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Enhanced expectancies improve movement efficiency in runners

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Abstract

We followed up on recent findings demonstrating that enhancing performers' expectancies can improve their performance. Specifically, we examined whether providing experienced runners with positive feedback regarding their movement efficiency would increase running efficiency. Two groups of experienced runners ran on a treadmill at 75% of their maximum oxygen consumption ($\dot{V}O_{2max}$) for 10 min. One group (enhanced expectancy) was provided with (fabricated) feedback about the efficiency of their running style every 2 min. A control group was not given feedback. Oxygen consumption decreased in the enhanced expectancy group across measurement times (every 2 min for 10 min), but remained the same in the control group. In addition, performance perceptions changed only in the enhanced expectancy group, indicating a perception of greater ease of running and reduced fatigue when assessed after compared with before running. Finally, positive affect increased from a pre- to a post-test in the enhanced expectancy group, in contrast to the control group. Our findings show that enhanced expectancies can have a positive effect on movement efficiency and running experience. They add to the accumulating evidence for the social-cognitive-affective-motor nature of motor performance.

Keywords: *Feedback, oxygen consumption, positive affect, running*

Introduction

Can movement efficiency be enhanced in experienced athletes by changing their mindset? Consistent with work in other arenas of health and functioning (Crum, Corbin, Brownell, & Salovey, 2011; Crum & Langer, 2007; Hess, Aumann, Colombe, & Rahhal, 2003; Langer, Djikic, Pirson, Madenci, & Donohue, 2010), over the past few years there has been converging evidence to suggest that motor performance and learning can be improved by providing individuals with "positive" information about their performance or expected performance. In various studies (Badami, VaezMousavi, Namazizadeh, & Wulf, in press; Chiviacowsky & Wulf, 2007; Lewthwaite & Wulf, 2010b; Wulf, Chiviacowsky, & Lewthwaite, 2011), participants on novel motor tasks demonstrated improved performance and learning (e.g. movement accuracy, balance) when given feedback indicating they were performing well. In the present study, we wished to determine whether movement efficiency or economy – a characteristic of skilled performance (e.g. Guthrie, 1952) – could be further enhanced in experienced performers by providing them with positive feedback about their efficiency, thereby raising performance expectancies.

Starting with the observation that learners appeared to prefer to receive feedback after successful rather than unsuccessful trials (Chiviacowsky & Wulf, 2002), several researchers have demonstrated that motor learning can be enhanced by providing feedback after trials with relatively small compared with larger errors (Badami et al., in press; Chiviacowsky & Wulf, 2007; Chiviacowsky, Wulf, Wally, & Borges, 2009; Saemi, Wulf, Varzaneh, & Zarghami, 2012). Speculation that these effects were largely motivational in nature (Chiviacowsky & Wulf, 2002) were confirmed in studies by Badami and colleagues who showed that feedback after "good" trials led to increased intrinsic motivation (Badami, VaezMousavi, Wulf, & Namazizadeh, 2011) and self-confidence (Badami et al., in press). Thus, these authors provided the first direct evidence that feedback emphasizing successful performance, while ignoring less successful attempts, benefits learning because of its positive motivational effects.

In a related line of research, studies on normative feedback in which (fabricated) information about a

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peer group's performance scores is provided in addition to the learner's own performance scores, differential effects on motivation and motor performance or learning in response to "positive" versus "negative" normative feedback have been reported (e.g. Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008; Lewthwaite & Wulf, 2010b; Triplett, 1898; Wulf, Chiviacowsky, & Lewthwaite, 2010). For example, Hutchinson and colleagues (2008) found that (false) feedback indicating above-average performance increased participants' performance on a handgrip isometric force production task relative to feedback indicating below-average performance. In addition, participants' self-efficacy and task enjoyment increased. Social-comparative information, or normative feedback, not only affects performance while it is provided but can have more permanent effects on motor learning, as reflected in retention (Lewthwaite & Wulf, 2010b) and transfer test performance (Wulf et al., 2010) in classic motor learning paradigms. In one study, the learning of a balance task was enhanced by positive relative to negative normative feedback and, interestingly, a no-normative feedback control condition (Lewthwaite & Wulf, 2010b). In another study, bogus feedback about a peer group's average block-to-block improvement resulted in enhanced transfer performance on a timing task if it conveyed to the learner that his or her own improvement was higher than average, compared with lower than average (Wulf et al., 2010). Thus, favourable social-comparative information can affect not only learners' level of improvement during practice, but also the degree to which task skill is retained and generalizable.

