The Journal of Sport and Exercise Science, Vol. 7, Issue 3, 1-9 (2023)

www.jses.net

JSES

ISSN: 2703-240X

No effect of facial expression on running economy in collegiate soccer players

Brian C. Rider[1*], Grace L. Ditzenberger[1], Haven L. Westra[2], Thomas J. Sprys-Tellner[1], Brooke T. Hedglen[1], Alexander H.K. Montoye[2]

[1]*Department of Kinesiology, Hope College, USA*
[2]*Department of Integrative Physiology and Health Science, Alma College, USA*

A R T I C L E I N F O

Received: 02.08.2022
Accepted: 12.10.2022
Online: 27.10.2023

Keywords:
Smile
Affect
Ergogenic aid

A B S T R A C T

The facial feedback hypothesis (FFH) states that activation of facial muscles (i.e., smiling and frowning) can elicit emotional experiences within an individual. A positive emotional experience could result in a more "relaxed state" and result in improved running economy (RE). The purpose of this study was to determine if smiling while running would lead to an improvement in RE among a group of collegiate soccer players. Twenty-four Division III collegiate soccer players (females n = 14, males n = 10) completed four, six-minute running blocks at 70% of velocity at VO_2 max. The order of bouts was randomised with participants serving as their own controls. Participants completed running blocks while smiling (Smile), frowning (Frown), consciously relaxing their hands and upper bodies (Relax), and running as they "normally" would (Control). Each block was separated by two minutes of passive rest. Cardiorespiratory responses were recorded continuously, and participants reported perceived exertion (RPE) after each condition. A repeated measures analysis of variance (ANOVA) was run on all primary variables with a significance level set a priori at 0.05. There were no significant differences in RE across conditions ($p > 0.05$; Smile: mean = 33.7 $mL\cdot kg^{-1}\cdot min^{-1}$, SD = 4.4; Frown: mean = 34.2 $mL\cdot kg^{-1}\cdot min^{-1}$, SD = 4.1; Relax: mean = 34.2 $mL\cdot kg^{-1}\cdot min^{-1}$, SD = 4.1; Control: mean = 34.2 $mL\cdot kg^{-1}\cdot min^{-1}$, SD = 3.9). Our findings suggest smiling does not significantly improve RE among a group of collegiate soccer players. Further studies should examine this topic in other athlete groups and at various running intensities.

1. Introduction

Running economy (RE) is a multifaceted concept that is impacted by numerous physiological and biomechanical variables (Barnes & Kilding, 2015b). It is most commonly expressed as an individual's steady-state oxygen consumption while running at a submaximal speed (Barnes & Kilding, 2015b; Saunders et al., 2004). Runners with a high RE utilise less oxygen and thus require less energy to maintain a given pace. As such, RE is frequently cited as a stronger determinant of running performance than maximal oxygen consumption (VO_2 max; Saunders et al., 2004). Additionally, RE can account for the difference observed in elite endurance athletes' performance with otherwise similar VO_2 max values, with some studies indicating a difference in RE between

[*]Corresponding Author: Brian Rider, Department of Kinesiology, Hope College, USA, rider@hope.edu

runners of up to 30% (Conley & Krahenbuhl, 1980; Daniels, 1985). Because of its importance in race performance, training methods to improve RE have been widely researched in the fields of sport and exercise science (Barnes & Kilding, 2015a, 2015b).

Training to improve RE frequently focuses on altering runners' biomechanics. Spatiotemporal modifications (e.g., minimising vertical oscillations and self-selecting stride length; Cavanagh & Williams, 1982), kinetic and kinematic factors (e.g., leg stiffness and alignment of ground reaction forces, leg axis, stride angle, arm swing; Kerdok et al., 2002; Morin et al., 2007), and neuromuscular factors (e.g., muscle activation during propulsion, agonist–antagonist coactivation; Kyröläinen et al., 2001) are variables which can be modified to improve RE. Additionally, improving leg strength (via resistance and plyometric training) can reduce the amount of work a runner needs to maintain a submaximal speed, resulting in an improved RE (Barnes & Kilding, 2015a).

Previous research has also demonstrated the efficacy of psychological strategies for enhancing RE. Hill et al. (2020) examined the effect of mindfulness training on 31 moderately trained runners. Running economy was significantly improved among the experimental group who completed an eight-week mindfulness training program. Psychological strategies to improve RE often focus on inducing a "relaxed state" while running. Such a "relaxed state" may improve RE by reducing the runner's overall effort and subsequently the body's oxygen demand. As such, techniques that can induce this "relaxed" (i.e., parasympathetic) response among participants during running have shown positive associations between a relaxed state and improved RE (Hatfield et al., 1992; Smith et al., 1995; Williams et al., 1991). Smith et al. (1995) assessed the RE of 36 trained runners and found the most economical runners relied more heavily on relaxation techniques compared to the least economical runners. Moreover, Caird et al. (1999) enrolled seven trained runners into a 6-week intervention that combined both biofeedback instruction and relaxation techniques. The authors discovered that the runners were 7.3% more economical following the intervention when utilizing these strategies.

