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PHYSICAL EXERTION IN SIMPLE REACTION TIME AND CONTINUOUS ATTENTION OF SPORT PARTICIPANTS[1]

HARALAMBOS TSORBATZOUDIS, VASSILIS BARKOUKIS, APOSTOLOS DANIS, GEORGE GROUIOS

Sport Psychology Laboratory
Aristotelian University of Thessaloniki

Summary.—To investigate the effect of physical exertion on simple reaction time and continuous attention of sport participants, an experiment was conducted with 46 male university students and 12 male cyclists. The subjects were assigned to three experimental and two control groups. The subjects of the experimental groups were asked to perform, following a 5-min. period of warming up, a high intensity exercise protocol for 5 min., on a mechanically braked cycle ergometer (Group A) or a moderate intensity exercise protocol for 30 min. on the same cycle ergometer (Groups B and C). Shortly before and immediately after the physical exercise subjects of all groups were asked to perform a test of simple reaction time and continuous attention. The subjects of the control groups were asked to perform at rest both tests of the simple reaction time and the continuous attention twice, with a 10-min. and a 35-min. interval between the first and second attempts, respectively. The results did not support the notion that exercise of moderate or high intensity influences significantly the cognitive performance of aerobically trained or untrained subjects. The results are discussed in the light of the current research findings concerning exertion and human psychomotor performance.

A number of theoretical approaches have been developed over the last 40 years to describe and explain the relationship between physical exertion and information processing or mental functioning after exercise. The findings concerning the effects of physical activity on mental functioning are widely contradictory. A number of studies (cited by Tomporowski & Ellis, 1986) suggested that physical arousal has either facilitating or debilitating effects on mental functioning shortly after exercise. On the other hand, Tomporowski, Ellis, and Stephens (1987), Zervas (1990), and Zervas, Danis, and Klissouras (1991) indicated that strenuous exercise has no significant aftereffects on mental functioning.

With regard to reaction time, the research findings are also ambiguous. Meyers, Zimmerli, Farr, and Bashnagel (1969), Lofthus and Hanson (1980), and Travlos and Marisi (1995) noted no significant effect for physical activity on reaction time. On the other hand, Stull and Kearney (1978) reported increased motor time as a result of the increased physical fatigue. Similarly,

[1]Please address correspondence and requests for reprints to Dr. H. Tsorbatzoudis, Aristotelian University of Thessaloniki, Department of Physical Education and Sport Sciences, 54 006 Thessaloniki, Greece.

Williams, Pottinger, and Shapcott (1985) reported an enhancement of reaction time after strenuous physical exercise.

A number of researchers suggested that physical fitness strongly influences information processing. However, Marisi, Dallaire, and Travlos (1987), Tomporowski, *et al.* (1987), Zervas, *et al.* (1991), and Travlos and Marisi (1995) did not confirm this speculation. Their results suggested a nonsignificant difference on mental task performance after physical activity between individuals high and low in fitness.

Travlos and Marisi (1995) attributed the conflicting results of the literature (a) to the alternative influences of the arousal of the central nervous system and physical fatigue of the skeletal-motor system on mental functioning and (b) to the fact that some mental functions are not affected by the increased intensity of exercise to exhaustion, while some other mental functions are impaired.

The present study has been designed to test the hypothesis that physical exertion induced by two different exercise protocols, i.e., aerobic versus anaerobic physical exercise, affects significantly and differently the simple reaction time and continuous attention of trained and untrained individuals.

Method

Subjects

Forty six male university students, who were not participating in any form of aerobic exercise, and 12 top level male cyclists [a total of 58 subjects ($M=20$ yr., $SD=3.2$)] voluntarily participated. The subjects were then assigned to three experimental groups ($n=12$ per group) and two control groups ($n=11$ per group) (see Table 1).