Even more subtle manipulations can provide a boost to participants' expectancy regarding their performance and, in turn, enhance their motor performance. In a recent study, older individuals (women with an average age of 64 years) were informed, before practising a complex balance task (stabilometer), that their active and experienced peers typically did well on that task (Wulf et al., 2011). Compared with not receiving this information (control group), this simple statement resulted in increased self-efficacy as well as superior learning outcomes (i.e. retention performance). The general comment on a peer group's performance apparently alleviated the concerns older adults may have had when confronted with a novel and relatively challenging balance task, and consequently facilitated their performance and learning.

Thus, there is converging evidence that a person's motivation or mindset impacts motor performance and learning (e.g. Chabalaev, Sarrazin, Stone, & Cury, 2008; Feltz, Chow, & Hepler, 2008; Hutchinson et al., 2008; Lewthwaite & Wulf, 2010b; Wulf & Lewthwaite, 2009). Interestingly, some findings indicate that motor performance can be influenced almost immediately and positively by enhancing ability perceptions or self-efficacy (e.g. Hutchinson et al., 2008; Lewthwaite & Wulf, 2010b). Information indicating that one's performance is less-than-perfect, or even uncertainty about how one is performing (relative to others) due to lack of information, presumably activates self-regulatory processes in attempts to manage thoughts and affective responses (Carver & Scheier, 1978; Schmader, Johns, & Forbes, 2008). Yet, the exploration of the role of positive self-evaluations and affective responses in facilitating automatic control and movement efficiency is currently limited. As Wulf and Lewthwaite (2010) point out, "It may be that active self-regulatory activities do not ensue, or at least demand less effort and attention, when positive self-regard and optimal task performance are experienced" (p. 95).

In the present study, our goal was to further explore the potential impact of positive feedback on motor performance. In previous studies (e.g. Badami et al., in press; Chiviacowsky & Wulf, 2007; Hutchinson et al., 2008; Lewthwaite & Wulf, 2010b), such effects have been restricted to relatively inexperienced participants performing novel tasks and overall performance measures (e.g. throwing, timing, or golf putting accuracy; duration of squeezing a hand dynamometer; deviations of a balance platform from horizontal). Therefore, we wished to provide insight into the potential breadth of these effects by examining whether movement efficiency could be enhanced through mindset manipulations in experienced performers. Movement efficiency (together with movement accuracy and consistency) has long been recognized as an important attribute of skilled performance (Guthrie, 1952). If the same movement outcome is achieved with less energy, the movement pattern is considered more efficient or economical (Sparrow & Newell, 1998). The physical energy required to produce movements can be measured by various metabolic indices, such as oxygen consumption or heart rate. Researchers who have examined energy expenditure as a function of practice have shown that movement efficiency increases (e.g. Durand, Geoffroi, Varray, & Prefault, 1994; Lay, Sparrow, Hughes, & O'Dwyer, 2002; Sparrow, Hughes, Russell, & Le Rossignol, 1999). Changes in energy expenditure are presumably a function of increased movement efficiency associated with greater movement stability (e.g. Lay et al., 2002), minimized co-contractions, and generally more economical muscle activation patterns.

In the present study, we attempted to enhance the performance expectancies of experienced runners by persuading them that they had an efficient technique. Considering the extent of their training, one might assume that experienced runners have developed a high degree of efficiency that would be relatively difficult to improve further. Nevertheless, we speculated that the seemingly powerful effects of positive feedback might extend to skilled performers and be observable in measures of movement efficiency, such as oxygen consumption ($\dot{V}O_2$) (e.g. Baden, McLean, Tucker, Noakes, & St. Clair Gibson, 2005; Schücker, Hagemann, Strauss, & Völker, 2009). For this purpose, we compared $\dot{V}O_2$ in two groups of runners who ran on a treadmill at 75% of their maximum oxygen consumption ($\dot{V}O_{2max}$). While running, one group (enhanced expectancy) was provided with fabricated feedback statements about the efficiency of their running style, while a control group was not given this type of feedback. In addition to measuring the two groups' $\dot{V}O_2$ and heart rate while running, we assessed their rating of perceived exertion (Borg, 1985), as well as their performance perceptions and affective responses before and after running.

