Acta Psychologica **35** (1971) 298–308; © *North-Holland Publishing Company*

PSYCHOPHYSIOLOCIGAL REACTIONS TO UNDERSTIMULATION AND OVERSTIMULATION*

MARIANNE FRANKENHAEUSER, BO NORDHEDEN, ANNA-LISA MYRSTEN and BIRGITTA POST

The Psychological Laboratories, University of Stockholm, Stockholm, Sweden

ABSTRACT

Catecholamine output, heart rate, and performance efficiency were examined in 28 *S*s during two contrasting stimulus conditions, one of understimulation, and one of overstimulation. During understimulation the subject spent 3 hr performing a vigilance task, and during overstimulation he was exposed for the same time period to a complex sensorimotor test. Both understimulation and overstimulation produced a significant increase of adrenaline and noradrenaline release as compared with a control condition involving a medium amount of stimulation. Subjects who excreted relatively more adrenaline performed significantly better during understimulation, whereas subjects with relatively lower excretion rates of adrenaline tended to perform better under overstimulation. When performance efficiency was related to heart rate it was shown that high-heart rate subjects performed better during understimulation, while low-heart rate subjects performed better during overstimulation.

1. INTRODUCTION

Understimulation and overstimulation represent two contrasting disturbing influences, both of which may be considered typical psychosocial stressors of today's environment. Overstimulation is easily produced in the laboratory by, for example, exposing the subject to several simultaneous sensory signals, requiring a high response rate. Understimulation, characteristic of many monotonous work situations, may be induced in the laboratory by, for example, depriving the subject of sensory stimuli and/or social contacts.

The aim of the present investigation was to examine physiological

* The statistical work was carried out by O. Jonsson and the catecholamine analyses by B. Linell. U. Carlquist participated in the data collection. Financial support was obtained from the Bank of Sweden Tercentenary Fund, the Swedish Medical Research Council (Project No. 40X-997), and the Swedish Council for Social Science Research.

and psychological reactions to understimulation and overstimulation in a laboratory setting. Since catecholamine output has been shown to play an important part in the regulation of behaviour in different stress situations (see e.g. surveys by FRANKENHAEUSER, 1971; PÁTKAI, 1970), it was considered to be of interest to relate catecholamine output under these two stimulus conditions to behavioural and autonomic reactions.

A visual vigilance test and a sensorimotor test on simultaneous capacity were chosen as mental performances characteristic of conditions of understimulation and overstimulation, respectively. Performance in these two tests was examined in each of two 3-hr sessions, in which successive measurements were made of catecholamine output, heart rate, and subjective reactions. Catecholamine secretion was also measured in a control session involving a medium amount of stimulation.

2. METHOD

2.1. *Subjects and general design*

Twenty-eight students from a Swedish school for policemen volunteered as subjects. Their ages ranged between 18 and 24 yr (mean 21.4), their body weights between 65 and 107 kg (mean 77.5), and their heights between 175 and 193 cm (mean 183.0). They were paid 150 Sw. cr. for their participation.

Each subject took part in two experimental sessions, representing understimulation and overstimulation, respectively, and a control session, representing a 'normal' or medium amount of stimulation. The sessions were separated by one week, each session starting at 8 a.m. and lasting about 4 hr. The order of sessions was alternated so that half of the subjects had understimulation first, and half had overstimulation first. The control session was always last in the series. During understimulation a vigilance test was performed, and during overstimulation the subject was exposed to a complex sensorimotor test requiring simultaneous capacity. The control condition, which was spent by the subjects reading magazines, served to provide baseline values for catecholamine excretion, and urine samples were collected at points in time corresponding to sampling during the two experimental conditions.

The subjects had been informed in advance of the conditions which might affect the variables to be studied, in particular catecholamine output, and which had to be avoided prior to sessions, e.g., the intake of caffein-containing beverages, alcohol, and drugs, as well as mental stress and heavy physical work. In a short interview at the beginning of each session it was ascertained that instructions had been followed. To standardize conditions as far as possible a light breakfast was served in the laboratory before sessions.

