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Effects of acute aerobic exercise on exogenous spatial attention

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ABSTRACT

Objectives: This study investigates the effect of acute aerobic exercise on exogenous spatial attention and executive control.
Designs and Method: Participants performed an exogenous cueing discrimination task in three situations: at rest, while exercising, and immediately after exercising. The stimulus–response compatibility effect was also measured at each exercise condition.
Results: The results in the rest session showed the typical facilitation effect at the 100 ms Stimulus Onset Asynchrony (SOA) and the inhibition of return (IOR) effect at the 1000 SOA. While the facilitation effect was present in the three exercise conditions and there was not any significant difference in the magnitude of the effect between them, the IOR effect was significant only in the rest session. The stimulus–response compatibility effect was of a similar magnitude in the three exercise conditions.
Conclusions: This study demonstrates that, compared to a rest condition, an acute bout of aerobic exercise performed during or even immediately before the spatial task, modulates the deployment of exogenous spatial attention.

The relation between exercise and cognitive performance is a current topic of research (see McMorris, Tomporowski, & Audiffren, 2009, for a review). In the present study we investigated the effect of an acute bout of aerobic exercise, performed during and prior to the cognitive task, on the deployment of exogenous visual spatial attention, measured by means of a typical exogenous cueing task, and on executive control. Executive control, considered as the mechanism involved in decision making, error detection, generation of novel responses and inhibition of automatic unwanted responses (Posner & DiGirolamo, 1998), was measured by means of the response compatibility or Simon effect. That way, we obtained an index of the difficulty in inhibiting an automatically-activated response. In effect, when a stimulus is presented to the right visual hemifield, participants respond more rapidly with their right hand than with their left hand. In that case, when a left response is required, the automatically-activated right-hand response has to be inhibited.

The ability to move and focus attention across space is crucial in sport contexts, to select and give priority to the processing of stimuli that are relevant for behaviour (Allard, Brawley, Deakin, & Elliott, 1989). In the laboratory, it has been repeatedly shown that cueing participants to a specific spatial location speeds up reaction time (RT) to a target presented at the cued location and often enhances response accuracy on cued location trials as compared to uncued location trials (e.g., Posner, Snyder, & Davidson, 1980). Note that visuospatial attention can be driven endogenously, by means of central symbolic and informative cues, or exogenously, by means of peripheral (informative or not informative) cues. When the peripheral direct cue does not predict the target location, as in the present study, the cueing effect is purely exogenous in nature and depends on the time interval between the cue and target presentation, i.e., the cue-target Stimulus Onset Asynchrony, or SOA. At short SOAs participants typically perform better on cued location trials than on uncued trials. However, the reverse pattern of data is typically found at long SOAs (i.e., longer than 250 ms), an effect that has been termed inhibition of return (IOR; Posner, Rafal, Choate, & Vaughan, 1985).[1] The facilitation effect observed at short SOAs is

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[1] The particular pattern of RT as a function of SOA on exogenous cueing tasks does depend on other factors such as the type of task (detection, discrimination). Note though that a comprehensive review on exogenous visual spatial attention effects goes beyond the scope of this brief report. See Klein (2000) or Lupiáñez (2010) for such a review.

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considered the result of the automatic capture of attention by the cue. The IOR effect observed at longer SOAs is typically interpreted as a cost in returning to an already attended spatial location (Klein, 2000). However, recent research has shown that IOR can be observed even when attention does not have to return to previously cued locations (see Lupiáñez, 2010 for a review). Thus, the IOR effect is interpreted as a cost in detecting the appearance of the target, due to the habituation of attention at the location where it was previously captured (Dukewich, 2009). In other words, the target would be less novel and therefore would capture attention to a lesser extent when it would appear at the previously cued location, as compared to when it would appears at new (i.e., uncued) locations.

The facilitation and IOR effects have been typically measured in controlled laboratory environments where participants performed the task at rest. However, in various sport situations spatial attention is deployed while the observer is under physical load that increases his/her physiological activation. To the best of our knowledge, there are not studies in the literature that have investigated the effect of exercising on the deployment of exogenous visual spatial attention. This is rather surprising given the relevance of exogenous spatial attention in multiple sport situations, e.g., a tennis player that has to focus his/her attention on the ball ignoring all type of peripheral stimuli that may appear abruptly, such as a camera flash. The closest approximation to this issue comes from studies that have compared performance between sportsmen/women and non-athletes in a visual spatial exogenous attention task, but always at rest (e.g., Lum, Enns, & Pratt, 2002).

