The silent period in the masseter muscle of patients with TMJ dysfunction

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The silent period (SP) following a jaw jerk elicited during sustained contraction in the masseter muscles has been studied in two groups of subjects, one with and one without, acute and distinct symptoms of TMJ dysfunction. The subjects with acute TMJ dysfunction symptoms showed significantly shorter latency and longer duration of the silent period and the period of their depressed activity (DA) was also significantly longer than in the group without TMJ dysfunction. The duration of the SP of both muscles was symmetrical in about 60 % of subjects in each group. This study validates that the duration of the silent period may be a useful diagnostic tool of clinical interest.

Key-words: Electromyography; neurophysiology; reflex; temporomandibular joint syndrome

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EMG recordings of the electrical activity in the jaw muscles have proved to be a valuable aid in the study of muscle function (*Møller* 1966) and reflex activity (*Ahlgren*, 1969, *Hannam, Matthews & Yemm*, 1969, *Widmalm, & Hedegård*, 1976) in the chewing apparatus. Two kinds of reflex response are of special interest: the jaw jerk elicited by a tap on the chin during mandibular rest (Fig. 1) and during isometric contraction (Fig. 2) of the jaw elevator muscles. The jaw jerk during mandibular rest has been discussed earlier (*Widmalm & Hedegård*, 1976). This study has been focused on the period of inhibition of the electrical activity, called the silent period (SP)*), following a jaw jerk elicited during isometric contraction. *Bessette, Bishop & Mohl* (1971) found that the duration of this silent period in the electrical activity of the masseter muscles was longer in patients with TMJ dysfunction than in healthy people and proposed that it may be a useful diagnostic tool of clinical interest. *Widmalm & Hedegård* (1976) found that the masseteric silent period has a latency of about 12 ms and is normally followed by a period of

*) The secondary silent period with long latency will be referred to as the *late SP*. The silent period with short latency will be referred to as the *early SP* or as the *SP*, without prefix.

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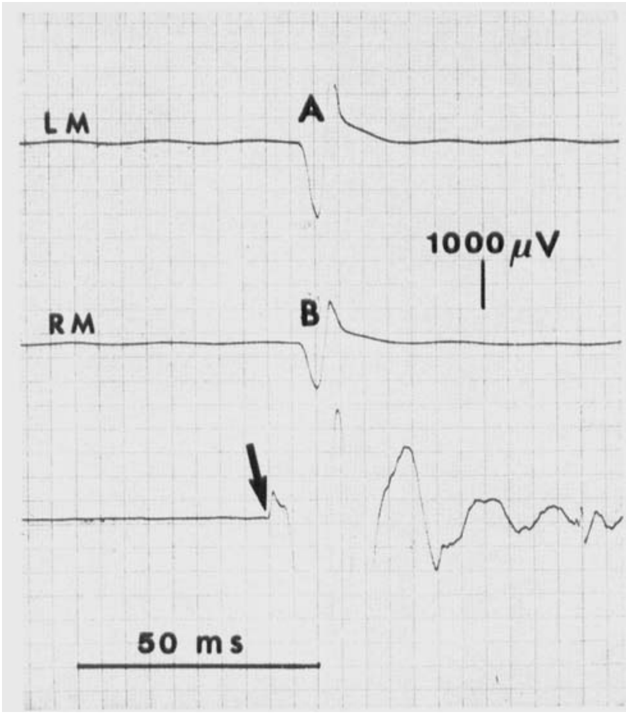

Fig. 1. Monosynaptic myotatic reflex potentials (MSP) evoked during mandibular rest in the left masseter (LM) at A, and in the right masseter (RM) at B by tapping the chin with a reflex hammer and thus eliciting a jaw jerk. The arrow marks the start of the vibrations evoked by the tapping and displayed by the phonochannel.

depressed electrical activity (duration about 5—15 ms) before the activity reaches the same level as before the tap on the chin (Fig. 2). The authors also observed that a chin tap sometimes also induces a secondary SP with a latency of about 58 ms and about the same duration as the first SP with short (12 ms) latency.*

The purpose of this study was:

1. To record SP and depressed activity (DA) in the masseter muscle using equipment previously described (*Widmalm & Hedegård,* 1974).

