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INFLUENCE OF PHYSICAL EXERTION ON MENTAL PERFORMANCE WITH REFERENCE TO TRAINING [1, 2]

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Summary.—The aim of this study was to assess the effect of physical exertion (treadmill) on mental performance (matching a comparison design). Nine pairs of monozygotic twins (boys aged 11 to 14 yr.) were randomly divided into two groups, one trained and one untrained, while eight boys of the same age served as a control group. The trained group underwent a specifically designed program lasting six months. The trained and untrained groups performed on the treadmill for 20 min. at a running speed intensity above their individual anaerobic thresholds. Mental performance was evaluated by analysing mean number of correct answers, time taken to reach correct answers (decision time), and wrong answers. A 3×2 (group $\times$ pre/posttest) analysis of variance with repeated measures on the last factor yielded no significant differences; however, significant pre- versus posttest differences on correct answers and decision times occurred among the exercised groups.

Rigorous physical activity is traditionally related to fatigue and detrimental influence on the cognitive functions. However, contemporary studies have not led to a definitive conclusion that physical exertion affects mental performance. The results of previous studies have been classified by McGlynn, Laughlin, and Rowe (1979) into those which indicated a beneficial relationship (Lybrand, Andrews, & Ross, 1954; McGlynn, Laughlin, & Bender, 1977; Raviv & Low, 1990), those which show a detrimental effect (Gutin & DiGennaro, 1968b; Hancock & McNaughton, 1986; Stockfelt, 1973), those which yield no significant relationship (Flynn, 1972; Zervas, 1990), and those which found an inverted U-curve relationship between physical exertion and mental performance (Davey, 1973).

Mental performance seems to be related to fitness as fit groups performed significantly better than the unfit groups on various mental tasks (Gutin & DiGennaro, 1968a, 1968b; Sjobery, 1980; Weingarten, 1973). Contrarily, Tomporowski, and Ellis (1986) reported no significant differences on a free-recall memory task between subjects high and low in fitness after a strenuous run to exhaustion on a motorized treadmill.

Regarding the influence of physical exertion on reaction time, Meyers, Zimmerly, Farr, and Baschwagel (1969) reported a stepping exercise had no effect. Stull and Kearney (1978) found that motor time increased significantly with the progressive increase in fatigue. Contradictory results were re-

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ported by Hanson and Lofthus (1978) and Lofthus-Hanson (1980). Specifically, in the first case the total reaction time for the preferred limb increased significantly, while in the second it was unaffected.

In the published studies the contradictions and discrepancies apparent with respect to the effect of intensive physical exertion on various types of cognitive functions persuaded us to conduct the present experiment. The main purpose was to examine the hypothesis that physical exertion improves mental performance, measured as number of correct responses, decision times, and number of wrong responses on the Cognitrone Test. Further, we hypothesized that trained subjects would perform better than untrained ones.

Method

Subjects

Eighteen (18) boys, ages 11 to 14 years ($M = 13.1$, $SD = 1.02$), served as experimental subjects in this study. These experimental subjects comprised nine monozygotic (MZ) pairs of twins. Zygosity was determined on the basis of morphological, dermatoglyphic, and red blood cell antigen similarities (Klissouras, 1971). These subjects were divided into two groups, one trained and one untrained. Eight (8) more boys, ages 12 or 13 years ($M = 12.7$, $SD = .52$), served as control subjects.

Design

The experimental subjects (twins) were randomly divided into two groups. One twin was placed in the first experimental group and the other twin (the brother) was placed in the second experimental group. The first group followed a training program for 25 weeks. After this period both experimental groups were pretested, underwent a strenuous physical exertion on the treadmill, and were posttested. The control group were pretested, rested for 60 minutes, and were posttested. Posttest scores were compared to assess the effectiveness of physical exertion on mental performance.

The Training Program

This study was part of a larger research project in which the first experimental group followed a training program three times weekly for nearly six months (25 weeks). The program consisted of a 15-min. warm-up (stretching and free exercises) and a 60-min. ($\pm$15 min.) interval or continuous running. The intensity was individualized and assessed on the basis of personal speed, measured as the anaerobic threshold of 4 mmol/l. The second experimental group and the control group underwent only the regular physical education classes held in schools two to three times weekly by the physical education teachers. These classes were also attended by the first experimental group. The school physical education program may be rated as a light physical activity.

