Activation of the arousal response and impairment of performance increase with anxiety and stressor intensity

J. TIMOTHY NOTEBOOM, KERRY R. BARNHOLT, AND ROGER M. ENOKA
Department of Kinesiology and Applied Physiology, University of Colorado at Boulder, Boulder, Colorado 80309-0354

Received 11 December 2000; accepted in final form 27 July 2001

EXPOSURE TO LABORATORY STRESSORS, such as electric shock, mental math, physical challenge, and public speaking, typically elevates cognitive and physiological arousal (1, 5, 12, 17, 26, 28). Although the heightened arousal can impair the performance of motor tasks, the relation between a stressor and the change in arousal varies markedly across individuals (2, 24, 22).

Two factors that influence an individual’s response to stress are the average level of anxiety (3, 29, 30) and the intensity of the stressor (19). Subjects with high levels of trait anxiety, which is an index of the average level of anxiety, typically respond to stress with greater elevations of cognitive and physiological arousal and impairment of motor performance, compared with subjects who have low levels of trait anxiety (10, 14, 27, 31, 32). For example, subjects with high trait anxiety had poorer performances during ball throwing (32), motor-cross competition (10), and precision shooting tasks (27). Similarly, subjects who received a greater number of shocks were less steady during a balance task than those who received fewer shocks (19). These findings suggested the hypothesis that motor performance is influenced by both the level of anxiety and the intensity of an imposed stressor.

To investigate the association between arousal and motor output, we examined the moment-to-moment control of a precision task in the presence and absence of a variable-intensity stressor in subjects with moderate and low trait anxiety. The purpose was to determine the effect of trait anxiety and stressor intensity on arousal and motor performance during a pinch task. Subjects were exposed to incremental levels of a noxious electric shock. We expected to find that steadiness of a submaximal pinch task would be reduced during the stressor conditions, especially for the moderate anxiety subjects, and that the reduction in steadiness would be associated with the intensity of the electric shock.

METHODS

Eighty-two potential subjects (37 men, 45 women) were recruited from the general population and completed Spielberger’s State-Trait Anxiety Index (STAI-Trait portion), which is a widely used index of the average level of anxiety. After sorting by sex, the subjects whose scores were at the extremes of the distribution were selected for the study. Subjects with the 26 highest and the 14 lowest scores for the men and women were assigned to one of three groups: a control group (5 women, 5 men), a moderate-anxiety group (8 women, 8 men), or a low-anxiety group (7 women, 7 men). The subjects with the highest scores were randomly assigned to either the control or the moderate-anxiety group, whereas subjects with the lowest scores where placed in the low-anxiety group.

The 40 subjects (20 men, 20 women) were aged 18–40 yr. The subjects had no history of mental pathology, including any diagnosis of an anxiety disorder, or upper extremity injury for at least 6 mo. Each subject in the moderate- and low-anxiety groups participated in a protocol that involved multiple presentations of a noxious stimulus followed by a

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baseline period (Fig. 1). Subjects in the control group performed two baseline periods. Subjects who completed the initial trait anxiety form were paid $10. Those subjects qualified for the study, on the basis of their trait anxiety score, were paid an additional $15 for their 45-min participation in the stressor study. The Institutional Review Board at the University of Colorado approved all experimental procedures, and all subjects gave their informed consent before participation in the study.

Cognitive Assessment of Anxiety

The level of state anxiety was assessed with the STAI-State test and with the visual analog mood scale (VAS). State anxiety was determined at the beginning and end of the experiment, whereas the VAS measurements were made at seven time points throughout the experiment (Fig. 1): at the start of the protocol (time point 1), after instructions about the stressor were given but before the stressor phase (time point 2), after each 2-min stressor bout (time points 3, 4, and 5), and at the middle and end of the baseline phase (time points 6 and 7). The VAS is a 100-mm line anchored at either end with descriptive polar phrases, such as "Not at all anxious" on the left side of the 100-mm line and "Very anxious" on the right (8, 9). The subjects were asked to place a vertical line bisecting the 100-mm line to indicate the perceived level of anxiety at the moment.

