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ORIGINAL ARTICLE
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Maximal aerobic capacity can be increased by enhancing performers' expectancies

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ABSTRACT

BACKGROUND: Maximum aerobic capacity (VO_{2max}) is widely accepted as the best measure of cardiovascular fitness and aerobic power. The present study investigated whether enhancing participants' performance expectancies through positive social-comparative feedback would increase VO_{2max}.

METHODS: Participants were experienced runners who regularly ran for exercise or competitively. All participants completed two VO_{2max} tests within a 2-week period at similar times of the day. Before the second test, enhanced expectancy group participants were informed that their aerobic capacity on the first test was above the group average, whereas control group participants were told the second test was for validation purposes. Measurements taken were relative to VO_{2max}, as well as pulmonary ventilation, respiratory exchange ratio, heart rate, and ratings of perceived exertion.

RESULTS: The enhanced expectancy group demonstrated a significant increase (+3.28%) in VO_{2max} from test 1 (61.1±2.8 $mL \cdot kg^{-1} \cdot min^{-1}$) to test 2 (63.7±2.9 $mL \cdot kg^{-1} \cdot min^{-1}$, P=0.007), whereas the control group's VO_{2max} decreased significantly (-4.11%, test 1 =59.4±2.9 $mL \cdot kg^{-1} \cdot min^{-1}$, test 2 =57.8±2.3 $mL \cdot kg^{-1} \cdot min^{-1}$, P=0.027). No group differences were found with respect to other performance measures (pulmonary ventilation P=0.22, heart rate P=0.97, respiratory exchange ratio P=0.11, rate of perceived exertion P=0.13).

CONCLUSIONS: The results show that maximum aerobic capacity is, in part, a function of the performer's self-efficacy expectations. These findings add to the increasing evidence demonstrating social-cognitive-affective influences on (maximum) motor performance.

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In recent years, there has been accumulating evidence showing that enhanced performance expectancies often have immediate beneficial effects on motor performance as well as positive longer-term influences on motor skill learning.[1-3] Expectancies have been enhanced in various ways such as setting criteria that purportedly indicate good performance, but that can be reached relatively easily, and have been found to result in improved performance or learning.[2, 4, 5] Other findings come from investigations into the effects of positive feedback, where highlighting successful rather than less successful trials has been demonstrated to increase motor learning.[6-8] Expectancies can be enhanced in rather subtle ways, such as simply informing subjects that their peers typically did well on a novel balance task, and this statement has resulted in superior motor skill learning compared to not receiving this information (control group).[1]

Social-comparative feedback is a potent basis for evaluating one's own competence. In one study, balance learning was enhanced by (false) positive feedback suggesting above-average performance, compared with a control condition or a negative-feedback condition.[14] In another study, participants showed greater tolerance for sustained effort in a continuous force production task when they believed their performance was above average.[9] Positive feedback has been found to not only lower perceived exertion[9] or perceptions of effort,[10] but also to increase self-efficacy[9] and perceived competence,[11] reduce concerns and nervousness about performance and ability,[1] as well as increase satisfaction with performance[12] and positive affect.[10] As a result of these positive motivational influences, qualitative differences are seen in movement control. For example, relative to no or negative feedback, participants who received positive feedback regarding their balance performance exhibited greater automaticity and movement efficiency.[13] Additionally, in trained runners positive feedback enhanced running efficiency of participants who ran at 75% of their maximum aerobic capacity (VO_{2max}) for 20 min.[10]

Overall, there is consistent evidence demonstrating that enhanced performance expectancies positively impact movement effectiveness and efficiency.[14] One question that remains to be answered is whether maximum aerobic performance can also be affected by performers' expectancies. Maximum aerobic capacity is generally seen as the best measure of cardiovascular fitness[15, 16] and incremental treadmill protocols used to measure VO_{2max} are considered highly reliable.[17-19] Yet, based on the findings outlined above, we speculated that VO_{2max} might be influenced by the performer's expectancies. Therefore, in the present study, we examined whether enhancing athletes' expectancies would influence their maximum aerobic capacity.