An intriguing study by Brick et al. (2018) investigated a novel, simple strategy to improve RE that required no equipment or week-long training programs. The authors examined whether creating different facial expressions while running could affect RE. The authors recruited 24 recreational runners (mean VO_2 max = 44.8 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$, SD = 5.7) who completed a treadmill run at 70% of velocity at VO_2 max. During four separate six-minute stages, participants were instructed to either "smile," "frown," use a relaxation technique involving their thumb and pointer finger (relax), or run "normally" (control). The authors hypothesised that smiling would improve the runners' economy, a belief grounded in the *facial feedback hypothesis* (FFH) which states that activation of facial muscles (i.e., smiling and frowning) can elicit emotional experiences within the individual (Tourangeau & Ellsworth, 1979). Brick et al. (2018) found that smiling improved the runners' RE by approximately 2.8% when compared to a frowning (Cohen's d = -0.23) and control condition (Cohen's d = -0.19). There was no difference when smiling was compared to a relaxed condition, in which participants were instructed to act as if they were carrying a potato chip between their finger and thumb. Additionally, perceived exertion (RPE) was greater when participants were instructed to frown (mean = 12.29, SD = 1.88) while running compared to both smiling (mean = 11.25, SD = 1.94) and relaxing (mean = 11.38, SD = 1.76) conditions. The authors hypothesised that smiling stimulated the "relaxed emotional state" within the runners, leading to lowered sympathetic activation and muscle tension and thus resulting in reduced VO_2 among the runners.

The FFH, a well-known theory in psychology, postulates that facial movements can provide sensorimotor feedback that can elicit an emotional response (Tourangeau & Ellsworth, 1979). This is incorporated into the larger theoretical concept of "embodied cognition." Embodied cognition asserts that the mind and body influence one another and that an individual's emotions are closely related and are, in fact, often *affected* by physical movement, manipulation and expression (Glenberg, 2010; Shapiro, 2014). This body-mind relationship has been demonstrated in subsequent work (Chang et al., 2014; Strack et al., 1988) and suggests that both smiling and frowning could directly affect how the body responds to an exercise bout. Whereas smiling has the potential to positively impact affective response and emotional state (and thus RE), frowning could result in the opposite effect (Coles et al., 2019). However, influencing one's emotional state via manipulation of facial muscles leading to a subsequent improvement in RE, though theoretically sound, (Coles et al., 2019), requires additional research. Despite their novelty, the findings of Brick et al. (2018) have not, to our knowledge, been reproduced. In light of the current "replication crisis" in both natural and social sciences, it is essential to examine if previous results can apply to a variety of populations to ensure the robustness of scientific findings (Aarts et al., 2015; Baker, 2015). With a clearer understanding of the impact facial expressions may have on RE, then coaches and athletes of various sports can determine whether to utilise this technique in their training.

Therefore, the purpose of this study was to determine the generalisability of the findings of Brick et al. (2018) via examining the effect of smiling on RE in a group of non-recreational runners. Additionally, we aimed to address some of the self-reported limitations in Brick et al. (2018). Specifically, we included the measurement of blood lactate (BLa) during each stage in an effort to elucidate a potential physiological mechanism to explain the potential benefit of smiling on RE. We also matched the sex of participant and the research staff administering the cues to mitigate any confounding influences on self-report measures due to researcher-participant interactions. Lastly, we chose soccer players because of their similar aerobic fitness levels to recreational runners in the previous study (Brick et al., 2018), their reliance on and familiarity with running as a training/conditioning tool, and our desire to determine whether smiling's effect on RE was transferable across different athlete populations and age groups. Based on the findings of Brick et al. (2018), we hypothesised that the smiling condition would result in a modest improvement in RE when compared to the frowning and control conditions.

2. Methods

The current study employed a repeated-measures design that consisted of two sessions. Sessions were completed at the same time of day (± two hours) and separated by 3 – 10 days to minimise effects of circadian patterns or risk of residual fatigue, respectively. Participants were instructed to refrain from caffeine and food two hours prior to testing and strenuous exercise 24 hours prior to testing. Session one consisted of an incremental, treadmill-based VO_2 max test, which was used to determine each participant's running speed during session two. Demographic measurements were also recorded during session one. Session two consisted of four, six-minute running blocks during which three separate relaxation-cues and one control block were administered. Each block was separated by two minutes of passive rest. The order in which the cues were administered ("smiling", "frowning", "conscious relaxation", "control") was balanced using a Latin square design with each participant serving as his or her own control.

2.1. Participants

Twenty-four Division III collegiate soccer players (females n = 14, males n = 10) participated in this study. All participants reported no underlying medical conditions and were accustomed to treadmill running. Participants completed a health history questionnaire (Bredin et al., 2013) and were briefed on all experimental procedures and possible study risks before providing written informed consent. At no point were the participants informed as to the previous study's hypothesis or results (Brick et al., 2018). The study was approved by the college's Human Subjects Review Board Committee and adhered to the ethical standards of the Helsinki Declaration. The sample size was identical to that of Brick et al. (2018), who established the sample size based on a moderate effect size (f = 0.25), with a power of 0.80, an alpha level of 0.05, a modest correlation between repeated measures (r = 0.50), and four conditions.

2.2. Apparatus

Height was assessed to the nearest 0.1 centimeter using a wall stadiometer (Detecto, Webb City, MO). Weight and body composition were assessed via bioelectrical impedance using a Tanita Body Composition Analyzer (Tanita BF-350, Arlington Heights, IL). Resting blood pressure (BP) was measured manually via a standard adult cuff sphygmomanometer and stethoscope. Resting heart rate (HR) was measured via manual palpation of the radial artery. Blood lactate (BLa) was taken using Standard Universal Precautions and a Lactate Plus Analyzer (Nova Biomedical, Walthman MA, USA). Respiratory variables (VO_2 max, maximal carbon dioxide production [VCO_2], respiratory frequency, tidal volume, minute ventilation [VE], and respiratory exchange ratio [RER, ratio of VCO_2:VO_2]) were measured using the TrueOne 2400 Parvo Medics metabolic cart (Parvo Medics; Salt Lake City, UT) throughout both exercise tests. A Hans Rudolph (Shawness, KS) mask which fully covered the nose and mouth was used to allow participants to create the required facial expressions. Heart rate was assessed continuously using the Polar RS400 (Polar Electro Oy, Kempele, Finland) chest strap monitor, which was fitted just below the xiphoid process of the sternum.