Physiological Assessment of Arousal

Several variables were assessed during the experiment to quantify the level of physiological arousal. The measurements included moment-to-moment changes in heart rate, blood pressure, and electrodermal activity using electrodes placed on the left hand. Heart rate and blood pressure were measured with an inflatable cuff that was placed over the proximal portion of the middle finger and connected to a Finapres device (Ohmeda, Louisville, CO), which enabled the moment-to-moment assessment of cardiovascular function (16). Electrodermal activity was measured with electrodes (Biopac, Santa Barbara, CA) that were placed on the distal pads of the fourth and fifth fingers. Electrodermal activity measures the bioelectric characteristics of the skin by applying a direct current to the skin, and recording the skin conductance (4). The flow of current along the skin is influenced by the activity of the eccrine sweat glands, which are innervated by the sympathetic branch of the autonomic nervous system. A Biopac data acquisition system was used to record the electrodermal activity, heart rate, and blood pressure data.

Pinch Grip

The effect of heightened arousal on motor performance was examined with a submaximal isometric pinch grip, which was assessed at multiple intervals during the protocol (Fig. 1). The experiments were conducted with the subjects seated in a quiet room. The right arm rested on the arm of the chair with the elbow at a right angle and the wrist midway between maximum supination and maximum pronation. Electromyographic (EMG) activity was assessed with pairs of surface electrodes that were attached to the skin over the first dorsal interosseus muscle of each hand and the flexor digitorum superficialis muscle of each forearm. The diameter of the electrodes over the hand muscle was 4 mm, and the diameter for those over the forearm muscle was 8 mm. The center-to-center distance between the electrodes was 1 cm for the hand and 2 cm for the forearm. In addition, electrodes (8-mm diameter) were placed over the right upper trapezius muscle to record the activity of a postural muscle that was not directly involved in the pinch grip task.

The apparatus used for the pinch grip task was 4 cm wide and weighed 1.2 N. It comprised a force transducer (ATI Mini-40) that was mounted on a wooden platform. The sensitivity of the force transducer was 0.12 N/V. The apparatus was held between the distal pads of the thumb and index finger of the right hand. Contact surfaces of the apparatus had a rough texture (sandpaper) to ensure a secure grip.

Data from the force transducer were displayed on an oscilloscope, which was positioned 1 m in front of the subject at eye level. The target force of 4 N was indicated as a line on the oscilloscope. At four times during the protocol, the subject was instructed to match the exerted force with the target force as accurately as possible. Subjects were given up to 1 min of practice with this task. Force and EMG data were sampled at 1,000 Hz with the Biopac data acquisition system and stored on computer disks for later analysis.
Experimental Protocol

The session lasted ~25 min, and it was divided into two phases (Fig. 1): a stressor phase (10 min) and a baseline phase (8 min). The subjects in the anxiety groups received electric shocks during the stressor phase, whereas those in the control group did not receive any electric shocks. All subjects were provided information, via the consent form and from the experimenter, that an electrical shock stressor may be used during the study. However, before the actual stressor condition, subjects did not know whether they were in the control or a stressor group. The stressor phase preceded the baseline phase because pilot tests indicated that subjects experienced higher levels of anticipatory anxiety at the beginning of the study, which declined as the protocol progressed. A subset of five subjects in the moderate-anxiety group was tested on 2 separate days to determine the reliability of the baseline measurements. The intraclass correlations (ICC) for the physiological variables ranged from \( r = 0.71 \) to \( r = 0.89 \).

The outcome variables were cognitive and physiological arousal and steadiness during a submaximal pinch grip. Cognitive arousal was evaluated at the beginning and end of the stressor with the state anxiety index (Fig. 1A) and at seven time points during the protocol with the VAS (Fig. 1A). Physiological arousal (heart rate, blood pressure, and electrodermal activity) and steadiness (force and EMG) were measured three times during the stressor phase and once during the baseline phase (thin horizontal line in Fig. 1A).