Procedure

The subjects of the experimental group A (untrained male university students) were asked to perform, following a 5-min. period of warming up, a high intensity exercise protocol for 5 min. on a mechanically braked cycle ergometer (Monark 868). The initial work load was 250 Watts. To maintain the subjects' heart rate at 180–190 bpm, the initial work load was adjusted ±25 Watts after Min. 2 of the exercise protocol according to the subjects' heart rate. The subjects' heart rate was continuously recorded via a sport tester (PE 3000). Blood samples (20 μl) were taken from the ear at 3 and 5 min. after the completion of the exercise protocol to estimate the maximum concentration of lactate (Mader, Heck, Foehrenbach, & Hollmann, 1979). Blood samples were analyzed photometrically via the Boehringer Enzymatic Method (149993). Shortly before and immediately after the physical exercise subjects were asked to perform tests of simple reaction time and continuous attention. The subjects of the control group A (untrained male university

students) were asked to perform, at rest, both simple reaction time and continuous attention tests twice with a 10-min. interval between the first and second attempt.

The subjects of the experimental group B (untrained male university students) and the experimental group C (male competitive cyclists) were asked to perform, following a 5-min. period of warming up, a moderate intensity exercise protocol for 30 min. on the same cycle ergometer. The initial work load varied to cause a heart rate of 150 bpm. During the first 5 min. of the exercise protocol, the work load was adjusted in such a way that the subjects' heart rate was 150–160 bpm until the completion of the test. The subjects' heart rate was continuously recorded via a sport tester (PE 3000). Blood samples (20 μl) were taken from the subjects' ear immediately after the completion of the exercise protocol to determine the lactate concentration (Mader, *et al.*, 1979). Shortly before and immediately after the physical exercise, the subjects of the experimental groups B and C were asked to perform the tests of simple reaction time and continuous attention. The control group B–C was asked to perform both the simple reaction time and continuous attention tests twice at rest, with a 35-min. interval between the first and second attempt.

Cognitive Tasks

Simple reaction time.—A self-developed computer program, installed into an IBM compatible PC, was used to estimate the subjects' performance on simple reaction time to both visual and auditory stimuli. The subjects' operation panel consisted of two sensitive hand buttons (2.5 cm in diameter) and two sensitive foot pedals (10 cm × 19 cm); the weights of the subject's finger and foot, respectively, were sufficient to open the connections. The two hand buttons were 10.5 cm apart and the two foot pedals 8 cm apart. The response movement was horizontally directed from right to left for the right upper and lower limb and from left to right for the left upper and lower limb.

The subjects were instructed to place the index finger of the right hand on the 'home' button to start each trial. Depression of the 'home' button extinguished the visual stimulus (a highlighted bar on the top of the screen) after a random foreperiod delay of 1 to 4 sec. The subjects were instructed to release the 'home' button after the appearance of the stimulus on the screen and to press as soon as possible the other hand button. Each subject performed 20 trials with his right hand (10 reactions to a visual stimulus and 10 to an auditory stimulus). The same procedure was followed with the left hand, as well as with the right and left foot.

Reaction time was "the measure of the time delay from the arrival of the suddenly presented and unanticipated visual or auditory stimulus to the

beginning of some predetermined motor response to it" (Grouios, 1987, p. 2; 1991, p. 18), which was the removal of the subject's finger or foot from the 'home' button and the 'home' pedal, respectively. Movement time was, accordingly, "the measure of the time delay which was necessary for the subject to remove his finger or foot from the 'home' button and the 'home' pedal, respectively, and press the second button or pedal" (Grouios, 1989, p. 71; 1992, p. 145). Mean reaction time and movement time scores of the 80 trials were calculated for each subject separately. All scores were recorded to the nearest .01 second.

Continuous attention.—The Vienna-Test System (Schuhfried, 1984) was used to estimate the subjects' continuous attention. The duration of the test was 4.5 min. The test consisted of five triangles periodically appearing in random order on the screen. The subjects were required to press a key button whenever two peaks of the five triangles on the screen were oriented downwards. The program allowed the measurement of the subjects' correct, wrong, and missing answers as well as the mean decision time to the nearest .01 second. Decision time was calculated as the time delay from the sudden and unanticipated appearance of the triangles on the screen to the subject's correct response to it.

