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Original Article

The effects of external and internal focus of attention on physiological responses during running

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ABSTRACT

Ziv G, Meckel Y, Lidor R, Rotstein A. The effects of external and internal focus of attention on physiological responses during running. *J. Hum. Sport Exerc.* Vol. 7, No. 3, pp. 608-616, 2012. The purpose of this study was to examine the influence of external focus of attention and internal focus of attention instructions on physiological responses in experienced adolescent basketball players (n = 17; mean age = 15.1±0.6 years). After a 10-min warm-up at a running velocity equal to 60% of the heart rate reserve, participants ran on a treadmill under two 10-min conditions: (a) internal focus instructions – focusing on the legs and running motion, and (b) external focus instructions – focusing on a film of a basketball game that did not provide visual feedback on running speed. It was found that oxygen consumption and respiratory exchange ratio did not significantly differ among the three conditions. It was concluded that an external focus of attention that does not provide additional visual feedback pertinent to the task of running (e.g., a film clip from the runner's perspective that shows advancing in a virtual environment) does not affect physiological measures or improve running economy. **Key words**: PSYCHOPHYSIOLOGY, ATTENTION, ATHLETIC PERFORMANCE, AEROBIC EXERCISE.

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INTRODUCTION

The effects of attentional focus instructions on the learning of a motor task have been studied extensively in the motor learning and sport and exercise psychology literature (see Wulf, 2007 for an extensive review). An external focus of attention leads one's attention to the movement effects, while an internal focus of attention leads one's attention to the movements themselves (Wulf & Dufek, 2009). It has been found that an external focus of attention leads to improved learning and performance (see Al-Abood et al., 2002; Wulf et al., 1999; Wulf et al., 2000; Wulf & Su, 2007; Zachry et al., 2005). The main reason for the superiority of the external focus of attention over the internal focus of attention is that the external focusing promotes automatic movement control, while the internal focusing constrains the motor system by intervening with automatic processes (Wulf, 2007). This explanation is supported by findings of electromyography (EMG) studies, which show that reduced muscle activation accompanies the improved performance when using external focus in dart throwing (Lohse et al., 2010) and vertical jump (Wulf et al., 2010). This reduced muscle activation accompanying improved performance suggests that coordination within the muscles is optimized (Wulf et al., 2010).

Although the benefits of an external focus of attention are quite consistent for learning a new motor skill, particularly discrete closed-motor skills, the relationship between attentional focus and endurance activities is inconsistent (Masters & Ogles, 1998). A number of studies suggested that an external focus might be beneficial to endurance athletes (e.g., Gill & Strom, 1985; Morgan et al., 1983; Pennebaker & Lightner, 1980). For example, in one study (Gill & Strom, 1985), participants performed more repetitions in a leg extension endurance task under external focus condition (i.e., looking at a collage) when compared to internal focus conditions (i.e., focusing on feelings in the legs). In contrast, others suggested that an internal focus might have greater benefits (e.g., Connolly & Janelle, 2003; LaCaille et al., 2004). For example, female varsity rowers performed better (i.e., rowed for a longer distance) on a rowing ergometer under internal focus conditions (i.e., focusing on breathing and body) than under external focus conditions (i.e., focusing on collages and answering general questions about them) (Connolly & Janelle, 2003).

Most studies on the use of attentional focusing instructions measure performance. When measuring performance, several intervening factors can affect results, among them motivation, fatigue, and nutrition. It is less known whether attentional focus affects physiological responses to sub-maximal exercise, in which the task intensity and duration is predetermined and is not influenced by subjective psychological or physiological variables. One such measure is the oxygen consumption at a sub-maximal running velocity, which also represents the running economy (Saunders et al., 2004).

Up to now, only one study examined the effects of attentional focus on running economy. This study, by Schücker et al. (2009), found benefits of an external focus of attention. The external focus of attention was set as a film showing an urban running setting from a runner's perspective at a velocity similar to that of the treadmill. However, such an intervention not only allows for an external focus of attention, it also presents visual feedback of running velocity to the participant on the treadmill.

The importance of visual information in controlling movements was examined in one study, which showed that the preferred transition speed from walking to running was not controlled only by biomechanical factors (Mohler et al., 2007). In this study, when the visual flow rate was higher than the actual treadmill velocity, preferred transition speeds from walking to running were lower, and when the visual flow rate was lower than the actual treadmill velocity, preferred transition speeds were higher. As the authors suggested, it appeared that the visual flow of information became calibrated to energetic or mechanical aspects of gait, and thus contributed to the control of locomotion. In another study (Prokop et al., 1997), differences in the visual flow led to changes in self-chosen walking velocities. The authors of this study suggested that individuals choose their walking velocity based on both visual information and leg proprioceptive velocity information.