We hypothesized that group differences in $\dot{V}O_2$, and perhaps heart rate, would increase across time, such that they would remain constant in the enhanced expectancy group while increasing in the control group, or decrease in the enhanced expectancy group and remain constant in the control group. We also speculated that the rating of perceived exertion of participants in the enhanced expectancy group would be lower than that of participants in the control group. Finally, we predicted that participants' performance perceptions and positive affect would increase in the enhanced expectancy but not the control condition.

Methods

Participants

Altogether, 20 participants (10 males and 10 females, 5 of each sex in each group) recruited from local running clubs volunteered to take part. All participants were part of a running team and trained for competition. Their mean age was 26.4 years (enhanced expectancy group: 27.2 years, $s = 6.6$; control group: 25.0 years, $s = 4.9$). On average, they had been running for 7.8 years (enhanced expectancy group: 6.3 years, $s = 6.8$ [two extreme cases with 1 and 25 years of running, respectively, are responsible for the relatively large standard deviation]; control group: 9.3 years, $s = 4.3$), ran 48.6 km per week (enhanced expectancy group: 50.4 $km \cdot week^{-1}$, $s = 30.4$; control group: 46.7 $km \cdot week^{-1}$, $s = 37.0$), and ran 5.0 times per week (enhanced expectancy group: 5.0 times, $s = 1.8$; control group: 5.1 times, $s = 1.9$). Participants were not aware of the specific purpose of the study, and all gave their informed consent.

Apparatus, task, and procedure

Participants attended the exercise physiology laboratory individually on 2 separate days, separated by approximately 1 week. They were quasi-randomly assigned to the enhanced expectancy or control groups to stratify by gender. Specifically, the first male and female who arrived were assigned to the enhanced expectancy condition, and the next male and female to the control condition, until there were 10 participants (5 males, 5 females) in each group.

On Day 1, participants were asked to sign an informed consent form and fill out a short demographic questionnaire. They then ran a standardized graded exercise test (UNLV graded exercise test protocol; L.A. Golding, personal communication, 22 July 2011) on a treadmill (Treadmill Control; Quinton Instruments Co., Seattle, WA) to determine their $\dot{V}O_{2max}$. Expired gases were analysed using a metabolic cart (ORCA Cardiopulmonary Test System; ORCA Diagnostics Co., Santa Barbara, CA), and heart rate was monitored (Polar T31 Heart Rate monitor; Polar Electro Oy, Kempele, Finland). During the graded exercise test, participants first walked at 3 mph (4.83 $km \cdot h^{-1}$) for 3 min. The pace was then increased to a slow jogging pace (4.5 mph or 7.24 $km \cdot h^{-1}$) for 3 min. At the 6-min point, the participants started running at a pace they reported as their general steady running pace. They remained at this pace for the remainder of the test, and every 3 min the grade of the treadmill was increased by 3% until the participant was unable to continue. At this point the test was stopped. Participants were assumed to have reached $\dot{V}O_{2max}$ if the respiratory exchange ratio was greater than 1.0, or the oxygen consumption data demonstrated a plateau for about 30 s rather than a peak value.

To measure changes in performance perceptions, participants completed a customized questionnaire on Day 2, before and after running, on which they rated the ease of running and their degree of tiredness. On a scale from 0 ("not confident") to 10 ("very confident"), they rated their confidence or self-efficacy for the following aspects of running on the treadmill for 20 min at 75% of their $\dot{V}O_{2max}$: (a) "I will be able to complete the task easily"; (b) "The task will *not* be strenuous"; (c) "I will *not* be tired after 20 min"; and (d) "I will be able to run with ease". Changes in positive or negative affect as a function of feedback were assessed using the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). Participants completed the two 10-item subscales of the PANAS that assess positive affect (e.g. excited, strong, inspired, active) and negative affect (e.g. distressed, scared, irritable, afraid). They were asked to indicate "to what extent you feel this way right now, that is, at the present moment'' on a scale from 1 (''very slightly or not at all'') to 5 (''extremely'').

