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Physical exercise facilitates motor processes in simple reaction time performance: An electromyographic analysis

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Abstract

The aim of the current study was to assess the effects of physical exercise on simple reaction time performance. Participants performed a simple reaction time task twice, one time during physical exercise and another time without exercise. Electromyographic signals were recorded from the thumb of the responding hand to fraction reaction time in pre-motor and motor time. The results showed that exercise shortened motor time but failed to affect pre-motor time. This pattern of findings is consistent with previous studies examining the effects of physical exercise on choice reaction time.

Keywords: Exercise; Fractionated RT; Motor time; Pre-motor time; Visual intensity; Simple RT

Choice reaction time (RT) is generally been shown to be shorter when the task is performed simultaneously with an acute sub-maximal exercise (e.g. [6]). The fractionating of choice RT, using the onset of voluntary electromyographic (EMG) activity to dissect RT into pre-motor and motor time, has shown that exercise (i) interacts with visual stimulus intensity on the pre-motor time (PMT), which suggests that this variable affects retinal processing, and (ii) shortens the motor time (MT) [7], thereby revealing that this variable affects the contraction of the response agonist [10,14]. Exercise, therefore, alters the peripheral sensory and motor processes implemented during choice RT. Since exercise influences peripheral processes during choice RT, it seemed relevant to also test the influence of the exercise during simple RT. Direct assessment of the motor command in simple and choice performances revealed that the descending volley is more phasic in simple than in choice reactions (e.g. [3,4]). Given that peripheral motor processes differ across these procedures, it seems worthwhile to further assess the effects of exercise on simple RT.

Previous studies yielded inconsistent findings (for a review, see [13]). Physical exercise has been observed to exert a facilitating, detrimental, or no effect on simple reaction time performance (e.g. [9,1,5]). The objective of the present study was to assess the effects of exercise on simple RT using the same EMG analysis and the same stimulus intensity manipulation than those used by Davranche and Audiffren [6] in choice RT. In this aim, simple RT was fractionated into PMT and MT, with respect to the voluntary activity of the response agonists, in a manual task performed either concurrently with a pedaling task or at rest.

Since factors affecting the same processes generally interact [12], visual stimulus intensity was manipulated so as to determine whether exercise also affects the early sensory processes involved in simple RT task.

Twelve experienced players in decision-making sports[1] [five females and seven males, aged 22–50 ($M = 27$ years; S.D. = 8)] were tested. Informed consent was obtained from the participants. The maximal oxygen uptake ($\dot{V}O_{2\,max}$: $M = 44\,ml\,kg^{-1}\,min^{-1}$; S.D. = 8), the power at maximal oxygen uptake ($P\dot{V}O_{2\,max}$: $M = 279$ W; S.D. = 61), maximal heart rate (HR_{max}: $M = 183$ beats min^{-1}; S.D. = 10) and the power at ven-

[1] In decision-making sports as opposed to other sports (e.g. swimming, athletics), players are accustomed to simultaneously handle physiological and cognitive loads simultaneously (e.g. team sports, fighting sports and racket sports).

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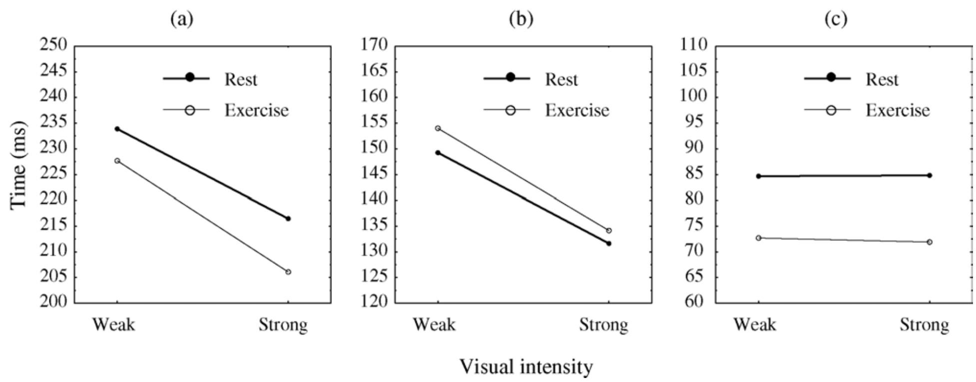

Fig. 1. Combined effects of physical exercise and signal intensity (RT; under-additive significant interaction), pre-motor time (PMT; marginally significant over-additive interaction) and motor time (MT; additive effects). (a) Reaction time, (b) pre-motor time, and (c) motor time.

tilatory threshold (P_{VT}:M = 146 W; S.D. = 32) were individually determined in a preliminary protocol (see [7] for more details).

Each subjects sat on a cycle ergometer (Ergoline 800S) in a dimly illumination room. Two LEDs, 7.5 cm apart, were presented horizontally at a distance of 60 cm in front of the participant. The green left LED (off) served as fixation point and as warning signal (on), the right red LED as imperative stimulus. A response key was fixed on the right handle of the bicycle's handlebar. Subjects were asked to respond as quickly and accurately as possible to the visual stimuli by pressing the key with his/her thumb (7.5 N). The EMG of the right thumb (*flexor pollicis brevis*) was recorded by means of paired surface Ag-AgCl electrodes (11 mm). This activity was amplified (gain 10 000), filtered (low frequency cut-off 10 Hz, high frequency cut-off 1 kHz) and digitized on-line (2 kHz).