Electric shock stressor. Subjects in the anxiety groups experienced a variable-intensity electric shock as the stressor. Two 1 × 1-cm carbon electrodes were attached to the dorsal surface (back) of the left hand over the fifth metacarpal. The electrode leads were attached to an electric stimulation device (Grass Instruments, Quincy, MA) that was used to deliver a noxious stimulus to the hand. The shocks were delivered during three 2-min bouts (Fig. 1), with the intensity of the shocks increasing across each successive bout. The shock was delivered as a 500-ms train of pulses with a frequency of 60 Hz and intensity ranging from 60 to 120 V. Two indicator lights were used to cue the subject regarding the possibility of an electric shock. When a red light was on, it was not possible for the subject to receive the electric shock, whereas a yellow light indicated that it was possible to receive up to eight electric shocks. The threat and no-threat conditions alternated in 20-s durations (Fig. 1B). The pattern of electric shocks was variable across the alternating 20-s cycles; however, this pattern was consistent across subjects. To further heighten the arousal response, the subject was told that the magnitude of the electric shock would vary across repetitions within each bout and that the intensity would increase across the three bouts. At the end of each 2-min bout (Fig. 1B), the 10-s pinch task was performed, the physiological measurements were made, and the VAS was assessed.

Data Analysis

The dependent variables for the cognitive assessment of anxiety were trait anxiety, initial and final measures of state anxiety, and multiple VAS scores. Trait and state anxiety were quantified using standardized scoring techniques (29). The VAS data were quantified by measuring the distance, in millimeters, from the left end of the 100-mm line to the point on the line where the subject marked the perceived level of anxiety. The dependent variables for the physiological arousal were heart rate, blood pressure, and electrodermal activity, which were assessed during four 10-s epochs at time points 3, 4, 5, and 7 (Fig. 1A).

The dependent variable for the pinch task was the coefficient of variation (SD/mean force × 100) for force during the 10-s intervals at time points 3, 4, 5, and 7. In addition, the EMGs of five muscles were recorded during the protocol. The interference EMG was rectified and smoothed at four time points throughout the experiment: a 10-s interval immediately after each of the three stressor bouts (time points 3, 4, and 5) and a 10-s interval at the end of the baseline phase (time point 7). These values were normalized relative to a 1-s recording of the rectified and smoothed EMG during a maximum voluntary contraction.

Statistical Analysis

A three-factor ANOVA (SPSS for Windows, SPSS) with two repeated-measures design (2 factors between and 1 within) was used to compare the dependent variables for the heart rate, blood pressure, and electrodermal activity between the three groups and sex, and across the time points. Three-factor ANOVAs with repeated-measures were applied to the cognitive assessment data of state anxiety and VAS, to the average EMG for the five muscle groups, and to the coefficient of variation for force for comparison between the three groups and sex, and across the time points. An alpha level of 0.05 was chosen for all initial statistical comparisons, with tests of simple main effects using 95% confidence interval methods when necessary to determine between-group and across-time differences. Data are reported as means ± SE in Figs. 2–4 and means ± SD in Table 1 and the text.

RESULTS

The effects of a noxious stressor on physiological and cognitive measures of arousal and pinch grip were determined for two groups of subjects who differed in the average level of anxiety. The stressor was a variable-intensity electric shock that was delivered to the left hand. The responses of subjects in the moderate- and low-anxiety groups were compared with baseline conditions and with a control group. The measurements were made during 10-s intervals at four time points during the 25-min protocol (Fig. 1). Initial analyses indicated no gender differences for any dependent variables; therefore, the data for men and women in each group were combined.

Cognitive Component of Arousal

Because subjects were assigned to groups based on trait anxiety scores, there were significant differences in trait anxiety between the moderate-anxiety (46.1 ± 4.6) and low-anxiety (27.7 ± 4.9) groups, with values similar to those reported by Palma and colleagues (23). Although the control group (36.7 ± 3.2) had a greater average trait anxiety score than the low-anxiety group, the values for the moderate-anxiety and control groups were similar (Fig. 2A). The state anxiety scores did not change over the course of the protocol for the control group (0.7 ± 5.4%), whereas they increased above the initial values (\( P < 0.03 \)) for the moderate-anxiety group (14.3 ± 12.0%). The average change in state anxiety for the low-anxiety group (7.4 ± 11.6%) was not
The state anxiety score for the moderate-anxiety group at the end of the protocol was significantly elevated from the value at the beginning of the protocol (P < 0.05), and was significantly greater than the control and low-anxiety groups (P < 0.01) (Table 1).

