ACTA NEUROBIOL. EXP. 1971, 31: 141—150

ELECTROMYOGRAPHICAL ANALYSIS OF REACTION TIME

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Among the many tests for the examination of the nature of skilled sensory-motor performance there are the measurements of latency period of motor reaction (Welford 1960). A measurement of the time that elapses between the onset of the signal and the onset of the response is one of the simplest methods of evaluating the speed of performance. Studies of reaction time are conducted for, among other things, the determination of the suitability for particularly dangerous and responsible occupations, as well as in examining the effects of fatigue and unfavorable environmental conditions on an operator (Galubińska 1962, Jethon et al. 1965, Carstocea et al. 1966, Ushakova 1966, Kovaleva 1967, Lyashok 1967, Malisheva 1967, Paranko and Vishchipan 1968).

The extension of the reaction time during a prolonged labor seems to be quite justified. It is a known thing that under such conditions as fatigue or sleepiness, it is more difficult to find proper solutions when a prompty action is necessary. Contrary to all expectations, the results of studies on the effects of both fatigue and working environment on the reaction time are not by any means uniform (Vasilev 1957, Carstocea et al. 1966, Gavrilescu et al. 1966, Malisheva 1967, Yurchenko 1967, Witte and Okhrimenko 1968, Angeleri et al. 1969, Calapay and Bellia 1969).

The authors expected to elucidate a certain vagueness which arose hence by means of the analysis of the recording of electrical activity of the muscles directly involved in the performance of a reaction. The surface electromyography, which has been used during the present studies, allows one to observe the muscular work for a longer time without limiting contraction strengths and makes possible an accurate determination of the onset of muscle action. In the experiments, described in the present paper, it was also intended to trace possible changes accompanying a prolonged task, considered as an experimental model of work with an automatized course of movements (Yevgenyeva 1953, Kosilov 1960, Angeleri et al. 1969) and requiring a constant concentration of attention.

METHODS

The task of the person, subjected to the experiments, was to perform a simple movement in the form of pushing a button or squeezing a rubber bulb as a response to an appointed signal. The signal, that is, a deviation from a line, drawn on a moving paper band (at a speed of 50 mm/sec), was applied at irregular intervals, on the average of 1.5 sec. The person examined had, therefore, to trace constantly the line and, according to instructions, to respond as quickly as possible. The experiments included a group of twelve persons, six of whom performed the test for as long as, according to their estimation, it was possible. The maximum time attained by an experiment amounted to 96 min.

Functional currents were received from the muscles by means of plate electrodes adhering to the skin over the surface of the following muscles: m. extensor carpi radialis longus or m. flexor carpi ulnaris (in the experiments with the use of a rubber bulb) and m. flexor carpi radialis or m. glexor digitorum sublimis (in the experiments with a push button).

RESULTS

The analysis of electromyograms was possible on the condition of a complete relaxation of the muscles during the intervals between successive reactions. The capability of relaxing their muscles was acquired by the persons examined by way of repeated trials which preceded the experiments proper. With the observance of this principle, it was evident that the reaction time consisted of two subperiods (Fig. 1): (i) the period

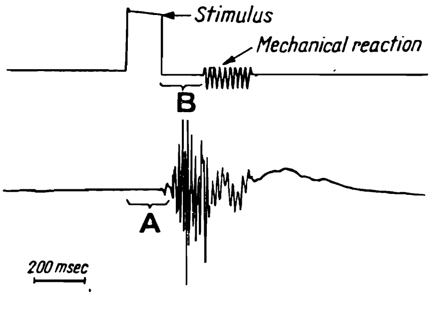

Fig. 1. Reaction time. Period *A*, the absence of electrical activity. Period *B*, action potentials preceding the occurrence of a mechanical reaction. Stimulus, deviation of the line drawn by the recorder. Mechanical reaction, pushing the button.

of a bioelectric silence (marked as period *A*) and (ii) the period preceding directly the mechanical reaction (period *B*), marked by the occurrence of electrical activity.

