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ORIGINAL ARTICLE

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Influence of time pressure and verbal provocation on physiological and psychological reactions during work with a computer mouse

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Abstract The overall aim of this study was to investigate whether time pressure and verbal provocation has any effect on physiological and psychological reactions during work with a computer mouse. It was hypothesised that physiological reactions other than muscle activity (i.e. wrist movements, forces applied to the computer mouse) would not be affected when working under stressful conditions. Fifteen subjects (8 men and 7 women) participated, performing a standardised text-editing task under stress and control conditions. Blood pressure, heart rate, heart rate variability, electromyography, a force-sensing computer mouse and electrogoniometry were used to assess the physiological reactions of the subjects. Mood ratings and ratings of perceived exertion were used to assess their psychological reactions. The time pressure and verbal provocation (stress situation) resulted in increased physiological and psychological reactions compared with the two control situations. Heart rate, blood pressure and muscle activity in the first dorsal interosseus, right extensor digitorum and right trapezius muscles were greater in the stress situation. The peak forces applied to the button of the computer mouse and wrist movements were also affected by condition. Whether the increases in the physiological reactions were due to stress or increased speed/productivity during the stress situation is discussed. In conclusion, work with a computer mouse under time pressure and verbal provocation (stress conditions) led to increased physiological and psychological reactions compared to control conditions.

Keywords Stress · Electromyography · Input device · Video display terminal · Physiological reactions

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Introduction

Musculoskeletal symptoms of the neck and upper extremity associated with work with visual display units (VDUs) are common. In 1999, approximately 60% of the Swedish work force used a VDU in their profession (Statistics Sweden 2000), and it is believed that this figure is increasing. It is thought that musculoskeletal symptoms among VDU operators have a multi-factorial aetiology. Non-neutral wrist, arm and neck postures, workstation ergonomics, duration of computer work and psychological and social factors such as time pressure and high perceived work load, are believed to interact in the development of these symptoms (Bongers et al. 1993; Faucett and Rempel 1994).

Experimental studies have shown that mental stress can induce muscle activity (Ekberg et al. 1995; Larsson et al. 1995; Lundberg et al. 1994; Wærsted et al. 1991, 1994; Wærsted and Westgaard 1996). In some of these experimental studies (Ekberg et al. 1995; Larsson et al. 1995; Lundberg et al. 1994), authors have used the Stroop Color Word Test (CWT) as a stressor, and the outcome has primarily been muscle activity in the trapezius muscles. Other authors have used a complex two-choice reaction-time task (Wærsted and Westgaard 1996; Wærsted et al. 1991, 1994) and focused on the muscle activity in the trapezius muscle, but also measured muscle activity in other body regions. The CWT and the two-choice reaction-time task require minimal physical activity during performance and are not easily transferred to real work situations using a VDU or a computer mouse.

The aim of this study was to investigate whether time pressure and verbal provocation have any effect on physiological and psychological reactions when working with a computer mouse. It was also hypothesised that physiological reactions other than muscle activity (i.e. wrist movements, forces applied to the computer mouse) would not be affected when working under stressful conditions.

Methods

Subjects

Fifteen subjects, 8 men and 7 women, volunteered to participate in the study, which had been approved by the Ethics committee. Subjects from various occupations were recruited from the Sahlgrenska University Hospital, Göteborg, and former fellow students of two of the authors (JS and JW). The mean age was 30 years (range 18–48 years), the mean body mass index (BMI) was 23.5 (range 20–28) and the median time with VDU work per week was 10 h (range 2–80 h). The subjects were all experienced computer mouse users and they all used their right hand to operate the mouse. Prior to the study, subjects were given written and verbal information explaining the experimental procedures. None of the subjects used medication for hypertension or any other cardiovascular disease and they were all free of upper extremity musculoskeletal disorders, as determined by an interview.

Experimental procedure

An adjustable VDU workstation was set up and the subjects adjusted the table and chair to fit their personal preferences. A Macintosh computer with a 13-in (33 cm) colour display and a standard keyboard was used. Before the measurements, subjects practised at the experimental workstation to familiarise themselves with the equipment and the task.

