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Sleeping and Waking Thought: Effects of External Stimulation

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Summary: This article describes some of the variables that distinguish waking and sleeping (REM) thought. Mentation reports from the waking state, as described here, tend to have more topic shifts than those from the REM state, which often have a single-theme storylike quality. It is assumed that heightened response thresholds to sensory stimuli, in conjunction with the state of high cortical activation typical of REM sleep, account for the storylike quality of REM imagery. In this experiment, an intermittent auditory stimulus was the model for environmental influences on waking mentation. It was hypothesized that the removal of this intermittent auditory stimulation, simulating in waking subjects the increased sensory thresholds of REM sleep, would decrease the number of topic shifts in spontaneous thought. It was expected that this reduction in number of topics would approach levels achieved in REM sleep. Thirty subjects participated in individual sessions in which they lay in a sound-attenuated, lightproof room with eyes closed. They were asked for mentation reports as follows: (a) after lying awake with external stimulation (W), (b) after lying awake without external stimulation (WO), and (c) after being wakened from REM sleep. Transcribed mentation reports were scored on seven content rating scales, including total recall count, a count of all words in which the subject was describing his/her experience during the previous interval, and number of thought units (TU) per report, a count of the distinct, thematically homogeneous thought sequences. Hotelling *t*-squared tests were performed with the different states as the independent variables and the scores on the cognitive scales as the dependent variables. The major factor distinguishing mentation reports of waking subjects and subjects wakened from REM sleep was the TU count, with waking subjects changing topics more frequently. Removal of the intermittent auditory stimulus reduced the number of topic shifts in waking subjects, with a significance approaching the 95% confidence limit.
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Many researchers have included a reduction in external sensory input among the major predisposing conditions for dreaming (1–4). Under conditions of reduced sen-

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sory input, there may be a considerable amount of daydreaming, fantasies, and imagery even during waking. Studies of the characteristics of waking mentation in a nonstimulating environment (5–8) have found that awake subjects gave reports of dramatic, bizarre, visual, and hallucinatory experiences. Foulkes and colleagues (6,7) obtained mentation reports from awake subjects using experimental methodology previously reserved for sleep studies. Many of the reports produced by their awake subjects were judged as hallucinatory and regressive.

In a study by Pope (8), an increase in environmental input yielded an increase in (a) the frequency of thought shifts, (b) the number of present-oriented thought segments, and (c) the time spent with consciousness focused on the present situation. Antrobus (9) placed subjects under conditions containing minimal nontask stimulation and required that the subjects detect simple auditory stimuli. Increasing the speed of signal presentation led to reduced reports of task-irrelevant cognitive activity, imagery, and fantasies. In another study by Antrobus et al. (5), increasing demands upon short-term memory and increasing financial reward for accuracy of detection also led to reduced reports of task-irrelevant cognitive activity. Moreover, Antrobus et al. (J. S. Antrobus et al., unpublished observations) found that mindwandering was far more pervasive than is usually thought and may compete for time and processing capacity with experimental tasks. They conclude that central decisions are continually made regarding the potential payoff for responding to environmental versus internal sources.

The general picture that emerges from these studies is that the cognitive system is continuously constructing events whether it has sensory input or not. If the information in the sensory environment is sufficiently salient or meaningful to the individual, the processing resources of the cognitive system will be largely devoted to processing that sensory information. Otherwise, the cognitive constructions may continue relatively independent of external stimulation. When patterned visual input is eliminated by closing the eyelids and lying in the understimulated environment of one's bedroom, mentation will become more "dreamlike."

REM mentation has been considered to have a storylike quality, described as the presence of a few long, thematically homogeneous thought sequences. This kind of thought contiguity seems to require the absence of disruption by external stimuli (10–12). Greater input from the environment might generate intrusions into the private thought sequences, breaking up the storyline and resulting in more numerous but shorter thought sequences.

The high sensory thresholds of REM sleep exclude the processing of many external stimuli (13). While individuals are asleep, most of the information available to them comes from long-term memory because of the exclusion of external stimuli. While they are awake, on the other hand, information comes from both internal and external sources (11,12,14).

This research examines the effect of external stimulation on mentation. It attempts to simulate the high thresholds of REM sleep by a reduction of stimulus input. Waking mentation reports were elicited after conditions of minimized external stimuli and also of intermittent auditory stimuli. These reports were compared with reports elicited from REM awakenings. The external stimulation was expected to generate intrusions in the subject's thought processes, leading to shorter but more numerous units of thought.

METHODS

Subjects

Thirty volunteer subjects (17 men and 13 women) completed the experimental procedures. Three additional subjects were dropped from the study because they failed to complete the entire experimental protocol, owing to scheduling difficulties. The ages of the subjects ranged from 16 to 41 years; the mean age was 25.37 years. All subjects were native English speakers. Subjects were told that the experimenter was interested in studying "any and all forms of mental content, such as thoughts, images, feelings, dreams, and anything else that might go through your mind."