Immediately following the completion of each running block, participants were asked to rate their perceived effort using the Borg Rating of Perceived Exertion (RPE) scale (Borg, 1982). As a recalled in-task measure of affective valence, participants were asked to report how good or bad they felt during each block using Hardy and Rejeski 11-point Feeling Scale (FS; Hardy & Rejeski, 1989). For perceived activation (a.k.a. arousal), participants were asked to report how aroused or 'worked up' they felt during the block of running using the six-point Felt Arousal Scale (FAS; Svebak & Murgatroyd, 1985). Each scale was presented to the participant from a researcher of the same sex. For a measure of focus on each cue provided, participants reported their attentional focus during the block on a Likert-type scale with verbal anchors 0 (none of the time), +5 (half of the time), and +10 (all of the time) (Brick et al., 2018).

2.3. Procedure

Session one. The participant's height, weight, body composition, resting heart rate, and resting blood pressure were measured. The scales used for assessing RPE, affective valence (FS), arousal (FAS), and attentional focus (AF) were explained prior to exercise testing. The participants completed a VO_2 max test to volitional exhaustion on a treadmill with continuous measurement of respiratory gas exchange using a metabolic cart. The test consisted of two-minute stages with a 1.9 km/h increment increase after each of the first three stages, followed by an increase of 0.96 km/h increments to volitional exhaustion. The final stage in which participants completed at least one minute was considered their maximal speed achieved during the test. Participants began the test at a self-reported "comfortable pace." Successful achievement of $\dot{V}O_2$ max was based on achieving a plateau in VO_2 (the final two stages of the test were within 2.0 $mL \cdot kg^{-1} \cdot min^{-1}$). Absent an observable plateau, $\dot{V}O_2$ max was based on the following two criteria: HR within 10 beats of age-predicted max (220 – age) and respiratory exchange ratio (RER) $\geq$ 1.10 (Balady et al., 2010). The treadmill incline was maintained at 0% throughout the test. During the last 30 seconds in each of the first three stages, participants were asked to report their RPE, affective valence (FS), and arousal (FAS), familiarizing them with the scales prior to session two. Following the VO_2 max test, the participants were asked to recount their attentional focus (AF) during the first 3 stages of the test to record their "normal" thoughts during treadmill running in a laboratory environment. Thoughts were categorised into the previous study's attentional focus categories of active self-regulation, involuntary distraction, internal sensory monitoring and active distraction (Brick et al., 2018). The participant's speed for session two was determined by calculating 70% of the final speed at which the participant reached their VO_2 max, which we hereafter denote as 70% of velocity at VO_2 max.

Session two. Participants warmed up by completing three minutes at 50% of the speed of their maximal speed on the VO_2 max test followed by two minutes at 70% of velocity at VO_2 max. Following the five-minute warm-up, participants had two minutes of passive rest and began the six-minute running blocks performed at 70% of velocity at VO_2 max at 0% grade. Each six-minute block was separated with a two-minute passive rest interval. Instructions were read by an investigator, of the same sex as the participant, from a script during the two-minute passive rest intervals and a reminder statement of the given cue was read to the participant at the end of each minute during the six-minute running block. Participants were asked to hold the attentional cue for as much of the six-minute running block as possible.

2.4. Facial expression cues

The attentional cues were read from a script taken directly from Brick et al. (2018). Prior to the smiling condition, participants were instructed: "For this running block, please focus 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."

Prior to the frowning condition, participants were instructed: "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."

For the conscious relaxation condition, the following instructions were read to the participants prior to running: "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."

Participants received the following instructions prior to the control condition: "For this running block, please focus on those thoughts you would normally focus on during running. For example, during your VO_2 max test you said you focused on (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 final sentence of each instruction was read to the participants after every minute of the running condition by the same investigator of the same sex (Brick et al., 2018). Immediately following each block, affective measures (RPE, FS, and FAS) were taken. Then, as a manipulation check, participants reported how long they were able to maintain each facial expression/attentional cue. They responded to a Likert-type scale from 0 – 10 with zero meaning "none of the time", 5 meaning "half of the time", and 10 meaning "all of the time." This scale was adopted directly from Brick et al. (2018). The same male and female investigator who delivered the instructions prior to each running block administered the affective measure scales and conducted the post session interview. This was done in an effort to ensure consistency in approach by the research team (the same female investigator was responsible for the female participants and the male investigator male participants).

Next, BLa was measured within 30 seconds of the completion of the stage via finger stick. The tip of the index finger of one hand was first sterilised with a 70% isopropyl alcohol prep pad (Medline Industries, Inc., Mundelein, IL). The finger was then lanced and approximately 0.5 – 0.7 μl of blood was applied to the edge of the test strip where it was analyzed Lactate Plus Analyzer (Nova Biomedical, Walthman MA, USA).

Lastly, the cue instructions for the upcoming stage were read during the final minute of the rest interval. Upon completion of session two, participants were asked to recount their specific thoughts during each of the four running blocks. These thoughts were further categorised into the attentional focus categories. Following the completion of this session, participants were informed of the study purpose and hypothesis.