The subjects participated in a control situation (Control 1), a stress situation (Stress) and, at the end of the experiment, a second control situation (Control 2). In the control situations, subjects edited eight, five-line paragraphs of text (two pages) with no time constraints imposed. In each line, at a random location, one to four characters were highlighted using coloured text. Subjects were instructed to highlight the coloured characters with the computer mouse and then delete the characters by hitting the delete key on the keyboard with the hand operating the computer mouse. Approximately 10–15 min later, in the stress situation, subjects were asked to perform the same task but do twice the amount of work (edit four pages). Here, subjects were asked to work "as fast as possible" and a time constraint of 40 s was imposed to complete each page of text editing. If the subjects could not complete editing the page of text, they were verbally prompted to use the "page down" key on the keyboard and continue with the text-editing task on the next page. Subjects were also verbally provoked every 15th s (e.g. "hurry up" or "come on, you can do it faster"). The verbal provocation was given by the same test leader throughout the experiment (JS).

Physiological and psychological reactions

Heart rate and heart rate variability

Heart rate (HR) and heart rate variability (HRV) were measured with the Polar Vantage NV heart-rate monitor and data were analysed using Polar Precision Performance software version 2.0 (Polar Electro Oy, Kempele, Finland). The heart rate was recorded "beat by beat" and then the data were filtered using an automatic procedure contained within the Polar software system. The low-frequency (LF) domain (0.04–0.15 Hz) and the high-frequency (HF) domain (0.15–0.40 Hz) of the HRV power spectrum were calculated using the Polar software system, and the LF:HF ratio (LF/HF ratio) was calculated, together with the mean HR. The HF component of the power spectrum reflects parasympathetic activity and the LF component reflects sympathetic activity with vagal modulation; mental stress has been shown to lower HRV and effect an increase in the LF/HF ratio (Kristal-Boneh et al. 1995).

Blood pressure

Systolic and diastolic blood pressure (SBP and DBP, respectively) were recorded with an ambulatory blood pressure monitor (CardioTens; Medikolt International AB, Skärholmen, Sweden). This equipment has been tested for validity and reliability (Barna et al. 1998), and the algorithm used in the apparatus adhered to the recommendations of the Association for the Advancement of Medical Instrumentation. SBP and DBP were recorded once during the control situations midway through the task. During the stress situation, SBP and DBP were measured approximately 1 min after the start of the text-editing task.

Forces applied to the computer mouse

An instrumented Apple ADBII computer mouse was used to measure the forces applied to the sides and button of the computer mouse. The force-sensing computer mouse was fully operational, and similar in weight, feel and appearance to an ordinary Apple ADBII computer mouse. The design and measurement accuracy of the force-sensing computer mouse has been validated, described and discussed in detail elsewhere (Johnson et al. 1993, 1994). The force data were analysed using a program written in Labview 4.0 (National Instruments, Austin, Texas, USA). The program identified each time the computer mouse was used (termed a grip episode), and kept track of idle periods, which were defined as any period the mouse was not used for 1 s or longer. For each grip episode the program calculated the mean force, peak force and grip duration. At the end of the experiment, subjects were asked to apply maximum voluntary contractions (MVCs) to the sides and button of an Apple ADBII computer mouse equipped with load cells.

