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Sustained facial muscle activity during REM sleep

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SUSTAINED FACIAL MUSCLE ACTIVITY
DURING REM SLEEP

by

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STATEMENT BY AUTHOR

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

ABSTRACT

Few studies have been undertaken to explore whether REM EMG suppression is exhibited in facial muscles other than the mentalis. The present study is an investigation of facial muscle activity during REM sleep in ten vivid dreamers. Sustained facial muscle activity (FMA) was observed during paradoxical sleep in six of the ten subjects. The FMAs observed ranged from a minimum criterion of 6 seconds to sustained FMA "bouts" of up to 59.5 seconds in duration. The FMAs observed had voltages which ranged from a minimum criterion of 4.0 v to maximum bursts of 78 v. Across the 6 subjects who exhibited FMAs, there was a total of 19 events. EMG activity was usually observed in the corrugator, although it was sometimes observed in the zygomatic, frontalis, and masseter. The potential relevance of sustained facial muscle activity to emotion experienced during REM is discussed.

INTRODUCTION

The psychophysiological description of sleep has relied heavily on the electroencephalographic (EEG) measurement of brain activity. EEG assessment of sleep was first undertaken during the 1930s by Loomis, Harvey, and Hobart (1937). They discovered that sleep is not a unitary phenomenon but, rather, is composed of several EEG-defined "sub-states" or stages. Loomis et al. labeled the various stages A, B, C, D, and E. The "A" stage represented relaxed wakefulness, and the "E" stage represented deep sleep. Descent from relaxed wakefulness into deep sleep was characterized as entailing a progressive slowing of the EEG signal. This "slowing" was also accompanied by the appearance of periodic EEG events known as K-complexes and spindles and by the gradual increase in amplitude of the EEG signal. It was also noted that electroencephalographically defined sleep was not simply a descent into very slow and powerful stage "E" sleep, but rather a cyclic phenomenon; i.e., it was observed that brain activity decreased and increased systematically over the course of the night.

About 15 years after the initial EEG studies of sleep, Aserinsky and Kleitman (1953), and later Dement and Kleitman (1957), discovered, via electrooculographic techniques (EOG), that the ascendant form of stage B sleep was accompanied by very rapid eye movements. This stage of sleep became known as rapid eye movement (REM) sleep, or paradoxical sleep, and was found to be associated with the experience of dreaming.

After Dement And Kleitman discovered that dreaming occurs primarily during REM sleep, Jouvet (1959) discovered, via electromyographic techniques (EMG), that cats lose all muscle tonality in the nuchal region during REM sleep. Jouvet claimed that loss of muscle tonality provided the "single most reliable marker of paradoxical sleep" (Jouvet, 1967). In 1961, Berger, following Jouvet's lead, demonstrated that in humans there is a profound decrement during REM sleep in extrinsic laryngeal muscle tonality. This finding has been generalized to include all skeletal muscle. Hobson (1988) describes the EMG measure of muscle tonality in relation to sleep as follows:

> When electrodes are placed on the skin over the middle of a muscle, the electrical signals that arise during movement or in the active maintenance of an erect posture can be recorded. The EMG potentials of must muscles decrease when one lies down at sleep onset, but some persist until the beginning of the brain-activated state REM; then all are obliterated. In humans, the best muscles for recording this state-dependent suppression of EMG activity are in the upper neck, just underneath the chin. (Hobson, 1988)

Since the 1960s it has been suggested that the "atonia" observed during REM sleep is a consequence of the widespread inhibition of motor neurons during REM sleep (e.g., Pompeiano, 1964; Hodes & Dement, 1964; Chandler, Chase, & Nakamura, 1980). This is to say that the muscle atonia which occurs during REM sleep is related to the blockade of efferent impulses which, in turn, disallow contraction of skeletal muscle. The resultant state is one in which, during REM sleep, skeletal muscle is relaxed or electromyographically silent.

Currently, sleep is classified into stages based upon all three types of electrophysiological data: i.e., the electroencephalogram, the electrooculogram, and the electromyogram. Information from each of these measures allows for the classification of sleep into five different stages which are subsumed under the broad categories of NREM and REM sleep. For the purposes of this paper, only REM sleep will be defined. Paradoxical sleep is characterized by a low-voltage, mixed-frequency EEG pattern which may be accompanied by rapid eye movements and is, by definition, accompanied by an absence of muscle tonality, particularly in the mentalis or sub-mentalis muscles (Rechtschaffen & Kales, 1968).