2.2. *Understimulation*

The subject was isolated in a semi-sound proof chamber during an anticipation period of 70 min, and two consecutive work periods of 90 min each. Urine samples were collected and self-estimates made during 10-min pauses after the anticipation period and the first work period, and at the end of the second work period.

The anticipation period was designed so as to evoke feelings of expectancy. At the beginning of the period the subject was informed that the experiment proper would not start until he had become adapted to the light conditions in the chamber, and the heart rate, which was continously monitored, had reached a stable level. The task to be performed later was introduced as part of a test battery used in the selection of test-pilots and astronauts, who were said generally to regard it as difficult.

The task performed during the work periods was a modified form of the *vigilance test* described by McGrath (1963). The subject was instructed to observe a visual signal, which was lit for 0.75 sec at 1.50 sec intervals, and to report each increase in signal intensity ('relevant' signal) by pressing a button. The stimuli were presented automatically according to a predetermined random schedule, the relevant signals occurring at irregular intervals. Immediately before testing began, the intensity of the relevant signal was determined for each subject by the method of limits, the absolute threshold value corresponding to the intensity at which 80 % correct responses were given. Each of six consecutive 30-min periods contained 16 relevant signals. Responses were recorded by a two-channel ink-writer (Elema Mingograph), and the scores were the number of correct responses within each 30-min period.

2.3. *Overstimulation*

The session comprised a 70-min anticipation period followed by two consecutive work periods of 90 min each. Urine samples were collected and self-estimates made in 10-min pauses after the anticipation period and the first work period, and at the end of the second work period. The anticipation period was designed in essentially the same way as in the understimulation session (see above).

During the work periods a sensorimotor test of *simultaneous capacity* was performed. The subject's task was to respond to green, yellow, blue, white, and red signals by pressing, with his two index fingers, a button of the corresponding colour. In addition, he had to respond to a white signal, appearing at irregular intervals on either side of the stimulus board, by pressing a pedal with his right or left foot. He also had to attend to auditory signals of high vs. low frequencies, given through head-phones, by pulling a right- or left-hand lever. The complete test comprised six consecutive 30-min parts of equal difficulty, each containing 540 stimuli. Responses were recorded by an electronic device, and scores were the number of correct responses within each 30-min period.

2.4. *Catecholamine excretion*

At the beginning of each session, the subject emptied his bladder. Three urine samples were collected by voluntary voiding after 70, 170, and 260 min. The urine volume was measured and pH adjusted to 3.5 with 2 N HCl. The samples were stored at -18°C until analyzed by the fluorimetric method of EULER and LISHAJKO (1961).

2.5. *Heart rate*

Heart rate was measured by an electronic pulsemeter (San Ei PM-101), an electrode being applied to the left index finger in the understimulation session and to the left ear in the overstimulation session. Readings were made three times during anticipation, and five times during work.

2.6. *Subjective reactions*

Self-estimates of 'unpleasantness', 'boredom', 'irritation', and 'concentration' were obtained by the method of magnitude estimation, three times during understimulation and overstimulation, respectively. A standard state, in terms of each variable, was defined outside the experimental situation and assigned the numerical value of 10. The standard state for 'unpleasantness' was defined as the experience in a dentist's waiting room, for 'boredom' as the experience of attending a dull lecture, for 'irritation' and 'concentration' as the state typical for that particular time of the day. If the subject felt twice as bored, irritated, etc., as the standard state, he should report 20, while, if his reactions represented only half of the intensity of the standard state, his estimate should be 5, and so on.

3. Results

3.1. *Performance during understimulation and overstimulation*

Fig. 1 shows vigilance performance and simultaneous capacity under the conditions representing understimulation and overstimulation, respectively.

Performance in the vigilance task showed a rapid decline over time, and a marked improvement immediately after the 10-min rest inserted between the two work periods. This time course is typical of vigilance performance. Analysis of variance showed that changes over time were significant ($F = 3.1$; $p < 0.05$; $df = 5/135$).