2. To compare the duration of these SPs with those previously published.

3. To compare a group of patients suffering from acute and distinct symptoms of TMJ dysfunction with a group of subjects without such symptoms. The variables used were:

a) Latency of the early SP
b) Duration of the early SP
c) Duration of DA

MATERIAL AND METHODS

Recording apparatus. Electrical activity was recorded on a DISA (Type 14 A 30) 3-channel electromyograph. Rectangular tin electrodes (DISA 13 K 60) were attached 1 cm apart on the skin over the middle of the superficial part of the masseter, with the long axes of each electrode at right angles to the direction of the muscle fibres.

Vibrations elicited in the masticatory apparatus by the tap on the chin were detected by a piezoelectric accelerometer microphone (EMT 25 C, Siemens-Elema) attached with double stick tape in the center of the subject's forehead. A sound amplifier (EMT 22 — Siemens Elema), with filters for maximum sensitivity around

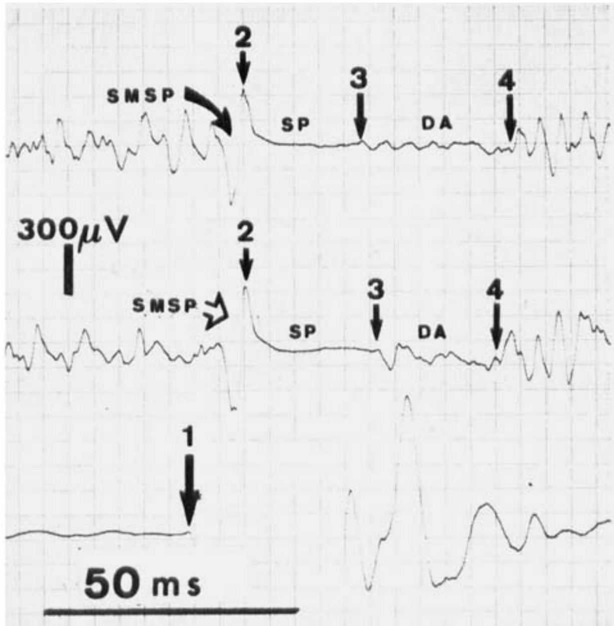

Fig. 2. Reflex response elicited in the left (upper channel) and the right (middle channel) masseter by a tap on the chin with a reflex hammer when the subject is clenching the teeth in maximal intercuspidation. Superimposed monosynaptic myotatic reflex potentials are marked SMSP. Vibrations from the tap are displayed by the phonochannel (lower channel). Latency of the silent period (SP) is measured horizontally between arrows 1 and 2. Duration of SP is measured between arrows 2 and 3. Duration of depressed activity (DA) is measured between arrows 3 and 4.