Materials and methods

Participants

Twenty-four aerobically trained participants (control (CON) males N.=6, CON females N.=5, enhanced expectancy (EE) males N.=7, EE females N.=6) participated in the study. Two additional female participants were recruited but did not return for testing after completing the first trial, and are therefore not included in the data analysis. All were experienced runners who ran 2-3 times a week for exercise, or ran competitively. All were low-risk as determined by responses from the American College of Sports Medicine Health Risk Questionnaire. The study was approved by the university's institutional review board (approval #710761) and adheres to the principles set forth by the Helsinki Declaration. All participants provided signed informed consent prior to participation.

Apparatus, task, and procedure

Participants were asked to refrain from strenuous physical exercise during the day prior to as well as on the day of testing.[20] Prior to exercise testing, participants' age (CON males =28±8 years (mean±SD), CON females =31±5 years, EE males =29±7 years, EE females =38±13 years), body mass (CON males =83±13 kg, CON females =62±8 kg, EE males =77±12 kg, EE females =65±5 kg), and height (CON males =180±8 cm, CON females =163±11 cm, EE males =180±7 cm, EE females =171±6 cm) were obtained, and body composition was determined using a tetrapolar bioelectrical impedance analysis system (ELG III, Bioanalogics, Portland, OR)[21] (CON males =22±6%, CON females =30±4%, EE males =16±6%, EE females =29±4%). Graded exhaustive exercise tests for the determination of VO_{2max} were performed using an open circuit respiratory metabolic system (Moxus, AEI Technologies, Pittsburgh, PA, USA). The respiratory metabolic system was calibrated prior to each test as described by the manufacturer.[22] A telemetry heart rate monitor (Polar Electro Inc., Lake Success, NY, USA) was utilized to determine heart rate throughout the maximal exertion test. The progressive exercise tests began with a warm-up on the motor-driven treadmill (T914, Nautilus, Vancouver, WA, USA) that was usual to the endurance-trained athletes. Each participant self-selected his or her speed and grade combination to reflect a warm up protocol they typically used prior to a difficult exercise bout. Following the warm-up, an initial speed of 132.1 m · min^{-1} and grade of 0% was completed. Speed was then increased by 26.8 m · min^{-1} every 2 min until a self-selected comfortable running speed was reached. Following this stage, speed remained constant, and grade was increased 3% with each 2-min stage until the participant reached a voluntary termination point. Upon completion of the VO_{2max} test, participants were allowed a self-selected cool down period. The maximal aerobic capacity was taken as the greatest 30-sec average for oxygen consumption during the test. Pulmonary ventilation (V_{Emax}), maximal heart rate (HR_{max}), and respiratory exchange ratio (RER_{max}) were recorded at this time interval. Ratings of perceived exertion (RPE_{max}) were obtained at the end of each stage, using Borg's 20-point RPE Scale.[23]

Within 14 days, participants returned to perform another maximal exertion test. The second VO_{2max} test utilized the same speed and grade combinations as in the initial VO_{2max} test. Participants were randomly assigned to one of two groups, the enhanced expectancy (7 males, 6 females) and control (6 males, 5 females) groups. Prior to the second test, enhanced expectancy group participants were provided (false) social-comparative feedback. While looking at a data sheet, the experimenter mentioned, in a relatively casual tone, that the participant's VO_{2max} on the first test was higher than the group's average. The control group was informed that the second test was for validation purposes. Upon completion of the second VO_{2max} test, participants were allowed a self-selected cool down period. They were then debriefed regarding the purpose of the study. The dependent variables of VO_{2max}, V_{Emax}, HR_{max}, RER_{max}, and RPE_{max} were recorded as previously described.