Muscle activity

Muscle activity from four separate muscles was collected at 1 kHz using a commercial electromyography (EMG) system (ME3000P4, Mega Electronics, Kuopio, Finland). The muscles examined were the right first interosseus (FDI), the right extensor digitorum (ED), and the pars descendens of the right and left trapezius muscles. The electrodes for the FDI and ED were placed as recommended by Perotto (1994), and for the trapezius, as recommended by Mathiassen et al. (1995). Self-adhesive surface electrodes (M-00-S; Medicotest, Ølstykke, Denmark) were placed in pairs with a 35-mm inter-electrode distance. For the FDI muscle, the electrodes were modified (cut), resulting in an inter-electrode distance of 25 mm. Before attaching the electrodes, the skin was dry shaved and cleaned with alcohol. At the beginning of the recordings the subjects performed standardised MVCs to obtain the maximal voluntary electrical activity (MVE) in the FDI and the ED. MVE in the FDI and the ED was set with maximum static contraction against manual resistance for a minimum of 3 s. Reference voluntary electrical activity (RVE) in the right and left trapezius muscles was set with the shoulders flexed to 90°, thumbs up and a 1-kg dumb-bell held in each hand for a minimum of 3 s. The raw data was recorded on-line using a portable PC and monitored in real-time for quality control. The muscle activity was derived by full-wave rectification and filtering of the EMG signal using a time constant of 100 ms. Data were analysed using ME3000P software version 1.5 (Mega Electronics), and the 50th percentile of the EMG signal was calculated.

Wrist movements

A two-axis electrogoniometer (Model XM65, Penny and Giles Biometrics, Blackwood, Wales, UK) and a data logger (Model DL 1001, Penny & Giles) were used for recording flexion/extension (F/E) and radial/ulnar deviation (R/U) movements in the right wrist. Goniometry data were analysed using a program written in Labview 4.0. The program calculated the mean velocity and the mean power frequency (MPF) for both F/E and R/U. The MPF is defined as the centre of gravity for the power spectrum (Hansson et al. 1996).

Mood ratings

To describe mood during work, a Swedish stress/energy questionnaire was used (Kjellberg and Iwanowski 1989; Kjellberg et al. 1996). The checklist measures two factors, stress and energy, each comprising six items. Three adjectives within each factor are positively loaded and three are negatively loaded. The following items are included in the stress dimension: (positive) ''rested'', ''relaxed'' and ''calm''; (negative) ''tense'', ''stressed'' and ''pressured'', and the following in the energy dimension: (positive) ''active'', ''energetic'' and ''focused''; (negative) ''dull'', ''ineffective'' and ''passive''. The checklist uses a six-point scale (0–5) for each item, ranging from ''not at all'' to ''very much''. High values indicate a high stress and energy level, respectively. The means from the two different dimensions were calculated and the ratings were made immediately after each test.

Ratings of perceived exertion (RPE) and comfort

Subjects rated perceived exertion after each condition for five different body locations [neck/shoulder (scapular), right shoulder (upper arm), right forearm, right wrist and right hand/fingers] using a modified 0- to 14-point Borg scale (Borg 1990). In the analysis, ratings for the different body locations were summed and divided into two different categories, proximal (neck/shoulder and shoulder) and distal (forearm, wrist and hand/fingers).

Productivity

When comparing productivity across all three conditions, the mean duration of the time the computer mouse was gripped (grip episode duration) and the ratio between the number of editing changes made in the standardised text and the duration of the task, termed speed, were assessed.

Statistics

The descriptive data are presented as mean (SEM). A repeated-measures analysis of variance (RANOVA) was performed to test the null hypothesis that condition did not have any effect on the different variables assessed. The results from the RANOVAs are presented with the exact F-statistic and the corresponding *P*-value. Statistical significance was assumed for $P \leq 0.05$.

Due to technical problems, the results from two male subjects were excluded from the HR analysis, one female subject was excluded from the analysis of blood pressure and one male subject was excluded from the analysis of wrist movements.