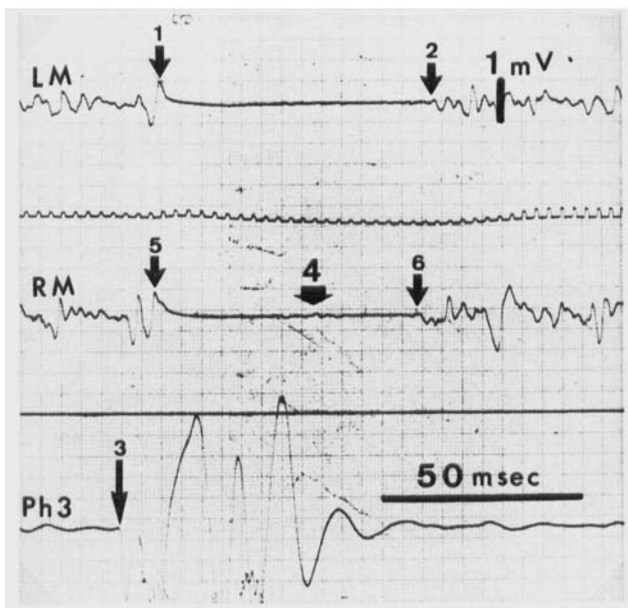

Fig. 3. Patient with acute and distinct symptoms of TMJ dysfunction. Early and late silent periods merging together without intermittent activity in the left masseter (LM) between arrows 1 and 2, and in the right masseter (RM) between arrows 5 and 6 with traces of intermittent activity at arrow 4. Start of vibrations from the reflex eliciting tap on the chin at arrow 3. EMG sensitivity 1 cm/ 1 mV. Paper speed 100 cm/s. Channel 2: mean voltage recording, channel 4 not used. Vibrations from the tap are displayed by the phonochannel (Ph 3). (Published also by Widmalm & Hedegård, *loc.cit.*).

100 Hz, was used to indicate the onset of the stimulus. A Mingograf 800 jet recorder with a frequency range D.C. to 1200 Hz, time marker and variable paper speed was used for synchronous recordings of EMG and vibrations. The EMG lower and upper cut-off frequencies were 20 Hz and 1 kHz. Before each experiment, the channels were calibrated and checked for phase displacement. A paper speed of 100 cm/s was used.

Subjects. Group I. 8 individuals, 5 males

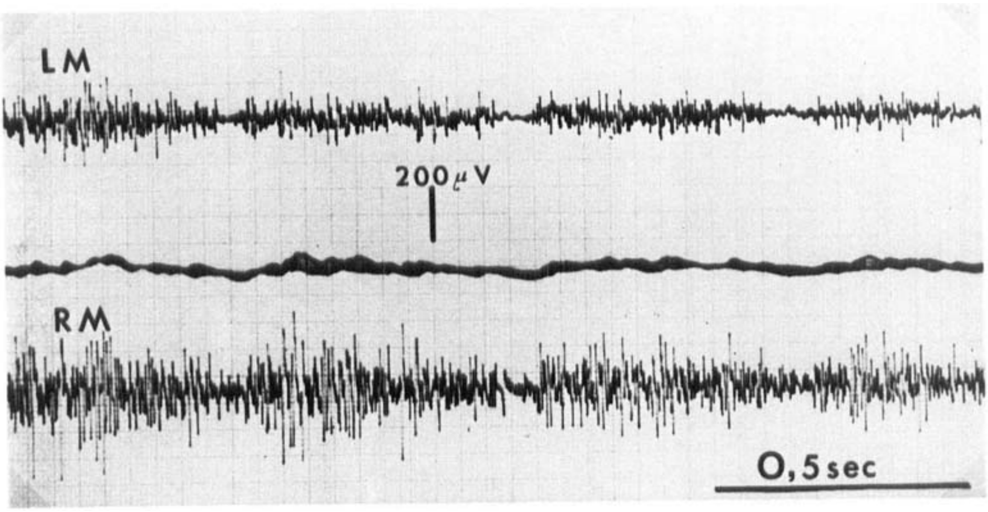

Fig. 4. Electrical activity in the left masseter (LM) and in the right masseter (RM). The subject is clenching the teeth together in maximal intercuspidation. Note the fluctuations in activity level. This subject had to be taught how to maintain the activity more constant by listening to the output of the loudspeaker before application of stimuli were attempted. EMG sensitivity 1 cm/200 μV. Paper speed 10 cm/s. Channel 2: mean voltage recording of activity in LM and RM.

and 3 females, mean age 33, without acute and distinct mandibular dysfunction symptoms.

Group II. 10 individuals, 3 males and 7 females, mean age 31, with acute and distinct symptoms of TMJ dysfunction as diagnosed by a specialist.