Procedure

Mental test.—Upon entering the laboratory, subjects were informed about the experiment. The mental test used in this study was the Cognitrone Test (Schuhfried, 1984), which consisted of four different designs projected onto the screen of the monitor at eye level. At the same time a fifth design was projected below the four. The fifth design was or was not identical to one of the four. When the design was identical, the subject was told to press a key on the monitor. Each set of designs was displayed for 2.5 sec. Subjects performed a succession of trials (50 stimuli) typical of the experiment that was to follow. Subjects performed three sets of trials (50 stimuli each) at pretest and three more at posttest. The time between sets of trials was only that needed to print out scores (about 2.5 min.), making the over-all time required 15 min. The interval between pre- and posttest was 60 min. During this period subjects of the control group were seated in the laboratory with no particular activity.

Performance was evaluated by analyzing mean numbers of correct and incorrect answers (responses), and the time taken (decision time) to give the former. This latency was defined as the elapsed time between presentation of the stimuli and pressing the key. The mean of each set of trials was recorded as the score. The average performance of the three sets of trials obtained at pretest was compared with the average performance at the posttest.

Physical exertion.—Upon completion of the mental pretest, subjects of the two experimental groups (trained and untrained) entered the Ergophysiology Laboratory, located at a distance of 50 meters from the Motor Behavior Laboratory, and underwent strenuous exertion on the treadmill. Subjects were informed that they would be performing a 5-min. warm-up running at 8 or 9 km/hr., followed by a 20-min. run at a stable speed ranging between 12 and 14 km/hr. and up a constant gradient of 1%. Speed was established for each pair of twins following a test conducted to determine the $VO_{2\ max}$ and the anaerobic threshold. It must be noted that one subject (the untrained) performed at a slightly lower speed because he had difficulty in following the same speed as his brother. Heart rate was measured every 30 sec. by a Memory heart-rate receiver attached to the body and analyzed by a computer (Takei) program. Blood lactate was measured from a sample of blood (20 μl) taken from an ear lobe at Minutes 1, 3, and 5 of recovery. The highest value for the three samples was assumed to be representative of the concentration of blood lactate. Analysis of the samples was made by a Beckman Model 42 photometer, using the enzymatic method of Boehringer Manheim (No. 256773).

Fifteen minutes after the physical exercise subjects again entered the Motor Behavior Laboratory and performed the mental posttest task consisting of three further sets of trials. Control subjects performed the mental posttest one hour after the pretest. Throughout this time, these latter subjects were seated in the laboratory, again without any specific activity.

RESULTS

The means and standard deviations for heart rate and blood lactate are presented in Table 1. Heart-rate data indicated no significant differences between the trained ($M = 187.3$ bpm, $SD = 10.5$) and untrained ($M = 189.5$ bpm, $SD = 7.5$) subjects. On blood lactate concentration no significant difference appeared between trained and untrained subjects (Table 1).

TABLE 1

MEANS AND STANDARD DEVIATIONS FOR SPEED, BLOOD LACTATE, AND HEART RATE

Group	*n*	Speed km/hr.		Lactate mmol/l		Heart Rate bit/min.	
		M	*SD*	*M*	*SD*	*M*	*SD*
Trained	9	13.03	.70	4.63	1.84	187.25	10.5
Untrained	9	12.96	.69	5.22	1.44	189.50	7.5

The means and standard deviations for $VO_{2\ max}$ in Table 2 showed no significant difference between the trained and untrained groups on the absolute $VO_{2\ max}$ value (ml/min.). There was a significant difference ($p < .05$) between the trained and untrained groups on the relative $VO_{2\ max}$ value (ml/kg × min.), the trained group obtaining a higher mean than the untrained group. This is attributed to a slight increase of the body weight observed in the untrained group.

TABLE 2

MEANS AND STANDARD DEVIATIONS FOR $VO_{2\ max}$

Group	*n*	lit/min.				ml/kg × min.			
		Pretest		Posttest		Pretest		Posttest	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Trained	9	2.08	.43	2.37	.45	52.07	3.56	57.49	3.63
Untrained	9	2.10	.41	2.32	.47	54.02	3.85	55.38	3.27

The means and standard deviations for number of correct responses, number of wrong responses, and decision times for each group are presented in Table 3. A 3 × 2 (group × pre/posttest) analysis of variance with repeated measures on the last factor was carried out, the dependent variables being number of correct responses, number of wrong responses, and decision times.