Subjects agreed to be free of all drugs and alcohol for 2 days prior to the experiment. All subjects participated in an adaptation session with the same format and in the same location as the daytime experimental session.

Biopotential recording apparatus

A Grass model 78 polygraph was used for electroencephalograph (EEG), electromyograph (EMG), and electro-oculograph (EOG) recordings. EEG, EMG, and EOG were recorded during the waking conditions in order to verify that the subject was indeed awake and during the sleep condition in order to ascertain when the subject was in the REM state. EEG was recorded from two unipolar scalp electrodes at C3 (left central, using the international 10–20 system) and at C4 (right central) and from two bipolar electrodes at left and right midtemporal-parietal sites referenced to vertex (CZ). EOG was recorded from right and left outer canthi locations, referred to the electrically linked mastoids. EMG was recorded from submental electrodes. REM sleep and waking were defined according to the criteria of Rechtschaffen and Kales (15). REM onset was established when any two of the EEG, EMG, or EOG parameters showed polygraphic changes indicating REM sleep.

Sleep room

The sleep room was a sound-attenuated, electrically shielded, lightproof chamber, ~10 × 15 ft. There was a two-way intercom system for communication between the experimental and sleep rooms.

During both waking conditions, white noise (50 dB) was introduced into the subject's room in order to mask sounds produced by the subject's movements. For the waking conditions, the subject lay supine in the bed in the same room that was used for the subsequent REM awakenings.

External stimuli tape

The external stimuli tape consisted of small portions of radio broadcasts. The portions came from many different types of radio broadcasts and included portions of talk shows, news, sports, advertisements, music programs, etc., from a variety of New York AM and FM radio stations. During the external stimuli condition, the taped broadcasts interrupted white noise every 20–30 s and lasted from 10 to 15 s with an average length of 10 s.

Procedure

During the experiment, subjects were asked for mentation reports as follows: (a) after lying awake with external stimulation (W), (b) after lying awake without external stimulation (WO), and (c) after being awakened from REM sleep.

Waking conditions. For each condition, mentation was elicited from subjects after six ordered intervals of the following lengths: 3, 6, 9, 6, 3, and 6 min. Only the three 6-min intervals were used for later analysis. The other intervals were included along with the 6-min intervals to prevent the subject from developing an expectation regarding when he/she would be called. Mentation reports were solicited by standardized questions as follows: (a) "Please tell me everything that was going through your mind before I called you." and (b) "Was there anything else or can you give me any more detail about what you've told me?" The subjects were then asked to give a numeric alertness rating: "If zero is dead asleep and ten is the boundary between waking and sleeping, can you give me some number to show how alert you were just before I called you?" The subjects' responses were tape-recorded and transcribed without the addition of punctuation.

If there were any gross body movements or if the subject fell asleep during this period, the subject was immediately interrupted and asked for a mentation report. After the completion of the report, the experimenter requested that the subject try to remain still or try to remain awake, respectively. Mentation reports elicited from these periods were not included in the data analysis.

Half of the subjects were block randomly assigned to the external stimuli-free condition first and the external stimuli condition second, and the other half were assigned to the conditions in the opposite order.

REM condition. The REM condition took place within a week of the waking conditions, sometimes preceding the waking conditions and sometimes following them. Mentation reports were elicited from subjects wakened after a minimum of 10 min of REM sleep. If there were any gross body movements or observable artifacts during this period, the awakening was delayed until an additional 6 min of uninterrupted REM was recorded.

REM awakenings were made from three REM periods following a minimum initial 90 min of uninterrupted sleep.

Analysis of the data

Scoring mentation reports. All transcribed mentation reports were independently scored by three judges on a thought unit scale modeled after the Structural Coding System for Verbal Output devised by Klinger (16). Each thought unit (TU) contained a distinct, thematically homogeneous thought sequence. The division of mentation reports into TUs is illustrated in the appendix.

All transcribed mentation reports were also scored by three judges on seven scales of the Psycholinguistic Coding Manual (17): total recall count (TRC), implicit speech, explicit speech, visual nouns, visual action, visual modifiers, and spatial relations. The rating scales of this manual were developed as a method of reliably counting the words in several classes relevant to sleep mentation reports. Judges were required to score a separate test set of 50 reports and obtain a correlation >0.90 with criterion scores on TRC, the most complex of the variables.

TRC is a count of all words in phrases in which the subject was describing something that had occurred during the previous period. Verbal intrusions ("ah," "um"), corrections, repetitions, and commentary upon the experience are deleted. The two speech scales are counts of the words spoken, quoted, or paraphrased in the mentation report. The four visual imagery scales provide counts of words used in describing persons, animals, or objects "visualized" in the mentation report.