All subjects were dentulous and no individual was aware of any health problems, except for the symptoms of TMJ dysfunction. Originally group I contained nine subjects, but one was excluded because the taps were too painful. Group II contained fourteen patients — two felt the taps too painful and two were excluded from the statistical analysis since they had early and late SPs merging together (Fig. 3).

Test conditions. Each subject was given a briefing on the purpose of the test and also a test period, during which he could follow his own performance by listening to the electrical activity through the loudspeaker of the DISA Electromyograph. Special attention was given to teach the subject to keep the electrical activity at an approximately constant level during the sustained contraction (Fig. 4).

Experiment. SPs were induced by a light tap on the chin with a reflex hammer during sustained contraction of the masseter muscles with the subject clenching the teeth in maximal intercuspidation. The taps of the hammer were delivered with as little variation as possible in force and rate. The subjects were told to report immediately if the taps felt painful. The number of taps given was ten per subject. (2 taps/s).

Measurements on recordings. The times to be measured are indicated in Fig. 2.

Latency of the early SP: The time from the first distinct fluctuation in the vibration registration to the last clear-cut peak of activity preceding the SP.

Duration of the early SP: The time from the last clear-cut peak of activity to the first distinct deflection of the baseline due to returning activity.

Duration of the depressed activity (DA): The time from end of the early SP to the point where electrical activity reaches the original level.

Severity of dysfunction. The patients in group II were asked to judge the severity of their dysfunction according to a three graded scale: 1 = mild symptoms; 2 = moderate symptoms and 3 = severe symptoms. The specialist who referred all the patients likewise used a threegraded scale to assess the severity of their dysfunction during the objective examination.

Statistical methods. For each subject, the following variables were investigated in the masseter muscles

A. Latency of the early silent period (SP)

B. Duration of the early silent period (SP)

C. Duration of the depressed activity (DA)

The difference between the left and right sides for each record was measured and analysed using the sign test.

The method of nested or hierarchical analysis of variance (*Brownlee*, 1965), was used based on the model:

$$x_{ijk} = \mu + G_i + P_{ij} + \varepsilon_{ijk}$$

where G_i = group means (group factor)
i = group number $i = 1, 2,$
P_{ij} = individual means within groups (individual factor) j= individual number in the group number i.
ε_{ijk} = random variables k = replication number.

Ten registrations from each individual were used. The ε_{ijk}:s are supposed to be independent and normally distributed. The assumption of normality was tested by the Kolmogorov-Smirnov test (*Lindgren*, 1968), and the hypothesis of normality was accepted (level of significance was α = 0.05).

The scores from the subjective and objective judgements of the dysfunction degree were compared by a χ^2 test.

The hypothesis of randomness and independency was tested using the 'mean square successive difference test' (*Brownlee*, 1965). The coefficient of *intra*-individual variation (CV_w) within groups was calculated according to:

$$CV_w = \sqrt{\frac{\Sigma SD_i^2}{n}} \cdot \frac{100}{\bar{\bar{x}}}$$

and the coefficient of average *inter*-individual variation (CVb) according to:

$$CV_b = \sqrt{\frac{\Sigma (\bar{x}_i - \bar{\bar{x}})^2}{n}} \cdot \frac{100}{\bar{\bar{x}}}$$

where $\bar{x}_i$ = mean value for the i:th individual
$\bar{\bar{x}}$ = group mean
SD_i = standard deviation for the i:th individual
n = number of individuals in the group

RESULTS

Latency of the early SP. No significant differences between left (LM) and right (RM) masseter were found within subjects. Significant differences between individuals in groups were found. Mean latency of the early silent period was 12.0 ms in group I and 11.2 ms in the group with acute TMJ dysfunction symptoms. The 0.8 ms difference was significant at the 2.1 %-level in the LM and at the 4.8 %-level in the RM.