The general view of the muscle atonia that accompanies rapid-eye-movement sleep (REM) is that it is an all-or-nothing phenomena (e.g., Horne, 1988). In the "all" state, the individual is considered to be in a virtual state of paralysis which is produced by centrally mediated motor inhibition and accompanied by muscle atonia. In the "nothing" state, there is little or no motor inhibition as result of neuropathological conditions, and consequently the individual does not exhibit atonia and is capable of emitting elaborate behavioral sequences (Schenck et al., 1985).

Despite the "all-or-nothing" view of REM sleep atonia, it is recognized that there are storms of efferent impulses that cannot be contained, and thus break through the general inhibition as phasic muscle activity (Chase & Morales, 1989; Hobson, 1990). This phasic activity is observed as twitching of the extremities and in facial musculature. Although it has been long known that extremities are differentially affected by motor inhibition, this observation has only been made with respect to phasic activity; i.e., phasic activity is more likely to occur in the extremities and the facial musculature than in trunk muscles. This observation seems to suggest that peripheral musculature is somehow more resistant to the motor inhibition of REM sleep. Interestingly, under anesthesia it has been demonstrated the muscles of the upper face are particularly resistant to pharmacologically induced motor inhibition (Markku et al., 1988). A similar sensitivity to centrally mediated motor inhibition may occur during REM sleep.

Apart from the emergence of phasic activity, it is generally accepted that sustained muscle activity does not occur during REM sleep in normal subjects. Although the present investigator could locate no earlier reference to it, it was observed in our own recordings that facial electromyographic (EMG) activity could persist for many seconds during REM sleep. Appearance of sustained facial muscle activity during REM sleep seems to be an exception to the "all-or-nothing" principle of atonia.

The present study was an attempt to systematically document the occurrence of sustained facial activity (FMA) during REM sleep. In order to maximize the chance of observing FMAs during REM sleep, it was reasoned that since facial muscle activity is strongly associated with emotion during waking, sustained facial EMG during REM sleep may be more likely to occur during intensely experienced affective dreams. Consequently, only subjects who reported having extremely vivid dreams were recruited for this study.

METHODS

Subjects

Subjects were undergraduate students at the University of Arizona. There were 7 women and 3 men, with a mean age of 22.1 years (18-28). On a sleep questionnaire, study participants reported being vivid dreamers (scoring 4 or 5 on a Likert scale of 0 to 5).

Apparatus

Recordings were made with a Grass model 8-16E electroencephalograph. Grass miniature silver chloride surface electrodes (5 mm in diameter) were used to obtain electroencephalograms (EEGs), electrooculograms (EOGs), and electromyograms (EMGs). The standard sleep montage, including EEGs, EOGs, and the mentalis EMG, utilized 8A5 EEG amplifiers. EOGs were set on a sensitivity of 7 V/mm, with a frequency bandwidth of 0.3 to 15 Hz. EEGs were set on a sensitivity of 5 V/mm, with a frequency bandwidth of 0.3 to 35 Hz. Mentalis EMGs were set at a sensitivity of 2 V/mm, with a frequency bandwidth of 5 to 70 Hz. Facial muscle activity was recorded on high-frequency amplifiers (Grass model 8A5HF). Each of the 8A5HF amplifiers was set on a sensitivity of 2 V/mm, with a frequency bandwidth of 30 to 300 Hz. The low-frequency filters were set at 30 Hz to ensure that the signal tracing was free from slower confounding signals such as sweat artifacts and EEG.

Electrode Placements

The montage used for the sleep study included the standard configuration for polysomnography, as recommended by Rechtschaffen and Kales (1968). In addition to the standard sleep montage, five facial EMGs were recorded. Four of the five EMGs were obtained from all subjects at locations over the frontalis (FR), corrugator (COR), zygomatic (ZYG), and masseter muscles (MAS). The fifth EMG was derived from over either the nuchal region or the sternocleidomastoid muscle (see Figure 1). The mentalis electrodes were separated by approximately 2 cm. Facial EMGs, except for the nuchal region, had an interelectrode distance of less than 1.5 cm and were placed asymmetrically. This is to say that the FR, COR, and MAS were placed only on the left side of the face while the ZYG was located on the right. Such a montage was selected in order to keep the number of electrode sites to a minimum. All EMG recordings were bipolar.

