}), mean percent of VO_{2max} during all conditions was

75.04% (*SD* = 5.44%) and mean percent of heart rate maximum was 82.47% (*SD* = 5.12%), both indicating vigorous intensity running (e.g., Norton, Norton, & Sadgrove, 2010).

Running Economy. RM-ANOVA revealed a difference in VO_2 between conditions, F (3, 69) = 5.88, p = .001. Mean VO_2 (Table 2 and Fig 1) was lower during smiling than frowning (Mean difference, [*MD*] = -0.94 ml/min/kg, p = .006, d = -0.23) and control (*MD* = -0.76 ml/min/kg, p =.040, d = -0.19). A small reduction in VO_2 was noted during smiling in comparison with relaxing (*MD* = -0.74 ml/min/kg, d = -0.18), but this did not reach statistical significance (p =.080). Fourteen participants (58.33%; four females) were most economical during smiling, five during frowning (20.83%; three females), and four during control (16.67%; three females). Only one participant (female) was most economical when relaxing.

Heart Rate. Due to an equipment malfunction with one participant, data were only available for 23 participants. No differences in heart rate were noted between conditions (p = .231). There was a significant order effect, however, F (3, 66) = 27.63, p < .001, η_p^2 = 0.56 and small increases in heart rate were recorded on successive blocks (i.e., 1st to 2nd block, etc.). No order effects for block number were apparent for any other variable (all p > .05).

Perceived effort. RM-ANOVA revealed a difference in perceived effort between conditions, F (3, 69) = 4.81, p = .004. Perceived effort (Table 2) was higher when frowning than both smiling (*MD* = 1.04, p = .012, d = 0.58) and relaxing (*MD* = 0.92, p = .045, d = 0.49). There were no differences between any other pairs of conditions (all p > .05).

Affective valence and activation. No difference in affective valence was noted between conditions (p = .266). There was a difference in activation, however (Table 2), F (2.22, 51.07) = 7.28, p = .001. Activation was higher during frowning than all other conditions; smiling (*MD* = 0.79, p = .006, d = 0.71), relaxing (*MD* = 0.67, p = .032, d = 0.59), and control (*MD* = 0.69, p = .030, d = 0.61).

Secondary variables. Secondary respiratory responses are also presented in Table 2. Of these, V_E was different between conditions F (3, 69) = 2.79, p = .047, but post hoc comparisons did not reveal a difference between any two conditions. VCO_2 was also different between conditions F (2.39, 54.85) = 3.69, p = .025, with a greater VCO_2 produced during frowning than smiling (*MD* = 0.91 ml/min/kg, p = .030, d = 0.21).

Manipulation check and attentional focus. The manipulation check revealed no difference in instruction adherence between conditions (p = .312). Manipulation adherence was high (>81%) across all conditions (see Table 2). A follow-up independent samples t-test also suggested no difference in adherence between genders during any condition (all p > .05)

The brief post-session interview revealed further insight into runners' thought content during each condition. During smiling, 17 participants (70.83%) engaged in pleasant thoughts (e.g., of family members, amusing events). Of these, 11 (64.71%) were most economical when smiling. Five runners (20.83%) reported only simulating the smiling expression and of these, three (60%) were most economical in this condition. When frowning, eight runners (33.33%) reported imagined effort-related sensations or simulating facial expressions of effort (e.g., as experienced during intense running). Eight other runners reported simulating frowning only and five runners (20.81%) reported engaging unpleasant thoughts (e.g., of political events). Of the five runners most economical when frowning, one reported a focus on sensations at the end of a marathon, another engaged unpleasant thoughts but deliberately attempted to stop these, and one found the expression difficult to maintain (60% adherence).

Eleven runners (45.83%) reported that they previously used the hands/upper-body relaxation cues during usual running (as instructed by a coach), including the one runner who was most economical in this condition. Two runners (8.33%) reported engaging additional thoughts to relax (e.g., repeating rhymes, counting breaths), but one runner did report excessive conscious control of the manipulation, despite doing this normally during running.

Finally, during the control condition, nine runners (37.50%) reported normal, irrelevant distractive or reflective thoughts (e.g., daydreaming, work-related thoughts). However, six (25%) reported difficulty engaging 'normal' thoughts in the unusual laboratory setting.