After completing both questionnaires, participants stepped on the treadmill. Following a 1-min warm-up walk at 3 mph, the speed was increased to one that corresponded to 75% of the participant's $\dot{V}O_{2max}$. We used a metabolic equation (cf. guidelines of the American College of Sports Medicine), in which we entered the person's $\dot{V}O_{2max}$, weight, and desired target $\dot{V}O_2$, to determine the (initial) speed of the treadmill. If necessary, the speed of the treadmill was adjusted slightly to get as close as possible to the participant's sub-maximal pace, and the speed remained constant from the 6-min mark onwards at 0% grade. All recordings at 10 min were within ± 5 ml · kg^{-1} · min^{-1} of the participant's 75% $\dot{V}O_{2max}$.

The experimental manipulation was provided beginning at 10 min into the sub-maximal (75% $\dot{V}O_{2max}$) run on Day 2. Participants assigned to the enhanced expectancy group were given a feedback statement regarding their purported running efficiency (''You're doing great. Your oxygen consumption is in the top 10th percentile for your age and gender''), and a similar statement was provided every 2 min (see Table I). No feedback was given to the control group.

Also starting 10 min into the run, participants' heart rate and $\dot{V}O_2$ were recorded, and measurements were repeated at 12, 14, 16, 18, and 20 min. The $\dot{V}O_2$ readings were based on the average of three readings taken around each minute mark. For example, the 10-min $\dot{V}O_2$ baseline reading was the average of the participant's $\dot{V}O_2$ readings at 9′55″, 10′00″, and 10′05″ min. The reason we averaged across three readings was that the $\dot{V}O_2$ value was assumed to be somewhat more reliable than after a single reading. After heart rate and $\dot{V}O_2$ readings, participants were also asked to rate their perceived exertion using Borg's (1985) 15-point rating of perceived exertion scale that was presented on a poster in front of them. Rating of perceived exertion provides a quantitative indication of a subjective sensation of effort. The format of the scale requires participants to respond to the question ''How hard are you working?'' on a scale from 6 (''no exertion at all'') to 20 (''maximum exertion''). Readings of the various dependent measures ($\dot{V}O_2$, heart rate, rating of perceived exertion) were taken every 2 min, consistent with the time interval of the feedback statements.

Table I. Statements provided to enhanced expectancy group participants at various times during running.

Time	Statement
10 min	You're doing great. Your oxygen consumption is in the top 10th percentile for your age and gender
12 min	You look very relaxed. You are a very efficient runner
14 min	You're doing really well. Your oxygen consumption is still in the top 10th percentile for your age and gender
16 min	You still look very relaxed. You are a very efficient runner
18 min	Your oxygen consumption is still in the top 10th percentile for your age and gender

The test was stopped after 20 min, and participants filled out post-test measures of perceived performance and affect. Both questionnaires were identical to the ones participants completed before they started running, with the exception that the items regarding performance perceptions were written in the past tense (e.g. ''I was able to complete the task easily''). Responses ranged from 1 (''not at all how I felt'') to 10 (''very much how I felt''). Finally, a manipulation check was conducted to determine whether the participants in the enhanced expectancy group believed the comments regarding their performance provided to them while running. Specifically, they were asked, ''Did you believe your performance was in the top 10th percentile for your age and gender?'' After answering this question, participants were debriefed and any questions they had were answered.

Statistical analysis

Given known physiological differences between men and women (e.g. in $\dot{V}O_{2max}$), gender was included as a factor in all analyses. Oxygen uptake, heart rate, and rating of perceived exertion were analysed in separate 2 (group: enhanced expectancy vs. control) × 2 (gender: male vs. female) × 6 (time: 10 min, 12 min, 14 min, 16 min, 18 min, 20 min) analyses of variance (ANOVAs) with repeated measures on the last factor. As the performance perception scores were highly correlated (Cronbach alpha coefficients of 0.89 for the pre-test and 0.75 for the post-test), they were averaged across the four questions and analysed in a 2 (group: enhanced expectancy vs. control) × 2 (gender: male vs. female) × 2 (time: pre- vs. post-test) ANOVA with repeated measures on the last factor. Participants' affective state was analysed in a 2 (group: enhanced expectancy vs. control) × 2 (gender: male vs. female) × 2 (affect: positive vs. negative) × 2 (time: pre- vs. post-test) ANOVA with repeated measures on the last two factors.