Since visual flow can affect gait and locomotion, it is possible that it can also affect the physiological responses to walking or running. Indeed, changes in gait patterns, such as in stride length, vertical oscillation of body center of mass, arm motion, and shoulder rotation, can be related to running economy (Anderson, 1996). While Schücker et al. (2009) presented interesting findings for the benefit of an external focus, the physiological basis for these findings was not clear. Moreover, it is possible that it was the visual feedback rather than the external focus per se that led to the differences in running economy. Therefore, the purpose of our study was to examine whether internal focuses and external focuses that do not provide any visual feedback influence the physiological responses of runners. It was assumed that without the visual feedback, no differences in physiological variables would be found between external and internal focus of attention.

MATERIAL AND METHODS

Participants

Seventeen male adolescent basketball players (mean age = 15.1±.6 years; mean basketball experience = 6.6±2.5 years) from two teams in an elite youth basketball league were recruited for this study. The players practiced approximately five times per week; each practice sessions lasted about two hours. In addition, the players played one league game each week. The basketball players were selected to participate in the current study since they were active athletes who were used to running. However, athletes/players from other sports (e.g., soccer and team handball players) could have been selected as well. A signed consent form was received from the parents of all participants. The study was approved by the Ethics Committee of the Zinman College of Physical Education and Sport Sciences. Descriptive statistics of the physical and physiological characteristics of the basketball players are presented in Table 1.

Table 1. *Descriptive statistics of the physical and physiological characteristics of the basketball players (mean±SDs).*

Variable	Value
Height (cm)	181.1±11.6
Body mass (Kg)	71.2±15.3
Percent fat (%)	7.9±2.7
Resting HR (beats·min^{-1})	74±7
Estimated VO_2max ($mlO_2 \cdot kg^{-1} \cdot min^{-1}$)	52.4±6.9

Procedure

Upon arrival at the Exercise Physiology Laboratory, the participants remained seated for 15 minutes, after which resting heart rate (HR) was measured using a chest strap HR transmitter system combined with a Polar Beat wristwatch (Polar®, Polar Electro, Kempele, Finland). The resting HR was subtracted from an estimated Maximal HR in order to calculate the HR reserve (HRR). Maximal HR was estimated using the following equation: HRmax= 208-0.7*age. This formula explains 80% of the variance in maximal HR

(Tanaka et al., 2001). Participants' body mass and height were then measured and recorded using an electronic scale and a stadiometer (Seca Deutschland, Hamburg, Germany), respectively. Two-compartment body composition (fat mass and fat free mass) was estimated using the sum of three skinfolds (triceps, subscapular, and chest) using a Lafayette skinfold caliper (Lafayette Instrument Company, Lafayette, IN, USA).

After completing these preliminary measurements, each participant ran at a velocity matching 60% of his HRR for 30 minutes. We selected 60% of HRR since we wanted to ensure that all participants ran at a sub-maximal velocity that was below their lactate threshold. The first 10 minutes were used to warm up the participants so that they would reach steady-state. This was followed by two consecutive 10-min conditions: (a) external focus, and (b) internal focus. The warm-up was completed with no attentional focus instructions. The internal and external focus conditions were counter-balanced. Under the internal focus condition, participants were instructed to focus on their moving legs and feet, and under the external focus condition they were instructed to focus on a video of a final game of the European Basketball League that was shown on a laptop computer screen placed in front of them at eye level. The instructions regarding the focus of attention were recorded on a CD and were repeated every 15 seconds throughout the relevant condition. During the internal focus condition, the statements "focus on the running motion" and "focus on the movement of your legs" were spoken and alternated every 15 seconds. During the external focus condition, the statements "focus on the basketball game" and “focus on the defensive and the offensive game of the teams" were provided and also alternated every 15 seconds. Since the attentional focus instructions were given to the participants every 15 seconds, a manipulation check for the implementation of the focus instructions was not performed. We assumed that in the sterile conditions that existed in the laboratory, the basketball players should have no difficulties following the internal focus instructions.

Throughout the 30-min run, the participants were connected to a metabolic cart (K4, Cosmed, Rome, Italy). Breath-by-breath physiological measurements were recorded and the values of the last seven minutes under each condition of the following variables were used for further analysis: oxygen consumption (VO_2), ventilation (VE), respiratory rate (RR), and respiratory exchange ratio (RER). These four values from the last seven minutes under each condition were averaged for further analysis. Lastly, the rate of perceived exertion (RPE) on a 1-10 scale (Borg, 1982) was recorded at the last minute of each condition.