2.5. Data analysis

Physiologic data (relative and absolute VO_2, VCO_2, respiratory frequency, tidal volume, VE, RER, HR) from minutes 4 – 6 of each six-minute block were extracted and averaged to ensure steady-state values. All variables of interest (relative and absolute VO_2, VCO_2, respiratory frequency, tidal volume, VE, RER, HR, BLa, RPE, FS, FAS, and AF) were compared across the four conditions (Smile, Frown, Relax, Control) using repeated-measures analysis of variance and a p-value of $p \leq 0.05$ to indicate statistical significance. In the case of a significant F-statistic, post hoc analyses were conducted with Holm-Bonferroni sequential p-value adjustment (Holm, 1979). Additionally, Cohen's d effect sizes were calculated for between-group comparisons to understand the magnitude of differences among groups, and were interpreted as minimal (< 0.20), small (0.20 – 0.49), medium (0.50 – 0.79), large (≥ 0.80; Cohen, 1992). All analyses were conducted in SPSS version 24.0 (IBM Corp., Armonk, NY).

3. Results

Participant demographics can be found in Table 1. The sample had above average fitness, with mean VO_2 max values in the 75th percentile for women and the 70th percentile for men; body composition values were similar, with mean body fat percentage in the 50th percentile for women and 65th percentile for men (Kaminsky et al., 2015).

Table 1: Demographics of study participants.

Variables	Total n = 24	Females n = 14	Males n = 10
Age (years)	20.0 (1.0)	20.4 (1.1)	20.5 (0.9)
Body mass (kg)	70.3 (10.4)	65.4 (6.7)	77.0 (11.1)
Height (cm)	173.5 (9.0)	168.4 (6.6)	180.7 (6.8)
Body composition (%fat)	20.0 (4.2)	22.0 (3.1)	13.2 (4.1)
VO_2 max ($mL \cdot kg^{-1} \cdot min^{-1}$)	48.4 (6.6)	44.6 (4.7)	53.8 (5.1)

Note: All data are presented as means (standard deviation).

While statistical analyses on the minute-by-minute VO_2 kinetics within each stage were performed, we developed Figure 1 for visualization of minute-by-minute relative VO_2 across all four attentional cue conditions. Mean steady-state relative VO_2 in minutes 4 – 6 was similar across the four conditions indicating no differences in RE across groups, $F(3, 69) = 0.935$, $p = 0.429$.

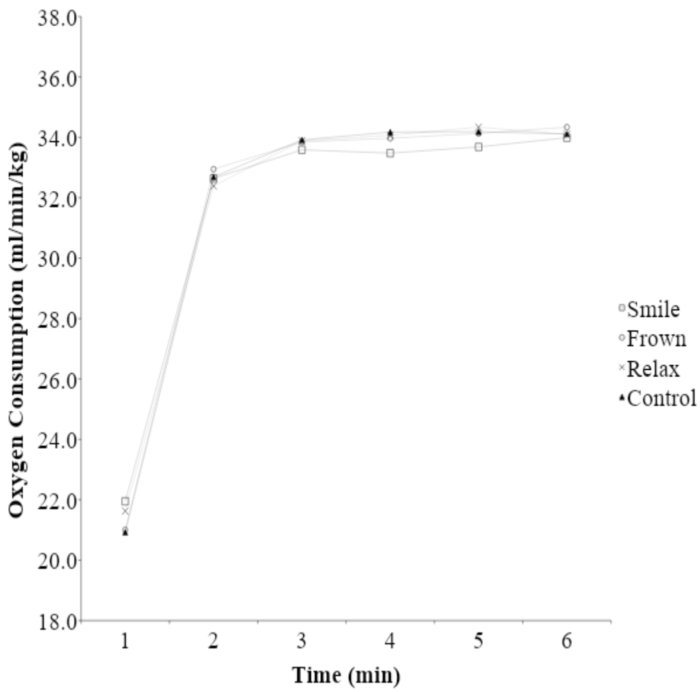

Figure 1: Oxygen consumption for each condition (data represent mean values for each minute). Mean steady-state data for minutes 4 – 6 of each stage were included in the statistical analyses. No significant differences were observed between conditions.

Table 2 presents an overall comparison of physiologic and psychological data across the four attentional focus conditions. The ANOVA test statistic was significant for relative VCO_2, $F(3, 69) = 3.232$, p = 0.028, but post hoc analyses revealed no pairwise differences across conditions (p's > 0.05). Conversely, no differences across conditions were found for respiratory frequency, $F(3, 69) = 1.335$, $p = 0.270$; tidal volume, $F(3, 69) = 2.233$, $p = 0.092$; VE, $F(3, 69) = 0.224$, $p = 0.879$; RER, $F(3, 69) = 1.528$, $p = 0.215$; HR, $F(3, 69) = 0.264$, $p = 0.851$; BLa, $F(3, 69) = 0.219$, $p = 0.883$; RPE, $F(3, 69) = 0.463$, $p = 0.709$; FS, $F(3, 69) = 0.934$, $p = 0.429$; FAS, $F(3, 69) = 0.740$, $p = 0.532$; or AF, $F(3, 69) = 0.527$, $p = 0.665$.

The effect sizes (Table 3) were all small or minimal, indicating little clinical difference among any of the conditions for any of the variables. The manipulation check test revealed that participants reported maintaining a smile for 67.1% of that running block. While this point estimate was lower than adherence to the other conditions (Frown 72.9%, Relaxed 70.4%, Control 70.8%), there were no significant differences between conditions in instructional adherence, $F(3, 69) = 0.527$, $p = 0.665$. The post-session interviews provided insight into the attentional focus of the participants during each running block.

During the smile condition block, 10 participants (42%) focused on "happy thoughts." Of these, three (30%) were most economical when smiling. Eight participants (33%) reported focusing on making a smile with their face and of those only three (38%) were most economical in this condition. Four participants (17%) reported being distracted by their mask and of those, one participant (25%) was equally economical during this condition and also during the frowning condition. One (25%) participant focused on "school work" they had yet to complete and was most economical during this condition. One (25%) participant focused on their breathing during the smiling condition, but this was not their most economical running block.