In contrast, numerous studies have investigated the effects of exercise on executive control (see Hillman, Erickson, & Kramer, 2008; Tomporowski, 2003; for reviews of chronic and acute exercise). For instance, Pontifex, Hillman, Fernhall, Thompson, and Valentini, (2009) showed that participants' RT in a working memory task (that involved executive control) improved during an acute bout of aerobic exercise as compared to a rest condition. However, other studies have shown the reverse pattern of data, with an impaired performance on incongruent trials on a flanker (control) task while exercising (e.g., Pontifex & Hillman, 2007). Meanwhile, Davranche, Hall, and McMorris (2009) failed to show any effect of acute aerobic exercise on participants' performance on congruent or incongruent trials in a flanker task. Therefore, the effect of exercise on executive control is currently not clear (see Etnier & Chang, 2009, for discussion on this issue).

The present study was designed to investigate the effect of acute aerobic exercise on the deployment of exogenous visual spatial attention and on executive control. Executive control plays an important role in open sports given the complexity and variability of situations that typically require emitting novel responses and, in some occasions, the inhibition of automatic behaviours. In contrast with previous accounts (although see Audiffren, Tomporowski, & Zagrodnik, 2009; Del Giorno, Hall, O'Leary, Bixby, & Miller, 2010; Lambourne, Audiffren, & Tomporowski, 2010), we measured participants' performance in the cognitive task in three different situations in the same experiment: At rest, while exercising, and immediately after an acute bout of aerobic exercise, when participants returned to their baseline heart rate.

Pesce and co-workers (e.g., Pesce, Capranica, Tesittore, & Figura, 2002, 2003) have suggested that performing a visual endogenous attention task (i.e., with predictive cues) while exercising induced an increased allocation of attentional resources when participants have to focus on local or global stimulus features after a validly cued trial, and a greater ability to refocus these resources following an invalidly cued trial. Assuming that aerobic exercise has similar effects on exogenous attention (note that, contrary to Pesce et al., we used non-predictive peripheral cues) we predict that the acute bout of aerobic exercise will increase the cueing effect at the short SOA and reduce, or even eliminate, the IOR effect at the long SOA with respect to performance on the visual spatial task at rest. Additionally, we will investigate whether exercising can affect the deployment of visual attention even when the exercise is performed immediately before the cognitive task. We did not have a priori hypotheses regarding the modulation of the response-compatibility effect by exercise given the contradictory results present in the literature.

Methods

Participants

Twenty undergraduate students (two females; age range: 18–29 years old; mean age: 22 years old) from the Faculty of Physical Activity and Sport Sciences (University of Granada, Spain) took part in the study in exchange of course credits. All of the participants informed to practice at least 2–3 (1-h aprox.) sessions of sport/fitness per week. All reported normal hearing and normal or corrected-to-normal vision. The experiment reported in this paper was conducted according to the ethical requirements of the local committee.

Apparatus and materials

Participants were fitted with a S610i Polar monitor (Polar Electro, Finland) to control their heart rate during the threshold session and the experimental session. A Monark 864 cycloergometer was used to obtain participants' aerobic (AET; Mean = 116 b min^{-1}; SD = 14 b min^{-1}) and anaerobic (ANT; Mean = 152 b min^{-1}; SD = 18 b min^{-1}) thresholds and to conduct the experiment proper. The cycloergometer was adapted to accommodate each participant's height. A Lactate Pro lactate test meter and Lactate Pro strips (ARKRAY, Inc., Japan) were used to measure participants' levels of blood lactate during the threshold session. A 19" LCD laptop Toshiba PC was used to present the stimuli in the spatial attention task. The centre of the laptop screen was situated at 60 cm (approx.) from the participants' head and at his/her eye level. The stimuli consisted of two boxes ($3.80^\circ \times 4.80^\circ$) with their border in light grey colour displayed on a black background, one to the left and the other to the right of the fixation point, a cross ($0.4^\circ \times 0.4^\circ$) displayed in light grey colour at the centre of the screen. The inner edge of these placeholder boxes (where the target was presented) was at 5.5° from the fixation point. The cue consisted of the flickering (increasing the line-width of the border) of one of the boxes for 50 ms. The target was an X or an O (1°) displayed in white colour for 100 ms at the centre of one of the boxes. Two response buttons connected to the computer USB-2 port were used to collect participants' left and right responses. The E-Prime software (Psychology Software Tools, Pittsburgh, PA, USA) was used to control for stimulus presentation and response collection.

Procedure and design

The participants visited the lab in four separate occasions, always at the same time of the day (between 4 pm and 7 pm). In the first session, the threshold session, their AET and ANT were obtained using the Astrand protocol (Astrand & Rodahl, 1986) with the cycloergometer. Prior to the start of the effort test, the participant was told to rest for 10 min approximately and then his/her basal heart rate was annotated. The Astrand protocol consisted of a submaximal incremental effort test with a fix cadence of 60 revolutions min^{-1}, starting with a power of 75 W and with increments of 25 W every 2 min. The level of blood lactate was measured 30 s