NEURODYNAMICS OF CENTRAL PROCESSES DURING EXPERIMENTAL PROLONGED PAIN IN MAN

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It has been reported [6] that the photosensitivity of the eye is increased during weak and depressed during strong nociceptive sensation. An increase in the sensitivity of the dark-adapted eye has been observed under the influence of brief nociceptive and sudden cold stimulation [3, 5], while its sensitivity is depressed throughout the course of the adaptation curve by 15-18% relative to normal (in respect of optical density) in pathological processes associated with prolonged and constant pain. The evidence favoring the phased nature of the changes in the reflex processes during pain is fairly convincing [1, 2, 4, 9]. The experimental reproduction of the clinical findings [8] and the determination of the time during prolonged nociceptive stimulation when the increase in photosensitivity initially observed is changed into a decrease [5] are of theoretical interest.

The objects of the present investigation were to determine the specificity of the action of nociceptive stimulation by an electric current on the optic analyzer and to study the adaptation curves and latent periods of the motor reflex against this background. In this case, adaptometry and reflexometry were used as methods of verifying the neurodynamic changes during exposure to pain.

EXPERIMENTAL METHOD AND RESULTS

Altogether 88 adaptometric experiments (including 33 control) were carried out on 11 healthy persons aged 19-25 years, possessing normal eyesight. The type ADM adaptometer and the type ISE01 electrical stimulator were used in the experiments.

Nociceptive stimulation of moderate intensity was applied to the second phalanx of the middle finger (area of both electrodes 0.5 cm^2). The parameters of the stimulating current (80 cps, duration of each pulse 2 msec) were chosen to correspond to the lability of the nociceptive receptors. Three variants of the experiments were used.

In series I (15 experimental and 11 control investigations), after preliminary adaptation to light for 9 min, the intensity of illumination of the inner surface of the sphere of the adaptometer being 1250 apostilb. The increase in photosensitivity in the course of 1 h was determined. Figures of constant area were used as test object. Every 5 min the threshold of photosensitivity of the right and left eyes was recorded. Each reading was verified three times and the mean calculated. The threshold of sensitivity was expressed as unit of optical density. After determination of the initial one-hour curve, de-adaptation was carried out and the investigation repeated, and this time electrical nociceptive stimulation was applied, starting simultaneously with the beginning the adaptation. In the control investigations in the second half of the experiment, no nociceptive stimulation was applied. In seven experiments the investigation was carried out in the reverse order and the interval between taking the adaptation curves was 30 min.

In series II (20 experiments) electrical stimulation was applied 50 min after the beginning of dark adaptation and it lasted for 5-10 min, after which dark adaptation continued for a further 10 min.

During analysis of the results of series I a regular lowering of photosensitivity was observed almost throughout the course of the adaptation curve by 6-10% relative to the individual control. The initial part of the curves in six cases was steeper than in the individual control. Hence, the model of prolonged nociceptive stimulation in general gave figures similar to those obtained clinically [8].

In 12 of the 20 experiments in series II a slight (0.1-0.15 unit) initial increase in photosensitivity was observed after application of the electrical nociceptive stimulus; during the next 1-3 min the photosensitivity fell by 0.2-0.4 units compared with the level observed before stimulation (18 of 20 cases). This lowering of photosensitivity persisted until the pain ceased. The curve returned to its initial level or slightly above (0.05-0.1 unit) it after 0.5-1 min.

In series III (20 experimental and 22 control tests), after de-adaptation (3000 apostilb, 5 min) the time was determined during which the subject began to distinguish a test object with a constant intensity of illumination (2 and 3 units on the scale of optical density). After determination of the individual background, nociceptive stimulation was applied, beginning in different experiments at the same time as adaptation, or 2, 3, and 4 min after the start of adaptation.

Analysis of the control results in series III showed that a steady (± 2%) background could be obtained at the 3rd-4th repetition of the de-adaptation—adaptation cycle.

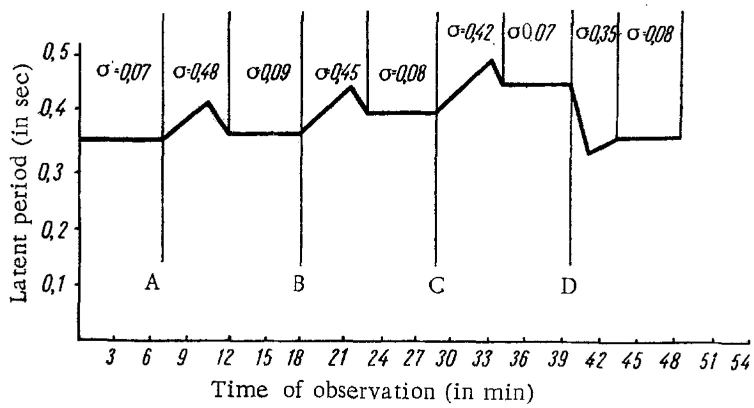
Pain applied simultaneously with the beginning of adaptation and 2 min thereafter increased by 20-40 sec the time required for differentiation of the test object. Stimulation applied at the 4th-5th minute of adaptation did not change this time or slightly reduced it. Bearing in mind that the mean time for differentiation of light of this intensity was $4^2/_3$ min, it may be concluded that the lowering of the photosensitivity of the eye during nociceptive stimulation took place in the course of $1^1/_2$-3 min, i.e., the results of series II were confirmed for the steepest part of the adaptation curve also.