Results

Over-all Analyses

Mean values and standard deviations for age, workload, heart rate, and lactate concentrations in the bloodstream of the experimental groups are presented in Table 1.

TABLE 1
Means and Standard Deviations For Age, Work Load, Heart Rate, and Maximum Lactate Concentrations of Experimental Groups

Group	Age, yr.		Work Load, Watt		Heart Rate, bpm		Maximum Lactate Concentration, mM/l	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Group A	23.2	3.2	245.8	14.4	177.8	9.7	10.8	1.6
Control Group A	20.3	1.6						
Group B	21.8	2.8	146.7	45.4	165.5	9.9	3.6	2.1
Control Group B-C	21.0	2.0						
Group C	16.3	1.5	164.5	41.1	168.9	7.9	1.8	0.6

Analyses indicated no statistically significant differences ($t = -0.70$) on heart-rate values between the aerobically trained (cyclists, $M = 168.9$ bpm, $SD = 7.9$) and untrained subjects (students, $M = 165.5$ bpm, $SD = 9.9$); however, with regard to maximum lactate concentrations, statistically significant

differences ($t = 3.89$, $p < .001$) were found between the aerobically trained ($M = 1.8$ mM/l, $SD = 0.6$) and untrained subjects ($M = 3.7$ mM/l, $SD = 2.1$).

Simple Reaction Time and Movement Time

The 5 × 2 (groups × pre/posttest) analysis of variance, with repeated measures on the last factor indicated no statistically significant interaction or main effects for groups for the simple reaction time and movement time. However, the analysis yielded significant main effects for the pre- and posttest scores for both simple reaction time and movement time ($F_{1,4} = 5.47$, $p < .05$ and $F_{1,4} = 27.07$, $p < .01$, respectively). The posttest values of the groups under investigation were consistently lower than the pretest values.

Continuous Attention

The 5 × 2 (group × pre/posttest) analysis of variance with repeated measures on the last factor for the continuous attention data (correct, wrong, and missing answers as well as decision time) yielded no significant interaction or main effects for the groups. However, statistically significant main effects were found for the pre- and posttest scores of the correct answers ($F_{1,4} = 10.88$, $p < .01$), the wrong answers ($F_{1,4} = 40.83$, $p < .001$), missing answers ($F_{1,4} = 10.39$, $p < .01$), and decision time ($F_{1,4} = 7.85$, $p < .01$). The posttest values of the examined groups were consistently better than the pretest values.

Discussion

The current results indicated systematic differences between the subjects' pre- and posttest performance for simple reaction time, movement time, and continuous attention. Since there were no significant differences between the experimental and control groups, these results may be attributed to the learning processes and the familiarization of the subjects with the test procedures and the equipment during experimentation. Thus, it seems that neither previous aerobic training nor the intensity or duration of the physical activity can influence significantly mental functioning after exercise.

These results are in line with Gutin and DiGennaro (1968) and Meyers, *et al.*'s (1969) findings which showed neither decrement nor improvement in simple reaction time performance after intense anaerobic exercise; however, these results disagree with a number of studies cited by Tomporowski and Ellis (1986), which suggested that aerobic exercise of moderate intensity facilitates cognitive performance.

Finally, with respect to the training level of the subjects, the results are in accordance with those of Marisi, *et al.*, (1987), Tomporowski, *et al.* (1987), Zervas, *et al.* (1991), and Travlos and Marisi (1995) which suggested that there were no significant differences between trained and untrained subjects concerning mental functioning after physical exercise.

In conclusion, the current results do not support the notion that exercise of moderate or high intensity influences significantly the cognitive performance of aerobically trained or untrained subjects in this kind of laboratory tasks. Based on previous research and present results, it is tenable to conclude that, if progress is to be made in understanding the relation between exercise and mental functioning, researchers must incorporate suitable control procedures to identify motivational or emotional effects that may influence performance on cognitive tests.

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