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Psychological Correlates of Spontaneous Middle Ear Muscle Activity During Sleep

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Summary: Nine subjects each spent four nights in the sleep lab during which middle ear muscle activity (MEMA) was recorded in addition to standard sleep monitoring. After an adaptation night, subjects were awakened four times on each experimental night: twice from rapid eye movement sleep and twice from stage 2; once from each stage in the presence or absence of MEMA. Detailed mentation reports were obtained, coded, and rated on scales of auditory involvement, emotional activity, bizarreness, hallucinosis, and clouding. Sleep stage was a better predictor of the mental activity of the sleeper than was the presence or absence of phasic activity on the above measures. Auditory ratings were no higher following MEMA than following non-MEMA arousals, but MEMA was associated with bizarre, discontinuous sleep mentation. Theoretical implications were discussed. **Key Words:** Sleep—Spontaneous middle ear muscle activity—Tonic-phase model—Sleep state model—Dreams.

Foulkes (1962) showed that some kind of sleep mentation occurs almost continuously throughout sleep and that qualitative distinctions between "dreamlike" and "thoughtlike" processes noted following arousals from different sleep stages could be differentiated quite reliably *within* the rapid eye movement (REM) state depending on whether or not the eyes actually were moving immediately prior to an arousal. On one hand, Foulkes' paper severely qualified the earlier state-specific linking of REM sleep and dreaming, while on the other, it pointed towards the importance of phasic activity within sleep stages as a more sensitive determinant of dream-like mentation. Recent research has lead to new theoretical formulations of sleep [i.e., the tonic-phasic model conceived by Moruzzi (1963) and extended by Grosser and Siegal (1971)] and to more and better ways to measure an increasing number of physiological events [i.e., phasic integrated potentials (PIPS), Rechtschaffen et al. (1970); phasic muscle activation, Pivik and Dement

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Christine Sawicki was killed in an automobile accident late in 1981. With respect and in sorrow, we dedicate this paper to her memory.

Parts of this paper were presented to the 1980 APSS Meeting in Mexico City.

(1970); and spontaneous middle ear muscle activity (MEMA), Pessah and Roffwarg (1972)]. Studies of mental processes during sleep are now quite plentiful, and new conceptualizations have led to the development of more objective schemas for classifying mental events (Hall and Van de Castle, 1966; Foulkes, 1971, 1978; Hunt et al., 1980).

Studies by Pessah and Roffwarg (1972) and by Roffwarg et al. (1975) have established that MEMA must be considered as an important phasic event. The Pessah and Roffwarg (1972) paper described the distribution of MEMA during sleep, and both papers questioned the psychological correlates of MEMA. In the present study, the relationship between MEMA and the sleeper's mental activity was examined more extensively. In so doing, a large number of all-night records of MEMA were obtained and are compared with the findings of Pessah and Roffwarg (1972).

Finally, a paradigm was developed for this study that allows one to examine the contrasting predictions about psychophysiological relationships that follow from the "state" model of sleep (Aserinsky and Kleitman, 1953; Dement and Kleitman, 1957) with those of the tonic-phasic model (Moruzzi, 1963; Grosser and Siegal 1971).

METHODS

Subjects

Nine people—6 females and 3 males, aged 17–43 years ($\bar{X}$ = 24.2, SD = 8.14)—participated in this study.[1,2] All were volunteers; most were recruited from an Introductory Psychology course. All had stated that they were relatively frequent dream recallers (five or more dreams recalled per week), and each person received $10.00 for each sleep lab night. The general design of the study was made clear to each participant prior to his/her agreeing to sleep in the lab.

Apparatus

A Nihon Kohden model ME-175E electroencephalography (EEG) machine was used to record 13 channels of physiological information. This machine was the final recording instrument for all of the following signals. The measurement of MEMA was accomplished using a Madsen impedance audiometer model ZS75-IC, modified at the factory to allow the probe tones to be varied in 5 db steps, from 70 to 90 db SPL. Madsen also recalibrated the unit for use with 45 cm of tubing

[1] Nine additional participants spent one or two nights in the lab but the data from these were rejected for the analyses because of the presence of frequent MEMA artifacts. The latter were most commonly due to mouth breathing and snoring, and were frequent enough in REM and stage 2 so as to render the identification of spontaneous MEMA very difficult. This represents a serious and expensive practical problem for researchers attempting to study MEMA, for all candidates for this study had been interviewed and had told us that they neither snored nor mouth-breathed during sleep, to the best of their knowledge.

[2] Preliminary data from an earlier study of nine people were omitted because of low MEMA counts. We contacted Roffwarg and found that by changing the time constant on our EEG machine, our measures of MEMA increased to a level very close to those reported by Pessah and Roffwarg (1972) (see Table 1).

between the ear probe and the remote transducer unit. The ear probe was inserted into an ear mold of soft plastic that was custom made by Dominion Ear Molds for each participant. The mold was sealed to the pina with Duo surgical adhesive (after Pessah and Roffwarg, 1972). The output from the impedance audiometer was sent to a 20-gain, AC-coupled isolation amplifier en route to the EEG machine. A Kulite semiconductor strain gauge (type DGP-100-500) was taped to the probe tip of the impedance audiometer to detect external movement of the tubing or the probe tip. The output of the strain gauge was amplified by an AC-coupled, 1000-gain amplifier having a 2-s time constant and a 0.5- to 40-Hz window. This artifact-detecting system was sensitive enough to be activated by blood volume changes in the ear of the sleeper (see Fig. 1), and any fine head or probe tube movements were easily detected.