Results

Manipulation check

All 10 participants in the enhanced expectancy group reported believing the bogus feedback that was given to them during the test.

Oxygen consumption

The $\dot{V}O_{2max}$ of the control (mean 47.5 $ml \cdot kg^{-1} \cdot min^{-1}$, $s = 6.6$) and enhanced expectancy groups (45.2 $ml \cdot kg^{-1} \cdot min^{-1}$, $s = 6.9$) did not differ significantly ($F_{1,18} < 1$). The $\dot{V}O_2$ of both groups across measurement times is shown in Figure 1. The control group tended to have higher $\dot{V}O_2$ values than the enhanced expectancy group. Most importantly, those values remained relatively stable in the control group, but decreased in the enhanced expectancy group. The interaction of group and time was significant ($F_{5,80} = 4.83$, $P < 0.001$, $\eta^2 = 0.23$). (The interaction of group and time was also significant when $\dot{V}O_{2max}$ was included as a covariate: $F_{5,75} = 4.96$, $P < 0.001$, $\eta^2 = 0.25$.) Follow-up ANOVAs for each group indicated that, while the control group's increase in $\dot{V}O_2$ across measurement times did not change significantly ($P = 0.11$), the enhanced expectancy group's decrease in $\dot{V}O_2$ was significant ($P = 0.003$, $\eta^2 = 0.33$). The main effects of group ($F_{1,16} = 2.48$, $P < 0.05$) and time ($F_{5,80} < 1$) were not significant. Men had generally higher $\dot{V}O_2$ values than women. The main effect of gender on $\dot{V}O_2$ was significant ($F_{1,16} = 5.49$, $P < 0.05$, $\eta^2 = 0.26$). There were no interactions of group and gender ($F_{1,16} < 1$), time and gender ($F_{5,80} < 1$), or group, time, and gender ($F_{5,80} < 1$).

Heart rate

Heart rate did not differ across the two groups (see Figure 2). The main effect of group was not significant ($F_{1,16} < 1$). In general, heart rate increased over time from an average of 157 to 161 $beats \cdot min^{-1}$, with the main effect of time being significant ($F_{5,80} = 11.51$, $P < 0.001$, $\eta^2 = 0.42$). The increase in heart rate over time was somewhat higher for females (156 to 161 $beats \cdot min^{-1}$) than males (159 to 162 $beats \cdot min^{-1}$). The time $\times$ gender interaction was significant ($F_{5,80} = 2.99$, $P < 0.05$, $\eta^2 = 0.16$). The main effect of gender was not significant ($F_{1,16} < 1$), and neither were the interactions of group and time ($F_{5,80} = 1.44$, $P > 0.05$), group and gender ($F_{1,16} = 1.53$, $P > 0.05$), and time, group, and gender ($F_{5,80} < 1$).

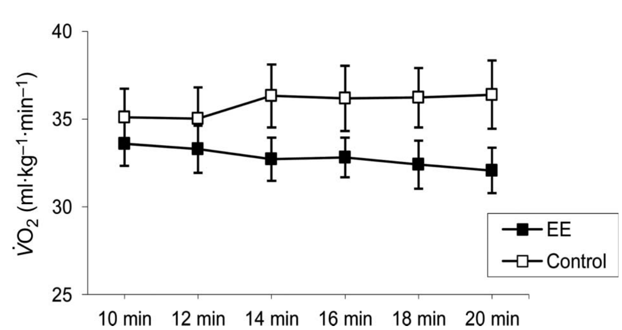

Figure 1. Oxygen uptake for the enhanced expectancy (EE) and control groups across measurement times.

Rating of perceived exertion

Perceived exertion increased in both the control (10.1 to 11.7) and enhanced expectancy groups (10.2 to 11.2) over time (see Figure 3). The main effect of time was significant ($F_{5,80} = 14.25$, $P < 0.001$, $\eta^2 = 0.48$). The interaction of group and time ($F_{5,80} = 1.13$, $P > 0.05$) and the main effect of group ($F_{1,16} < 1$) were not significant. None of the other interactions were significant (all $F_{1,16} < 1$).