Period *A* was insignificantly shortened during the first trials (Fig. 2),

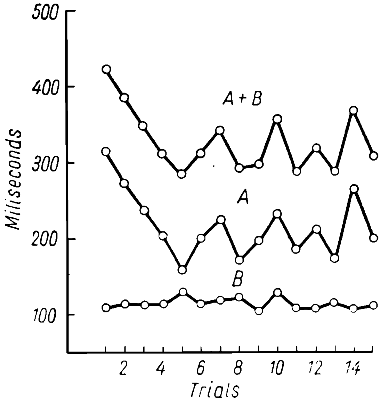

Fig. 2. Mean values of reaction time (period $A+B$), of period *A* and period *B*, calculated for the first fifteen trials of an experiment on six individuals.

but in the course of an experiment it fluctuated within wide limits more than once exceeding the initial values. Period *B* displayed considerably smaller fluctuactions and was fairly constant for particular individuals, being contained between 90 and 160 msec (of a modal value case of in particular persons). The reaction time depended, therefore, on changes in the length of periods *A* and *B*. During the measurements of a general value of reaction time in successive trials, despite a fatigue felt by the experimental subject, no significant changes were observed even in prolonged experiments. In addition to very small values of time, considerably delayed reactions were recorded, which shall be elucidated by the results of further analysis presented below.

First of all, intertrial reactions were observed in all the subjects. These were full motor (Fig. 3*AB*) or abortive reactions visible in an electromyogram only (Fig. 3*C*). At the same time, a stimulus, applied directly after the intertrial movement, frequently remained without any response (Fig. 3*A*). Intertrial reactions appeared periodically, frequently accompanied by complaints of fatigue. They might be also evoked by diverting an individual's attention from the work performed by, for instance, asking him a question which required reflection. When an intertrial movement was simultaneous with the application of a stimulus (Fig. 3*B*), it might be erroneously considered as a correct reaction with a very short time of latency. Without analyzing the electromyogram which revealed the beginning of a response it was indistinguishable from the reaction to a stimulus. This explains why, despite fatigue, seemingly very quick responses may occur which in fact are intertrial movements.

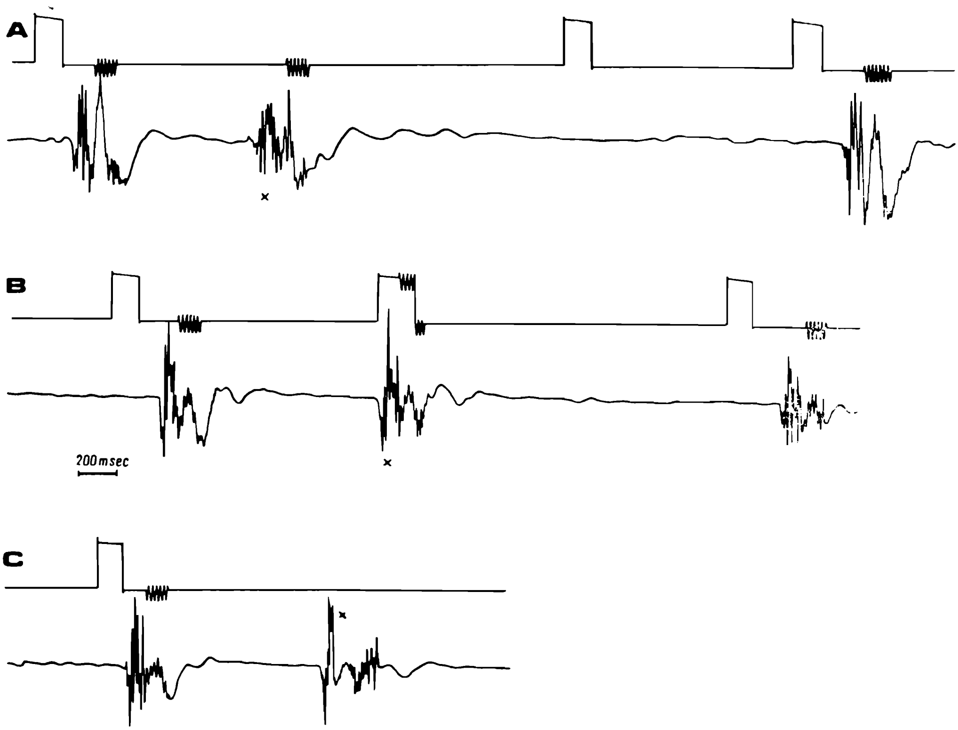

Fig. 3. Intertrial reactions (marked by crosses). *A:* Single intertrial reaction; absence of response to the next stimulus in succession. *B:* The onset of the electrical activity of reaction coincides with a stimulus. *C:* An intertrial abortive reaction (absence of mechanical effect).

In addition to the changes described above, abortive responses to stimuli were observed in an electromyogram (Fig. 4*A*). In these cases the mechanical effect was considerably decreased or even invisible. An individual either did not perceive the lack of a mechanical reaction, or immediately repeated the trial of performing a movement. In the latter case (Fig. 4*B*) the electromyographical recording showed a characteristic picture of two or more responses, directly following each other and of which the last one was mostly accompanied by a motor effect. This caused a prolongation of the general reaction time by an increase in the length of period *B*. At the same time, no conspicuous differences were recorded in the amplitude of potentials of abortive and full motor reactions. It was only in the cases in which the individual examined repeatedly tried to perform a movement that the amplitude of potentials of the abortive reaction was mostly lower as compared with the full motor reaction.