Auditory thresholds were assessed using a Beltone model 10D audiometer, and a Welch-Allyn otoscope model 24000 was used to check the external auditory canal for obstruction. A Sony TC-270 stereo tape recorder was used to monitor speech and ambient noise in the sleeper's room. One channel was used to power a speaker in the recording room; the other was connected to an external input in the EEG machine so that a continuous audio record was obtained. A cassette recorder (Sears #19298) was used to tape all experimental arousals.

The sleep room and the recording room were shielded, air-conditioned, and had good sound attenuation.

Design and Procedure

All volunteers were interviewed and screened for snoring and mouth breathing. All were asked to complete Jackson's (1967) Personality Research Form (PRF). Participants spent four or five nonconsecutive nights in the lab. The first was an adaptation/MEMA artifact-screening night, and on each of the next three nights, there were four arousals: two from REM sleep and two from stage 2—one from each stage in the presence of MEMA (single or multiple bursts preceding the buzzer by less than 5 s), the other during a relative absence of phasic activity (and no MEMAs for at least 30 s prior to the arousal). The order of arousals each night was randomly determined, and occasionally the requirements for all arousals could not be met and an extra night was scheduled. In no case were there more than five arousals on any night. MEMA was scored whenever a signal appeared on the MEMA channel that was greater than twice the base-line[3] amplitude and then only when there was no activity on any of the three MEMA artifact-detecting systems (ear probe strain gauge, laryngeal electromyograph (EMG), or audio

[3] It is important to record changes in middle ear pressure with enough sensitivity to detect fluctuations that are likely due to changing blood volume in and around the middle ear cavity (these are time-locked to heart rate activity). Signals twice this amplitude during sleep we defined as spontaneous MEMA; they are very similar to waking activity in the middle ear system when the middle ear reflex is activated by a 100-db tone. Each deflection (approximately 0.2–0.6 Hz) of criterial amplitude was counted separately. MEMA measurement was made using a probe tone of either 80 or 85 db, depending on the strength of the MEMA reflex. At sound levels below 80 db, the signal-to-noise ratio prevented reliable detection of MEMA.

channel). It was also important to rule out, as false positives, any activity on the MEMA channel that was time-locked with respiratory inhalation.

On night one, volunteers arrived at the lab 1½ h prior to their normal sleep onset time. They were familiarized with the lab, given an otoscopic examination, and tested for normal hearing (thresholds below 25 db for 125 and 8000 Hz, and below 15 db for 750, 1500, and 3000 Hz as tested in the sleep lab).

On all lab nights, standard sleep recording electrodes were attached to each person: $C_3 - A_1$, $C_4 - A_1$; left eye, A_1; right eye, A_1 (over outer canthus); bipolar submental EMG (all as in Rechtschaffen and Kales, 1968). Additional measures included $FP_1 - A_1$, $T_4 - A_1$, heart rate (bipolar, subclavical placements), and respiration rate (thoracic strain gauge). Four more channels were required to record MEMA and to screen for MEMA artifacts. These were the MEMA signal from the ear probe tip sealed in the ear mold, the ear probe strain gauge, the ambient noise microphone, and finally the bipolar laryngeal EMG. Before sleep each night, the sleeper was told what would be done that night: either that they would sleep undisturbed (adaptation night) or that they would be awakened four times from various stages and phases of sleep and that they should try to retain their last sleeping mentation prior to hearing the buzzer. They were also told what questions would be asked of them, and the emotional rating scale was explained very carefully.

As electrodes were being applied and again before leaving the lab in the morning, each person filled out brief presleep and postsleep questionnaires on which they were asked to report on their reactions to the previous day or night.

Arousal Procedure

On the three experimental nights, four arousals were undertaken in the following manner. After the sleep recording had begun, the experimenter tossed a coin to determine whether the first arousal would be from REM or from stage 2. A second toss established whether MEMA should be present or absent. The sleeper had to be in the required stage for a minimum of 5 min before an arousal could be made. On the average, 10–15 min elapsed in either stage before an awakening took place. For a MEMA arousal, an attempt was made to wait for a series of signals or bursts of MEMA, but occasionally, in people in whom MEMA was infrequent, arousals followed single activations. For non-MEMA, the minimum requirement was no middle ear activity for 30 s, although on many occasions several minutes of MEMA quiescence would precede an awakening. An attempt was made to time arousals to coincide with a relative absence of other phasic activity, though this was more difficult during REM, for rapid eye movements occur in conjunction with MEMA about 60% of the time.

When the record indicated that it was appropriate to arouse the sleeper, a buzzer[4] was sounded and the person's name was called over the intercom. An

[4] The buzzer was a Sonalert model SC628, activated by a variable current that produced a tone varying between 69 and 97 db at the pillow. On the adaptation night, each participant was asked to estimate what loudness would awaken him/her quickly without producing a startle reaction that might impair recall. Occasionally, the current level was adjusted following the first arousal.

initial response from the sleeper occurred within 10 s, following which the experimenter asked several specific questions during each arousal: (1) "Hello——, can you tell me your very last sleeping thought?" (2) "Can you remember any more details?" (3) "On a scale of one to five where one is very low and five is very high, would you rate your emotional involvement with that latest sleep thought?" (4) "Can you recall any other earlier sleeping thoughts?" (5) "Thank you—you may go back to sleep now."

RESULTS

Sleep Records and the Reliability of MEMA During Sleep

The sleep records were coded and then scored for sleep stages; wake, slow sleep (combining stages 1, 3, and 4), stage 2, and REM. Phasic counts of MEMA and rapid eye movements were also obtained. Table 1 summarizes the sleep stage results calculated separately for each of the three experimental nights and averaged over all nine subjects. These data show that a relatively normal sleep was obtained by most participants.