When frowning, 12 participants (50%) reported focusing on "making their face frown." Yet, only two (16%) were most economical during this condition. Six participants (25%) focused on negative and unpleasant thoughts (people they don't like, bad memories), but only one (16%) was most economical doing this. Of the five runners who were not most economical while frowning, one reported thinking of their summer plans, another said they were "relaxed" when frowning, another reported being unsure how to frown, and the final two focused on creating a frowning expression with their face (80% and 100% adherence).

Table 2: Outcomes for variables during each condition.

Measures	Smile	Frown	Relax	Control
Relative VO_2 ($mL{\cdot}kg^{-1}{\cdot}min^{-1}$)	33.72 (4.04)	34.15 (4.08)	34.17 (4.11)	34.16 (3.91)
VCO_2 ($mL{\cdot}kg^{-1}{\cdot}min^{-1}$)	31.40 (4.29)	31.93 (4.25)	32.01 (4.17)	32.12 (4.11)
Respiratory frequency (breaths/min)	42.17 (6.96)	40.61 (6.88)	40.85 (6.88)	40.31 (6.44)
Tidal volume (L/breath)	1.65 (0.34)	1.69 (0.39)	1.69 (0.38)	1.76 (0.41)
Minute ventilation (VE, L/min)	67.55 (16.26)	67.01 (16.19)	67.59 (15.96)	67.82 (15.40)
Respiratory exchange ratio (RER)	0.93 (0.04)	0.94 (0.05)	0.94 (0.05)	0.94 (0.05)
Heart rate (HR, bpm)	166.04 (15.35)	165.96 (14.65)	165. 25 (15.33)	166.21 (14.36)
Blood lactate (BLa, mmol/L)	1.91 (1.18)	1.85 (1.11)	1.90 (1.12)	1.84 (1.17)
Rating of perceived exertion (RPE)	11.71 (2.56)	11.83 (1.97)	11.58 (2.36)	11.46 (2.02)
Affective valence (FS)	1.75 (1.87)	1.29 (1.60)	1.63 (1.91)	1.75 (1.62)
Arousal (FAS)	2.67 (1.20)	2.71 (1.30)	2.50 (1.35)	2.50 (1.25)
Manipulation check (%)	67.10 (22.70)	72.90 (19.90)	70.40 (20.70)	70.80 (22.40)

Note: All data are presented as means (standard deviation).

Table 3: Effect sizes for all participants during each condition.

Measures	SvF	SvR	SvC	FvR	FvC	RvC
Relative VO_2 ($mL{\cdot}kg^{-1}{\cdot}min^{-1}$)	0.11	0.11	0.11	0.01	0.00	0.00
VCO_2 ($mL{\cdot}kg^{-1}{\cdot}min^{-1}$)	0.13	0.14	0.17	0.02	0.05	0.03
Respiratory frequency (breaths/min)	0.23	0.20	0.28	0.04	0.05	0.09
Tidal volume (L/breath)	0.12	0.12	0.21	0.01	0.08	0.09
Minute ventilation (VE, L/min)	0.03	0.00	0.02	0.04	0.05	0.01
Respiratory exchange ratio (RER)	0.10	0.15	0.22	0.04	0.10	0.07
Heart rate (HR, bpm)	0.01	0.05	0.01	0.05	0.02	0.07
Blood lactate (BLa, mmol/L)	0.06	0.02	0.06	0.05	0.01	0.05
Rating of perceived exertion (RPE)	0.06	0.05	0.11	0.12	0.19	0.06
Affective valence (FS)	0.26	0.07	0.00	0.19	0.29	0.07
Arousal (FAS)	0.03	0.13	0.14	0.16	0.16	0.00
Manipulation check (%)	0.27	0.15	0.17	0.12	0.10	0.02

Note: Smile vs. Frown (SvF), Smile vs. Relax (SvR), Smile vs. Control (SvC), Frown vs. Relax (FvR), Frown vs. Control (FvC), Relax vs. Control (RvC).

Of the six participants (25%) who were most economical during the relax condition, four (66%) focused on their hands and/or upper body being “relaxed” during the running block. Of the remaining two participants (33%) who were most economical during this block, one (17%) reported focusing on breathing and the other reported emptying their mind and thinking about “nothing.” Lastly, during the control condition, seven participants (29%) focused on their breathing. Of these, four (57%) were the most economical during this period. Six (25%) reported singing songs in their head or planning out the rest of their schedule for the day, but none of them were most economical during this period.

4. Discussion

The null hypothesis was retained as the results were unable to demonstrate improvements in RE across facial conditions, thus failing to reproduce the results of Brick et al. (2018) within a group of collegiate soccer players. Additionally, all effect sizes were small or minimal, indicating a weak, if any, relationship of our measured variables with facial expression.

Our study closely replicated the methods used by Brick et al. (2018) yet also sought to address several of the self-reported limitations. Notably, we added BLa measures in each of the conditions. If BLa had demonstrated a delayed or minimised increase from the baseline measurement, it may have served as a potential physiologic mechanism explaining why smiling improved RE. Specifically, a reduction in BLa during a given running condition would suggest that the physiological demand of the running bout was lower and the participant experienced a less intense and more aerobic running bout. However, BLa variables were unchanged across facial expression conditions. This along with no significant differences in other relevant markers (HR and RPE) across conditions suggests that the facial expression did not induce a “relaxed state” among our participants. Our study also purposely matched the sex of participant and the research staff providing the cues. This change acted to mitigate any confounding influences on self-report measures due to researcher-participant interactions.