Data analysis

All data are reported as mean±standard deviations. VO_{2max}, V_{Emax}, HR_{max}, RER_{max}, and RPE_{max} data were each analyzed in 2 (group: enhanced expectancy, control) x 2 (gender: males, female) x 2 (test: 1, 2) analyses of variance (ANOVAs) with repeated measures on the last factor. Statistical significance was accepted at the $P<0.05$ level.

Results

Oxygen consumption

The enhanced expectancy and control groups did not differ significantly in any anthropometric variable for the same sex ($P>0.05$), and both groups had similar VO_{2max} values on test 1 (Table I, Figure 1). Yet, participants in the enhanced expectancy group showed an increase VO_{2max} on test 2, prior to which they had received positive feedback, whereas control group participants demonstrated a decrease. The group x test interaction was significant, F (1, 20)=16.30, $P<0.001$, $\eta_p^2=0.45$. Follow-up ANOVAs for each group indicated that the enhanced expectancy group's increase in VO_{2max} (+3.28%) was significant, F (1, 12) =10.35, P=0.007, η_p^2 =0.46. Also, the decrease in the control group's VO_{2max} (-4.11%) was significant, F (1, 10) = 6.72, P=0.027, η_p^2 =0.40. There were no main effects of test or group, Fs (1, 20) <1. Males had higher VO_{2max} values relative to females, F (1, 20) = 9.41, P=0.006, η_p^2 =0.32. No other interaction effects were significant.

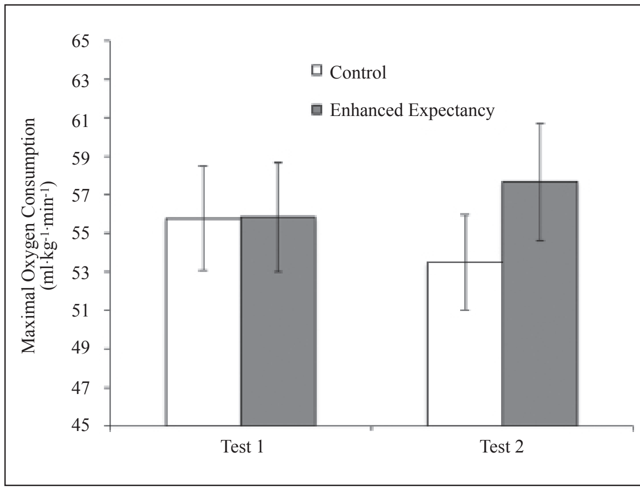

Figure 1.—Maximal oxygen consumption in the enhanced expectancy and control groups during test 1 and test 2. Error bars indicate standard errors.

Pulmonary ventilation

Even though the enhanced expectancy group tended to show a numeric increase in V_E from test 1 to test 2, while the control group's values remained the same (Table I), the interaction of group and test was not significant, F (1, 20) =1.62, P=0.22. Male participants had higher V_{Emax} than females, F (1, 20)=25.82, $P<0.001$, η_p^2 =0.56. None of the other main or interaction effects were significant.

TABLE I.—*Performance measures in the enhanced expectancy and control groups.*

Variable	Female control (N.=5)		Female enhanced xpectancy (N.=6)		Male control (N.=6)		Male enhanced expectancy (N.=7)	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
VO_{2max}	51.4±5.2	48.4±4.5	49.7±7.1	50.7±6.5	59.4±10.2	57.8±8.4	61.1±9.9	63.7±10.7
V_{Emax}	85.3±7.5	86.4.±7.5	89.0±14.9	90.2±13.6	133.3±43.4	131.0±33.3	130.1±15.2	140.4±17.9
RER_{max}	1.07±0.06	1.13±0.06	1.09±0.02	1.09±0.03	1.11±0.03	1.12±0.03	1.11±0.05	1.12±0.06
HR_{max}	184.2±10.8	185.6±9.9	178.7±7.3	178.3±8.4	187.7±9.3	183.3±15.0	180.0±12.1	177.9±15.2
RPE_{max}	15.0±1.0	16.6±2.6	15.3±1.6	15.0±1.9	16.5±1.5	16.3±2.0	16.9±1.3	16.3±1.5

Heart rate

Maximum heart rate did not vary as a function of test, group, or gender (Table I). No main or interaction effects reached significance for HR_{max}.