Duration of the early SP. There were significant differences between LM and RM in 40 % of the subjects but they were not systematic. No difference was found between left and right sides for the groups as a whole. The average duration was 17.2 ms in group I and 23.9 ms i.e. 6.7 ms longer, in the group with TMJ dysfunction symptoms. The difference was significant at the 0.1 %-level in the LM and at the 0.2 %-level in the RM.

Duration of the period of depressed activity (DA). Duration of the DA was 5.8 ms in group I and 13.2 ms i.e. 7.4 ms longer in the patients with acute TMJ dysfunction symptoms. The difference between groups was significant at the 0.6 %-level.

Habituation. No signs of habituation (= the gradual adaptation to a stimulus) were found.

Dysfunction degree. There was no agreement between the patients' and the examiner's judgement of the degree of dysfunction.

Coefficients of variation. A comparison, within and between groups, of the coefficients of intra- and interindividual variation showed that they were of about the same magnitude, regarding each variable.

DISCUSSION

Sources of variation

Age, sex and dentition. The two groups had comparable mean ages but sex distribution was unequal. As significant differences in reflex activity in the masseter muscles have now been related to TMJ dysfunction, the age, sex and dentition must be considered in future studies.

Rebound of the teeth. Any separation and subsequent rebound of the teeth when the chin was tapped would seriously alter the experimental conditions. That no separation occurred was carefully checked by examining the vibration registrations which clearly reveal rebound contacts (*Widmalm & Hedegård*, 1976).

Intra- and interindividual variability. As can be seen in Table I, the coefficients of intra- and interindividual variation were as a whole of the same magnitude in both groups *regarding each variable.* This means that the groups were expectedly maximally homogeneous in relation to the measuring technique, i.e. the observed variation between individual means may not be regarded as dependent on anything except random variation. It indicates also that the TMJ dysfunction affects only the level and not the stability of the variables. It should be noted that a number of about 10 registrations from each subject is necessary for an adequate estimation of the intraindividual variation and that knowledge about both the intra- and the interindividual variation is essential for a judgement of the homogeneity.

Asymmetry of SP duration. Bessette et al. (1971) indicated that, although symptoms of TMJ dysfunction are predominantly unilateral, asymmetry in SP duration between the two sides did not, as a rule, occur. They repeated registrations at least twice to determine reproducibility of EMG traces. The finding of asymmetry of SP duration in subjects of both groups in the present study emphasizes the necessity of at least 10 consecutive registrations per subject for a suitable statistical analysis and motivates classification of subjects regarding involved sides in future studies. The number of taps would have to be reduced, of course, if unpleasent for the subject.

Latency and duration of the SP — Comparison with other reports

a) *Group I — Subjects without acute symptoms of TMJ dysfunction.* When the chin is tapped during strong clenching of the teeth in centric occlusion, the usual

Table I. *Latency and duration of SP and DA in subjects without (Group I) and with (Group II) acute and distinct symptoms of TMJ dysfunction*

	Group I (8 subjects)			Group II (10 subjects)			
	$\bar{\bar{x}}$	CV_w	CV_b	$\bar{\bar{x}}$	CV_w	CV_b	P
Latency of SP in LM (n = 10)	12.1	8	8	11.2	7	4	2.1
Latency of SP in RM (n = 10)	11.9	7	8	11.1	6	5	4.8
Duration of SP in LM (n = 10)	17.3	14	17	23.4	18	16	0.1
Duration of SP in RM (n = 10)	17.2	14	20	24.3	16	20	0.2
Duration of DA in LM (n = 10)	5.8	47	67	13.4	40	48	0.6
Duration of DA in RM (n = 10)	5.8	52	59	13.1	56	49	0.6

Abbreviations: SP = silent period, RM = right masseter, LM = left masseter, n = number of individual observations, $\bar{\bar{x}}$ = total mean in ms, CV_w = coefficient of *intra*individual variation in %, CV_b = coefficient of *inter*individual variation in %.
P = probability of no difference between groups (in %). (The difference is regarded significant if $P < 5.0$.)

reflex response of the masseter muscles consists of a superimposed monosynaptic myotatic reflex potential (SMSP), a silent period (SP) and a period of depressed activity (DA) (*Widmalm & Hedegård*, 1976). The mean latency of the SP in this study (12.0 ms) was similar to that of *Goldberg* (1972) with 12.1 ms. The SMSP was easily elicited during this latent period in most subjects by *Widmalm & Hedegård* (1976) and again in this study, but *Hufschmidt & Spuler* (1962) reported inhibition without a previous SMSP if the jaws were closed tightly.

