# THERE IS A RELATIONSHIP BETWEEN INTENSITY OF EXERCISE AND REACTI ON TIME ON LATERALLY CONCORDANT AND DI SCORDANT STI MULI 

Erika Zemková ${ }^{1}$, Peter Miklovič ${ }^{\mathbf{2}}$ and Dušan Hamar ${ }^{\mathbf{1}}$<br>${ }^{1}$ Faculty of Physical Education and Sport, Bratislava, Slovakia<br>${ }^{2}$ Faculty of Electrical Engineering and Information Technology, Bratislava, Slovakia

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#### Abstract

The study investigates a relationship between intensity of exercise and reaction time on laterally concordant and discordant stimuli, respectively. A group of 16 karate performers underwent in different days stepwise exercises on cycle ergometer with initial workload of 100 W increased by 20 W per minute up to exhaustion. During exercise subjects had to press, as fast as possible, the button attached to the cycle ergometer on the left or right handle. In the first case, they pressed the button in accordance with the location of stimulus on the screen, whereas in the second responded on left stimulus with right hand and vice versa. Stimuli were randomly generated by computer-based system FiTRO Reaction check, which also measures corresponding reaction time (RT). Prior to the test a measurement of RT in non-fatigue conditions, using the same diagnostic system, was provided. The protocol consisted of 2 sets of 20 stimuli while mean of 16 the best reaction times in better of two trials was taken for the evaluation. Results showed that at the beginning of exercise, at heart rate of about 120 bpm , reaction time slightly decreased (from 351.6 $\pm 40.0 \mathrm{~ms}$ to $330.7 \pm 38.2 \mathrm{~ms}$ ). This phase was followed by plateau in RT (on average $355.4 \pm$ 44.6 ms ) from heart rate of about 130 to 155 bpm . As intensity of exercise increased, particularly beyond 160 bpm , also increase in RT became steeper ( $\max 394.0 \pm 54.8 \mathrm{~ms}$ at heart rate of 180 bpm ). However, a significantly ( $\mathrm{p} \leq 0.05$ ) greater increase in reaction time (from about 160 bpm ) was found when responding on laterally discordant (from $457.0 \pm 47.3 \mathrm{~ms}$ to $508.4 \pm 53.5 \mathrm{~ms}$ ) than concordant stimuli (from $378.2 \pm 43.7 \mathrm{~ms}$ to $412.5 \pm 48.0 \mathrm{~ms}$ ). It may be concluded that exercise of moderate intensity contributes to faster responses on visual stimuli, whereas fatigue induced by strenuous exercise is associated with an increase in reaction time.


Key words: intensity of exercise, reaction time, stimulus-response compatibility

## I ntroduction

Already in early 1960s has been known about positive effect of warm-up on reaction time (e.g., Laufberger, 1960), namely in form of exercises of low intensity (e.g., Zelený et al., 1957; Vasiljeva et al., 1958; Woodworth, Schlossberg, 1959; Havel, Veselý, 1960). On the other hand it is known that exerciseinduced fatigue may increase reaction time (e.g., Zelený, Michal, 1960). It has been found (Zemková et al., 1998) about 8\% improvements in reaction time after exercise of moderate intensity, whereas its 18\% increase was observed after strenuous exercise above anaerobic threshold.

It means that post-exercise response time depends on its type, improves after aerobic exercise but is negatively affected by anaerobic exercise. Besides intensity of exercise also stimuli compatibility may determine individuals' response.

For instance, using the right hand rather than left to catch a ball that suddenly takes an unexpected bounce to the right is more "compatible" because both the hand being used to catch it (right) and the direction the hand is moving (to the right) are similar to the direction the ball is moving (to the right). Research has clearly established (Schmidt, Wrisberg, 2004) that for a given number of S-R choices, RT is faster the more compatible the $S-R$ pairs. Experience showed that a highly experienced athlete can overcome the disadvantage of $\mathrm{S}-\mathrm{R}$ incompatibility. For a given number of stimulus-response alternatives, the greater the amount of practice, the shorter the choice RT (Schmidt, Wrisberg, 2004). With extreme amounts of practice, high-level performers can produce reactions that approach automatic processing. Moreover, research of Ward et al. (2002) showed that experienced tennis players have significantly faster decision time due to detection regularities in their opponent's movements.

Thus, besides amount of practice also its nature is important. As practice with the same S-R combinations increases, that is, the same stimulus always leads to the same response, choice RT becomes faster. This phenomenon is seen quite often in sport situations when a performer produces the same responses to the same stimuli on repeated occasions.