One theory to explain the findings by Brick et al. (2018) is that focusing on creating and maintaining facial expressions distracts from the running task. In other words, the facial expression itself may not have mattered as much as focusing on creating the facial expression. These types of attentional cues can provide a distraction from an unpleasant activity and have been shown to improve affective valence and lower RPE (Philippen et al., 2012), whereas attentional cues that bring focus to the activity (e.g., “lengthen your stride”, “relax your arms”) results in poorer RE (Hill et al., 2019; Schücker & Parrington, 2019). In the previous study by Brick et al. (2018), five runners reported focusing solely on smiling and, of those five, only three were the most economical while smiling; in contrast, 17 participants reported focusing on pleasant thoughts (active/involuntary distraction) and, of those, 11 were most economical. In the current study, participants’ focus ranged across all attentional cues, without any apparent relationship between the reported attentional cues and RE across conditions. There was also no clear trend of the influence of participants’ focus on RE, so this study does not provide group- or individual-level evidence of how focus on certain attentional cues may affect RE.

Another possibility is the differences among our participants’ self-reported ability to focus on the cue (see *manipulation check* Table 2). To determine how reliably the participants were creating the facial cue, following the treadmill test participants were asked to report how focused they were during each stage. Brick et al. (2018) participants reported being able to focus on the facial cue 82% – 85% of the time whereas our participants reported focusing for 67% – 72% of the running bout. This difference in attentional focus between study participants could possibly explain the difference in RE. Perhaps maintaining a smile for 80% of a running bout (or longer) is necessary to see an improvement in RE. However, as a practical matter, encouraging runners to “smile” for a long period of time (nearly the entirety of a race that could be far longer than six minutes) regardless of any potential change to RE, appears impractical. Brick et al. (2018) admits this, stating that "…periodic or occasional smiling (as opposed to continuous smiling) may be most appropriate during sustained endurance activity" (p. 18).

An important difference between participants' perception of running could explain our lack of significant findings. Theoretically, people will engage in activity they find pleasurable and avoid those they find unpleasurable (Higgins, 2006). Hedonic motivation theory holds that the more enjoyable an exercise task is, the more positively mood is impacted post-exercise (Raedeke, 2007). While we did not directly assess weekly running volume or motivation for running, it is reasonable to think that the participants in the previous study likely had both higher running volumes and more positive experience in running than our soccer players. Brick et al. (2018) participants reported running on average 39.4 ± 15.6 km/week. The soccer coaches estimated our players were only running an average of 16.1 – 32.2 km/week as part of their normal off-season conditioning. Feeling Scale (FS) scores demonstrate a difference in positive affect. Indeed, when examining recalled in-task affective valence between the two groups, Brick et al. (2018) participants reported greater FS scores compared to ours (Smile: 2.58 ± 1.77 vs. 1.75 ± 1.87; Frown: 1.96 ± 1.83 vs. 1.29 ± 1.60; Relax: 2.50 ± 1.50 vs. 1.63 ± 1.91; Control: 2.54 ± 1.25 vs. 1.75 ± 1.62). Even a small difference in FS scores may result in differences in affect and the standard deviations do not suggest a greater variability in our participants' scores compared to those in the previous study (Brick et al., 2018). These FS scores speak to "experiential differences" and so it would appear as though the effect of smiling on how the previous study's participants "experienced" running was more positive compared to our soccer players (Hogg et al., 2010). Williams et al. (1991) found that among a group of trained male runners, a correlation existed between lower reported negative affect and improved RE. Therefore, perhaps the participants who already had a greater affinity towards running (recreational runners) would more likely be impacted by smiling while running. The reported affective valence scores reflect a more positive experience among the previous study's runners compared to our participants, suggesting that despite the running test being a similar experience *physiologically*, emotionally the pleasant vs. unpleasant nature of the task was different, potentially contributing to the difference in findings between studies (Brick et al., 2018). This is supported by some past literature that has found a relationship between positive affect and endurance performance (Blanchfield et al., 2014; Philippen et al., 2012).

Future studies should examine more practical applications of this technique. For example, field testing where running performance (time) is measured in place of RE would more directly assess the practical application of smiling or other facial expressions while running. Also, designing a protocol using electromyography (EMG) to measure changes in muscle activation when smiling and frowning could elucidate possible physiological causes behind any differences in RE. It is worth noting the possibility that smiling will not positively affect RE in someone who doesn't already have a positive perception of running or whose training is not focused on improving running performance. Soccer performance relies on fine motor skills developed over time (passing, dribbling, shooting) and is unlikely to be significantly impacted by improvements in a player's RE. Though improvements in RE could indirectly affect soccer performance (improved training and conditioning) any direct impact on soccer performance is unlikely. Therefore, coaches, trainers, and players may need to be considered when evaluating the RE results and if they are important for that sport's performance.

While our study did build upon previous research (Brick et al., 2018) and closely followed their protocol notable limitations to our study exist. First, the sample size did not allow for robust sub-analyses by age or training status, which may have impacted results. Additionally, only one running intensity was chosen, so it is unclear if facial expression may affect RE at higher or lower running intensities. An additional limitation was the inability of the investigators to directly observe whether participants were compliant with the instructions during each facial condition. The manipulation check was meant to account for this, however due to the use of a facemask to collect expired gases, it was not possible to know for certain the duration that participants spent modulating their face into a smile or frown during each condition. Yet, it is important to note that the ability to accurately capture EMG while wearing the sensors under the mask necessary to obtain inspired/expired gasses would prove challenging. Likely, any amount of noise the mask would add to the EMG recording would render the data difficult to interpret. Lastly, an important point to consider is that we did not account for participants' emotional status prior to testing. High levels of stress or emotional distress could have influenced the participants' response to the facial expression manipulation. Though we aimed to mimic their study design, not accounting for emotional state prior to testing precluded us from using this as a potential explanation for our disparate findings.