Results

The RANOVAs showed significant differences between conditions on HR, SBP and DBP, but not on the LF/HF ratio (Table 1 and Fig. 1). There was also a significant

Table 1. Means (SEM) of the different parameters assessed in the three conditions. A repeated-measures analysis of variance (*RANOVA*) was performed to test whether the different conditions had any effect on the outcome parameters assessed. The exact F-statistic and the *P*-value are also presented. (*LF* Low frequency, *HF* high frequency, *%MVC* % maximum voluntary contraction, *%MVE* % maximum voluntary electrical activity, *%RVE* % reference voluntary electrical activity)

Parameter	Recording condition			RANOVA	
	Control 1	Stress	Control 2	Exact F	*P*-value
Blood pressure ($n=14$)					
Systolic (mmHg)	130 (2.9)	136 (3.5)	128 (2.6)	12.20	0.0013
Diastolic (mmHg)	82 (1.3)	86 (1.6)	80 (1.3)	11.48	0.0016
Heart rate parameters ($n=13$)					
Heart rate (beats/min)	77 (2.6)	82 (2.7)	77 (2.4)	4.59	0.036
LF/HF Ratio	1.9 (0.40)	3.0 (0.88)	2.5 (0.57)	0.87	0.45
Mood ratings ($n=15$)					
Stress (scale step)	1.7 (0.18)	3.0 (0.25)	1.6 (0.13)	23.37	< 0.0001
Energy (scale step)	3.1 (0.18)	3.4 (0.17)	3.1 (0.20)	3.09	0.078
Forces applied to computer mouse ($n=15$)					
Side mean force (%MVC)	0.8 (0.08)	0.9 (0.11)	0.7 (0.08)	2.68	0.106
Side peak force (%MVC)	1.3 (0.14)	1.5 (0.19)	1.2 (0.11)	2.52	0.119
Button mean force (%MVC)	1.4 (0.14)	1.5 (0.15)	1.4 (0.13)	2.78	0.099
Button peak force (%MVC)	3.5 (0.38)	4.2 (0.46)	3.5 (0.33)	8.30	0.005
Wrist flexion/extension ($n=14$)					
Mean power frequency (Hz)	0.72 (0.05)	0.96 (0.07)	0.74 (0.04)	12.73	0.0011
Mean velocity (°/s)	16.5 (1.39)	21.9 (1.89)	18.3 (1.79)	19.12	0.0002
Wrist radial/ulnar deviation ($n=14$)					
Mean power frequency (Hz)	0.44 (0.03)	0.58 (0.03)	0.41 (0.03)	18.41	0.0002
Mean velocity (°/s)	9.9 (0.92)	11.8 (1.14)	11.3 (1.46)	18.68	0.0002
Muscle activity ($n=15$)					
First dorsal interosseus (%MVE)	8.7 (2.14)	11.7 (2.83)	10.3 (3.23)	14.28	0.0005
Extensor digitorum (%MVE)	7.8 (0.55)	9.7 (0.78)	7.9 (0.60)	16.05	0.0002
Right trapezius (%RVE)	28.3 (5.92)	45.1 (10.1)	31.8 (5.58)	5.17	0.022
Left trapezius (%RVE)	10.9 (2.84)	20.4 (5.69)	12.9 (2.75)	1.85	0.20
Ratings of perceived exertion ($n=15$)					
Proximal (scale step)	6.3 (1.24)	10.6 (1.51)	7.0 (1.05)	9.70	0.0026
Distal (scale step)	5.3 (1.40)	8.6 (1.58)	6.3 (1.36)	3.18	0.075
Productivity ($n=15$)					
Speed	0.22 (0.007)	0.32 (0.015)	0.26 (0.007)	28.81	< 0.0001
Grip duration (s)	3.1 (0.11)	2.2 (0.09)	2.6 (0.08)	44.59	< 0.0001