Respiratory exchange ratio

RER_{max}, was higher on the second test compared with the first test, F (1, 20) =7.10, P<0.015, η_p^2 =0.26, mainly due to the control group's tendency to show a greater increase in $RER_{max.}$ The interaction of group and test failed to reach significance, though, F (1, 20)=2.88, P<0.11, η_p^2 =0.13. There were no other significant main or interaction effects.

Rate of perceived exertion

There was a tendency for the enhanced expectancy group to show a reduction in RPE_{max} from test 1 to test 2, while the opposite was the case for the control group, but the interaction of group and test was not significant, F (1, 20)=2.48, P=0.13, η_p^2=0.1. Also, males tended to have a higher RPE than females, F (1, 20)=2.84, P=0.107, η_p^2=0.12. However, none of the main or interaction effects were significant.

Discussion

The present study showed that maximal aerobic capacity (VO_{2max}) can vary as a function of the performer's mental outlook. While both groups of experienced runners had similar VO_{2max} values on the initial test, enhancing the runners' expectancies before the second test, by providing them with positive social-comparative feedback, resulted in a significantly increased VO_{2max} (+3.28%). In contrast, without such feedback, the control group demonstrated a significant reduction in maximal oxygen consumption (-4.11%) on the second test. While the cause of this reduction is not clear — perhaps participants were reluctant to run to exhaustion for a second time within a relatively short period of time — it is interesting that this effect was more than offset by positive feedback about their performance.

Maximal oxygen consumption is typically assumed to be an objective and reliable measure of aerobic physical fitness, yet the intertwined nature of movement, cognition, emotion, and the influence of the social context in which performance takes place, has become increasingly obvious in recent years.[13] Maximum performance does not appear to be an exception to this rule.[24, 25] Social-cognitive-affective variables that have unfavorable influences on performance include conditions that reduce or threaten individuals' performance expectancies, such as those that promote an entity view of ability,[26] involve feedback suggesting non-optimal performance,[4] or heighten stereotype threat.[27, 28] In contrast, conditions that enhance performance expectancies by alleviating performers' concerns, reducing perceived task difficulty, suggesting an incremental view of ability, defining success liberally or in positive normative terms typically result in performance improvements. Aside from anecdotal evidence that expectations of future performance success can potentiate even more success,[3] numerous experimental studies have demonstrated the benefits of enhanced expectancies for motor performance and learning.[7, 9, 11]

The present findings are in line with previous findings demonstrating increased movement efficiency with enhanced expectancies,[9, 10, 13] however we are the first to show that maximal aerobic capacity can vary as a function of the individual's self-efficacy expectations. While it may seem surprising that no group differences were found with respect to any other measured cardiovascular or metabolic indicators, similar findings have been reported in other studies with respect to heart rate and RPE.[10, 29] Maximal aerobic capacity (VO_{2max}) is considered to represent the interplay between cardiopulmonary measures (oxygen delivery to the working muscles) and the ability of the tissues to uptake and utilize oxygen for energy, often displayed as the Fick equation: VO_2=heart rate x stroke volume x (a-v) O_2 difference.[30-32] Although we observed no difference with respect to heart rate in the present study, from a physiological standpoint it appears that enhancing a performer's expectancies prior to a maximal exercise bout could beneficially influence both oxygen availability and delivery (we observed a non-significant, but perhaps practically relevant, increase in pulmonary ventilation in the enhanced expectancy group on test 2) as well as utilization at the tissue level. With regards to oxygen utilization, as a previous investigation [10] has provided evidence that the oxygen consumed during treadmill running at submaximal intensity is reduced under enhanced expectancy conditions, it is possible that a cumulative effect during the course of a progressive maximal test is to reserve oxidative enzymes and substrates for utilization while working at a maximal level. While further investigation is necessary, it is tempting to speculate that subtle benefits to both oxygen delivery and oxygen utilization were responsible for the increase in VO_{2max} that we observed in the enhanced expectancy group in the present study.