Performance perceptions

Performance perception scores on the pre- and post-tests for both groups can be seen in Figure 4. While the scores increased from pre- to post-test in both groups, there was a greater increase for the enhanced expectancy group. The main effect of time (pre- vs. post-test) was significant ($F_{1,16} = 5.26$, $P < 0.05$, $\eta^2 = 0.25$). In addition, the interaction of group and time was significant ($F_{1,16} = 5.26$, $P < 0.05$, $\eta^2 = 0.25$). Follow-up ANOVAs for each group

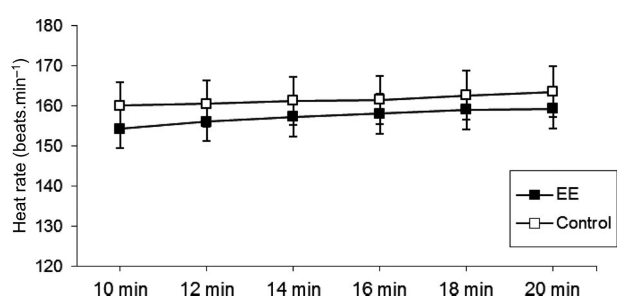

Figure 2. Heart rate for the enhanced expectancy (EE) and control groups across measurement times.

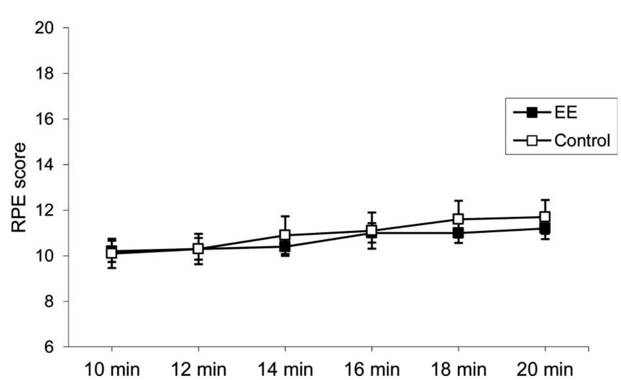

Figure 3. Rating of perceived exertion (RPE) scores for the enhanced expectancy and control groups across measurement times.

indicated that the enhanced expectancy group's performance perceptions increased significantly from pre- (6.8) to post-test (8.6) ($F_{1,27} = 12.05$, $P < 0.01$, $\eta^2 = 0.57$), whereas those of the control group remained the same (8.0) ($F_{1,27} < 1$). The main effects of group and gender, and the group × gender interaction, were not significant (all $F_{1,16} < 1$). There were no significant interactions of time and gender $F_{1,16} = 1.82$, $P > 0.05$) or time, gender, and group ($F_{1,16} = 3.20$, $P > 0.05$).

Positive and negative affect

Positive and negative affect scores for both groups on pre- and post-tests are shown in Figure 5. Positive affect was generally greater than negative affect. This finding was confirmed by a significant main effect of affect ($F_{1,16} = 106.50$, $P < 0.001$, $\eta^2 = 0.87$). Also, positive affect increased from pre- to post-test, whereas negative affect decreased. The interaction of affect and time was significant ($F_{1,16} = 11.39$, $P < 0.01$, $\eta^2 = 0.42$). Importantly, the enhanced expectancy group showed greater positive affect than the control group on the post-test. The main effect of group ($F_{1,16} = 6.93$, $P < 0.05$, $\eta^2 = 0.30$), as well as the interaction of group, affect, and time were significant ($F_{1,16} = 5.01$, $P < 0.05$, $\eta^2 = 0.24$). *Post-hoc* tests, with Bonferroni adjustments for multiple comparisons, indicated that positive affect was significantly higher in the enhanced expectancy group relative to the control group on the post-test ($F_{1,18} = 15.13$, $P < 0.001$, $\eta^2 = 0.46$). In contrast, there was no significant group difference in positive affect on the pre-test ($F_{1,18} = 2.69$, $P > 0.05$), and negative affect did not differ between groups on the pre-test or post-test (all $F_{1,18} < 1$). None of the other main or interaction effects were significant.