Figure 1 is a sample recording showing an arousal from REM sleep in the presence of MEMA. Early in the record, slight movement artifacts (swallowing?) were clearly seen on the MEMA artifact channel; this was followed by general phasic inactivity. A single MEMA deflection preceded the arousal buzzer (audio channel) by approximately 1 s. One purpose in measuring many phasic systems simultaneously was to attempt to make arousals in the presence of only one phasic event at a time. In the present investigation, MEMA arousals from REM sleep were made when simultaneous rapid eye movements were occurring on 37.5% of the arousals. In another 12.5% of the arousals, eye movements occurred within ±2 s of the MEMA, and in the remaining 50.%, MEMA was independent of eye movement activity for more than 2 s.

Another way of looking at the relationship between rapid eye movement and MEMA is simply to correlate the number of instances of each event per REM period. This analysis is detailed in Table 2. There, correlations are mostly positive and are only weak to moderate in strength. In fact, an average magnitude of association of 0.32 is found for all 9 subjects. Squaring that figure shows that only about 10% of the variance is common to rapid eye movements and MEMA.

TABLE 1. *Mean sleep stage percentages for the three experimental nights ($n = 9$)*

Stage	Night 1	Night 2	Night 3
Awake + movement (%)	14.3	8.0	8.6
Stage 2 (%)	46.1	48.7	45.4
Slow sleep (stages 1, 3, and 4; %)	27.5	24.5	28.8
REM (%)	12.1	18.9	17.3
Total sleep time (h)	6.44	6.60	6.82

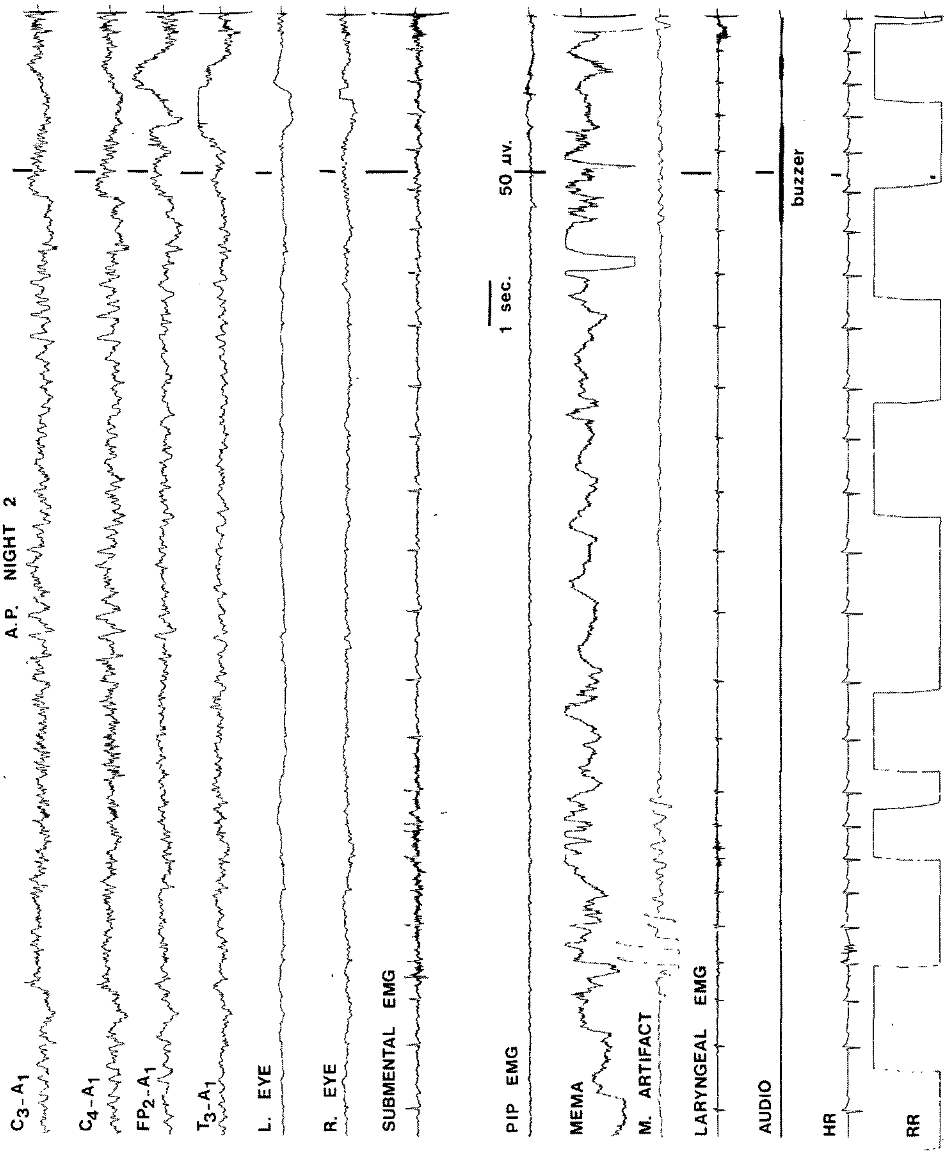
A.P. NIGHT 2
C_3-A_1
C_4-A_1
FP_2-A_1
T_3-A_1
L. EYE
R. EYE
SUBMENTAL EMG
PIP EMG
MEMA
M. ARTIFACT
LARYNGEAL EMG
AUDIO
HR
RR
1 sec.
50 µv.
buzzer