It may be suggested after the discussion of these results that in man, during nociceptive stimulation of average intensity, a central pain focus inhibiting the zone of the optic analyzer is formed in the course of 1-3 min, thus producing (subjectively) primary adaptation to pain. The phenomenon described is confirmed by the fact that during nociceptive stimulation dilatation of the pupil takes place, so that the increase in photosensitivity is mainly peripheral. This means that the observed lowering of the photosensitivity of the eye can be attributed entirely to central processes.

In order to extend these conclusions to the interaction between the pain and motor analyzers, 35 observations were made (including 10 control) in the form of measurement of the latent periods of the motor reflex against the background of prolonged pain.

Experiments were carried out on 10 persons aged from 18 to 30 years. The type RRM-59 radioreflexometer was used with a key 1—key 2 circuit. The subject was instructed to press a button (key 2) on the appearance of a flash from a red light (key 1). The time constant of ignition of the lamp and of operation of the button was fixed. The latent period was determined every 10-25 sec. After stabilization of the background so that the scatter of the latent periods did not exceed ±3% in not less than 10 measurements, nociceptive stimulation was applied by the same method as during adaptometry. The increase in the current stopped when the subject gave a sign. Measurements of the latent periods were continued until the values became stable. From time to time the subject gave information about his sensations. After stabilization of the latent periods the current was increased steadily (without warning) and stabilization of the latent periods again was awaited. After stabilization had been obtained the current was switched off and the latent periods were recorded for a further 10 min. The whole investigation lasted for 30-50 min depending on the time taken for stabilization of the latent periods. The fatigue control consisted of measurement of the latent periods for 50 min without nociceptive stimulation. During analysis of the results of the individual experiments the mean values of the initial results and the values of the stabilized latent periods were calculated. In the intervals between the stable levels the amplitude of the variations of the latent periods was assessed (by calculating the value of σ), and compared with the value of σ for the controls. Hence, statistical analysis of the results was used within the limits of the individual experiment, for general treatment was complicated by the fact that each subject was investigated for a different length of time.

These experiments revealed a considerable variation of the latent periods during the first 3-5 min of a new level of nociceptive stimulation (σ) for the experiment 0.42, σ for the control 0.08), and at the 2nd-4th minute a peak was observed in the value of the latent periods (15-30% higher than the initial level). Immediately after this peak the curve fell for 1-2 min and the scatter of the latent periods was reduced, although the curve remained at higher levels than before stimulation. At the first level of nociceptive stimulation the increase (compared with the initial figures) was 5%, at the second 14%, and at the third 21%.



Changes in latent periods of the motor reflex under the influence of prolonged nociceptive stimulation of increasing intensity. A) nociceptive stimulation; B) increase in strength of nociceptive stimulation; C) second increase in strength of nociceptive stimulation; D) current switched off.

Removal of the stimulus in 60% of cases was accompanied by a rapid decrease in the latent periods, by the appearance of visible fluctuations in the curve and, starting from the 3rd-5th minute, by stabilization of the values at a level extremely close to the original (see figure). In ten experiments the subjects did not react at once to cessation of the stimulation, and in two cases disappearance of the pain was not noticed until $1^1/_2$ min later. The curve of the latent periods fell steadily to its initial level. Subjectively, the sweep of the curve corresponded to the sensation of intensive pain, with a peak indicating a diminution of sensation, and stabilization of the values indicating "habituation" to the stimulus, amounting in some cases to complete indifference to it.

The impression was created that at each new level of nociceptive stimulation the nervous processes responsible for adaptation to pain passed through a state of unstable equilibrium. This was confirmed by the variations in the latent periods of the motor reflex (parallel to the diminution of sensation) with the gradual increase in inhibition (positive peak of the latent periods). After the appearance of a stable focus in the limits we have examined, stabilization of the nervous processes was observed.

It may be concluded from a comparison of the results of adaptometry and the reflexometric experiments that the formation of such a focus during prolonged pain may take place in the course of 1-4 min after the onset of stimulation. This focus can hardly be called static, for in most cases the pain disappeared immediately after cessation of stimulation. It should be noted that the gradual lowering of the electrical sensitivity of the area of skin stimulated by an electric current of nociceptive order of magnitude cannot be attributed completely to the local action of the stimulus. It must be remembered that central neurodynamic adjustments take place in these conditions, leading to partial adaptation to pain.

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