High performance expectancies are assumed to prepare the mover for successful movement by exerting their effects at cognitive, motivational, neurophysiological, and neuromuscular levels.[14] This ensures that goals are effectively coupled with intended actions (termed goal-action coupling).[14] In contrast, a lack of such expectations appears to promote an internal or self-focus, task-incompatible thoughts and concerns, anxiety, negative affect, and superfluous neuromuscular activity.[29, 33] When running with high intensity, self-related thoughts likely include breathing or movement form, both of which have been shown to degrade running efficiency.[33] Such conditions could help to promote off-task and self-focused attention supported by the so-called default mode network [34] — thereby exposing performers to obstacles to optimal performance [35] and potentially explaining why the control group in the present study displayed a decreased in VO_{2max} on the second test.

Conclusions

The present findings demonstrate that VO_{2max} is not a fixed capacity but depends, at least to some degree, on the performer's self-efficacy expectations or confidence. Additionally, "neutral" control conditions do not necessarily result in the highest values. Our findings may have implications for other settings, where coaches or others could facilitate movement efficiency relatively easily by providing positive motivational statements.

References

1. Wulf G, Chiviacowsky S, Lewthwaite R. Altering mindset can enhance motor learning in older adults. Psychol Aging 2012;27:14-21.
2. Palmer K, Chiviacowsky S, Wulf G. Enhanced expectancies facilitate golf putting. Psychol Sport Exerc 2016;22:229-32.
3. Rosenqvist O, Skans ON. Confidence enhanced performance? – The causal effects of success on future performance in professional golf tournaments. J Econ Behav Organ 2015;117:281-95.
4. Chiviacowsky S, Wulf G, Lewthwaite R. Self-controlled learning: the importance of protecting perceptions of competence. Front Psychol 2012;3:458.
5. Trempe M, Sabourin M, Proteau L. Success modulates consolidation of a visuomotor adaptation task. J Exp Psychol Learn Mem Cogn 2012;38:52-60.
6. Chiviacowsky S, Wulf G. Feedback after good trials enhances learning. Res Q Exerc Sport 2007;78:40-7.
7. Clark SE, Ste-Marie DM. The impact of self-as-a-model interventions on children's self-regulation of learning and swimming performance. J Sports Sci 2007;25:577-86.
8. Saemi E, Porter JM, Ghotbi-Varzaneh A, Zarghami M, Maleki F. Knowledge of results after relatively good trials enhances self-efficacy and motor learning. Psychol Sport Exerc 2012;13:378-82.
9. Hutchinson JC, Sherman T, Martinovic N, Tenenbaum G. The Effect of Manipulated Self-Efficacy on Perceived and Sustained Effort. J Appl Sport Psychol 2008;20:457-72.
10. Stoate I, Wulf G, Lewthwaite R. Enhanced expectancies improve movement efficiency in runners. J Sports Sci 2012;30:815-23.
11. Ávila LTG, Chiviacowsky S, Wulf G, Lewthwaite R. Positive social-comparative feedback enhances motor learning in children. Psychol Sport Exerc 2012;13:849-53.
12. Wulf G, Lewthwaite R, Hooyman A. Can ability conceptualizations alter the impact of social comparison in motor learning? Journal of Motor Learning and Development 2013;1:20-30.
13. Lewthwaite R, Wulf G. Social-comparative feedback affects motor skill learning. Q J Exp Psychol (Hove) 2010;63:738-49.
14. Wulf G, Lewthwaite R. Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. Psychon Bull Rev 2016;23:1382-414.