The test on simultaneous capacity showed an initial learning effect, followed by a plateau, and a gradual decline. In this case the rest pause did not markedly affect performance. Analysis of variance showed that changes over time were statistically significant ($F = 20.6$; $p < 0.001$; $df = 5/135$).[1]

It is interesting to note that simultaneous capacity was maintained at the same level for nearly 2 hr, while there was a pronounced vigilance decrement already after 30 min

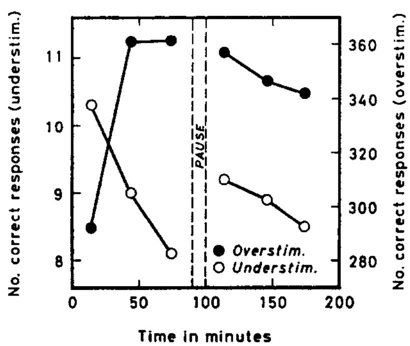

Fig. 1. Mean performance during understimulation (vigilance task) and overstimulation (choice-reaction task).

3.2. *Catecholamine excretion*

Fig. 2 shows mean results for adrenaline and noradrenaline excretion during understimulation, overstimulation, and the control condition.

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[1] For details of the statistical analysis the reader is referred to Nordheden, 1970, unpubl. manuscript.

During understimulation and overstimulation, respectively, the first values (representing the anticipation period) as well as the second and third set of values (representing successive work periods in tests on vigilance and simultaneous capacity) were consistently higher than the control data for corresponding points in time. The time course also differed between conditions. Adrenaline excretion showed a slight decrease over time in the control condition, a slight increase during understimulation, and a pronounced increase during overstimulation. Noradrenaline excretion decreased both during the control condition and during understimulation, and increased during overstimulation. Diuresis was relatively constant over time and did not differ markedly between conditions.

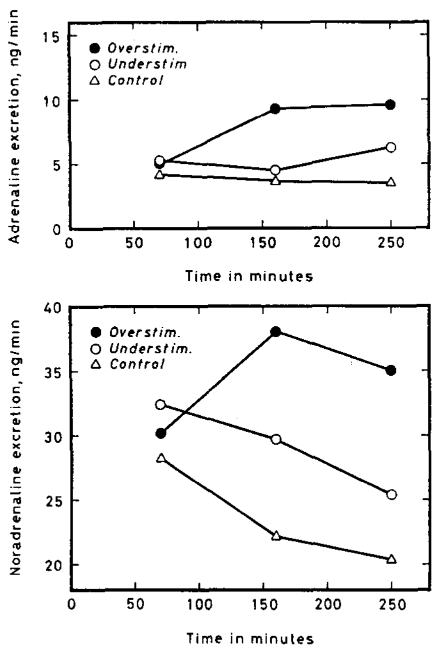

Fig. 2. Adrenaline excretion (upper diagram) and noradrenaline excretion (lower diagram) during experimental and control conditions. The first values during experimental conditions represent anticipation periods, the second and third values successive work periods.

Three-way analyses of variance were carried out for adrenaline and noradrenaline excretion. For adrenaline excretion significant differences were found between treatments ($F = 43.7$; $p < 0.001$; $df = 2/54$), and over time ($F = 7.3$; $p < 0.01$; $df = 2/54$) as well as a significant interaction between treatments and time ($F = 12.7$; $p < 0.001$; $df = 4/102$). Similarly, significant differences were found for noradrenaline excretion between treatments ($F = 17.5$; $p < 0.001$; $df = 2/54$) and over time ($F = 5.9$; $p < 0.01$; $df = 2/54$) as well as for interactions between treatments and time ($F = 12.3$; $p < 0.001$; $df = 4/102$).

3.3. *Heart rate*

Mean time-response curves for heart rate during anticipation and work in the understimulation and overstimulation conditions, respectively, are shown in fig. 3. Vigilance performance during understimulation was accompanied by a decrease in heart rate as compared with the preceding anticipation period. In contrast, the test on simultaneous capacity representing overstimulation induced an increase in heart rate. A three-way analysis of variance showed significant differences between treatments ($F = 9.5$; $p < 0.01$; $df = 1/29$) and over time ($F = 3.7$; $p < 0.05$; $df = 2/58$) as well as a significant interaction between treatments and time ($F = 41.1$; $p < 0.001$; $df = 2/58$).