The cognitive component of arousal was also assessed with the VAS. Each subject completed the VAS at seven time points during the experiment (Figs. 1A and 2C). The VAS scores did not change over the course of the protocol for the control group (16.4 ± 16.8 mm). Similarly, there were no between-group or within-group differences in VAS scores during the baseline period for the anxiety groups. In contrast, there were several within-group differences for the moderate- and low-anxiety groups. For subjects in the moderate-anxiety group, the VAS scores during the baseline phase (time points 6 and 7) were significantly less than those for the three stressor time points (time points 3–5) and the value before the stressor onset (time point 2). In contrast, for the subjects in the low-anxiety group the only significant difference was between the VAS scores after bout 3 (time point 5) and the end of baseline (time point 7).

The VAS scores differed across the three groups at several time points. At time point 5, which occurred immediately after the most intense electric shock, the VAS scores for the moderate-anxiety (59.9 ± 24.4 mm) and low-anxiety (28.4 ± 24.3 mm) groups were significantly greater than the scores for the control (14.6 ± 23.4 mm) group (P < 0.003). Similarly, the VAS score for the moderate-anxiety group (45.8 ± 28.8 mm) was greater than those for the low-anxiety (19.5 ± 25.4 mm) and the control (20.0 ± 24.0 mm) groups at time point 2, which represents a state of anticipatory anxiety. VAS scores after bouts 1 and 2 (time points 3 and 4) were not different between the moderate-anxiety and control groups (P = 0.053). Taken together, these data indicate that during the stressor condition, especially for subjects with moderate levels of trait anxiety, there was a significant increase in cognitive arousal.

Physiological Arousal

Heart rate, systolic blood pressure, diastolic blood pressure, and electrodermal activity were measured at four time points during the protocol (Fig. 1). Overall, the changes in physiological arousal were relatively minor. For example, the heart rate at time point 5 (75.1 ± 12.7 beats/min) was significantly elevated above baseline (70.7 ± 10.7 beats/min), which represented a modest relative increase (5.9 ± 13.3%). Similar effects were noted for systolic blood pressure but not diastolic blood pressure (Table 1). The greatest change was recorded for electrodermal activity. When values were collapsed across time, electrodermal activity was significantly greater for the moderate-anxiety group (263 ± 111.6 S) compared with the control group (144.7 ± 111.5 S) (P < 0.04) (Table 1) but not the low-anxiety group (206.9 ± 111.5 S). However, there were no differences between groups across time (Fig. 3B).

Pinch Grip

The submaximal pinch grip was performed on four occasions during the baseline and stressor phases (horizontal bars in Fig. 1). Fluctuations in force during the pinch grip, which were quantified as the coefficient of variation for force, varied across groups and time, but

![Image]

Fig. 2. Assessment of cognitive arousal. A: trait anxiety scores based on the Spielberger index. B: percent change (%Δ) in the state anxiety score from the beginning to the end of the experiment. C: scores on the VAS at 7 time points during the 25-min experiment. Values are means ± SE.
not between sex. There were no significant differences in the coefficient of variation during the baseline period for the control (1.65 ± 0.63%), low-anxiety (1.95 ± 2.54%), and moderate-anxiety (2.10 ± 0.64%) groups. Similarly, there were no differences in the coefficient of variation for the control (1.91 ± 0.92%), low-anxiety (2.39 ± 0.90%), and moderate-anxiety (2.77 ± 1.08%) groups at time point 3 (Fig. 4C). For the moderate-anxiety subjects, however, the coefficient of variation at time point 5 (3.78 ± 1.6%) was significantly elevated compared with baseline (2.10 ± 0.51%) \((P < 0.04)\).

The time-by-group interaction was significant \((P < 0.03)\), with the coefficients of variation for the moderate-anxiety group at time points 4 (2.60 ± 0.84%) and 5 (3.78 ± 1.6%) significantly greater than the values at

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Table 1. Comparison of physiological and cognitive data by group and time