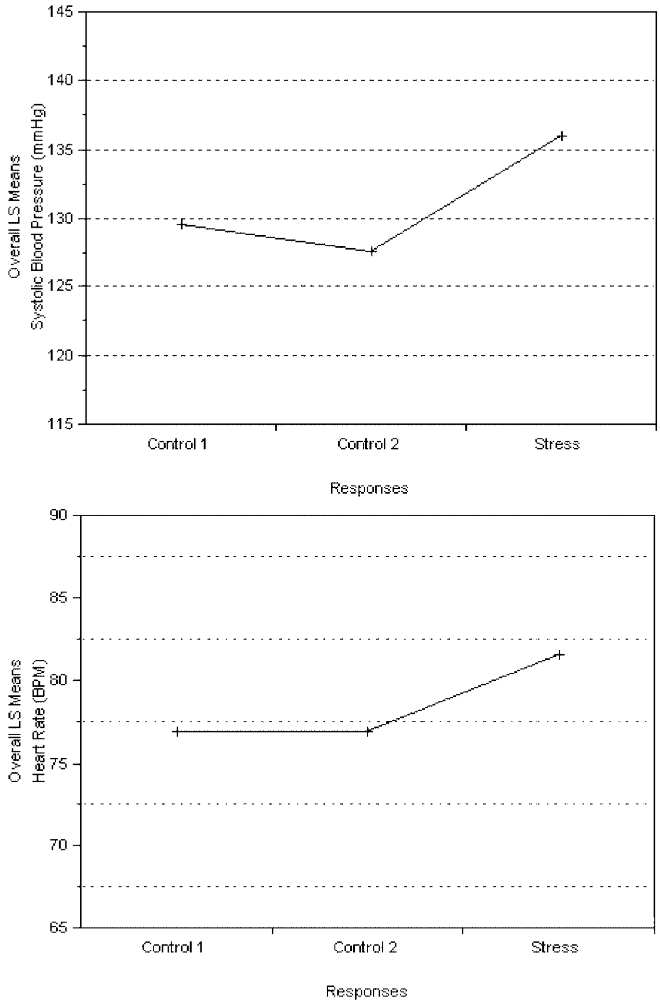

Fig. 1. Least-square (*LS*) means of systolic blood pressure (mmHg; upper graph) and heart rate (beats per minute, *BPM*; lower graph) in the control and the stress conditions

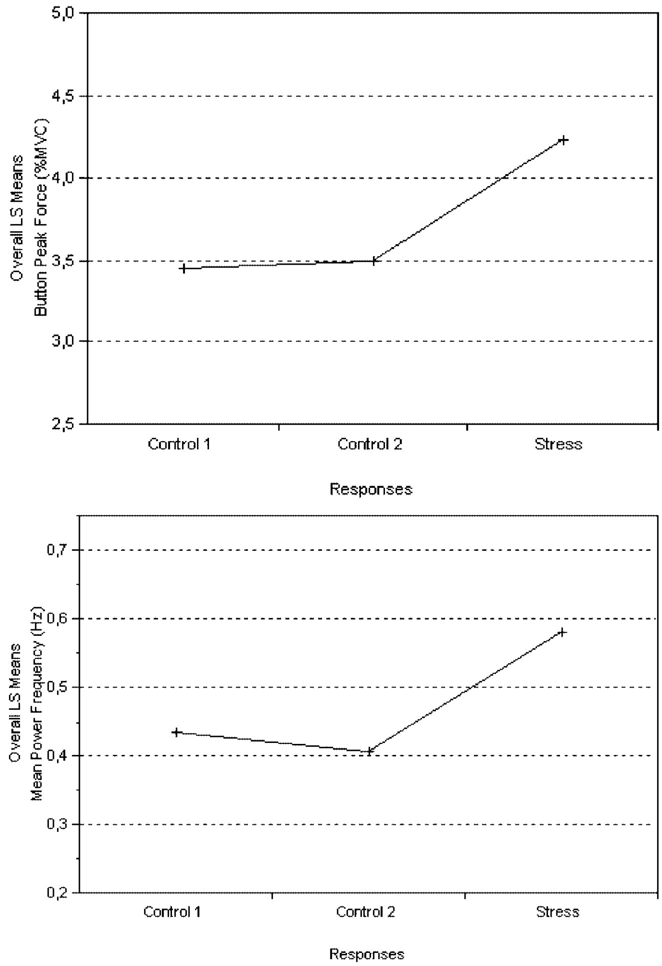

Fig. 2. LS means of button peak forces (% of maximal voluntary contraction, *%MVC*; upper graph) applied to the computer mouse and mean power frequency of the wrist in radial/ulnar deviation (lower graph) in control and stress conditions

effect of condition on the subjective ratings of stress and RPE proximally, but not on ratings of energy or RPE distally (Table 1).