Discussion

The aims of this study were to compare the effects of brief contact attentional focus cues to smile, frown, consciously relax the hands and upper-body, or engage normal thoughts (control) on running economy (RE), physiological, and perceptual responses during running. The first and second hypotheses, that RE would be improved and heart rate reduced during smiling in comparison with the other conditions, were partially supported. Specifically, this is the first study to demonstrate an improved RE (lower VO_2) during smiling in comparison with frowning and participants 'normal' thoughts. In total, 14 of 24 participants (58.33%) were most economical when smiling. Although the lower VO_2 during smiling in comparison with relaxing did not reach statistical significance, only one participant was most economical when consciously attempting to relax, despite 11 of 24 runners (45.83%) being familiar with the relaxation cue. No differences in heart rate were noted between conditions, though an order effect for block number was apparent. The third hypothesis, that effort perception and activation would reduce and affective valence increase during smiling in comparison with frowning, was also partially supported. Specifically, a second novel finding of the present study was an increased effort perception during running when frowning in comparison with smiling and relaxation conditions. No differences were noted for affective valence, though perceived activation was higher when frowning than all other conditions.

Overall, smiling reduced the oxygen cost of running at a vigorous intensity by 0.94 ml/min/kg (2.78%) in comparison with frowning and by 0.76 ml/min/kg (2.23%) compared with control. A greater volume of CO_2 was also produced when frowning than smiling (0.91 ml/min/kg; 2.91%). The improved RE is toward the lower end of the 2% to 8% reported for short-term training modes (e.g., Moore, 2016) but is greater than the smallest worthwhile change for RE (2.2% to 2.6%) suggested by Saunders, Pyne, Telford, and Hawley (2004). As such, the improved RE can be considered a real and worthwhile change. Furthermore, the lower VO_2 when smiling is equivalent to the 2% to 3% improvement noted by Turner, Owings, and Schwane (2003) following six-weeks of plyometric training in distance runners, and the 1.7% to 2.1% observed by Barnes et al. (2013) after 13 weeks of heavy resistance training in male cross-country runners. Incorporating the facial feedback hypothesis (e.g., Tourangeau & Ellsworth, 1979) and embodied emotion (e.g., Niedenthal, 2007), the improved RE suggests manipulated smiling (i.e., enjoyment smiles) may prime a more relaxed emotional state. In turn, this may reduce sympathetic nervous system activity, muscle activation, and tension (e.g., Williams et al., 1991), culminating in the lower VO_2 and VCO_2 observed when smiling. Though heart rate did not differ between conditions, the order effect for block number (heart rate data only) suggests cardiovascular drift (CVD); the progressive increase in heart rate during constant workload exercise (e.g., Foss & Keteyian, 1998), may have had a greater influence on heart rate than the attentional manipulations. During running, CVD can be influenced by body temperature change (e.g., Buresh, Berg, & Noble, 2005) which may account for the heart rate data observed.

Differences in gender responses to smiling should also be noted. Of 13 male participants, 10 (76.92%) were most economical when smiling in comparison with only four of 11 females (36.36%). Previous studies have reported gender differences in perceptual responses during exercise. Most pertinently, Boutcher, Fleischer-Curtain, and Gines (1988) indicated that males reported lower effort perception in the presence of a female experimenter during cycle ergometry. Similar effects were not observed for female participants or in a same-gender experimenter condition. Boutcher et al. (1988) suggested their findings may be the result of opposite-gender concerns about self-presentation (e.g., social appropriateness, fit to the social situation) and self-image. Relevant to the present study, a male experimenter requesting female participants to smile in an unfamiliar social setting may, inadvertently, have invoked concerns over self-presentation and self-image. Although no gender differences in manipulation adherence were reported, it is possible that some females may not have produced a ‘real’ or Duchenne smile. More expressive facial expressions are known to increase the intensity of emotional responses (e.g., Davis, Senghas, & Ochsner, 2009). Accordingly, non-Duchenne or less intense smiles, concerns over self-presentation, or both, may have reduced the efficacy of smiling as a relaxation cue for some study participants.

The lack of effect for the attentional cue to relax the hands and upper-body is in line with previous findings for brief contact interventions with runners (Smith et al., 1995) and research incorporating psychological methods such as biofeedback and PMR (e.g., Hatfield et al., 1992). It may be that longer-term training is required to reduce RE using cues to relax the hands and upper-body (e.g., Caird et al., 1999), particularly for runners who are not familiar with this attentional cue. It is noteworthy, however, that many participants reported using this cue previously during normal running, and 14 of 24 participants (58.33%) reported relaxing during session one (i.e., normal thoughts). Considering this, an additional explanation may be provided by the Multi-Action Plan Model (e.g., Bortoli, Bertollo, Hanin, & Robazza, 2012). Applied to endurance activity (e.g., Bertollo et al., 2015), this model suggests that an automatic attentional focus facilitates optimal performance for well-learned actions. In contrast, excessive monitoring and an over-controlled attentional focus (i.e., reinvestment; Masters & Maxwell, 2008) may disrupt automatic skill execution when individuals attempt to consciously control task performance. As such, participants familiar with the relaxation cue may control the relaxation process relatively automatically under normal circumstances. Increased conscious monitoring and control, as indicated by one study participant, may have disturbed automated processes and reduced the efficacy of the relaxation cues as a result.