<table>
<thead>
<tr>
<th>Heart Rate, beats/min</th>
<th>Systolic Blood Pressure, mmHg</th>
<th>Diastolic Blood Pressure, mmHg</th>
<th>Electrodermal Activity, S</th>
<th>STAI State Anxiety</th>
<th>VAS Anxiety, mm</th>
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</thead>
<tbody>
<tr>
<td><strong>Control group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>68.2 ± 11.8</td>
<td>130.2 ± 15.9</td>
<td>83.5 ± 15.4</td>
<td>169.9 ± 90.8</td>
<td></td>
</tr>
<tr>
<td>Bout 1</td>
<td>68.4 ± 11.4</td>
<td>126.8 ± 23.2</td>
<td>83.2 ± 18.2</td>
<td>140.0 ± 68.8</td>
<td>32.8 ± 6.4</td>
</tr>
<tr>
<td>Bout 2</td>
<td>70.9 ± 12.5</td>
<td>128.8 ± 21.6</td>
<td>85.7 ± 18.9</td>
<td>133.5 ± 58.2</td>
<td>18.4 ± 16.8</td>
</tr>
<tr>
<td>Bout 3</td>
<td>73.3 ± 14.8 129.1 ± 9.9</td>
<td>84.7 ± 11.8 135.3 ± 58.8</td>
<td>32.5 ± 7.1</td>
<td>17.5 ± 15.5</td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>68.2 ± 11.8</td>
<td>130.2 ± 15.9</td>
<td>83.5 ± 15.4</td>
<td>169.9 ± 90.8</td>
<td>12.7 ± 14.0</td>
</tr>
<tr>
<td><strong>Low-anxiety group</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>70.9 ± 11.1</td>
<td>138.9 ± 19.2</td>
<td>83.9 ± 13.1</td>
<td>189.9 ± 103.4</td>
<td>26.5 ± 3.9</td>
</tr>
<tr>
<td>Bout 1</td>
<td>72.0 ± 12.4</td>
<td>142.3 ± 20.0</td>
<td>87.1 ± 14.1</td>
<td>206.0 ± 107.3</td>
<td>15.6 ± 12.4</td>
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<tr>
<td>Bout 2</td>
<td>77.6 ± 11.1</td>
<td>145.6 ± 20.2</td>
<td>87.5 ± 13.4</td>
<td>244.9 ± 129.7</td>
<td>25.9 ± 26.9</td>
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<tr>
<td>Baseline</td>
<td>71.5 ± 11.8</td>
<td>136.3 ± 17.9</td>
<td>85.3 ± 16.0</td>
<td>186.9 ± 103.6</td>
<td>8.4 ± 10.8</td>
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<td><strong>Moderate-anxiety group</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Initial</td>
<td>72.6 ± 9.0</td>
<td>136.4 ± 20.8</td>
<td>81.7 ± 14.0</td>
<td>216.4 ± 100.1</td>
<td>35.3 ± 8.6</td>
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<tr>
<td>Bout 1</td>
<td>73.6 ± 10.4</td>
<td>139.9 ± 23.4</td>
<td>82.4 ± 13.5</td>
<td>346.8 ± 233.2</td>
<td>29.9 ± 19.9</td>
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<td>Bout 2</td>
<td>74.5 ± 9.8</td>
<td>139.7 ± 23.7</td>
<td>84.1 ± 13.9</td>
<td>283.6 ± 120.0</td>
<td>41.9 ± 26.3</td>
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<tr>
<td>Baseline</td>
<td>74.4 ± 8.6</td>
<td>128.7 ± 23.8</td>
<td>80.6 ± 15.2</td>
<td>207.1 ± 85.0</td>
<td>10.1 ± 8.6</td>
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</tbody>
</table>

Values are means ± SD. STAI, Spielberger’s State-Trait Anxiety Index; VAS, visual analog mood scale. *P < 0.05 vs. initial; †P < 0.05 vs. bout 3 for Low-anxiety and control groups; ‡P < 0.05 vs. bout 1, bout 2, and bout 3; ††P < 0.05 vs. all other values. *P < 0.05 vs. initial, bout 1, bout 2, and bout 3.

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Fig. 3. Percent changes from baseline in the physiological measures of arousal. A: heart rate. B: electrodermal activity. C: systolic blood pressure. D: diastolic blood pressure. Values are means ± SE.
the corresponding time points for the control group (1.66 ± 0.85 and 1.88 ± 1.58%, respectively) (P < 0.02) (Fig. 4C). Although the coefficient of variation for the low-anxiety group did not differ across the four time points, it was greater than the value for the control group at time point 4 (2.62 ± 0.73 vs. 1.67 ± 0.85%) (P < 0.02). Similarly, there was a significant main effect for group, with the coefficient of variation for the moderate-anxiety group (2.81 ± 0.84%) significantly greater than the value for the control group (1.78 ± 0.85%) (P < 0.017) (Fig. 4A). These data indicate that presentation of the electric shock reduced the steadiness of the pinch grip irrespective of the level of trait anxiety but that only those subjects with moderate levels of trait anxiety experienced a change in steadiness with variation in stressor intensity.