For example, the experienced karate performer knows which response is most appropriate for various punches an opponent might produce. However, these athletes have to perform quick and accurate responses during all competition, thus also in fatigue in the end of 3 min of repeated karate-matches. To our knowledge, there is no information on relationship between intensity of exercise and reaction time on laterally concordant and discordant stimuli, respectively. Therefore the aim of the study was to investigate the effect of stimuliresponse compatibility on reaction time during exercise on the cycle ergometer with stepwise increasing intensity up to exhaustion.

## Methods

Subjects
A group of 16 karate performers (age $22.1 \pm$ 1.3 y , height $178.5 \pm 3.5 \mathrm{~cm}$, and weight 78.8 $\pm 6.8 \mathrm{~kg}$ ) volunteered to participate in the study. All of them were informed of the procedures and of the main purpose of the study.

Test protocols and diagnostic equipments Subjects underwent stepwise exercise on cycle ergometer. Initial workload of 100 W was increased by 20 W per minute up to exhaustion. Heart rate was monitored by means of SportTester. During exercise subjects had to press, as fast as possible, the button attached to the cycle ergometer on the left or right handle (Fig. 1). In the first case, they pressed the button in accordance with the location of stimulus on the screen (compatible stimuli-responses), whereas in the second responded on left stimulus with right hand and vice versa (incompatible stimuli-responses).

Stimuli (yellow circle on black background) were randomly generated by computer-based system FiTRO Reaction check, which also measures corresponding reaction time. Prior to the test a measurement of reaction time in non-fatigue conditions, using the same diagnostic system, was provided. The protocol consisted of 2 sets of 20 stimuli while mean of 16 the best reaction times in better of two trials was taken for the evaluation.


Figure 1 Task execution - response on laterally concordant (a) and discordant stimuli (b), respectively during stepwise exercise on the cycle ergometer

Statistical analysis
Ordinary statistical methods including average and standard deviation were used. A Wilcoxontest was employed to determine the statistical significance of differences between reaction time in pre-fatigue and fatigue conditions, $p<$ 0.05 was considered significant.

## Results

It has been found (Fig 2) that at the beginning of exercise, at heart rate of about 120 bpm , reaction time slightly decreased (from $351.6 \pm$
40.0 ms to $330.7 \pm 38.2 \mathrm{~ms}$ ). This phase was followed by plateau in RT (on average $355.4 \pm$ 44.6 ms ) from heart rate of about 130 to 155 bpm. As intensity of exercise increased, particularly beyond 160 bpm , also increase in RT became steeper (max $394.0 \pm 54.8 \mathrm{~ms}$ at heart rate of 180 bpm$)$. Results also showed (Fig. 3) a significantly ( $\mathrm{p} \leq 0.05$ ) greater increase in reaction time (from about 160 bpm) when responding on laterally discordant (from $457.0 \pm 47.3 \mathrm{~ms}$ to $508.4 \pm 53.5 \mathrm{~ms}$ ) than concordant stimuli (from $378.2 \pm 43.7 \mathrm{~ms}$ to $412.5 \pm 48.0 \mathrm{~ms}$ ).


Figure 2 Relationship between heart rate and reaction time


Figure 3 Reaction time on laterally concordant and discordant stimuli during stepwise exercise on cycle ergometer

## Discussion and conclusion

Decrease in reaction time at the beginning of exercise may be ascribed to warm-up. Its positive influence on speed of responses due to increase in physical and mental arouse has been proved by several authors (e.g., Kasjanov, Fruktov, 1952; Kasjanov, Fruktov, 1953; Laufberger, 1960; Greguš, 1964; Lekszás, Nieke, 1965).

For example, Wirth already in 1927 reported shortening of reaction time after walking. Such a positive effect of exercise on cognitive functioning may be attributed to an enhanced activation of peripheral component (muscle contraction) and central nervous system integrity (Hogervorst et al., 1996), primarily reflecting cognitive processing speed (Birren et al., 1980).