In addition to the laboratory tests, a 20-m shuttle run test was completed during regular basketball practice sessions in order to estimate participants' VO_2max. In this test, participants were required to run back and forth between two markers placed 20 m apart at a gradually increasing pace that was dictated by auditory beeps (St Clair Gibson et al., 1998).

Statistical analyses

Descriptive statistics are presented as means±SDs. A one-way analysis of variance (ANOVA) with repeated measures was used to assess differences between the physiological variables in the three running conditions. A Fisher LSD post-hoc test was performed to determine the differences among the three conditions. Observed power and effect sizes were calculated as well. The statistical significance level for all statistical analyses was set at alpha =0.05.

RESULTS

The physiological and RPE responses of the basketball players to the warm-up and the two experimental conditions are presented in Table 2. No significant differences were found in any of the physiological variables between the internal focus condition and the external focus condition. As a secondary analysis, we examined differences in physiological variables between the two experimental conditions and the 10-min warm-up. Significant differences were found in VE($F(2,30)=15.1$, $p<0.001$, $\eta 2=0.50$, power=1.00), RR ($F(2,30)=23.73$, $p<0.001$, $\eta 2=0.60$, power=1.00), HR($F(2,30)=24.62$, $p<0.001$, $\eta 2=0.62$, power=1.00), and RPE($F(2,30)=4.97$, $p<0.05$, $\eta 2=0.25$, power=0.77). Post-hoc calculations indicated that VE, RR, HR, and RPE were higher in the external and internal conditions than in the warm-up.

Table 2. *The physiological and RPE responses of the basketball players to the two experimental conditions (means±SDs).*

Variable	Internal Focus	External Focus
VO_2 ($mlO_2\cdot kg^{-1}\cdot min^{-1}$)	42.23±4.54	41.91±4.62
Ventilation (L·min-1)	79.72±17.38	80.67±17.80
Respiratory rate (breaths·min^{-1})	47.90±7.56	48.65±8.18
HR (beats·min^{-1})	159±5	158±6
Respiratory exchange ratio	0.88±.07	0.88±.06
RPE	3.94±1.91	3.75±1.39

DISCUSSION

The main finding emerging from our study was that an external focus of attention that does not provide visual feedback of running velocity to participants performing a running test does not lead to different physiological responses or to improved running economy (as measured by the participants' VO_2) when compared to an internal focus of attention. In fact, the oxygen consumption was comparable during all three stages of the 30-min run, despite increases in VE, RR, HR, and RPE from the first 10 minutes (warm-up) to the final 20 minutes (external and internal conditions).

Studies in motor learning and sport and exercise psychology have typically found that an external focus of attention can be beneficial (e.g., Zachry et al., 2005). Two studies reported that relationships between improved performance when using external focus and reduced muscle activation as measured by EMG in dart throwing (Lohse et al., 2010) and vertical jump (Wulf et al., 2010) were observed. In one of those studies (Wulf et al., 2010), external focus of attention led to an improvement of 1.4 cm in vertical jump height ($\eta 2=0.49$), which was accompanied by reduced activation in the leg muscles. However, those studies measured performance, and to our knowledge no study has examined the underlying physiological responses to sub-maximal efforts. Hence, we measured physiological responses and running economy at a fixed sub-maximal running speed, as they are not dependent on the participants' motivation or cooperation.

In addition, performances such as running speed or running duration can be influenced by a number of psychological factors, such as motivation, anxiety, and mood states. External focus of attention can benefit performance by directing one's attention away from psychologically unfavorable internal dialogues. However, running at 60% of HRR for 30 minutes should not be considered a difficult task that requires motivation or other psychological attributes from trained athletes. This is supported by the low RPE values of approximately three to four in this study (see Table 2). Therefore, the fact that an external focus of attention is useful for performance-based motor tasks, but not for an objective physiological variable (i.e., running economy) in a continuous and relatively easy sub-maximal run, is reasonable.

We found only one study (Schücker et al., 2009) that examined the effects of attentional focus on running economy in trained runners. In this study, 24 runners (averaging 59 km per week, VO_2max: 56.37±5.15 $mlO_2 \cdot kg^{-1} \cdot min^{-1}$) were asked to perform a 30-min run under three 10-min counterbalanced conditions: (a) internal focus on legs and feet, (b) internal focus on breathing, and (c) external focus on a video of an urban running scene from the runner's perspective at approximately 12 $km \cdot hr^{-1}$. Running velocity was set to match 75% of the VO_2max of each participant (which was similar to the velocity of the external video clip – 11.79±0.93 $km \cdot hr^{-1}$). Running under the external focus condition resulted in the highest running economy (39.10±4.38 $mlO_2 \cdot kg^{-1} \cdot min^{-1}$), when compared with the internal focus on the legs (40.68±4.64 $mlO^2 \cdot kg^{-1} \cdot min^{-1}$) and on breathing (42.80±5.16 $mlO^2 \cdot kg^{-1} \cdot min^{-1}$). In addition, subjective rating of difficulty (on a scale of 1-easiest to 3-most difficult) was recorded, and the score for the external condition (1.38±0.65) was lower than both the internal-legs (2.17±0.70) and internal-breathing (2.41±0.65) conditions.