A trial began with the onset of the green LED (50 ms); 500 ms later the red LED was lit, either strongly (0.8 mcd) or weakly (0.2 mcd). Stimulus intensity was varied within blocks. The response extinguished the stimulus. The next trial started 200 ms after the response. In 20% of the trials, the red LED was not lit and subjects were not to respond in order to avoid anticipation. Within a block (68 trials), stimulus intensity (strong versus weak) was presented equally often according to a pseudo-random series. The first two blocks were practice blocks and were discarded. After a warm-up period (5 min), the subjects performed three consecutive blocks during exercise (15 min while cycling at 50% of $P\dot{V}O_{2\,max}$ with a freely chosen pedal rate)[2] and three consecutive blocks at rest. The order of exercise and rest was counter-balanced across subjects.

Responses to catch trials represent 0.39% (ranging from 0 to 9%) of the total number of trials revealing that the subjects were not anticipating. Error proportions were too low for further analysis.

Repeated measures ANOVAs with exercise conditions (exercise versus rest) and visual stimulus intensity as within-subject factors show that mean RT was shorter during exercise (217 ms, S.D. = 20) than at rest (225 ms, S.D. = 17) (F(1, 11) = 5.3, $p < 0.05$, $\eta^2 = 0.11$). RT was longer to weak intensity signals (231 ms, S.D. = 17) than to strong intensity signals (211 ms, S.D. = 16) (F(1, 11) = 233.59, $p < 0.05$, $\eta^2 = 0.61$). In addition, an under-additive interaction between exercise and visual intensity was observed (F(1, 11) = 5.41, $p < 0.05$, $\eta^2 = 0.007$). Indeed, Newman–Keuls post hoc test shows that the effect of exercise was larger in the strong visual intensity (−10 ms, S.D. = 11) compared to the weak visual intensity (−6 ms, S.D. = 15) (Fig. 1a).

For pre-motor time, statistical analysis only revealed a significant effect of visual intensity (F(1, 11) = 213.21, $p < 0.05$, $\eta^2 = 0.73$). The mean PMT was longer in the weak visual intensity (152 ms, S.D. = 13) than in the strong visual intensity (133 ms, S.D. = 10). Main effect of exercise was absent (F(1, 11) = 2.04, $p = 0.18$, $\eta^2 = 0.03$), but the interaction between exercise and visual intensity was marginally significant on mean PMT (F(1, 11) = 3.57, $p = 0.08$, $\eta^2 = 0.005$) (Fig. 1b). Newman–Keuls post hoc test suggests that there was a deleterious effect of exercise on pre-motor processes in the weak visual intensity condition ($p < 0.05$; +6 ms, S.D. = 12). Moreover, the PMT distribution analysis reveals a marginal interaction between exercise and decile (F(9, 99) = 1.84, $p = 0.07$, $\eta^2 = 0.005$). Newman-Keuls analysis reveals that exercise lengthened the PMT of the two lasted deciles (ninth decile: $p < 0.05$, +9 ms, S.D. = 22; tenth decile: $p < 0.05$, +15 ms, S.D. = 33).

Mean MT was shorter during exercise (72 ms, S.D. = 17) than at rest (85 ms, S.D. = 18; F(1, 11) = 24.87, $p < 0.05$, $\eta^2 = 0.68$) and this facilitative effect was present for all deciles. Indeed, the MT distribution analysis reveals a main effect of exercise (F(1, 11) = 24.51, $p < 0.05$, $\eta^2 = 0.16$) and no significant interaction was observed between exercise and decile (F(9, 99) = 1.36, $p = 0.21$, $\eta^2 = 0.002$). MT was not influenced by signal intensity (F(1, 11) < 1) (Fig. 1c).

The EMG burst, measured through the α angle,[3] was steeper during exercise than at rest (F(1, 11) = 10.53, $p < 0.05$, $\eta^2 = 0.44$;

[2] The evolution of the pedaling rate during the three consecutive blocks performed while cycling was analyzed using a ANOVA (Blocks). In agreement with literature (e.g. [2]), an increase in pedal rate was observed (F(2, 22) = 34, $p < 0.05$). This result suggests that subjects adapt their pedal rate according to exercise intensity and duration in order to have an optimal energetic rate.

[3] Corresponds to the angle comprised by the EMG activity baseline and the line that joins the onset and peak of the rectified EMG activity waveform.

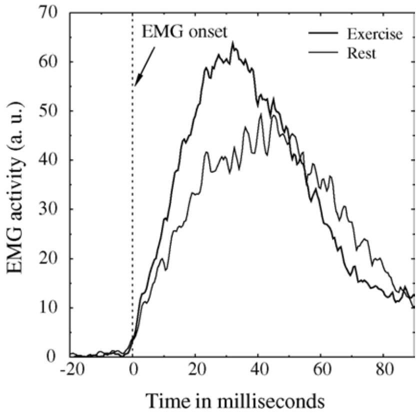

Fig. 2. Grand average of rectified electromyographic (EMG) activity during exercise (thick line) and rest (thin line).

$M = 37°$, S.D. = 15 versus $M = 30°$, S.D. = 16, Fig. 2), but the angle was not affected by signal intensity ($F < 1$).

The present study clearly indicates that exercise improves simple RT performance. Reaction time fractioning reveals that physical exercise improves late motor processes. The analysis of the EMG burst suggests that the motor unit discharge is better synchronized during exercise, thereby extending the results obtained for choice RT [7].

In addition, distributional analyses show that the effect of exercise consists of a shift of the whole MT-distribution. The benefit effect was consistent throughout all the deciles of the MT-distribution (10–14 ms) which suggests that exercise shortens RT without affecting its variance. Furthermore, it must be noted that visual intensity only affects PMT. The interaction between exercise and visual intensity on mean RT may suggest that these two factors affect at least a process in common [12]. However, this interaction being only marginally significant on PMT, conclusions regarding this interaction should be taken with caution.

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