TABLE 2. *Comparison of two measures of phasic activity in REM: Correlations between MEMA and REM frequencies within subjects*

Subject	Correlation	REM periods (n)	Significance level
AP	0.11	11	—
SR	−0.35	7	—
AML	0.53	16	0.05
LR	−0.28	9	—
NB	0.50	16	0.05
JH	0.02	9	—
TK	0.42	9	—
PB	0.52	11	—
MB	0.21	9	—

The Pessah and Roffwarg (1972) data on the distribution of MEMA across the night are impressive and were taken as normative by the present authors. In Table 3, we summarize their Table 1, and the data from the present study are arranged in the same manner to facilitate comparisons. A similar pattern emerges. Most striking is the very small within-subject variability across nights and the relatively large intersubject differences. The inclusion of data from subject MB in the present report results in elevations in means above those reported previously, but we could not find any artifacts in her records or other reason to justify discarding her MEMA counts.[5] Figure 2 shows the high MEMA activity of MB prior to a REM MEMA arousal. With or without MB, the distribution of MEMA approximates that of Pessah and Roffwarg (1972) reasonably closely, although it appears that we may have found a greater proportion of our MEMA in REM sleep than they did. In summary, the above data on the distribution of spontaneous MEMA during sleep corroborate their findings and further establish the reliability of this type of phasic event.

The effectiveness of our experimental design in identifying sleep epochs containing large and small amounts of MEMA was assessed by using mean MEMA density scores in a state (REM or stage 2) by phasic event (MEMA or no MEMA) ANOVA. MEMA density scores were obtained by calculating the ratio of the number of 2-s periods of record containing MEMA to the number of 40-s epochs of

[5] Dr. K. Benson told us at the Association for the Psychophysiological Study of Sleep 1980 Annual Meeting that she had recorded in excess of 3000 MEMA per night from a normal subject who had vivid auditory imagery.

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FIG. 1. Electrophysiological activity immediately preceding a MEMA arousal from REM sleep. Channels 1–4 display central, frontal, and temporal EEG activity. Examination of channels 5 and 6 show occular quiescence, although the subject is in REM, as EMG (channel 7) and EEG show. Unintegrated PIP EMG is seen on channel 8; difficulties with integrating circuits prevented further use of PIPs in this study. This MEMA record (channel 9) was selected because it displays artifact, middle ear reflex quiescence, and spontaneous MEMA quite clearly. MEMA artifacts (channel 10) are seen to accompany brief EMG activity. The laryngeal EMG, audio, and respiration rate channels (11, 12, and 14) supply additional safeguards against false-positive MEMA counts. Heart rate (channel 13) was also recorded.

TABLE 3. *Middle ear muscle activity (MEMA) and stage of sleep*

Study	REM sleep (%)	Deflections	Total MEMA In REM sleep (%)	Total MEMA In NREM sleep (%)	MEMA/min REM sleep (*n*)	MEMA/min NREM sleep (*n*)
Pessah and Roffwarg (1972)[a]						
Mean	19.6	314.5	80.4	19.6	3.00	0.2
SE (corrected)	±3.71	±275.07	±11.3	±11.13	±2.13	±0.28
Present study[b]						
Mean	16.46	447.65	87.00	13.00	8.081	0.922
SD	±8.10	±988.57	±17.48	±17.48	±18.78	±2.12
SE	±1.59	±193.87	± 3.43	± 3.43	± 3.68	±0.42

[a] Calculations based on a total sleep time of 400 min.
[b] Total sleep time varied from 358 to 520 min.

either stage 2 or REM immediately preceding the arousal. A logarithmic transformation was used to help normalize the distribution of the data. There were statistically significant main effects for both state ($F_{1,8} = 25.17$, $p < 0.01$) and phasic activity ($F_{1,8} = 16.89$, $p < 0.01$). MEMA is more frequent during REM sleep, and the MEMA/no MEMA effect shows that arousals intended to accompany high MEMA did indeed contain more MEMA than did those selected for their relative absence of MEMA. However, MEMA was frequently present early in both REM and stage 2 sleep epochs which were selected minutes later as containing low levels of MEMA. This situation is difficult to avoid, especially in subjects whose MEMA production is quite high. One must control for time of night effects in mentation studies, even though the distribution of MEMA over the night indicated that greatest MEMA density occurs early in sleep. Table 4 shows this to be true for MEMA in both REM and stage 2 sleep.

Personality Correlates of MEMA

The highly stable pattern of MEMA within participants suggested to us that it might be informative to correlate MEMA production with personality measures. PRF subscale scores were correlated with transformed MEMA frequency scores for the nine participants. Table 5 shows that of the 15 scales, "impulsivity" correlated negatively with MEMA scores, while the "infrequency" scale, Jackson's "lie" scale, showed a significant positive relationship to MEMA.

MEMA and Mentation Reports

Several sets of analyses were aimed at establishing the relationship between MEMA and mental activity during sleep. Data on recall proportions, subject- and experimenter-rated measures of emotional involvement, and bizarreness ratings of mentation reports were examined using ANOVA techniques.

The effect of phasic activity on recall has seldom been studied. We find the usual superiority of REM recall over stage 2 recall ($F_{1,8} = 61.6$, $p < 0.001$); but in addition, we can report that the presence or absence of MEMA has no overall effect on recall ($F_{1,8} = 0.95$, ns).[6] An effect of marginal strength can be seen for the interaction between state and phasic activity ($F_{1,8} = 3.81$, $p < 0.10$). Figure 3 shows that MEMA tends to facilitate recall in REM and inhibit it if the MEMA accompanies arousals from stage 2.