The only force parameter that was affected by condition was the button peak forces (%MVC) applied to the computer mouse (Table 1 and Fig. 2). In the other force parameters there was no significant effect of condition, although the forces tended to be higher in the stress condition compared to the two control situations (Table 1). Muscle activity from the FDI, the ED and the right trapezius muscle were all affected by condition (Table 1 and Fig. 3). Condition also had a significant effect on MPF and mean velocity of the wrist, both in F/E and R/U deviation (Table 1 and Fig. 2). The measures of productivity (grip episode duration and speed) were also affected by condition (Table 1 and Fig. 4).

Discussion

The intention of this study was to put subjects into two different work situations and evaluate how their physiological and psychological reactions changed from relatively relaxed conditions to simulated stressful work conditions. The time pressure and verbal provocation (the stress situation) resulted in increased physiological (HR and blood pressure) and psychological reactions (mood ratings). These increases indicate that the time pressure and verbal provocation met the objectives of creating a stressful work situation.

There was not only an increase in muscle activity, but also a more generalised increase, which included higher forces applied to the button of the computer mouse and more repetitive wrist movements when comparing the stress situation to the control situations.

Based on decreases in grip episode duration and increases in speed/productivity, part of the increases in the physiological parameters could be attributed to the fact that subjects worked faster in the stress condition compared to the control conditions. The productivity increase was approximately the same between the three recording sessions, with the greatest productivity being observed for the stress situation (Fig. 4). However, the magnitude of the differences in physiological parameters

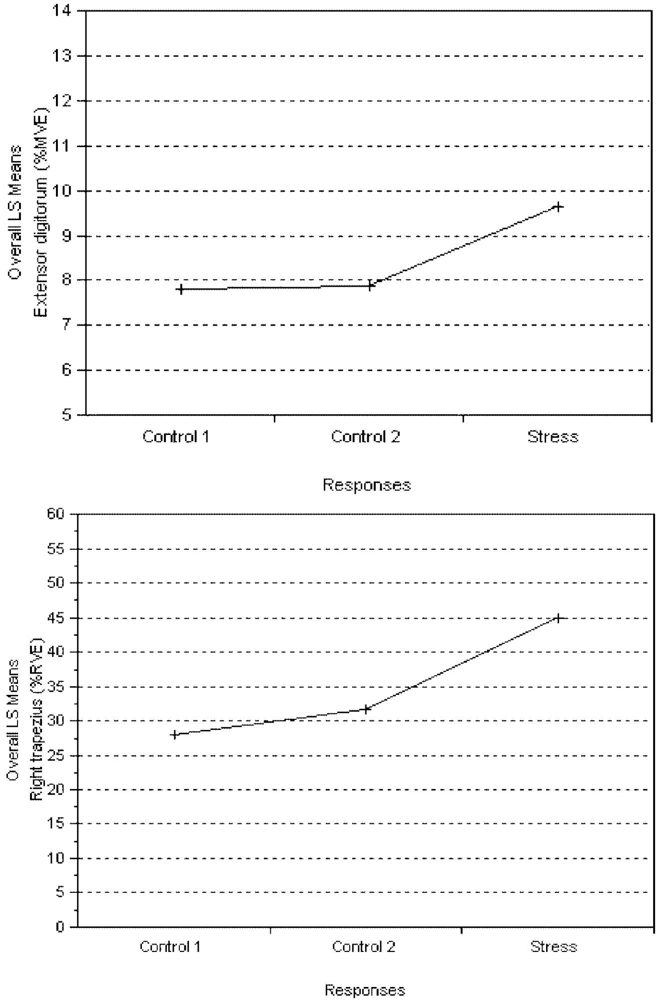

Fig. 3. LS means of muscle activity in the extensor digitorum (% maximum voluntary electrical activity, *%MVE*; upper graph) and in the right trapezius muscles (% reference voluntary electrical activity, *%RVE*; lower graph) in control and stress conditions