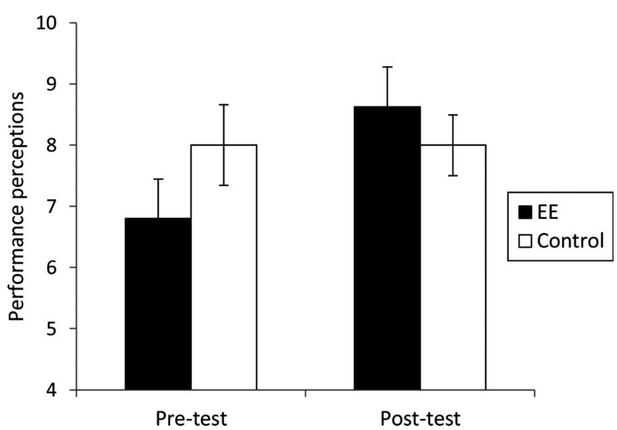

Figure 4. Performance perception scores for the enhanced expectancy (EE) and control groups on pre- and post-tests.

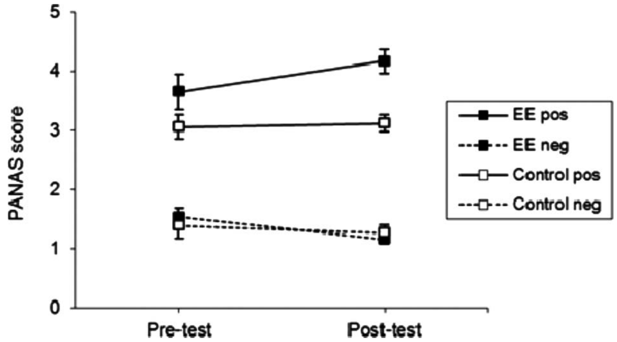

Figure 5. Positive and negative affect scores for the enhanced expectancy (EE) and control groups on pre- and post-tests.

Discussion

Providing runners with positive feedback about their performance (i.e. running efficiency) led to a decrease in $\dot{V}O_2$ consumption, or an increase in movement efficiency. Enhanced expectancy group participants, who were led to believe that they were efficient runners, showed a consistent and significant reduction in $\dot{V}O_2$, whereas control group participants demonstrated no significant change (with a trend towards an increase). Participants' heart rates and their ratings of exertion while running did not differ between groups. However, participants in the enhanced expectancy group displayed more marked changes in personal performance perceptions (related to ease of running, tiredness, etc.) and greater positive affect after running compared with the control group.

The most intriguing finding was the divergence of $\dot{V}O_2$ as a function of positive feedback versus no feedback. The significant reduction in $\dot{V}O_2$ across time seen in the enhanced expectancy group indicates an increase in movement efficiency, as the same work (i.e. running at a constant speed) was produced with less energy. It should be noted that this performance enhancement was seen in comparison with a "normal" or control condition – which one might assume would produce optimal performance in experienced runners. In most previous studies, effects of positive feedback were compared with those of negative feedback (rather than control conditions), and participants receiving positive feedback generally showed more effective motor performance or learning (Badami et al., in press; Chiviacowsky & Wulf, 2007; Hutchinson et al., 2008). However, Lewthwaite and Wulf (2010b) included a control group without feedback. They found that the control condition had similar effects as negative normative feedback on the learning of a balance task, with both groups being outperformed by a positive normative feedback group. This finding suggested that performance was *enhanced* by *positive* information, rather than being degraded by negative information. Therefore, in the present study, we chose the arguably more intriguing comparison between positive feedback and a no-feedback control condition.