**EMG Activity**

The average EMG was determined for five muscles at the same times that steadiness was assessed. Overall, there were no significant differences for any group across time for the five muscles. For example, the average EMG ranged from 9.46 to 10.3% of maximal voluntary contraction (MVC) for the first dorsal interosseus muscle in the right hand of subjects in the moderate-anxiety group. Similar values were recorded for the same muscle in subjects of the low-anxiety group (12.1 to 15.3% of MVC) and the control group (7.4 to 8.7% of MVC). Furthermore, a qualitative assessment indicated that subjects exhibited a range of patterns across the three stressor bouts. For the first dorsal interosseus muscle of the right hand, one subject had no change in amplitude, six subjects increased amplitude from bout 1 to bout 3, four subjects decreased amplitude from bout 1 to bout 3, and the remaining subjects had variable changes in amplitude across the three bouts. Similarly, for the right upper trapezius muscle, eight subjects had no change in amplitude, six subjects increased amplitude from bout 1 to bout 3, six subjects decreased amplitude from bout 1 to bout 3, and the remaining subjects had variable changes. These patterns were unrelated to the sex of the individual, subject group, or changes in steadiness. For example, Fig. 5 shows EMG data for bout 3 and baseline for two subjects in the moderate-anxiety group. Despite markedly different EMG patterns, the coefficients of variation for these two subjects were 3.0 and 7.1% for bout 3 and 1.7 and 2.9% for baseline. These data indicate that there were no significant differences between the stressor and baseline conditions for any of the three groups (P = 0.81) in the average EMG activity of the muscle involved in the pinch grip.

**DISCUSSION**

The purpose was to determine the effect of trait anxiety and stressor intensity on arousal and motor performance during a pinch task. Subjects performed a series of submaximal pinch grips during a baseline period and during presentation of an electric-shock stressor. We expected to find that the stressor would elevate arousal and result in a reduction in the accuracy of the pinch task. The main finding was that cognitive and physiological arousal increased with stressor intensity and was associated with decreases in

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**Fig. 4.** Coefficient of variation for force during the pinch-grip task. A: average data for the 3 groups of subjects, summed across the 3 stressor bouts (time points 3–5) and baseline time point 7. B: average data for 4 time points, summed across the 3 groups. C: group-by-time changes in the coefficient of variation.
steadiness, especially for subjects with moderate levels of trait anxiety. Previous studies have used electric shock as a stressor to heighten arousal (5, 7, 14, 21, 25). For example, Breznitz et al. (5) measured the effect of an electric-shock threat (no shock was given) on various components of arousal. The outcome measures were selected neuroendocrine and cardiovascular responses and a perceived level of tension. Heart rate, plasma epinephrine levels, and tension were elevated during the shock stressor compared with baseline. Similarly, electric shocks have been shown to impair the ability of subjects to perform a balancing task and for performance to be worse in subjects with high levels of trait anxiety (7, 25).

The magnitude of the arousal response appears to depend on the past experiences and emotional characteristics of an individual (19). As a consequence, previous investigations on the acute effects of stressors on performance have categorized subjects into groups on the basis of trait anxiety scores. When comparing the performance of subjects with high and low trait anxiety on a throwing task, Weinberg and Ragan (32) found that the more anxious subjects performed best in low-stress conditions, whereas the converse was true for subjects with lower levels of anxiety. Similar observations have been reported for other tasks, such as rifle shooting (27), motor-cross racing (10), and various physical performance tasks (13, 15).

We assessed the cognitive component of arousal with two indexes, Spielberger’s STAI and the VAS. The anxiety scores at the end of the test were significantly elevated compared with those before the test for the stressor groups, whereas the scores for the control group were essentially unchanged. Similarly, the VAS scores for the moderate-anxiety and low-anxiety groups were elevated significantly during the stressor condition compared with the control group. We found that state anxiety immediately after the stressor increased by \(10\%\) for the stressor groups, whereas the VAS scores at the three time points during the stressor conditions increased by \(200\%\) from baseline values for the moderate-anxiety subjects. These values are similar to those found previously with mental math and electric shock stressors (21).