Difficulties arise when comparing the duration of the SP because the determination of measuring points differ between authors. *Bessette et al.* (1971) chose an amplitude of 200 μV as the maximum level of electrical activity to indicate the end of the SP. In the present study there were registrations in which the amplitude never reached this level at any stage and it is therefore considered unwise to choose a fixed level of activity for assessment of a measuring point. *Widmalm & Hedegård* (1976) distinguished a period of depressed activity (DA) prior to the return of EMG at the original level. Thus, the mean duration of the SP (24 ms) of *Bessette et al.* (1971) is more suitably compared with the mean duration of the SP plus DA of this study (23 ms). *Goldberg* (1972), who did not classify his subjects, may have included DA when reporting SP durations of 23—38 ms. *Hufschmidt & Spuler* (1962) reported 60 ms for SP duration which is similar to the duration of merging early and late SPs (Fig. 3) (*Widmalm & Hedegård*, 1976).

b) Group II — Patients with acute symptoms of TMJ dysfunction. The mean durations of the SP and DA were both greater than the corresponding mean values of Group I (Table I). This result is in agreement with the finding of *Bessette et al.* (1971) that a significant difference in SP duration exists between the two groups. The mean value of SP plus DA for Group II in the present study was about 37 ms and the mean SP of *Bessette et al.* (1971) was 59 ms.

Possible causes of and factors influencing the reflex response

I. Vibrations elicited by the chin tap exciting muscle spindles or periodontal receptors. It is improbable that a tap on the chin during sustained contraction would elicit the reflex response by a displacement with separation of the teeth (*Widmalm & Hedegård*, 1976). A possible cause of the SMSP is that the vibrations elicited by the tap are transmitted to the masseteric muscle spindles.

The primary endings of the muscle spindles have a high sensitivity to small perturbations (*Matthews*, 1971) with concomitant Ia afferent acitivity and motoneurone facilitation. Vibrations are transmitted differently according to how tense the muscle tissue is due to effects of damping and resonance. Also rather small variations in vibration amplitude may affect the response since the change in the frequency of firing produced by sinusoidal stretching and releasing is very steep for the primary endings in the 10—100 μ range (*Matthews*, 1971).

Thus different degrees of tension in the relevant muscles may affect the reflex response and it is possible that the proportion of subjects with tense, stiff muscles is larger in the group with acute TMJ symptoms. This will be considered at grouping in future experiments.

Small vibratory movements of the teeth in the alveoli may be possible, due to the elasticity of the periodontal ligament, and small perturbations of the teeth in the sockets with an amplitude as small as 5 μ are sufficient to excite mechano receptors in the periodontium (*Fujii*, 1975).

II. Refractory state of alpha-motoneurones

An induced SP in the masseter muscle is almost consistently preceded by some reflex activation, seen in the EMG as an SMSP (Fig. 2). The synchronized discharge of some of the alpha-motoneurones causes them to be in a refractory state for about 30—150 ms, which will be recorded as the EMG SP. However, with increasing background excitation, this refractoriness is overcome at increasingly shorter intervals. Furthermore, only motoneurones which participated in the SMSP will show any refractoriness. Since only a small proportion do participate this refractoriness can obviously not fully explain the SP.