Electrode Impedances

EEG electrodes and references had initial test impedances (at "lights off") of less than 10 Kohms. EMG electrodes had initial test impedances of less than 5 Kohms,

FIGURE 1

ELECTRODE PLACEMENTS

with a differential impedances of less than 2 kohms. The rigorous criteria for EMG impedance values were selected to accommodate the observation that higher impedance values tend to make the discrimination of tonic artifacts from small voltage signals difficult (Tauber et al., 1977). Despite the maintenance of rigorous impedance values for the facial EMGs, electrodes frequently exceeded the 2 Kohm cutoff over the course of the all-night recording. Research assistants were trained to recognize when EMG electrodes were beginning to "go bad" and were instructed to reduce the gain to 3 V/mm and, if necessary, to 5 V/mm. Adjusting the sensitivities in such a fashion compensates for the presence of an enduring artifact but at the expense of missing low-voltage activity.

Experimental Routine

Subjects were monitored polysomnographically for a single night. Subjects came to the laboratory at 8:00 PM, were shown the instrumentation, signed a consent form, and were prepared for polysomnographic study. Subjects were informed that they were participating in a study of the physiology of REM sleep. Lights off occurred no later than 12:30 AM, and subjects were awakened no later than 8:30 AM. At least six hours of data were collected on each subject.

Scoring Procedures

Once the polysomnograms were obtained, they were scored by the author for stages of sleep in accordance with Rechtschaffen and Kales (1968) criteria. After sleep staging, records were assessed for sustained EMG activity during REM by the author and a research assistant. Sustained activity was defined as an event consisting of at least 6 seconds of activity, uninterrupted by no more than 1 second of inactivity. The 6-second criterion was adopted as a way of definitively discriminating between "phasic" and "tonic" activity. It was reasoned that if 6 seconds (20% of a 30-second epoch) is a long enough period to differentiate between stage 2 and stage 3 sleep (Rechtschaffen & Kales, 1968), then it should be substantially long enough to ascertain that an event is not simply phasic twitching. If an event was sufficiently long in duration, its amplitude was measured twice per second and averaged. Only events with an average voltage equal to or greater than 4μV were tabulated as acceptable examples of sustained activity. Any event tabulated as occurring during REM also met the following two additional criteria: (1) events were not accompanied by sustained activity in the mentalis, and (2) no event was accepted if it included four or more channels of EMG activity. The later were considered to be simply movement arousals or movement times.

RESULTS

Sustained facial muscle activity (FMA) was observed during REM sleep. FMAs occurred in six of ten subjects, and a total of 19 events was observed (as defined in the methods section). Figure 2 gives an example of sustained muscle activity during REM.

Figure 2 is an example of an FMA in the zygomatic muscle. The zygomatic is responsible for pulling the corners of the mouth upward and back. During wakefulness, zygomatic activity is associated with the expression/ experience of happiness (Schwartz et al., 1976a, 1976b). Although anecdotal, it is worth noting that the subject spontaneously awakened and reported having had a very funny dream. Figure 3 is an example of sustained facial muscle activity in the corrugator, which is terminated in a movement arousal.

Duration and Voltage of Events

Table 1 summarizes the nature of the events observed across all six of the subjects who exhibited facial muscle activity during paradoxical sleep. As mentioned previously (see Scoring Procedures), FMAs during REM were at least six seconds in duration, possessed an average voltage of greater

