Effects of trial importance on the accurate ball-stroking movements

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Introduction

People do not always act in a predictable manner when under psychological stress. There are many studies on the relationship between psychological stress and performance. Heart rates increase when psychological stress is experienced (Blanchard, 1979; Shapiro et al., 1993; Taggart et al., 1969; Videman et al., 1979). Van Gemmert and Van Galen (1997, 1998) demonstrated that axial pen pressure elevated when subjects performed a graphic task under cognitive stress.

In sports, players frequently face critical situations in which a single point might make a difference in the outcome of a game. Whitehead et al. (1996) reported that basketball free throws were more frequently overthrown when attempted in critical situations. However, the effects of stress on muscle activity during exercise have not been demonstrated. We previously reported that heightened arousal due to the importance of a trial increases muscle activity when subjects passed a ball through a gate (Matsumoto et al., 1999). In that task, subjects had only to control the direction and not the speed of a ball. Thus, the increase of muscle activity did not affect the performance. However, ball-game players are often required to control direction and speed of a ball. In such a situation, an increase in muscle activity might cause failure. Thus, the present study was designed to investigate how subjects react to heightened arousal when performing critical trials in a ball-stroking task that requires control of the direction and speed of the ball.

Methods

Eleven normal healthy right-handed female university students between 19 and 28 years of age served as subjects. They were informed of the purpose of the study and gave their informed consent to participate.

They were asked to use a special paddle to stroke a tennis ball (6.3 cm in diameter) that was rolling down a guide rail to a distant target circle (20.0 cm in diameter) (Figure 1). Four trials constituted one block. If a subject succeeded in the fourth trial (last trial = LT), she was given the number of successful trials as the score for each block. If she failed in the LT, no score was given regardless of whether she had succeeded in the previous trials (non-LT). Four blocks constituted one set, and 14 sets were carried out for each subject. In order to encourage the subjects to compete, the score for each set was written on a scoreboard.

Figure 1: Schematic drawing of the experimental setup.
The heart rate, surface EMGs of the flexor carpi radialis (FCR), extensor carpi radialis longus (ECR), pectoralis major (PM), and teres minor (TM) were recorded. Using three infrared photoelectric switches, the signal at which the ball passed the lower end of the guide rail (S1), the signal when the paddle started moving forward (S2), and the signal at which the ball passed an infrared switch on the board after being struck (S4) were recorded. The ball impact signal (S3) was measured by a strain gauge mounted on the paddle. The EMG latency of each muscle was calculated as the time from S1 to the EMG onset. Time from S1 to S2 (T1: latency of stroking movement onset), time from S2 to S3 (T2: movement time), and time from S3 to S4 (T3: stroked ball speed index) were calculated. Analysis of the EMG data consisted of calculating the averaged EMG (aEMG) of each muscle in the phase between the EMG onset and the impact.

Two-way ANOVAs (subject × condition) were used to assess the difference between the non-LT and LT. To compare the successful with the failed trials, two-way ANOVAs (subject × performance) were used. When a significant F value was detected, a post-hoc Tukey test was applied to examine the difference between the non-LT and LT and the successful and the failed trials. The level of significance was set at 5% for all analyses.

**Results**

The heart rate was significantly higher in the LT (78.2 ± 8.0 bpm) than in the non-LT (75.0 ± 7.3 bpm). No differences were found in the success rates (45.9 ± 13.8 % and 45.9 ± 21.0 % for the non-LT and LT, respectively). AEMGs were significantly greater in the LT than in the non-LT for all muscles (Figure 2). The T3 and EMG latency of TM was significantly shorter in the LT than in the non-LT (Figure 2).

In the successful trials, the aEMGs of ECR and TM were significantly greater in the LT than in the non-LT. In failed trials, the aEMGs were significantly greater in the LT than in the non-LT for all muscles. The T2, T3, and the EMG latency of TM was significantly shorter in the LT than in the non-LT.

In the non-LT, the T2 and T3 was longer in the failed than in the successful trials (Figure 3). In the LT, EMG latency of the FCR and the PM was longer in the failed than in the successful trials (Figure 3). There were no differences between success and failure for the aEMGs.

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**Figure 2:** AEMGs and the EMG latency of each muscle, T1, T2, and T3 (mean and standard deviation).

**Figure 3:** The EMG latency of each muscle, T1, T2, and T3 for the non-LT and LT (mean and standard deviation).
Discussion

Some studies have reported that a heart rate is high when a subject is aroused and low when he is not (Blanchard, 1979; Shapiro et al., 1993; Taggart et al., 1969; Videman et al., 1979). An increase in heart rate for the LT in the present study would indicate that a subject’s arousal level was higher in the LT than in the non-LT. The EMG amplitude was also greater in the LT than in the non-LT, but there were no clear differences in the EMG latencies. These results suggest that timing and force are controlled independently and that force control is more affected by arousal. The fast movement of the stroked ball (= short T3) under the heightened arousal may be induced by higher excitation of the alpha motoneuron pool. This is consistent with the finding that basketball free throws were more frequently overthrown when attempted during critical rather than non-critical situations (Whitehead et al., 1996).

These arousal-related differences were clearer in the failed than in the successful trials. In the successful trials, the EMG amplitude of two antagonist muscles, the ECR and the TM, was greater during heightened arousal; however, this was not so in the agonist muscles and the kinematic parameters. In the failed trials, the EMG amplitudes were greater for all muscles during heightened arousal, and this greater muscle activity made the movement of the paddle and the stroked ball faster. These results suggest that the high excitation of the alpha motoneuron with heightened arousal is suppressed in the successful trials in order not to change the performance; however, it is not sufficiently suppressed in the failed trials.

When the successful and the failed trials were compared, the failures differed according to arousal levels. With a lower arousal level (non-LT), the movement of the paddle and the stroked ball were both slow in failures. This suggests that the low activation of the motor centers due to the distraction of attention or the like causes the failure. In the situation of heightened arousal (LT), agonist muscles, the FCR, and the PM had slower starts in the failed than in the successful trials. There were no success-failure differences in the kinematic parameters. This may suggest that heightened arousal in the failed trials affected the relative timing between the agonist and antagonist muscles.

In conclusion, the arousal level and excitation of the alpha motoneuron pool increased in the important trials when subjects performed the accurate ball-stroking movements requiring control of direction and speed of the ball; this tendency was more pronounced in the failed than in the successful trials. During a heightened level of arousal, there was a success-failure difference in the relative timing between the agonist and antagonist muscles. The findings of the present study suggest that the heightened arousal tends to heighten the excitation of alpha motoneurons, and it sometimes disorders the temporal aspects of the motor program, which leads to failure.

References