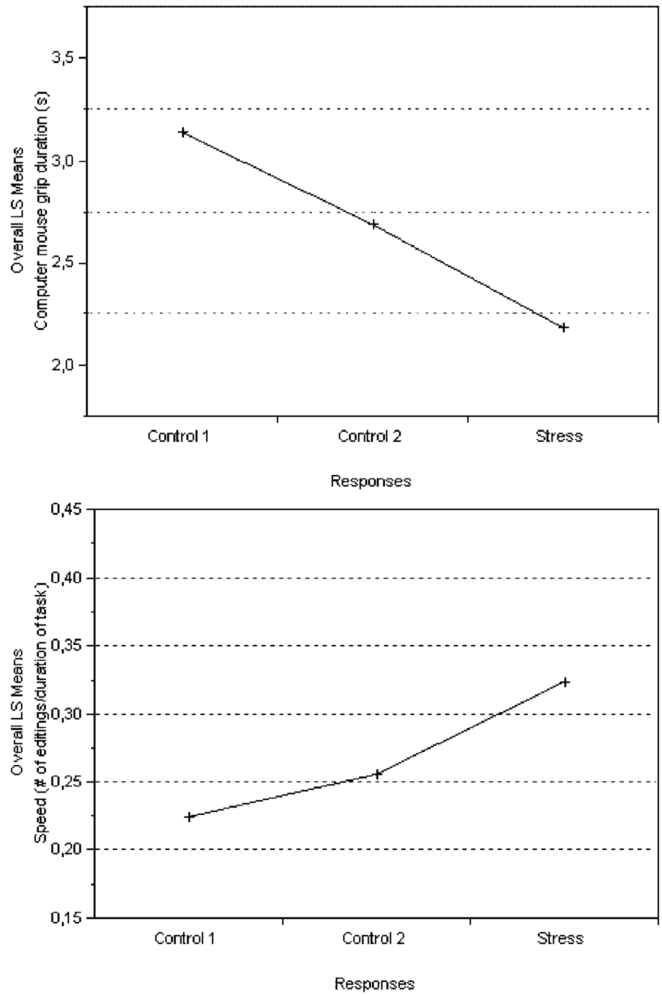

Fig. 4. LS means of computer mouse grip duration (seconds; upper graph) and speed (ratio between the number of editing movements and the duration of the task; lower graph) in the control and stress conditions.

between the first and second control recordings was much less than that observed between the control and stress conditions (Figs. 1, 2, 3). Therefore, this indicates that some of the increase in the physiological parameters was stress related. HR and SBP were probably only affected by stress, while the other physiological measures (EMG, forces and wrist movements) were probably affected by both stress and speed/productivity. Kohlisch and Schaefer (1996) concluded that the impact of motor activity on cardiac parameters (HR, blood pressure) could be neglected during common computer tasks (i.e. keystrokes at intervals of 300 ms or longer).

Muscle activity increased in three of the muscles (FDI, ED and the right trapezius) during the stress condition. Birch and co-workers (2000) have also investigated the effect of time pressure during simulated computer work and found that high time pressure combined with low precision and low mental demands resulted in higher EMG activity in the trapezius, infraspinatus, deltoid and ED muscles, but high precision and high mental demands did not result in any change in muscle activity. Perhaps with low precision and low mental demands subjects worked faster and this increased the muscle activity, but with high precision and high mental demands, subjects had a slower overall work pace and this was counterbalanced any increase in EMG. This indicates the importance of having some measure of productivity. Laursen and co-workers (1998) investigated the effect of increased speed and increased precision and found that the muscle activity in the shoulder muscles increased as the speed demand increased (four different levels of speed). In the study presented here, the results from the right trapezius muscle showed a tendency to increase as the speed/productivity increased (Fig. 3). However, the trend was much less marked in the ED muscle (Fig. 3). The muscle activity in the ED was 2% MVC higher in the stress situation than in the control conditions. This increase in muscle activity, which was probably due to a combination of stress and increased speed/productivity, could imply that individuals with poor psychosocial working conditions could be more prone to develop muscular fatigue. In the long run, this might be associated with an increased risk of developing discomfort and musculoskeletal symptoms in the forearm region.