Correct Responses

The analysis yielded no significant main effect for groups ($F_{2,23} = 1.03$, $p > .05$), but at pre- and posttest differences were significant ($F_{1,23} = 26.60$, $p < .001$). In other words, trained subjects gave significantly more correct responses at posttest ($M = 23.37$, $SD = .71$) than at pretest ($M = 20.70$, $SD = 1.94$; $t_8 = 4.06$, $p < .004$). Similarly, untrained subjects performed significantly better at posttest ($M = 23.25$, $SD = 1.27$) than on the pretest ($M = 21.96$, $SD = 1.34$; $t_8 = 2.91$, $p < .02$). No significant differences were observed in the control group's performances on pre- and posttest measures ($t_7 = 1.80$, $p > .05$). In general, the average improvement in correct responses was 11.42% for the trained group, 5.52% for the untrained group, and 2.35% for the control group. Analysis of variance disclosed a significant interaction ($F_{2,23} = 4.54$, $p < .02$) for correct responses. This reflected an improvement in the posttest scores of the two experimental groups, while the mean score of the control group remained relatively constant from pretest to posttest.

TABLE 3
MEANS, STANDARD DEVIATIONS, AND *F* RATIOS FOR CORRECT ANSWERS, DECISION TIME, AND WRONG ANSWERS

Group	*n*	Pretest		Posttest		*F*	*df*	*p*
		M	*SD*	*M*	*SD*			
Trained	9							
Correct		20.7	1.9	23.4	0.7	16.46	1,8	.001
Decision Time, msec.		139	4	125	17	33.24	1,8	.001
Wrong		3.9	2.2	4.6	1.7	2.70	1,8	
Untrained	9							
Correct		22.0	1.3	23.3	1.3	8.45	1,8	.02
Decision Time, msec.		145	14	128	12	55.80	1,8	.001
Wrong		3.6	2.9	3.4	3.9	.29	1,8	
Control	8							
Correct		22.4	0.8	23.0	1.0	3.22	1,7	
Decision Time, msec.		142	15	126	13	23.04	1,7	.002
Wrong		3.5	1.7	3.0	1.0	1.43	1,7	

Wrong Responses

An analysis of variance gave no significant group differences ($F_{2,23} = .45$, $p > .05$), no significant pre- and posttest differences ($F_{1,23} = .00$, $p > .05$), and no significant interaction ($F_{2,23} = 2.30$, $p > .05$).

Decision Time

The analysis of decision times yielded no significant group differences ($F_{2,23} = .16$, $p > .05$), and no significant interaction ($F_{2,23} = .36$, $p > .05$), but there were significant differences pre- and posttest ($F_{1,23} = 103.01$, $p < .001$). All groups performed significantly better at posttest, i.e., had smaller latencies. These differences may be attributed to learning.

DISCUSSION

The first purpose of this study was to investigate whether physical exertion affects mental performance, measured as number of correct responses, decision time to correct responses, and number of wrong responses. Analysis indicated no significant differences between the groups on all dependent measures. However, significant differences occurred for number of correct responses made on pre- and posttest trials by the trained and untrained subjects (twins), that is, the exercised groups performed significantly better at posttest than the control subjects. In this study there were significant differences in the speed at which individuals in all groups gave correct answers. This may be attributed to the varied rates at which subjects became familiar with the test process. It must be pointed out, however, that this rate was faster in the trained group of twins.

It is difficult to explain these differences specifically. It is possible that physiological activation of various parts of the neural system occurring during physical activity may be one such explanation (Lindsley, 1951). On the other hand, the idle state in which control subjects remained throughout this time might have had a contrary effect.

The second purpose of this study was to examine the differences between trained and untrained subjects. The analysis yielded no significant differences between these two groups. This may be attributed to the fact that, although the subjects of the one group trained for six months, there were no significant differences in fitness between them and their brothers in the second group.

In general, the results are of considerable interest for findings may be useful to teachers and parents but particularly to students themselves in the organization of both academic work and sports. In other words, intensive and relatively long-duration physical activity might be preceded by, or inserted between, various theoretical classes without impairing students' academic learning and achievement. In addition, the results provide a basis for further argument against the commonly held belief that exercise adversely affects mental performance.

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