Subject-rated estimates of their own emotional involvement with the mental events described during an arousal were also subjected to ANOVA procedures. Analysis showed that there were no significant differences in the participant's ratings of involvement following awakenings from any of the four experimental conditions, although the ordering of the means suggested that REM arousals might be more intense than those from stage 2. The anticipated association of phasic activity (MEMA) and emotionality in sleep mentation was not present.

Correlation coefficients were calculated between each subject's self-rated emotional involvement with a mentation report and the number of MEMA counted in the record immediately preceding the arousal. Table 6 indicates that the results were mixed. For four of the nine subjects, substantial and significant correlations were obtained, but two of those correlation coefficients were positive, while the other two, though equally strong, were negative. Three other correlations were essentially zero.

Experimenter-rated number of instances of emotional verbalizations reported during arousals (after Hall and Van de Castle, 1966) were also unhelpful in differentiating the sleep mentation samples. This analysis was very similar in outcome to the subject-rated scores just mentioned in that no significant differences were obtained, and the same weak tendency for REM reports to contain more emotional incidents was observed.

Each coded transcript was scored for instances of bizarre mental activity. Both state ($F_{1,7} = 9.71$, $p < 0.025$) and phasic effects ($F_{1,7} = 9.06$, $p < 0.025$) were discovered in these data. There was a larger amount of bizarre mental activity seen in REM than in stage 2 arousals, and MEMA was clearly associated with bizarreness, *independent* of which state it occurred in.

The above bizarreness scores were composed of the sum of six subscales from the Hunt et al. (1980) ratings of formal anomalies in dream experience. We summed over most categories in this system because the relatively small number of mentation reports, combined with the infrequent occurrence of experiences relevant to several categories, made separate analyses impractical. Two composite dimensions were isolated from the total bizarreness ratings. "Clouding" refers to instances of confusion in reasoning, memory, and action, as well as narrative discontinuities in the mentation protocals—unexplained sudden changes in setting. The analysis of the clouding measure also showed state ($F_{1,7} = 9.31$, $p < 0.025$) and tonic-phase ($F_{1,7} = 8.36$, $p < 0.025$) differences. Here too, a greater number of discontinuities were seen in REM than in stage 2 reports. MEMA was associated with higher clouding scores in both sleep stages than were seen if

[6] For this analysis and on all other ANOVAs reported, the three nightly replications of the four arousal conditions were treated as a separate "trials" factor during initial computations. Since no main effects or interactions between trials and other factors were significant, the factor was suppressed in the final analyses by the use of totals over all three nights.

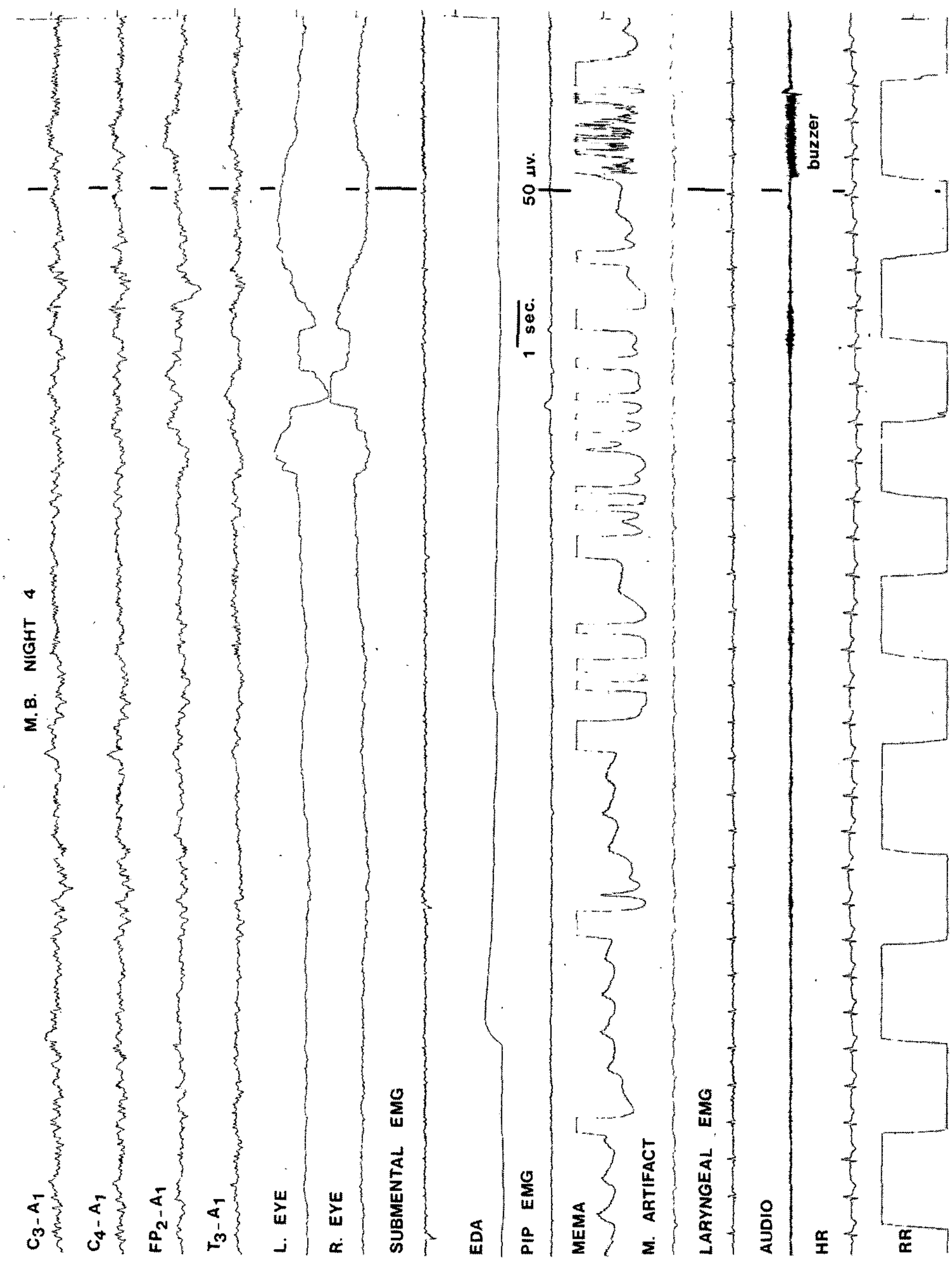
M.B. NIGHT 4
C3-A1
C4-A1
FP2-A1
T3-A1
L. EYE
R. EYE
SUBMENTAL EMG
EDA
PIP EMG
MEMA
M. ARTIFACT
LARYNGEAL EMG
AUDIO
HR
RR
50 μv.
1 sec.
buzzer