15. Saltin B, Astrand PO. Maximal oxygen uptake in athletes. J Appl Physiol 1967;23:353-8.
16. Shephard RJ, Allen C, Benade AJ, Davies CT, Di Prampero PE, Hedman R, *et al.* The maximum oxygen intake. An international reference standard of cardiorespiratory fitness. Bull World Health Organ 1968;38:757-64.
17. Drake V, Jones G, Brown JR, Shephard RJ. Fitness performance tests and their relationship to the maximal oxygen uptake of adults. Can Med Assoc J 1968;99:844-8.
18. Astorino TA, Willey J, Kinnahan J, Larsson SM, Welch H, Dalleck LC. Elucidating determinants of the plateau in oxygen consumption at VO2max. Br J Sports Med 2005;39:655-60; discussion 60.
19. Pivarnik JM, Dwyer MC, Lauderdale MA. The reliability of aerobic capacity (VO(2)max) testing in adolescent girls. Research Quarterly for Exercise and Sport 1996;67:345-8.
20. Navalta JW, Fedor EA, Schafer MA, Lyons TS, Tibana RA, Pereira GB, *et al.* Caffeine affects CD8+ lymphocyte apoptosis and migration differently in naive and familiar individuals following moderate intensity exercise. Int J Immunopathol Pharmacol 2016;29:288-94.
21. Peterson JT, Repovich WE, Parascand CR. Accuracy of consumer grade bioelectrical impedance analysis devices compared to air displacement plethysmography. Int J Exerc Sci 2011;4:176-84.
22. Medbo JI, Mamen A, Beltrami FG. Examination of the Moxus Modular Metabolic System by the Douglas-bag technique. Appl Physiol Nutr Metab 2012;37:860-71.
23. Borg G. Perceived exertion as an indicator of somatic stress. Scand J Rehabil Med 1970;2:92-8.
24. Marchant DC, Greig M, Bullough J, Hitchen D. Instructions to adopt an external focus enhance muscular endurance. Res Q Exerc Sport 2011;82:466-73.
25. Wulf G, Dufek JS. Increased Jump Height with an External Focus Due to Enhanced Lower Extremity Joint Kinetics. J Mot Behav 2009;41:401-9.
26. Jourden FJ, Bandura A, Banfield JT. The Impact of Conceptions of Ability on Self-Regulatory Factors and Motor Skill Acquisition. Psychol Sport Exerc 1991;13:213-26.
27. Baker J, Horton S. East African running dominance revisited: a role for stereotype threat? Br J Sports Med 2003;37:553-5.
28. Hively K, El-Alayli A. "You throw like a girl:" The effect of stereo-

type threat on women's athletic performance and gender stereotypes. Psychol Sport Exerc 2014;15:48-55.
29. Schücker L, Anheier W, Hagemann N, Strauss B, Völker K. On the optimal focus of attention for efficient running at high intensity. Sport, Exercise, and Performance Psychology 2013;2:207-19.
30. Acierno LJ. Adolph Fick: mathematician, physicist, physiologist. Clin Cardiol 2000;23:390-1.
31. Fagard R, Conway J. Measurement of cardiac output: Fick principle using catheterization. Eur Heart J 1990;11 Suppl I:1-5.
32. Bevegard S, Holmgren A, Jonsson B. Circulatory studies in well trained athletes at rest and during heavy exercise. With special reference to stroke volume and the influence of body position. Acta Physiol Scand 1963;57:26-50.
33. Schücker L, Hagemann N, Strauss B, Völker K. The effect of attentional focus on running economy. J Sports Sci 2009;27:1241-8.
34. Buckner RL. The serendipitous discovery of the brain's default network. Neuroimage 2012;62:1137-45.
35. Mckiernan KA, Kaufman JN, Kucera-Thompson J, Binder JR. A parametric manipulation of factors affecting task-induced deactivation in functional neuroimaging. J Cogn Neurosci 2003;15:394-408.

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