In terms of perceptual responses, the increased effort perception when frowning in comparison with both smiling and relaxing is in agreement with the findings of Philippen et al. (2012) and offers some support for the suggestion of a bidirectional relationship between frowning and perceived effort (e.g., de Morree & Marcora, 2010). However, the similarity with McCormick et al. (2016) (i.e., no difference in perceptual responses when frowning in comparison with control), and the lack of difference between frowning and control conditions in the present study is also important to note. In this regard, data on the content of participants' thoughts during each condition may also be important to consider. Specifically, distractive (e.g., daydreaming) and active self-regulatory (e.g., relaxing) cognitions are known to reduce effort perceived during endurance activity (Brick et al., 2014). They may do so by competing with sensory cues regarding informational (e.g., intensity) and emotional (e.g., negative associations) components of effort, reducing perceptual awareness of these sensations as a result (e.g., Brewer & Buman, 2006; Brick et al., 2014). The lower effort perceived when focused on pleasant thoughts (i.e., when smiling) or one's hands and upper-body (i.e., when relaxing) support this contention. In contrast, frowning, via increased muscle activation and a focus on effort-related or unpleasant thoughts (e.g., Larsen, Kasimatis, & Frey, 1992), may elevate the intensity and/or negative emotional components of effort sensations, increasing effort perception as a result. As such, differences in effort perception noted in this study may reflect both a reduction (i.e., when smiling/relaxing) and an elevation (i.e., when frowning) in perceptual awareness of effort-related sensations during running.

Despite this, and in contrast to Philippen et al. (2012), the present study did not find a difference in affective valence between any conditions. Furthermore, during all conditions (Table 2), most runners generally reported a positive affective state. However, differences in activation were noted, and activation was higher when frowning than all other conditions. Applying the circumplex model of core affect (Russell, 2003), core affect was considered low, but positive during smiling, relaxing, and control conditions. Specific emotional states associated with low positive affect include feeling calm and relaxed. The increased activation during frowning maintained a positive, but more activated affective state, one characterized by increased feelings of vigor and energy (e.g., Reed & Ones, 2006; Russell, 2003). As such, frowning may facilitate performance in some contexts by increasing activation. In support, Stanley, Lane, Devonport, and Beedie (2013) suggested that some individuals increase the intensity of emotions instrumentally – even unpleasant ones – if they are considered useful to goal attainment. Accordingly, upregulating positive activated affect before or during running (e.g., by frowning, or engaging arousing thoughts) may serve to increase vigor or effort expended on a task (de Morree & Marcora, 2010). The potentially negative impact on RE should be noted, however, and suggests that frowning should only be used as a regulatory strategy in a situationally-appropriate manner (e.g., Brick, MacIntyre & Campbell, 2015).

A number of limitations are apparent in the present study. Firstly, although participants were instructed to adopt specific facial expressions, the successful adoption of these could not be objectively ascertained. Due to constraints imposed by data collection (i.e., wearing a breathing mask), activation of the zygomaticus major and orbicularis oculi (smiling), or corrugator supercilii (frowning) muscles could not be objectively measured. Although participants' subjective reports indicated acceptable manipulation adherence in all conditions (all > 81%), future objective measurement of facial expression using facial EMG (e.g., McCormick et al., 2016) or facial feature tracking (e.g., Miles, Clark, Periard, Goecke, & Thompson, 2017) may reveal further insight into the effectiveness of smiling during endurance activity. Expression duration may also be important to consider as adherence in this study (i.e., ~80% over 6 min) indicated that prolonged smiling may be both impractical and difficult to maintain. Accordingly, periodic or occasional smiling (as opposed to continuous smiling) may be most appropriate during sustained endurance activity.

Perceptual responses during experimental tasks may also be subject to demand effects (e.g., Zizzo, 2010) and the self-report nature of the scales used (e.g., feeling scale, RPE) may exacerbate this outcome. Specifically, participants may adapt responses based on cues about what constitutes an expected response. This may be particularly relevant for the ‘face of intense effort’ instruction during frowning and subsequent responses on the RPE scale. Many precautions were taken to ensure demand effects did not occur, however. Firstly, participants were naïve to the hypotheses of the study, and were informed that all perceptual scales were routine exercise laboratory measures during session one. Furthermore, similar to Philippen et al. (2012), physiological measures were of primary interest and perceptual responses secondary from participants’ perspective. Finally, it seems plausible that participants subject to demand effects may also indicate an altered affective valence during smiling (e.g., feel *very good*) and frowning (e.g., feel *bad*). As such, no difference in affective valence between conditions suggests these responses were unlikely to be influenced by demand effects.