TABLE 4. *Distribution of MEMA density through the night*[a]

	Successive epochs							
Sleep stage	1	2	3	4	5	6	7	8
Stage REM	5.72	5.70	3.02	2.55	0.52	0.82	—	—
Stage 2	0.74	0.46	0.86	0.22	0.46	0.20	0.17	0.14

[a] Averaged over 27 experimental nights.

arousals were made when MEMA was absent. Much of this effect was due to the relatively low amount of clouding seen in reports from stage 2 without MEMA.

The second dimension was termed hallucinosis, for it is composed of perceived "intrusions" into the dream of material that would be classed as hallucinatory if the respondent was awake when experiencing them. In dreams these are almost entirely visual in quality. All three F tests were marginally significant; the means showed that both the REM state and the presence of MEMA point to a higher incidence of "hallucinatory activity" in the mentation of the sleeper.

MEMA and Auditory Imagery

The coded transcripts were rated on a five-point auditory activity scale, where a rating of *1* indicated total absence of auditory activity, a *3* showed a mixture of auditory and other sensory activity with no focus on the auditory, and a *5* was given only to reports that centered on conversations and/or environmental noise. Scores were increased when the participant was clearly involved in the production of the auditory activity.

The 2 × 2 ANOVA on those data showed a tendency for more auditory activity to be found in REM than in stage 2 arousal reports ($F_{1,8} = 3.68$, $p < 0.10$), but there was no evidence that MEMA leads to higher auditory ratings ($F_{1,8} = 0.06$, ns).

DISCUSSION

It has been demonstrated that MEMA can be recorded reliably in different laboratories (Pessah and Roffwarg, 1972; Benson and Zarcone, 1979; present study) using impedance audiometric procedures. Furthermore, there is reasonable agreement in those studies as to the polygraphic signature and number of spontaneous MEMA seen. There is even closer agreement on the temporal distribution of MEMA throughout the night. This latter agreement may be more important than is concensus on the first two because of variations in MEMA recording techniques.[7]

[7] We understand that researchers in Dr. Roffwarg's laboratory are developing a technique for the measurement of MEMA from tympanic membrane movement (H. Roffwarg, personal communication, 1980).

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FIG. 2. Frequent MEMA during REM sleep. Channels are identical to those described in Fig. 1, with the addition of electrodermal activity (EDA). On the MEMA channel, blood volume changes (time-locked to heart rate) again are seen during inactivity, and both single MEMA and MEMA bursts precede the arousal buzzer. Here, MEMA both precedes and accompanies eye movement activity.

TABLE 5. *Correlations between transformed[a] MEMA frequency scores and Personality Research Form subscale scores ($n = 9$)*

Subscale	r	Subscale	r
Achievement	−0.30	Harm avoidance	0.29
Affiliation	−0.43	Impulsivity	−0.65[b]
Aggression	−0.22	Nurturance	−0.07
Autonomy	−0.05	Order	0.31
Dominance	0.08	Play	−0.28
Endurance	−0.21	Social recognition	−0.04
Exhibition	−0.37	Understanding	−0.31
		Infrequency	0.87[c]

[a] $(MEMA/3)^{1/2}$ where MEMA equals number of MEMA per night per subject.
[b] $p < 0.06$.
[c] $p < 0.02$.

In the first work on MEMA in man, Pessah and Roffwarg (1972) noticed that MEMA occur most frequently during REM and in stage 2 periods immediately preceding REM. Lamstein et al. (1975), studying this association further, stated that MEMA is the lowest threshold indicator of the REM state seen in man. Perhaps the strongest evidence for MEMA as a precursor of REM comes from the Lamstein et al. (1977) finding that some narcoleptics who do not (yet) display REM-onset sleep patterns, do show MEMA at sleep onset. In the view of Roffwarg and his co-workers, the occurrence of MEMA outside of the REM state should be used to signal the coming of REM, rather than as signifying that MEMA is a phasic event typical of stage 2 and REM stages, and therefore exists "inde-