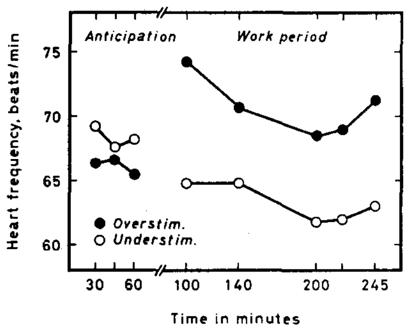

Fig. 3. Mean heart rate during anticipation and work periods under conditions of understimulation and overstimulation.

3.4. *Subjective reactions*

Fig. 4 shows mean self-estimates given at the end of the anticipation period, and at the end of each of the two successive work periods in the two experimental sessions. It is seen that understimulation and overstimulation were judged as equally unpleasant. The subjects felt more bored, less irritated, and less concentrated during understimulation as compared with overstimulation. With regard to changes over time the

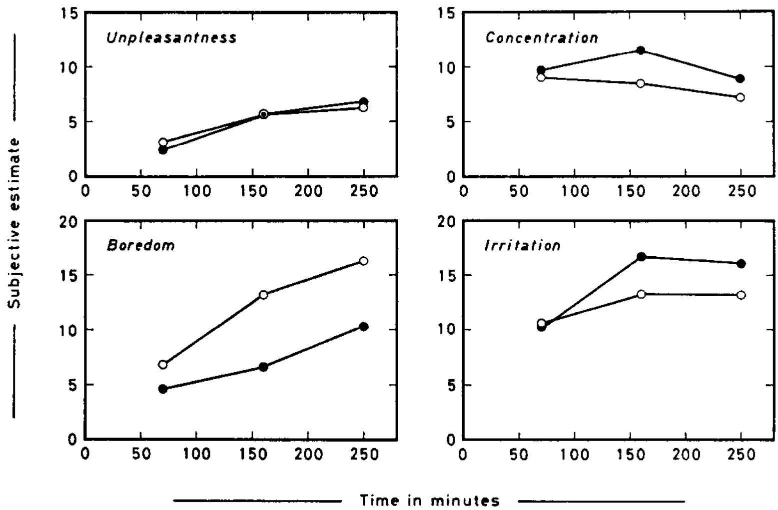

Fig. 4. Mean self-estimates of unpleasantness, concentration, boredom, and irritation during understimulation and overstimulation.

overall pattern indicates that the negative reactions increased as the sessions progressed.

3.5. *Mental efficiency as related to physiological arousal*

The relation between performance efficiency and physiological arousal (as measured by adrenaline output and heart rate) was examined by comparing the performance of high-arousal subjects and low-arousal subjects. On the basis of their adrenaline-excretion rates during understimulation and overstimulation, respectively, the subjects were divided into high-adrenaline groups and low-adrenaline groups (i.e., subjects above and below the median value of adrenaline excretion in each condition). Fig. 5 shows that performance in the vigilance task was consistently better in the high-adrenaline group ($F = 4.8$; $p < 0.05$; $df = 1/26$). In contrast, simultaneous capacity in the choice reaction test was consistently better in the low-adrenaline group. However, in this case the difference between groups was not statistically significant. The product-moment coefficient of correlation between adrenaline excretion and vigilance performance was 0.43 ($p = 0.05$), while the corresponding correlation for simultaneous capacity was not significant.

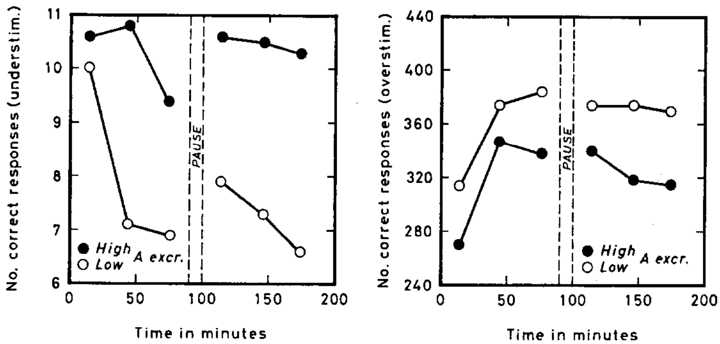

Fig. 5. Mean performance in subjects with high (above median value) and subjects with low (below median value) excretion rates of adrenaline (A) during understimulation (left-hand diagram) and overstimulation (right-hand diagram).