FIGURE 2

SUSTAINED FACIAL MUSCLE ACTIVITY IN THE ZYGOMATIC

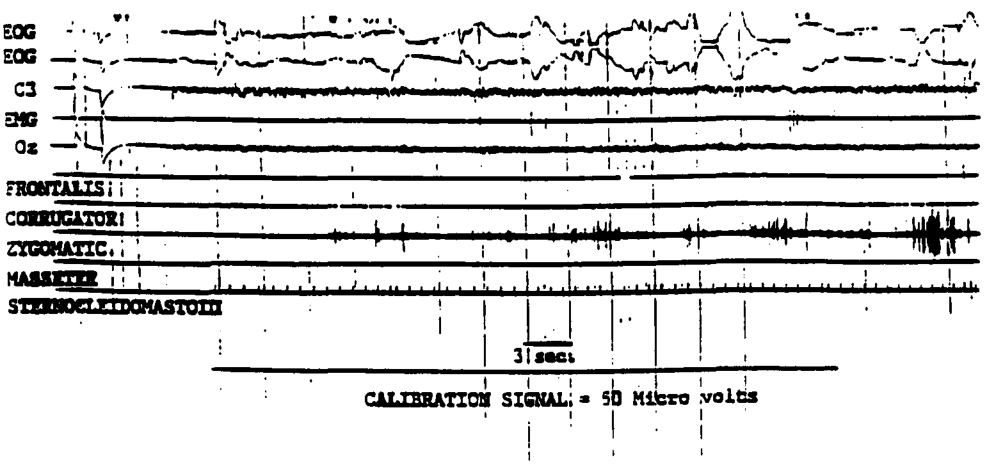


FIGURE 3

FACIAL MUSCLE ACTIVITY DURING REM

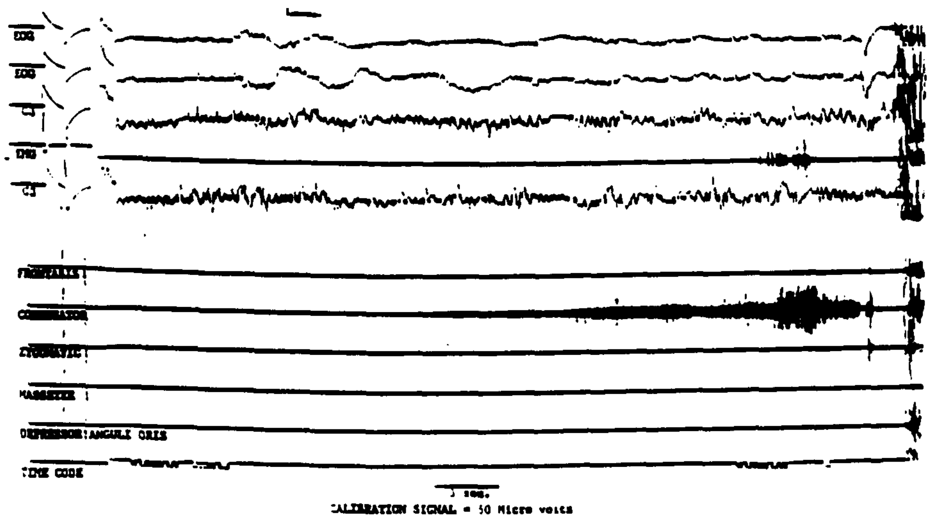


Table 1. Average magnitude and duration of facial muscle activity during REM.

SBJ	EMG	FMA	MAG	(SE)	DUR	(SE)
1	Z	1	5.60		59.5	
2	F,C	2	4.75	(0.75)	19.9	(12.35)
3	F,Z,M	4	10.32	(3.04)	15.4	(3.13)
4	F,C,Z	4	7.18	(0.45)	9.0	(2.80)
7	C	3	13.75	(3.90)	13.9	(3.90)
8	F,C	5	10.04	(2.62)	23.0	(4.74)

SBJ = Subject number; EMG = particular muscles; i.e., F = frontalis, C = corrugator, Z = zygomatic, M = masseter, FMA = number of criterion events, MAG = Average magnitude across events (V), Dur = Average Duration (seconds) across events, numbers in parentheses are standard error of the means.

than or equal to 4μV, were unaccompanied by sustained mentalis activity, and occurred in four or fewer channels on the recording. For the purposes of Table 1, if any single event entailed more than one channel of EMG activity, signals were averaged and represented as a single FMA. As will be discussed later, such averaging was rarely required (see Frequency and Pattern of FMAs).

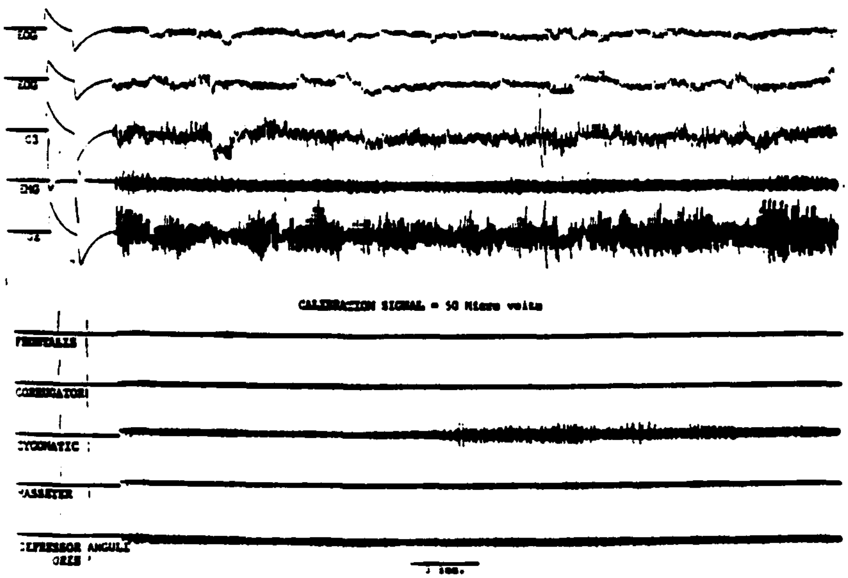
In general, the activity observed ranged from the 6-second criterion to sustained FMA "bouts" of up to 59.5 seconds in duration. Mean duration for all the events was 18.5 seconds (SE = 3.1). Facial muscle activity observed had voltages which ranged from the 4.0μV criterion to a maximum burst of 78μV. On average, (i.e., the average of the two-per-second samples for the duration of the event), the FMA events had voltages ranging from 4.7 to 13.7μV. Mean voltage across all 19 events was 9.2μV (SE = 1.1).