Based on the findings of this study, future research is required to determine the effectiveness of smiling in real-world, ecologically valid contexts, and with athletes of a higher performance (e.g., elite) standard. This may provide support for the potential performance benefits accrued by improving RE with periodic smiling. In addition, objective measurement of expression intensity may reveal further insights into the effects of ‘real’ smiling or frowning during endurance activity. Gender differences should also be explored to determine if experimenter influences, or alternative factors, account for the gender variations observed in this study. Finally, research on the effects of longer-term relaxation training, particularly with participants unfamiliar with attentional cues, may validate a focus on relaxing one’s hands and upper-body during endurance running.

This is the first study to experimentally investigate the effects of smiling, frowning, and relaxation cues on RE, heart rate, and perceptual responses during running. The novel findings suggest that smiling may improve RE and reduce effort perception during running. In contrast, frowning may increase effort perceived and activation during endurance activity. An attentional cue to relax the hands and upper-body was not more efficacious on any outcome. As such, the efficacy of smiling to improve RE and lower effort perception suggests periodic smiling may be beneficial to enhance running performance and as brief contact cue for psychological interventions (e.g., Meijen et al., 2016) with endurance participants.

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Table 1

Demographic and training characteristics of study participants

Variable	**Total (*n* = 24)**	**Men (*n* = 13)**	**Women (*n* = 11)**
Age (Years)	44.59 (10.80)	41.65 (11.62)	48.08 (9.03)
Body Mass (kg)	70.50 (13.15)	77.02 (12.01)	62.79 (10.21)
Height (M)	1.67 (0.09)	1.74 (0.06)	1.59 (0.06)
VO_{2max} (ml/min/kg)	44.81 (5.65)	47.79 (5.09)	41.28 (4.15)
vVO_{2max} (kph)	14.79 (2.00)	16.15 (1.41)	13.18 (1.25)
Heart rate max (bpm)	177.83 (11.85)	179.15 (9.59)	176.27 (14.40)
Running experience (years)	4.14 (3.01)	4.49 (3.76)	3.72 (1.90)
Running frequency (sessions/week)	3.60 (0.86)	3.54 (0.83)	3.68 (0.93)
Running volume (km/week)	39.40 (15.64)	41.42 (13.32)	37.02 (18.39)

Note. Mean values and standard deviation (*SD*) for each demographic and training characteristic

Table 2

Outcomes for primary and secondary variables during each attentional focus condition

Measure	**Smile**	**Frown**	**Relax**	**Control**	***p***	**Partial η^2**
Primary Variables						
VO_2 (ml/min/kg)	32.90 (4.05)	33.84 (3.99)	33.63 (3.89)	33.65 (4.18)	.001	0.20
Heart Rate[a] (bpm)	146.86 (14.46)	148.65 (14.41)	146.96 (16.02)	147.30 (13.84)	.231	0.06
Perceived Effort (AU)	11.25 (1.94)	12.29 (1.88)	11.38 (1.76)	11.63 (1.44)	.004	0.17
Affective Valence (AU)	2.58 (1.77)	1.96 (1.83)	2.50 (1.50)	2.54 (1.25)	.266	0.06
Activation (AU)	2.83 (0.96)	3.63 (1.13)	2.96 (1.12)	2.94 (1.20)	.001	0.24
Manipulation Check (%)	82.08 (16.41)	85.42 (13.51)	87.08 (8.59)	81.25 (16.50)	.312	0.05
Secondary Variables						
VCO_2 (ml/min/kg)	31.16 (4.22)	32.07 (4.40)	31.58 (4.07)	31.73 (4.49)	.025	0.14
Respiratory Frequency (bpm)	38.80 (7.39)	38.55 (9.40)	36.58 (7.57)	36.62 (8.36)	.079	0.10
Tidal Volume (L)	1.75 (0.45)	1.83 (0.52)	1.84 (0.50)	1.86 (0.55)	.083	0.10
Minute Ventilation (L/min)	65.64 (13.35)	67.16 (13.02)	64.95 (12.82)	65.02 (13.30)	.047	0.11
Respiratory Quotient (AU)	0.95 (0.04)	0.95 (0.05)	0.94 (0.04)	0.94 (0.04)	.298	0.05