A comparison between subjects who increased vs. subjects who decreased their adrenaline output during the vigilance test in relation to the preceding anticipation period, shows that 'increasers' (13 *S*s) performed consistently better than 'decreasers' (12 *S*s). The tendency was the same when the comparison was based on adrenaline increase (20 *S*s) vs. decrease (8 *S*s) from the control condition to the vigilance condition. None of these differences were, however, statistically significant. During overstimulation all subjects but two raised their adrenaline output during work.

A comparison was also made between performance efficiency of high-heart rate vs. low-heart rate subjects during understimulation and overstimulation. Fig. 6 shows that the data displayed the same tendency as in respect of adrenaline output: performance during understimulation was better in the high-heart rate subjects, and during overstimulation in low-heart rate subjects.

4. Discussion

The present results add new information to the problem of quantitative relations between the amount of external stimulation, sympatho-adrenomedullary activity, and behavioural efficiency. It was shown that subjects who had a relatively higher sympatho-adrenomedullary activity level (as measured by catecholamine secretion and heart rate) performed better during understimulation (vigilance test) while, conversely, subjects with relatively lower activation level performed better during overstimulation (test on simultaneous capacity). These results are

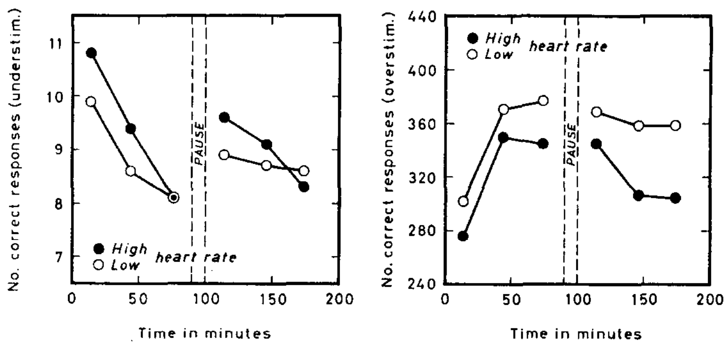

Fig. 6. Mean performance during understimulation (left-hand diagram) and overstimulation (right-hand diagram) in subjects with low (below median value) and subjects with high (above median value) heart rate.

consistent with the hypothesis of an inverted-U relationship between behavioural efficiency and activation level. The data are also in line with previous studies by Frankenhaeuser and her coworkers showing a positive relationship between adrenaline secretion and mental efficiency during conditions of low and moderate activation (e.g. FRANKENHAEUSER and RISSLER, 1970a; PÁTKAI et al., 1967). Furthermore, the finding that subjects who respond to monotonous mental work by increasing their adrenaline output tend to perform better than subjects who respond by adrenaline decrease, is also consistent with data from earlier investigations in our laboratory (e.g. JOHANSSON, 1970).

When evaluating the effects of different stimulus conditions on catecholamine release, it should be taken into account that adrenaline secretion is a sensitive indicator of anticipatory reactions, and, hence, secretion tends to diminish as uncertainty decreases and the subject gains better control over the situation (FRANKENHAEUSER and RISSLER, 1970a, b). It might be argued that the significantly lower adrenaline output during the control condition, which involved a medium amount of stimulation, as compared with the understimulation and overstimulation conditions, was associated with the fact that the control condition was always placed last in the series, when the subjects might have become habituated to the experimental situation at large (cf. FRANKENHAEUSER et al., 1967). If this were the case, adrenaline-secretion rates during the anticipation period at the beginning of each session would presumably have been affected most. This, however, was not the case: adrenaline secretion increased in the course of the understimulation and the overstimulation sessions, whereas secretion decreased in the control session. Hence, it may be concluded that the rise in catecholamine secretion was associated with excess and lack of external stimulation, respectively.

(Accepted April 5, 1971.)

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