The physiological effects of the stressor were modest, as indicated by changes in heart rate, systolic and diastolic blood pressure, and electrodermal activity for the two anxiety groups. However, diastolic blood pressure was not different compared with the control group, which is consistent with previous reports (1, 12, 21). In addition, the physiological effects were similar for the two anxiety groups. The relative changes in heart rate and blood pressure are similar to those
found with other stressors (6, 26, 28). Because these effects are small and variable across subjects, the moment-to-moment assessment of multiple variables has been recommended for a more accurate identification of the arousal response (20).

The elevated levels of arousal induced by the electric shock during the stressor were associated with reductions in the steadiness of the pinch grip. The change in VAS scores across the three stressors was similar to the change in steadiness over the same time points. As the intensity of the shocks increased across the three stressor bouts, we expected the coefficient of variation for force to increase, indicating a dose-response relationship. In general, the coefficient of variation for force did increase across the three stressors; however, the increase was only significant after bout 3 (time point 5) for the moderate-anxiety subjects, which is similar to previous findings (21). More specifically, the coefficients of variation after bouts 2 and 3 (time points 4 and 5) were significantly elevated for the moderate-anxiety group compared with baseline values and with the control group. In contrast, the increase in the coefficient of variation across the time points for the low-anxiety subjects was not significantly different, although it was elevated from the control group after bout 2. These data suggest that the intensity of the shock stressor did influence performance and was characterized by a nonlinear relation with the greatest reduction in steadiness occurring after the most intense noxious stimulus. However, because of the varying time course of the arousal response, it may be that the reduction in steadiness was a result of an accumulation effect of the stressor and not just the most recent electrical shock. Nevertheless, our data are similar to those of Weinberg and Hunt (31), who found that the performance of subjects with moderate trait anxiety was worse under high-stress conditions compared with subjects who had low levels of trait anxiety.

In contrast to the coefficient of variation for the force, the average EMG activity of muscles involved with the pinch grip, in addition to homologous muscles not involved in the task, was similar from baseline to the stressor condition and across subject groups. The lack of association between the coefficient of variation for force and the average EMG activity recorded with surface electrodes has been reported in other investigations of steadiness (11). In contrast, Laidlaw et al. (18) found with intramuscular EMG recordings of motor unit activity that reductions in steadiness were associated with increased variability of motor unit discharge. So, although the noxious stimulus did reduce the steadiness of the pinch grip, the effect was not so pronounced that it could be observed in gross multi-unit EMG recordings.

Arousal and performance measures were similar for men and women, which conflicts with previous results (21, 22) that women exposed to shock stressors had modest increases in arousal and experienced greater reductions in steadiness. Whereas trait anxiety measures in the previous experiments were similar for men and women, the subjects were not classified a priori into moderate and low trait anxiety groups (21). The mean trait anxiety for men and women in the moderate-anxiety group in our study was 47.3 ± 1.6 and 45.1 ± 0.8, respectively, whereas in a previous study (21) the scores were lower (33.1 ± 2.5 for men and 35.6 ± 3.4 for women). Therefore, the elevated levels of trait anxiety for men in the present study appears to have eliminated the gender difference in the response to the shock stressor. For example, the coefficient of variation during the shock stressors for men in the moderate-anxiety group (3.0 ± 0.3%) was greater than the same measure for men in the low-anxiety group (2.1 ± 0.2%) and for men in the previous study (2.1 ± 0.4%) (21).

In summary, subjects presented with an electric-shock stressor experienced significant changes in cognitive and physiological arousal compared with baseline and control subjects, especially those subjects with moderate levels of trait anxiety. Similarly, the noxious stimulus increased heart rate, systolic blood pressure, and electrodermal activity, whereas diastolic blood pressure was unchanged. Cognitive and physiological arousal increased with stressor intensity and was associated with decreases in the performance of the pinch grip. In addition, electric shock reduced the steadiness of the pinch grip irrespective of the level of trait anxiety, but only those subjects with moderate levels of trait anxiety experienced a change in steadiness with variation in stressor intensity. Although steadiness was markedly reduced with the highest intensity of shock, the interference EMG was unaffected by the stressor and appeared to indicate widespread activity in the involved limb.

The authors thank Dr. Robert Gotshall for the Finapres used in data collection. This study was funded by National Institute on Aging Grant AG-13929 (to R. M. Enoka) and the Foundation for Physical Therapy (to J. T. Noteboom).

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