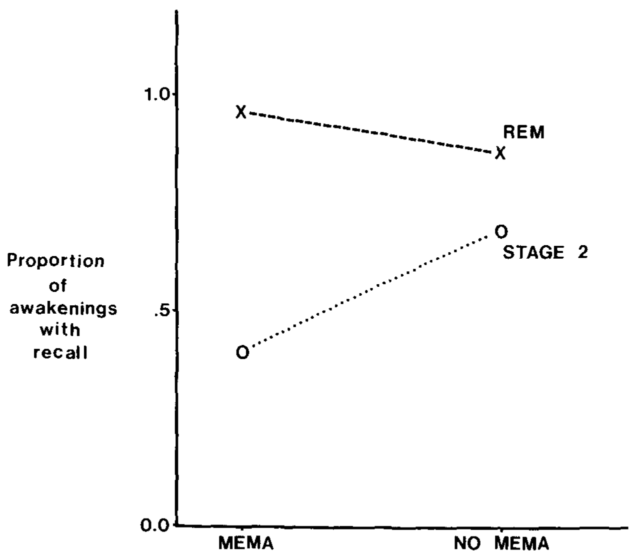

FIG. 3. Interaction between state (REM/stage 2) and phasic activity-inactivity (MEMA/no MEMA) for mentation recall.

TABLE 6. *Self-rated emotional involvement with the mentation report following an experiment arousal correlated with the number of MEMAs immediately preceding the arousal*

Subject	Sex	Correlation	Arousals (n)	Significance level
MB	F	0.08	7	—
LR	F	0.90	11	0.01
AML	F	−0.71	7	0.05
PB	F	−0.15	10	—
SR	F	0.00	7	—
TK	M	−0.21	10	—
JH	M	0.93	10	0.01
NB	F	0.00	12	—
AP	M	−0.85	9	0.01

pendent'' of sleep state, in some sense. Their interpretation is well founded and is consistent with data from all MEMA studies on the temporal distribution within stages and across the night. That distribution of MEMA lead Benson and Zarcone (1979) to postulate their notion of ''leakage'' of phasic MEMA from REM into stage 2; they too view occurrences of MEMA outside the REM state as unusual, even aberrant.

In choosing to examine psychological correlates of MEMA, we were interested in whether MEMA occurring during REM sleep and MEMA during stage 2 had similar effects on mentation reports. The incorporation of a state by phasic event or 2 × 2 analysis of variance model in this investigation permitted examination of ''state''- and ''phasic event''-specific effects separately (main effects), and the interaction term showed the relative influence one has on the other. Recall that Fig. 3 shows a tendency for MEMA to be associated with high recall during arousals from REM and with low recall when MEMA accompanies stage 2 awakenings. That finding is consistent with the possibility that state-specific effects of MEMA may occur. It should be added that similar state-specific effects of MEMA on the type of content reported during arousals were not seen. That is, the interaction terms in ANOVAs of bizarreness, clouding, and hallucinosis scores were all close to chance values. We have not reported enough evidence to discredit the notion that MEMA during stage 2 signals an impending REM period and thus has no separate significance, but the recall data, if replicated, would indicate that a more complex relationship between state and phasic activity may obtain. Future studies that continue to pit sleep states against phasic activity/inactivity in an ANOVA design may help resolve this issue.

The finding that neither subject- nor experimenter-rated emotional involvement was related to MEMA was not anticipated, for we had expected that MEMA, a phasic measure of presumed brainstem origin (Pessah and Roffwarg, 1972) and linked to PGO activity (Roffwarg et al., 1973; Lamstein et al., 1975), would influence the sleeper's involvement with ongoing mentation indirectly by disrupting it and perhaps by stimulating limbic structures as well. The data did point weakly towards higher involvement in REM than in stage 2 arousals, but no signs of phasic activity and changes in involvement were evident. Again, individual differences in response to MEMA seem to be the most likely explanation as to why these two measures showed no overall effects. Separate correlations for each subject of MEMA frequency and self-related involvement (Table 6) showed that for four of the nine participants, strong relationships existed; but for some, MEMA was associated with increases in involvement, while in others the opposite was as clearly indicated. For four other subjects, coefficients were very low. The net effect was that in the grouped data, effects cancelled out. It would be interesting and theoretically important to understand what produced these very different correlations. Sex differences do not provide the key: one male and one female showed very high negative correlations between MEMA and emotional reports; another male and female had high positive correlations.

Personality dimensions were examined in another attempt to account for the large intersubject variation in MEMA rates. PRF scores were of limited assistance. Of the 15 scales, only "impulsivity" and "infrequency" were related to MEMA frequency consistently. People who were controlled, deliberate, and nonemotional had higher MEMA counts than their more impulsive counterparts. The import of the correlation between "infrequency" and MEMA is unclear. Benson and Zarcone (1979) found a negative correlation between ego strength and MEMA rate during REM, which was consistent with their interests in phasic activity and psychopathology, but neither their study nor ours presents strong support for personality links to MEMA frequency; for example, their data on ego strength constituted the only one of 24 correlations with MEMA measures that was significant, so chance factors may have inflated that apparent association, as those authors point out. It would seem, therefore, that personality factors do not account for a very large proportion of the intersubject variance in MEMA production. Perhaps more cognitive dimensions should be related to MEMA in future studies.