Frequency and Pattern of FMAs

As can be seen in Figure 2, in this series of epochs only one muscle (the zygomatic) was "tonically" active, of the five muscles measured. This activation of a single muscle is in marked contrast to the more global, and differentially active, patterns exhibited in waking (see Figure 4; the waking activity pictured is that of a subject engaging in imagery for a "happy" event). Of the 19 events documented, 16 exhibited activation of a single muscle. The

FIGURE 4

FACIAL MUSCLE ACTIVITY DURING WAKING



remaining three instances exhibited EMG activity from two muscles. As indicated in Table 2, events involving two muscles occurred twice in the frontalis and corrugator and once in the zygomatic and masseter. Overall, and as can also be seen in Table 2, each subject had a different series of FMAs over the course of successive events. The most frequent FMAs occurred in the corrugator (13 events). Five events involved the zygomatic, three the frontalis, and one involved the masseter.

Morphology of Events

Apart from the magnitude, duration and frequency of the events, it was also noted that EMG signals differed as to their morphology. Three types of EMG signals were evident. The first type, which shall be referred to as a full signal, tended to reflect high voltage activity where the mean and peak amplitudes were similar. The full signal type of activity seems best exemplified by waking EMG activity (see Figure 4). The second type, which shall be referred to as a powerful intermittent signal, appears to occur frequently in REM and is typified by the zygomatic activity pictured in Figure 2. Finally, the third type, which shall be referred to as an equal amplitude spiking signal, appears to occur in both NREM and REM (see Figure 5). The equal amplitude spiking type of EMG, which may frequently be observed in the mentalis at the onset of

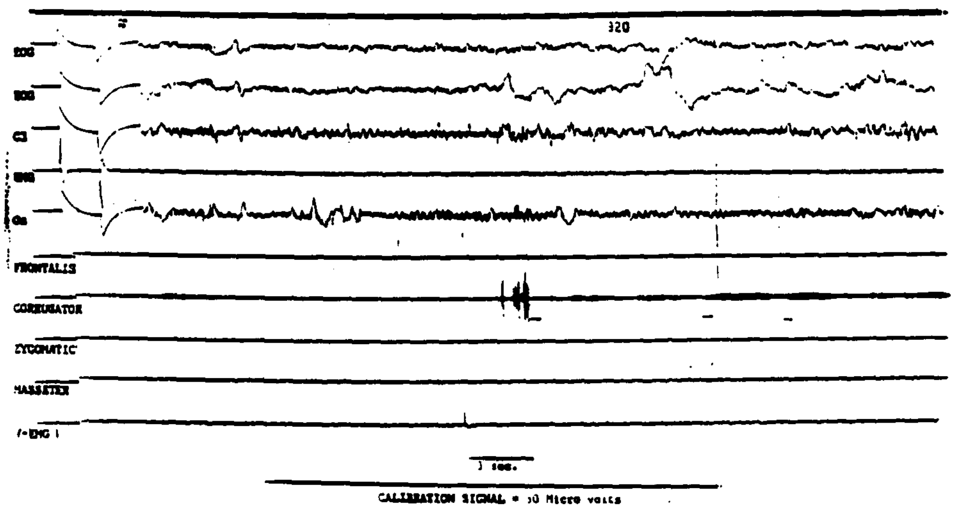
Table 2. Frequency and pattern of facial muscle activity during REM.