Abortive reactions, which occurred now and again, were mostly more numerous during prolonged experiments. At the end of an experiment, there also happened short pauses in work which occurred in the form of a lack of response to a few successive stimuli and which, as a rule,

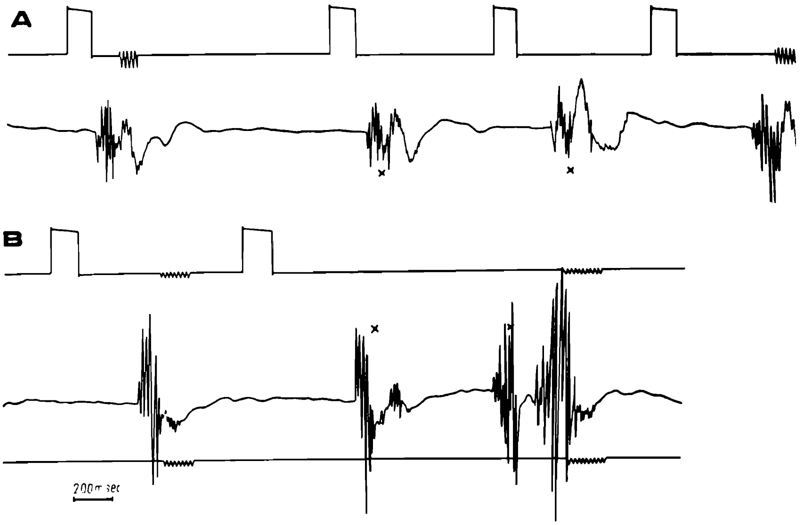

Fig. 4. Abortive reactions (marked by crosses), that is, those without a mechanical effect. *A:* Single abortive reactions as a response to two stimuli in succession; *B:* Three reactions following each other as a response to a single stimulus (two abortive reactions, the third with a mechanical effect).

were accompanied by complaints of fatigue. Ultimately, the individual examined stopped his work complaining of the incapability to continue it.

To check whether some changes took place in the speed of responding to stimuli during a prolonged work, the length of periods *A* and *B* were measured in successive trials. To obtain reliable data on period *A*, no account was taken of the trials in which the analysis of electromyogram revealed intertrial reactions. On the other hand, the trials in which abortive reactions occurred were taken into account. Measuring period *B*, only correct, full motor reactions were taken into consideration. It turned out that the length of period *B* at the end of an experiment mostly did not exceed the initial value. As mentioned above, period *A* displayed a considerable variability, but, even after a prolonged experiment, results not less positive than in initial trials were obtained in regard to the smallest limiting values. It was only the frequency of occurrence of reactions with longer period *A* that was slightly increased, which was expressed in an increase in the arithmetic modal or mean and in an increase of mean deviation in further minutes of the examination. Even these changes were, however, not always regular. The distribution of the values of period *A* in particular time intervals mostly displayed a right-hand asymmetry and no definite, shifts were found during the period of the experiment.

DISCUSSION

As it has been shown, during the study on the reaction time, several changes may occur which may be found only on the basis of an EMG recording. This is the reason why during the experiments conducted without a simultaneous EMG control, a possibility of errors, resulting from this fact should be taken into consideration. Thus, in regard to the trials during which only abortive reactions occurred, one should judge that the individual examined did not respond to the stimulus at all, which of course would be false. And vice versa, the intertrial reactions coinciding with a stimulus, might be erroneously considered as reactions with a very short latency period. In addition, without an EMG control, it is impossible to determine whether a possible prolongation of the reaction time during fatigue is connected with a change in the length of period *A* or *B*. According to what we know of successive stages of the process, taking place during the period between the onset of a stimulus and the onset of a motor reaction (Welford 1960), period *A* corresponds to the activities of the visual analyzer and to the conduction in nervous pathways, while period *B* is a time necessary for the muscles to develop a required strength. The extension of the reaction time by an increase in the length of period *B* would be a result of the muscle work fatigue (Merton 1954, Stepanov and Burlakov 1961, J. Wojtczak-Jarosz, in preparation), while in the case of the extension of period *A* one should consider the possibility of a process termed as a mental fatigue.