The performance-enhancing effects of positive feedback in the present study and that of Lewthwaite and Wulf (2010b) do not seem to be coincidental, as they are in line with findings from research examining effects of other social-cognitive variables on motor performance and learning. In general, it appears that information or practice conditions that act to alleviate individuals' concerns about their performance or to enhance performance expectancies tend to enhance the performance and learning of motor skills. For instance, informing performers that a task is learnable enhanced learning compared with a control condition with no such information, or information that performance would reflect an inherent ability (Wulf & Lewthwaite, 2009). Also, instructions inducing an external focus of attention consistently result in greater movement accuracy (Wulf, 2007) and movement efficiency (for reviews, see Lohse, Wulf, & Lewthwaite, in press; Wulf & Lewthwaite, 2010) than control conditions without attentional focus instructions or internal focus conditions. Finally, raising performers' expectancies by informing them that their peers performed well on a certain task (Wulf et al., 2011) or that they themselves were likely to perform well under pressure (McKay, Lewthwaite, & Wulf, 2012) has been found to result in improved performance or learning compared with not providing that information (control conditions). The present findings suggest that even experienced performers may not be immune to concerns and worries about their performance, and that their movement efficiency can be further enhanced by assurances that they are performing well.

While $\dot{V}O_2$ was affected by the feedback manipulation, there were no differential effects on heart rate. Although heart rate is often correlated with $\dot{V}O_2$ (e.g. Hall, MacDonald, Maddison, & O'Hare, 1998), an effect of certain variables on $\dot{V}O_2$, but not heart rate, is not uncommon either. For example, Schücker et al. (2009) found that runners' attentional focus (internal vs. external) had differential effects on their $\dot{V}O_2$ but not on heart rate. The exact mechanisms underlying these changes will need to be explored in future studies.

Not surprisingly, given commonly found relationships between ratings of perceived exertion and heart rate (Borg, 1982; Chen, Fan, & Moe, 2002), both heart rate and rating of perceived exertion increased over time, with no differences in either variable between groups. Yet, despite similar ratings of exertion during running, the enhanced expectancy group experienced greater change in perceptions of running ease and higher ratings of positive affect after running than the control group. This finding is consistent with those of McAuley and colleagues (McAuley, Talbot, & Martinez, 1999) and Hutchinson et al. (2008). For example, McAuley and colleagues reported that participants in a high self-efficacy condition (receiving positive bogus feedback) reported significantly greater positive wellbeing and less psychological distress and fatigue both during and after the activity than low self-efficacy participants exercising at the same relative intensity.

While effects of an individual's mindset on the body's physiological responses may appear surprising, expectancies have been implicated in the placebo effect (Malani & Houser, 2008), suggesting that expectancy cognitions can alter central processing of neural activity and thereby influence downstream physiological responses. For example, expectations have been found to influence physiological responses to food (e.g. the ghrelin response; Crum et al., 2011). With respect to running economy and movement efficiency, a number of studies have indicated that motivational factors can influence physiological efficiency (Crews, 1992; Martin, Craib, & Mitchell, 1995). Other researchers have demonstrated that interventions that utilize psychological strategies, including relaxation, self-talk, and attentional focus instructions (Caird, McKenzie, & Sleivert, 1999; Hatfield et al., 1992; Schücker et al., 2009; Smith, Gill, Crews, Hopewell, & Morgan, 1995) can alter running efficiency, including ventilation and oxygen consumption indices. Furthermore, the performer's focus of attention has been shown to affect motor unit recruitment, resulting in significant changes in force production and movement efficiency (e.g. Lohse, Sherwood, & Healy, 2011; Vance, Wulf, Töllner, McNevin, & Mercer, 2004). It may turn out that the effects of enhanced expectancies, positive feedback, attentional focus or other variables on movement performance and learning have some causal pathways in common. Yet, we will have to await the results of further research to provide us with more insight into these issues.

Overall, the present results are in line with a number of recent findings showing the relationship between feedback valence, performance perceptions, affect, and actual performance. They add to this literature by demonstrating that movement efficiency in experienced performers can be influenced almost immediately by altering their performance expectancies or mindset. We view these findings as another piece of evidence for the social-cognitive-affective-motor nature of motor behaviour (Lewthwaite & Wulf, 2010a). To what extent the increase in running efficiency, and perceptual and affective experience, is practically meaningful remains to be determined. However, the effectiveness of relatively minor feedback statements clearly reveals a role for motivation in running performance. The value-to-(intervention) cost ratio of positive feedback might exceed or augment other physiological, biomechanical or psychological approaches to changing running economy – and, potentially, motivational and perceptual effects might promulgate into further advantages.

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