	Event						
SBJ	#1	#2	#3	#4	#5	#6	#7
1	Z	*	*	*	*	*	*
2	C	C(EAS)	*	*	*	*	*
3	F	Z	Z/M	Z	*	*	*
4	C	Z	F/C	C	*	*	*
7	C	C	C	*	*	*	*
8	C	C	C	F/C	C(EAS)	*	*

SBJ = subject, F = frontalis, C = corrugator, Z = zygomatic, M = masseter, * = no FMA, EAS = FMA primarily equal amplitude spiking type signal F/C and Z/M represent simultaneous activation of two muscles.

FIGURE 5

EXAMPLE OF EQUAL AMPLITUDE SPIKING ACTIVITY DURING <u>REM</u>



EMG suppression, occurred during REM as FMAs only twice and in two subjects (see Table 2). It is possible that the equal amplitude spiking type of EMG may correspond to single motor unit activity.

DISCUSSION

This study has shown that: (1) Sustained facial muscle activity in muscles other than the mentalis occurs during REM sleep, at least in vivid dreamers. (2) Subjects exhibit different patterns of muscle activation. These patterns may be related to the dreamer's affective experience. (3) There are fairly distinct morphologies to the EMG signals. These different wave forms may be related to different levels of motor inhibition.

FMAs Versus the "All-or-Nothing" Principle

The present results suggest that the "all-or-nothing" model of muscle atonia discussed in the introduction should be modified. It would fit the data better to conceive of the REM motor inhibition as existing along a continuum in which "sleep paralysis" and REM behavior disorder represent opposite extremes. Monitoring facial musculature may thus represent the optimal method for observing the extent to which individuals are motor inhibited or subject to partial motor disinhibition.

Affective Experience and the Occurrence of FMAs

The only inclusion criteria for this study was that subjects rated themselves as very vivid dreamers. This criterion was adopted based upon the reasoning that there would be sufficient "pressure" for sustained muscle activity to emerge against a background of generalized inhibition. Six of ten study subjects did exhibit FMAs. However, this study did not include a comparison group of non-vivid dreamers; therefore, one cannot be sure that vividness was the pivotal consideration.

FMAs and Expression of Affect

Although this study did not undertake a systematic investigation of the relationship between perceived dream affect and sustained muscle activity, a case example was presented (see Figure 2). In this instance, sustained zygomatic activity corresponded to the dream experience of humor. A question that arises in relation to this finding is, "what is the feasibility of inferring dream affect from REM FMAs?" In the absence of data from sleeping subjects, one can only make inferences from studies conducted during wakefulness. Schwartz et al. (1976a, 1976b) reported that different patterns of FMA activity, as measured by EMG, reliably accompanied the experience of emotion while subjects are engaged in imagery. For example, happiness was associated with increased activity in the zygomatic, depressor anguli oris, and the mentalis and with slightly decreased activity in the corrugator. However, such "pattern" definitions may not be appropriate for correlating

FMA with dream emotions. As mentioned earlier, EMG activity during REM tended to occur in only one muscle at a time.

Data presented in this study suggest that it may be possible to infer dream emotions from FMA insofar as the FMAs which did occur varied between and within subjects (see Table 2). Such variability would suggest that it is possible that differential activations may correspond to different affects. However, it remains to be shown that FMAs reliably correspond to dream affect, and that the intensity and duration of FMAs are related to perceived intensity of dream affect.

Morphology of Events and Motor Inhibition

Morphology of most of the events observed were of the powerful intermittent type (see Figure 2 and Morphology of Events). This type of EMG signal suggests that there is a mutual engagement of inhibitory and excitatory influences. Such a combination of influences would seem to support the proposition that, unlike "normal" atonia or RBD, events observed in this study represent some "middle ground" with respect to motor inhibition during REM. Further, the occasional appearance of equal amplitude spiking activity suggests that there is variability in the degree to which excitatory influences "override" motor inhibition. Such events as pictured in Figure 2 may represent stronger disinhibition, while events like Figure 4 may represent weaker disinhibition.

CONCLUSIONS

This study has demonstrated that, at least in some vivid dreamers, sustained muscle activity during REM sleep does occur. The existence of such activity suggests that motor inhibition during REM is not an "all-or-nothing" phenomenon, but rather that there are various intermediate states. This study of facial muscle activity during REM sleep has been limited by the use of a small sample, use of visual inspection for the quantification of EMG, and use of a single night between subjects design. Future studies should avoid these limitations.

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