Also increase of reaction time in fatigue induced by higher intensity of exercise was documented decades ago (e.g., Zelený et al., 1957; Zelený, Michal, 1960; Csinády, Nemessuri, 1962). Rojtbak and Dedabrišvili (1958) supposed that mainly local fatigue of exercising muscles plays an important role. Similar tendency was reported also in association of RT latency with mental work (e.g., Wirth, 1927; Geréb, 1962; Kotulán, Jaroš, 1964). Our results showing a relationship between reaction time and intensity of exercise are in agreement with these studies. Though the relationship between reaction time and oxygen uptake was documented (Zelený et al., 1957; Zelený, Michal, 1960), we have shown that greater rise in RT occur above 160 bpm, which may be estimated as an anaerobic threshold. Similarly, Chmura et al (1994) found that during exercise with increasing intensity up to exhaustion the multi-choice reaction time decreased until the intensity exceeded the lactate threshold by approximately $25 \%$, and then rapidly increased. Later study of Chmura et al. (1998) showed that young athletes are able to maintain for a relatively long time, or even increase, their psychomotor performance during exercise not only below but also above the lactate threshold. However, our findings showed that reaction time increased at
intensity above 160 bpm even in experienced karate performers. This effect became more evident when the location of the stimulus was not paired with the location of the responding hand (i.e., left with right and right with left) as compared to responses on compatible stimuli. It may indicate that also stimulus-response compatibility plays a role in speed of reactions. From practical point of view is therefore important to focus not only on the amount of choice RT practice but also on its nature, e.g., to increase the variety of stimulus-response choices that athletes must deal with in order to speed up their decision making. Warm-up in form of exercise of moderate intensity contributes to faster responses on visual stimuli, whereas fatigue induced by strenuous exercise is associated with increase in reaction time. More specifically, there is an exponential character between reaction time and heart rate during exercise, i.e. RT decreases toward intensity bellow aerobic threshold (about 120 bpm) followed by plateau (at $130-155 \mathrm{bpm}$ ) and then gradually increases after reaching estimated anaerobic threshold ( 160 bpm ) up to exhaustion. However, this effect beyond intensity above 160 bpm depends also on stimulus-responses compatibility, i.e. there is a steeper increase in RT while responding on laterally discordant than concordant stimuli.

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# POSTOJI RELACIJA IZMEĐU I NTENZI TETA VJ EŽBANJ A I BRZI NE REAKCI JE NA LATERALNO USKLAĐENE I NEUSKLAĐENE STI MULUSE 

## Sažetak

Ova studija istraživala je relacije između intenziteta vježbanja i brzine reakcije na lateralno usklađene i neusklađene stimuluse, respektivno. Skupina od 16 karatista sudjelovala je različitim danima u stupnjevitom vježbanju na bicikl-ergometru s inicijalnim opterećenjem od 100 W (wata) koji se povećavao za 20 W svake minute do iscrpljenja. Za vrijeme vježbe subjekti su trebali pritisnuti, što su brže mogli, tipku pričvršćenu na bicikl-ergometar na lijevoj ili desnoj strani držača. U prvom slučaju, pritiskali su tipku u skladu s lokacijom stimulusa na ekranu, dok su u drugom slučaju odgovarali na lijevi stimulus desnom rukom i obrnuto. Stimulusi su slučajno generirani računalom utemeljenim sustavom FiTRO provjere reakcije, koji također mjeri odgovarajuću brzinu reakcije (RT). Prije izvedbe testa, korištenjem istog dijagnostičkog sustava, provedeno je mjerenje brzine reakcije u uvjetima bez zamora. Protokol se sastojao od 2 skupa po 20 stimulusa pri čemu je 16 najboljih vremena reakcije u boljem od dva pokušaja uzeto u obzir za procjenu. Rezultati su pokazali da je na početku vježbanja, do srčane frekvenciji od oko 120 bpm , brzina reakcije lagano rasla (od $351.6 \pm 40.0 \mathrm{~ms}$ to $330.7 \pm 38.2 \mathrm{~ms}$ ). Ovu fazu prati plato brzine reakcije (prosječno $355.4 \pm 44.6 \mathrm{~ms}$ ) sa srčanim ritmom od oko 130 do 155 bpm . Kako intenzitet vježbanja raste, posebno iznad 160 bpm , također se povećava i vrijeme reakcije (maksimalno $394.0 \pm 54.8 \mathrm{~ms}$ kod srčanog ritma od 180 bpm ). Međutim, značajno ( $\mathrm{p} \leq 0.05$ ) veće povećanje vremena reakcije (na oko 160 bpm ) je pronađeno kad su registrirani odgovori na lateralno neusklađene (od $457.0 \pm 47.3$ ms to $508.4 \pm 53.5 \mathrm{~ms}$ ) nego usklađene stimuluse ( od $378.2 \pm 43.7 \mathrm{~ms}$ to $412.5 \pm 48.0 \mathrm{~ms}$ ). Može se zaključiti da vježbanje osrednjeg intenziteta doprinosi bržem odgovoru na vizualni stimulus, dok je umor induciran napornim vježbanjem povezan sa povećanjem vremena reakcije.

Ključne riječi: intenzitet vježbanja, vrijeme reakcije, stimulus-odgovor kompatibilnost

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Correspondence to:
Assoc. Prof. Erika Zemková, Ph.D.
Comenius University Bratislava
Faculty of Physical Education and Sport
Svobodovo nábrežie 9, 81469 Bratislava, Slovakia
Phone: +421 254411624
E-mail: zemkova@yahoo.com

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