Looking at the analyses of the Hunt et al. (1980) content ratings of the mentation reports, one sees that clouding, hallucinosis, and total bizarreness scores showed the same three things: a definite state effect was present, such that REM mentation was more clouded, hallucinatory, and bizarre. This basically replicates the findings of many researchers and is of no added significance here. Second, all three measures showed that MEMA was associated with high scores on these dimensions of sleep mentation. Third, the absence of significant interactions points to the conclusion that state and phasic effects in these instances must be *additive* rather than interactive. Clouding, hallucinosis, and bizarreness scores will be higher in arousals from REM than from stage 2 but will be even higher in REM if accompanied by MEMA; and in stage 2, arousals with MEMA will have higher ratings than those without MEMA. What about the similarity of these three measures? Bizarreness is essentially the combination of clouding and hallucinosis scores, and so it can be expected to show similar relationships to those pertaining to the two-component scores. It can be thought of as an index of the total amount of "unreality" seen in the reports. For over 90% of the instances of bizarre content in his study, Hunt found that mental confusion and visual distortion were present. Auditory distortions were very rare. Hallucinosis and clouding were scored on the basis of very different content in the sleep mentation, but the scores were nevertheless correlated. Hunt (1980) reported that correlations were obtained between hallucinosis and clouding in the range from $r = 0.36$ to $r = 0.55$. These figures show that between 13 and 30% of the variance is common to the two. Hallucinosis scores are essentially tallies of positive intrusions of perceived material that is highly improbable into ongoing mentation, while clouding is indicative of something more negative, showing a lacuna in narrative coherence or a confusional state where the subject is functioning cognitively in the way he might if intoxicated or mentally infirm.

Our failure to confirm the Roffwarg et al. (1975) finding that MEMA is associated with auditory imagery of the dreamer is less surprising when the methods of assessing auditory involvement are compared. In the present study, a simple five-point Likert scale was developed that assessed the amount of auditory activity detectable from the mentation report. Roffwarg et al. (1975) used a combination of cues to separate MEMA-positive from MEMA-negative reports. In addition to using the presence or absence of loud sounds, they looked for abrupt shifts in content, arguing that if their "phasic motor-dream imagery" hypothesis was correct, events in the dream resembling events that would trigger MEMA in a waking subject should coincide with MEMA. The theoretical approaches of the two studies were thus quite different, as were the operational definitions of auditory activity during sleep. With our auditory scale, we hoped to ascertain whether or not a MEMA/auditory equivalent of the REM/scanning hypothesis was tenable. The data do not support such an interpretation. When the number of abrupt perceived intrusions (Hunt's hallucinosis scale), the amount of confusion and number of sudden changes in setting (Hunt's clouding scale), and the auditory rating scales are examined separately, the present data suggest that it is the number of bizarre intrusions and discontinuities, rather than an abundance of auditory imagery per se, that is most clearly associated with MEMA. It is also worth noting that auditory imagery, when it was present, usually was not bizarre in nature. Less than 10% of the auditory imagery in this study was rated bizarre by Hunt. In fact, many MEMA bursts were associated wtih visual imagery. Part of that effect may be due to the frequent concurrence of MEMA and rapid eye movements in the REM state, but the data still point to an absence of auditory associations with MEMA.

What does all this mean? We think that these findings tie in quite closely with data from Rechtschaffen's laboratory on PIPs. Watson (1972) reported that PIPs were associated with an increased incidence of bizarre mental activity when his subjects were aroused from REM sleep. Other data (Rechtschaffen et al., 1972) supported Watson's (1972) dissertation. Those Chicago PIP studies lead us to consider looking at other phasic activities to see whether they too were associated with bizarreness, and the similarity of our findings with MEMA and the Rechtschaffen group's PIP data suggests that those measures, and perhaps *all* phasic activity during REM, produce distortions, discontinuities, and increases in bizarreness ratings. We are presently completing a study in which simultaneous PIP and MEMA monitoring allowed us to assess both PIP and MEMA arousals, and so we will soon have evidence to support or refute the above prediction.

The concept of sleep stages, proposed by Loomis et al. (1937), refined by

Aserinsky and Kleitman (1953) and Dement and Kleitman (1957), and formalized by Rechtschaffen and Kales (1968), has formed the basic theoretical approach guiding sleep research for over 25 years. The only serious challenge to this "stage" model has come from the proponents of the "tonic-phasic" model (Moruzzi, 1963; Grosser and Siegal, 1971).

Researchers interested in parallels between psychological and physiological events during sleep initially supported the stage model, finding that sleepers aroused from the REM state reported more dreams than they did when awakened from non-REM sleep (Dement and Kleitman, 1957). Foulkes (1962) challenged the early strong statements about the correspondence between dreaming and the REM state by showing that dreams occur in non-REM sleep as well. Studies from Rechtschaffen's laboratory on PIPs (Rechtschaffen et al., 1972; Watson, 1972) and from Roffwarg's group on MEMA (Pessah and Roffwarg, 1972; Roffwarg et al., 1973), in which attempts to correlate phasic events with specific types of mentation, are examples of studies in which implicit ties to the tonic-phasic model and support for it may be found.[8] It is surprising that prior to the present investigation, no study has compared the two models directly. This experiment was designed to do so: an equal number of arousals were planned from the REM state and from stage 2 sleep; half of the arousals from each state were to be preceded by MEMA, half during phasic quiescence.

What has been reported here provides strong support for the sleep stage model. In each of the ANOVAs there was a significant main effect for state; in every analysis, arousals from REM produced higher recall; and higher bizarreness, clouding, hallucinosis, and auditory involvement ratings than did similar arousals from stage 2 sleep. The tonic-phasic model was supported by analyses of Hunt's scales: MEMA was associated with higher scores on bizarreness, hallucinosis, and clouding dimensions than were arousals from phasically quiescent (no MEMA) sleep. In sum, the sleep stage model continues to be the most useful way of conceptualizing psychophysiological relationships during sleep, but additional precision may be gained by attending to phasic events (MEMA) within each sleep state.

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[8] This is not to say that the above authors reject the stage model, but simply that they are interested in phasic events that are not specific to only one of the traditional sleep stages.

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