The peak forces applied to the button of the computer mouse increased by 0.7% MVC during the stress situation compared to the control situations. Since there was only a small difference in applied force between the two control recording sessions, despite the difference in speed/productivity, the increase in applied forces observed in the stress situation is most likely an effect of stress. Whether the increase in applied forces (0.7% MVC) during the stress situation has any clinical relevance is uncertain; previous studies have reported differences between men and women in applied forces ranging from 0.5% to 1.7% MVC (Johnson et al. 2000; Wahlström et al. 2000), and intense computer mouse work may induce muscle fatigue in the forearm muscles (Johnson 1998). This could imply that individuals involved in intense computer mouse work and adverse psychosocial working conditions (i.e. stress, time pressure) could be at higher risk of experiencing fatigue and discomfort in the forearm. The increase in applied force to the computer mouse may also explain some of the increase in muscle activity in the hand and forearm (i.e. FDI and ED) and perhaps some of the increased muscle activity in the trapezius muscle.

The MPF and velocities from the mouse-operating wrist increased in the stress situation. This result could be expected since subjects worked faster, although it might have some practical implications since MPF has been associated with a higher prevalence of musculoskeletal disorders in female industrial workers (Hansson et al. 2000). The mean values of MPF during control situations were high compared to those reported in other studies of VDU work (Karlqvist et al. 1995; Lindegård et al. 2001). The higher values of MPF, both in F/E and R/U deviation, in this study were probably due to the repetitive nature of the text-editing task. However, there was an increase in MPF of about 0.2 Hz in F/E deviation and of about 0.15 Hz in R/U deviation. In a study of industrial workers who perform repetitive tasks, where an exposure/response relationship was found between wrist movements (MPF) and musculoskeletal wrist/hand disorders, the difference in MPF between the high and low exposure groups was about 0.25 Hz (Hansson et al. 2000). This could imply that subjects who perform VDU work under stressful conditions are at greater risk of developing wrist/hand disorders.

Limitations and implications

Whether the stressors used in this study are comparable with stressors that individuals are exposed to during daily work is uncertain, but the reactions to the stressors could mirror the reactions to different stressors encountered during ordinary work. It is also likely that the combination of stress and increased speed/productivity appears in combination in occupational settings. Since the order of the two different situations was not randomised, the increases in physiological and psychological reactions and physical load during the stress situation could be an effect of subjects working faster or an effect of time or learning. However, as discussed earlier, it is indicated that the increases in physiological and psychological reactions in the stress situation were stress related to at least some degree, and previous studies have shown that stress may increase muscle activity (Ekberg et al. 1995; Larsson et al. 1995; Lundberg et al. 1994; Wærsted and Westgaard 1996; Wærsted et al. 1991, 1994). There was most likely a learning effect, since the subjects performed the text-editing task faster during the second control recording session. This increase in speed/productivity in the second control recording session may explain the general pattern of the physiological reactions being slightly higher compared to those obtained in the first control recording session. We chose not to perform Bonferroni adjustments of *P*-values, although we made multiple comparisons, since the outcome parameters were not chosen at random. The decision as to whether or not to use Bonferroni adjustments remains a matter of controversy, some authors being of the opinion that adjusting statistical significance for the number of tests may create more problems than it solves (e.g. Perneger 1998). Finally, one potential limitation of this study was that the data collection for the two situations was made over a period of less than 5 min, which is a short time of exposure to a stressor. Future studies should investigate further these effects and extend the data collection time.

Conclusions

Work with a computer mouse under time pressure and verbal provocation (stress situation) led to increased physiological and psychological reactions compared to control conditions.

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