As mentioned in the introduction, the test has been treated as an experimental model of work in which the operations are automatically performed. During the work of this type such as, for instance, direct-line production, particular workmen perform partial operations which rapidly lead them to acquire skill (Wojtczak-Jarosz et al. 1970). Due to the absence of change in operations, such a work is frequently determined as monotonous. Likewise, in the test carried out, the work consisted in repeating over and over again one and the same simple movement, that is pushing the button or squeezing the rubber bulb which did not require control, while the attention of an individual was mostly focused on the signals exposed. The analysis of the changes, observed during the experiments, may help to understand some forms of man's behavior in the state of fatigue during work similar in character.

During a prolonged test, the individuals examined felt a fatigue expressed in a slight and inconstant extension of the period *A* and, sometimes, short pauses in the work. On the other hand, intertrial reactions were the most stable symptoms which accompanied the complaints of fatigue. They also occurred when an individual's was diverted from the work he did. Similar reactions, described as premature ones, were observed (Franaszczuk 1966) when a warning signal preceded the stimulus proper. In the experiments described here, there were no warning signals and, as it can be seen from the electromyograms, more than once the intertrial movements occurred as early as the beginning of the experiments. Thus, even with the application of a smaller number of stimuli, the results obtained without a simultaneous EMG control may be encumbered with errors of this type.

The intertrial movements occurred repeatedly every now and then and, at the same time, a stimulus applied directly afterwards happened to remain without response which resembled the picture of conditioned disinhibition, observed in the experiments conducted on animals. This seems to be the more interesting as usually fatigue is connected with the processes of increased inhibition in the central nervous system (Kosilov 1960, Mateev 1961, Kovaleva 1967, Malisheva 1967). In examining the mechanism of appearance of intertrial movements from this viewpoint, it seems that during a very monotonous work, there may exist a tendency to the repetition of a learned movement, independently of the actual need. Since, according to the assumptions of the experiment, the reactions should be performed only as a response to a signal, each different movement should be actively inhibited. Consequently, the appearance of a stereotype movement, independent of a stimulus, would be an expression of disorder in precisely this process of inhibition.

A separate discussion is due to abortive reactions. During work with automatized movements, it comes to the formation of a chain of conditioned reflexes in which impulses, coming from the muscles involved, are a signal for the next movement (Yevgenyeva 1953). During a prolonged repetition of the same simple movement, the experimental subject behaved again in the same manner as at the beginning of the experiment, checking whether mechanical operations in the form of pushing the button or squeezing the rubber bulb were performed or not. This would be indicative of a disorder in the activity of the motoric analyzer and, consequently, of a poorer perception of the changes which take place in the muscles involved. As a result, a repeated visual inspection was necessary to perform a simple operation, the same as that performed previously.

On the other hand, one cannot preclude the possibility that, in addition, a certain role was played here by the fatigue connected with muscle work, despite the fact that no increase was observed in the length of period *B* which might be a evidence of such a possibility. If we assumed, however, that, according to Merton (1954) and Lippold (1960), in this type of fatigue, there was a possibility of a decrease in the contractibility of muscle fibers, we might explain why the amplitude of potentials, which is supposed to depend on the number of motor units participating in the contraction, did not differ to any observable degree in the abortive reactions and full motor reactions. Namely, the action of the same number of motor units could not cause a full mechanical response, when the muscles were tired. Such an effect might be produced by the involvement of a greater number of motor units (Edwards and Lippold 1956, Lippold et al. 1960), which was manifested by a rise in amplitude of the motor reactions performed directly after the abortive ones. Thus, the persistence of a constant amplitude of potentials was not by any means an evidence of the preservation of muscular strength.

Leaving the problem of the origin of abortive reactions to further studies, the fact of their occurrence during fatigue seems to be worthy of attention. This means that the effort manifested by a bioelectric activity of muscles may be, during fatigue, not transformed into mechanical work at all.

SUMMARY

The reason for the investigation were the different results obtained by various authors who studied the effect of fatigue on the reaction time. It was expected to elucidate a certain vagueness by means of the analysis of the recording of electrical responses of the muscles directly involved in the performance of a reaction. In the present paper it was also intended to trace possible changes accompanying a prolonged task, considered as an experimental model of work with an automatized course of movements and requiring a constant concentration of attention.

It has been shown that during reaction time experiments, the possibility of errors concerning the appearance of the intertrial reactions and the abortive reactions should be taken into consideration. Because these changes appear only in the electromyogram, the measurement of the reaction time without EMG control may be unsatisfactory. The intertrial reactions, in the form of the repetition of trained movement, have appeared independent of an actual need during a decreased attention period, particularly after prolonged work. It has also been shown that the effort manifested by a bioelectric activity of muscles may be, during fatigue, not transformed into mechanical work at all.

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Received 23 June 1970