The theory that a more relaxed runner will have an economical advantage has experimental support. The established training methods to improve RE require considerable time and consistent application by the athlete. Thus, new techniques/tools that require less effort, time, and cost are of interest to coaches and runners. The concept of modifying one's facial expression during a run to improve RE is enticing due to its simplicity and is not easily dismissed because of its grounding in previously established psychological principles (i.e., FFH) and the findings of Brick et al. (2018). However, our results do not support the theory that smiling during a submaximal running bout will necessarily induce a relaxed state nor improve physiologic measures among collegiate soccer players. Nevertheless, that does not mean it could not still be beneficial for the type of recreational running population that Brick et al. (2018) studied. Therefore, relying on smiling to improve RE should be considered cautiously until future studies can affirm if, when, and in whom it may be most effective.

Conflict of Interest

The authors declare no conflict of interests.

Acknowledgment

We wish to thank our participants who gave their time and energy to make this study possible. We also would like to thank Dr. Kelley Strohacker (University of Tennessee) and Dr. Scott Conger (Boise State University) for assistance in manuscript review prior to final submission.

References

Aarts, A. A., Anderson, J. E., Anderson, C. J., Attridge, P. R., Attwood, A., Axt, J., et al. (2015). Estimating the reproducibility of psychological science. *Science, 349*(6251), 1–7. https://doi.org/10.1126/science.aac4716

Baker, M. (2015). Reproducibility crisis: Blame it on the antibodies. *Nature*, *521*(7552), 274–276. https://doi.org/10.1038/521274a

Balady, G. J., Arena, R., Sietsema, K., Myers, J., Coke, L., Fletcher, G. F., Forman, D., Franklin, B., Guazzi, M., Gulati, M., Keteyian, S. J., Lavie, C. J., Macko, R., Mancini, D., & Milani, R. V. (2010). Clinician's guide to cardiopulmonary exercise testing in adults. *Circulation*, *122*(2), 191–225. https://doi.org/10.1161/CIR.0b013e3181e52e69

Barnes, K. R., & Kilding, A. E. (2015a). Strategies to improve running economy. *Sports Medicine*, *45*(1), 37–56. https://doi.org/10.1007/s40279-014-0246-y

Barnes, K. R., & Kilding, A. E. (2015b). Running economy: Measurement, norms, and determining factors. *Sports Medicine – Open*, *1*, 1–15. https://doi.org/10.1186/s40798-015-0007-y

Blanchfield, A., Hardy, J., & Marcora, S. (2014). Non-conscious visual cues related to affect and action alter perception of effort and endurance performance. *Frontiers in Human Neuroscience*, *8*, 1–16. https://doi.org/10.3389/fnhum.2014.00967

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise*, *14*(5), 377–381.

Brick, N., McElhinney, M., & Metcalfe, R. (2018). The effects of facial expression and relaxation cues on movement economy, physiological, and perceptual responses during running. *Psychology of Sport and Exercise*, *34*, 20–28. https://doi.org/10.1016/j.psychsport.2017.09.009

Caird, S. J., McKenzie, A. D., & Sleivert, G. G. (1999). Biofeedback and relaxation techniques improves running economy in sub-elite long distance runners. *Medicine and Science in Sports and Exercise*, *31*(5), 717–722. https://doi.org/10.1097/00005768-199905000-00015

Cavanagh, P. R., & Williams, K. R. (1982). The effect of stride length variation on oxygen uptake during distance running. *Medicine and Science in Sports and Exercise*, *14*(1), 30–35. https://doi.org/10.1249/00005768-198201000-00006

Chang, J., Zhang, M., Hitchman, G., Qiu, J., & Liu, Y. (2014). When you smile, you become happy: Evidence from resting state task-based fMRI. *Biological Psychology*, *103*, 100–106. https://doi.org/10.1016/j.biopsycho.2014.08.003

Cohen, J. (1992). Statistical Power Analysis. *Current Directions in Psychological Science*, *1*(3), 98–101.

Coles, N. A., Larsen, J. T., & Lench, H. C. (2019). A meta-analysis of the facial feedback literature: Effects of facial feedback on emotional experience are small and variable. *Psychological Bulletin*, *145*(6), 610–651. https://doi.org/10.1037/bul0000194

Conley, D. L., & Krahenbuhl, G. S. (1980). Running economy and distance running performance of highly trained athletes. *Medicine and Science in Sports and Exercise*, *12*(5), 357–360.

Daniels, J. T. (1985). A physiologist's view of running economy. *Medicine and Science in Sports and Exercise*, *17*(3), 332–338.

Glenberg, A. M. (2010). Embodiment as a unifying perspective for psychology. *Wiley Interdisciplinary Reviews. Cognitive Science*, *1*(4), 586–596. https://doi.org/10.1002/wcs.55

Guglielmo, L. G. A., Greco, C. C., & Denadai, B. S. (2009). Effects of strength training on running economy. *International Journal of Sports Medicine*, *30*(1), 27–32. https://doi.org/10.1055/s-2008-1038792

Hardy, C. J., & Rejeski, W. J. (1989). Not what, but how one feels: The measurement of affect during exercise. *Journal of Sport & Exercise Psychology*, *11*(3), 304–317.

Hatfield, B. D., Spalding, T. W., Mahon, A. D., Slater, B. A., Brody, E. B., & Vaccaro, P. (1992). The effect of psychological strategies upon cardiorespiratory and muscular activity during treadmill running. *Medicine and Science in Sports and Exercise*, *24*(2), 218–225.