However, the external condition in the Schücker et al. (2009) study not only led the participants' attention externally, it also provided visual feedback of running velocity. Such visual feedback was unavailable to the participants during the internal focus of attention condition, as running on a treadmill does not provide the perception of actual forward movement.

It has been shown that changes in the visual flow of information can influence the perception of locomotion and lead to changes in the preferred transition speed from walking to running (Mohler et al., 2007), as well as to changes in self-chosen walking velocities (Prokop et al., 1997). In one study (Mohler et al., 2007) two experiments were conducted. In Experiment 1, 10 participants walked on a treadmill while velocity was increased at a constant rate until the participants decided to change their gait to running. The participants watched a video presenting a visual flow of lower, matched, or higher velocity than that of the treadmill. When the visual flow matched the treadmill's velocity, the transition speed from walking to running occurred at 2.11 $m \cdot s^{-1}$ (7.6 $km \cdot hr^{-1}$). However, when the rate of visual flow was slower than the treadmill velocity the transition from walking to running occurred at 2.18 $m \cdot s^{-1}$ (7.85 $km \cdot hr^{-1}$), and when the visual flow was faster than the treadmill's velocity the transition occurred at 2.04 $m \cdot s^{-1}$ (7.34 $km \cdot hr^{-1}$). In Experiment 2 of this study, 10 students had to choose their preferred walking velocity based on changes in visual flow (rather than having the treadmill's velocity dictated by the researchers). The results revealed a preferred walking speed of 1.29 $m \cdot s^{-1}$ (4.64 $km \cdot hr^{-1}$) when the visual flow matched their walking velocity, 1.41 $m \cdot s^{-1}$ (5.07 $km \cdot hr^{-1}$) in the visually slower condition, and 1.21 $m \cdot s^{-1}$ (4.36 $km \cdot hr^{-1}$) in the visually faster condition. As the authors suggested, in both experiments the only variable that changed was the visual flow.

Since it appears that visual flow information is related to changes in gait and locomotion, and since changes in gait (e.g., stride length, arm swing, shoulder rotation) can lead to changes in running economy (Anderson, 1996), it is possible that the presence of visual flow information can affect physiological responses to running. Hence, it could be suggested that that the available visual flow of information accompanying the external focus of attention in Schücker et al. study (2009) affected perception, and that the differences in running economy in this study were due to the visual perception of forward movement rather than to the external focus of attention per se.

The higher values of VE, RR, HR, and RPE during the external focus and internal focus conditions compared to the warm-up condition in the present study can be explained by the order in which these conditions were presented during the 30-min run. The increased ventilatory and cardiac responses from the 10th minute to the 30th minute were probably due to ventilatory and cardiac drift, and probably had little to do with the experimental conditions themselves. Such drift represents a rise in physiological responses as the duration of exercise is lengthened. Indeed, a number of studies showed that during prolonged sub-maximal aerobic exercise, ventilatory and cardiac drifts occur (e.g., Cheatham et al., 2000; Hanson et al., 1982; Rowland & Rimany, 1995). For example, an increase of 8.6% in oxygen uptake, 15% in HR, 11.7% in VE, and 14% in RR was found in adult females from the 10th minute to the 40th minute of a cycle exercise at 60% of VO_2max (Rowland & Rimany, 1995). In another study (Cheatham et al., 2000), HR of 10 adult males progressively increased from 143±14 beats·min^{-1} at the 10th minute of exercise to 163±17 beats·min^{-1} at the 40th minute of exercise.

CONCLUSIONS

In conclusion, the results of the current study suggest that an external focus of attention per se does not lead to changes in RPE or physiological responses (i.e., VO_2, VE, RR, RER, and HR) when running at sub-maximal velocities at 60% of HRR. Future work should attempt to compare different types of external focus that either do or do not provide actual visual feedback on running velocity. In addition, it is possible that an external focus of attention can benefit running performance, especially while running at higher velocities that lead to fatigue, or in performances that require motivation. Under such conditions, diverting the focus of attention away from uncomfortable sensations, such as muscular pain or shortness of breath, may lead to improved performance.

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