III. Renshaw inhibition

Recurrent inhibition is known to occur at other segmental levels where recurrent collaterals from alpha-motoneurones can act upon so-called Renshaw cells which cause inhibition of the alpha-motoneurones. Thus the output can be regulated in the alpha-motoneuron by this feed-back mechanism. There is no positive evidence however, that recurrent alpha-motoneurone collaterals do exist in the trigeminal system and several brainstem motoneurones certainly seem to lack recurrent inhibition (*Haase, Cleveland & Ross*, 1975).

IV. Disfacilitation after the initial excitation (unloading)

The myotatic contraction of extrafusal fibres causes the intrafusal fibres in the muscle spindles to slacken. The excitation of the annulospiral endings is thus interrupted with a concomitant pause in the Ia afferent discharge. A continuous discharge in these afferents will give a facilitation of the alpha-motoneurone activity and a pause in this facilitation thus causes a disfacilitation and a concomitant pause in the alpha-motoneurone discharge.

V. Inhibition from Golgi tendon organs

It is generally accepted that Ib fibres from Golgi tendon organs produce autogenetic inhibition, of alpha motoneurones via interneurones.

TMJ dysfunction may be associated with muscle spasm of the jaw muscles. The patients may have less ability to relax their muscles than normal, healthy people. It has been proposed that the Golgi tendon organs have a prolonged discharge after the muscle twitch in spastic muscles. This could thus produce a peripheral source of active inhibition causing the prolonged silent period in the patients (*Bessette et al.*, 1971). Patients with TMJ dysfunction symptoms have often tender areas and soreness in the regions where Golgi tendon organs are known to be usually located — at the musculotendinous junction. Then increased inhibiting Ib activity could be a defense reaction protecting the sensitive muscle from being overloaded. However, little is known about the presence of Golgi tendon organs in jaw muscles.

VI. Cutaneous factors

Shahani & Young (1973) stress the possible importance of cutaneous afferents as a possible cause of the later phase in the SP. According to them the latency of these influences will be comparatively long and regarding the experiments reported here, they might play a role in the very long SPs, the DA and the late SPs with long latency.

VII. Parkinson's disease

Patients with Parkinson's disease are known to have prolonged SPs in other muscles (*McLellan*, 1972), the duration of which are shortened after DOPA treatment. The effect of DOPA*) on patients with Parkinson's disease is probably mainly due to its effect on the basal ganglia. It is known that the descending noradrenergic system from the reticular formation mediates a suprasegmental influence on the segmental reflex regulation of alpha-motoneurone activity and that the firing rate of static gamma-motoneurones is increased after DOPA injection (*Grillner, Hongo & Lundberg*, 1967), which may cause an increased synthesis and liberation of noradrenaline from descending noradrenergic fibres (*Andén et al.*, 1966).

Unloading of muscle spindles depends on static-dynamic gamma-sensitivity. Increased static gamma-activity diminishes the unloading effect on muscle spindles and may thus shorten the duration of the SP. It is also known that activity in this noradrenergic system profoundly changes the reflex transmission in the spinal cord. If the bulbar level is likewise influenced, the jaw reflex mechanisms may also be affected. It may therefore be of significant importance to study the duration of the masseteric SP in patients with Parkinson's disease.

VIII. The general arousal reaction

Sensory inflow from e.g. occlusal interferences may influence the level of activity in the reticular formation and trigger an arousal reaction. Afferent inflow to the reticular formation from the psychic spheres can increase the excitability level in the reticular formation and trigger and influence its efferent activity. Thus we have a clear connection between psychological reactions and the duration of EMG silent periods and periods of depressed activity mediated by the regula-

*) DOPA = dihydroxy-phenylalanine.

tory task of the reticular formation. Its influence may be of paramount importance for the etiology of dysfunction of jaw muscles (*Ericsson & Riise*, 1974). Almost any kind of stimulus, including acoustic, has been shown to elicit a silent period and the possible connections with, and influence of, the different components of the general arousal reaction may be of significant importance to the study and treatment of TMJ dysfunction.

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