Note. Mean values and standard deviation (*SD*) for physiological data from the last 3 min of each 6 min block.
p-values and effect sizes (partial η^2) based on repeated measures ANOVA between conditions.
[a] Heart rate data from 23 participants only.
AU: Arbitrary Units

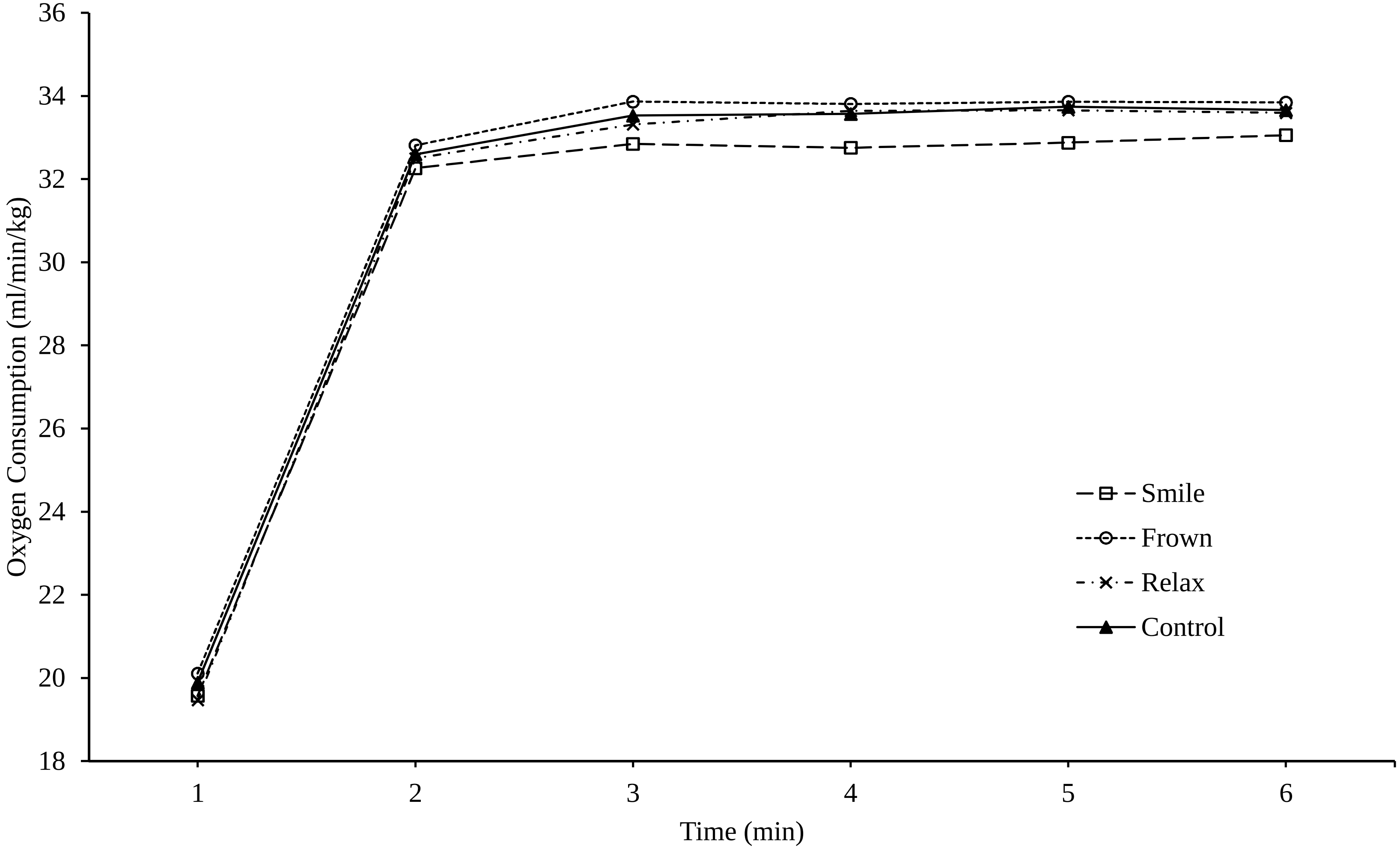

Fig. 1. Course of oxygen consumption for each condition (data represents mean value for each minute). Mean steady-state data inclusive of minutes 4 – 6 were included in the statistical analyses.

Highlights

Investigated the effects of smiling, frowning, and relaxation during running

Outcome measures included running economy, perceived effort, and affective state

Smiling improved running economy in comparison with frowning and a control trial

Perceived effort was higher when frowning in comparison with smiling and relaxing

Periodic smiling may be an effective attentional cue to enhance running performance