Higgins, E. T. (2006). Value from hedonic experience and engagement. *Psychological Review*, *113*(3), 439–460. https://doi.org/10.1037/0033-295X.113.3.439

Hill, A., Schücker, L., Hagemann, N., Babel, S. A., MacMahon, C., & Strauß, B. (2019). Attentional focusing in running: Implicit focus manipulations reflect the effects for explicit instructions. *International Journal of Sport and Exercise Psychology*, *19*(2), 203–214. https://doi.org/10.1080/1612197X.2019.1674898

Hill, A., Schücker, L., Wiese, M., Hagemann, N., & Strauß, B. (2020). The influence of mindfulness training on running economy and perceived flow under different attentional focus conditions – an intervention study. *International Journal of Sport and Exercise Psychology*, *19*(4), 564–583. https://doi.org/10.1080/1612197X.2020.1739110

Hogg, M.A., Abrams, D., & Martin, G.N. (2010). Social cognition and attitudes. In N. Carlson, G. N. Martin, & W. Buskist (Eds.), *Psychology* (pp. 646–677). Harlow: Pearson Education Limited.

Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics*, *6*(2), 65–70.

Kaminsky, L. A., Arena, R., & Myers, J. (2015). Reference standards for cardiorespiratory fitness measured with cardiopulmonary exercise testing: Data from the fitness registry and the importance of exercise National Database. *Mayo Clinic Proceedings*, *90*(11), 1515–1523. https://doi.org/10.1016/j.mayocp.2015.07.026

Kerdok, A. E., Biewener, A. A., McMahon, T. A., Weyand, P. G., & Herr, H. M. (2002). Energetics and mechanics of human running on surfaces of different stiffnesses. *Journal of Applied Physiology*, *92*(2), 469–478. https://doi.org/10.1152/japplphysiol.01164.2000

Kyröläinen, H., Belli, A., & Komi, P. V. (2001). Biomechanical factors affecting running economy. *Medicine and Science in Sports and Exercise*, *33*(8), 1330–1337. https://doi.org/10.1097/00005768-200108000-00014

Morin, J. B., Samozino, P., Zameziati, K., & Belli, A. (2007). Effects of altered stride frequency and contact time on leg-spring behavior in human running. *Journal of Biomechanics*, *40*(15), 3341–3348. https://doi.org/10.1016/j.jbiomech.2007.05.001

Philippen, P. B., Bakker, F. C., Oudejans, R. R. D., & Canal-Bruland, R. (2012). The effects of smiling and frowning on perceived affect and exertion while physically active. *Journal of Sport Behavior*, *35*(3), 337–353.

Raedeke, T. D. (2007). The relationship between enjoyment and affective responses to exercise. *Journal of Applied Sport Psychology*, *19*(1), 105–115. https://doi.org/10.1080/10413200601113638

Saunders, P. U., Pyne, D. B., Telford, R. D., & Hawley, J. A. (2004). Factors affecting running economy in trained distance runners. *Sports Medicine*, *34*(7), 465–485. https://doi.org/10.2165/00007256-200434070-00005

Saunders, P. U., Telford, R. D., Pyne, D. B., Peltola, E. M., Cunningham, R. B., Gore, C. J., & Hawley, J. A. (2006). Short-term plyometric training improves running economy in highly trained middle and long distance runners. *Journal of Strength and Conditioning Research*, *20*(4), 947–954. https://doi.org/10.1519/R-18235.1

Schücker, L., & Parrington, L. (2019). Thinking about your running movement makes you less efficient: Attentional focus effects on running economy and kinematics. *Journal of Sports Sciences*, *37*(6), 638–646. https://doi.org/10.1080/02640414.2018.1522697

Shapiro, L. A. (Ed.). (2014). *The Routledge handbook of embodied cognition* (1st Ed.). Routledge.

Smith, A. L., Gill, D. L., Crews, D. J., Hopewell, R., & Morgan, D. W. (1995). Attentional strategy use by experienced distance runners: Physiological and psychological effects. *Research Quarterly for Exercise and Sport*, *66*(2), 142–150. https://doi.org/10.1080/02701367.1995.10762221

Spurrs, R. W., Murphy, A. J., & Watsford, M. L. (2003). The effect of plyometric training on distance running performance. *European Journal of Applied Physiology*, *89*(1), 1–7. https://doi.org/10.1007/s00421-002-0741-y

Strack, F., Martin, L. L., & Stepper, S. (1988). Inhibiting and facilitating conditions of the human smile: A nonobtrusive test of the facial feedback hypothesis. *Journal of Personality and Social Psychology*, *54*(5), 768–777. https://doi.org/10.1037//0022-3514.54.5.768

Svebak, S., & Murgatroyd, S. (1985). Metamotivational dominance: A multimethod validation of reversal theory constructs. *Journal of Personality and Social Psychology*, *48*, 107–116. https://doi.org/10.1037/0022-3514.48.1.107

Tourangeau, R., & Ellsworth, P. C. (1979). The role of facial response in the experience of emotion. *Journal of Personality and Social Psychology*, *37*(9), 1519–1531. https://doi.org/10.1037//0022-3514.37.9.1519

Turner, A. M., Owings, M., & Schwane, J. A. (2003). Improvement in running economy after 6 weeks of plyometric training. *Journal of Strength and Conditioning Research*, *17*(1), 60–67.

Williams, T. J., Krahenbuhl, G. S., & Morgan, D. W. (1991). Mood state and running economy in moderately trained male runners. *Medicine and Science in Sports and Exercise*, *23*(6), 727–731.