All mentation reports were included in the data analysis. These included two reports (one from REM and one from W) with no recall. The word count scores were positively skewed. They were therefore normalized by the log $(X + 1)$ transformation (18) before being used. The four scales measuring visual imagery were arithmetically summed to form a combined visual scale. The two scales measuring aural experience were summed to form a combined auditory scale.

Reliabilities of variables. The mean correlation for each of three possible judge pairs was computed using the Fisher's r to z transformation. The reliability of the mean of the three judges' scores was then calculated using the Spearman-Brown equation. These interjudge reliabilities are presented in Table 1. The scores of the three judges were averaged for each mentation report, and these averages were used in the analyses.

RESULTS

The judges' scores for each of the mentation reports were averaged across the three occasions for each condition—REM, WO, and W—for each subject. Each subject's responses to the question of how alert he/she felt before being called was also averaged across the three occasions for each condition. Hotelling's one-sample t-squared tests were performed on the differences between the REM and WO, WO and W, and REM and W conditions.

Differences between the REM and WO conditions

Table 2 presents the differences between the REM and WO conditions. TU and TRC account for significant proportions of the variance of the difference between the REM and WO conditions. In the WO condition, as hypothesized, subjects produce more TUs and higher TRC. Alertness also accounts for a significant proportion of the variance of the difference between the two conditions. The summary visual and auditory variables are not significantly different between the two conditions, although each is higher during REM sleep. None of the individual visual and auditory variables (not included in Table 2) account for a significant proportion of the REM-WO variance.

Incremental multiple analysis of variance (MANOVA) tests (19,20) were performed to determine whether the significant t-squared tests were all describing the same difference or whether some of the dependent variables would add to the REM-WO difference already described by another dependent variable. It was hypothesized that once

TABLE 1. *Judge reliabilities*

Variable	REM	Waking
Total recall count (TRC)	0.96	0.95
Thought units (TU)	0.77	0.81
Visual	0.95	0.79
Auditory	0.86	0.83
Visual nouns	0.95	0.73
Visual modifiers	0.88	0.79
Visual action	0.83	0.69
Spatial relations	0.85	0.56
Implicit speech	0.68	0.47
Explicit speech	0.86	0.97

TABLE 2. *Differences between the REM and WO conditions*

Variable	Source	*df*	Sum of squares	Mean square	*F*	p	r^2	Mean[a]
TRC	Model	1	2.81	2.81	12.25	0.0015	0.297	−0.306
	Error	29	6.66	0.23				
	Total	30	9.47					
TU	Model	1	29.12	29.12	32.60	0.0001	0.529	−0.985
	Error	29	25.90	0.89				
	Total	30	55.02					
Visual	Model	1	1.56	1.56	2.11	0.157	0.068	0.228
	Error	29	21.43	0.74				
	Total	30	22.99					
Auditory	Model	1	0.71	0.71	1.30	0.26	0.043	0.154
	Error	29	15.76	0.54				
	Total	30	16.46					
Alertness	Model	1	1809.12	1809.12	209.17	0.0001	0.878	−7.77
	Error	29	250.82	8.65				
	Total	30	2059.93					

WO, awake without external stimulation. Other abbreviations defined in Table 1.
[a] Positive mean indicates REM > WO.

TRC was partialed out, the main difference between the conditions would be in the TU variable. Indeed, TU adds significantly ($p < 0.01$) to the variance accounted for by TRC.

Additional incremental MANOVA tests were performed to determine whether other variables would independently add to the variance accounted for by TU or TRC. TRC does not add significantly to the REM-WO variance already accounted for by TU. The visual and auditory variables do not add significantly to the variance accounted for by TU. Some of the incremental MANOVA tests are presented in Table 3.

The major difference in word count variables between the REM and WO conditions is in TU, which is higher in the WO condition. Once the variance accounted for by TU is removed, no other content variable accounts for a significant proportion of the REM-WO variance.

Differences between the WO and W conditions

It was hypothesized that mentation from waking subjects with external stimulation would have a greater number of TUs than mentation from subjects in a stimulus-reduced environment. Hotelling's one-sample *t*-squared tests were performed on the differences between the WO and W conditions. As shown in Table 4, the TU scale approaches significance with $p = 0.054$, with subjects producing more TUs during the W than the WO condition. TRC and the visual and auditory scales do not account for significant proportions of the variance between the WO and W conditions. One might have expected the mentation reports from waking subjects with external stimulation available to show an even greater difference in TU when compared with the mentation reports in the stimulus-reduced environment, but even in a stimulus-reduced environment, stimulation is available to subjects.

Differences between the REM and W conditions

As predicted by the model, REM and W were the two most divergent conditions in the present experiment, with the alertness measure, TU, TRC, and the visual scale all significantly different between the two conditions (Table 5).

TABLE 3. *Incremental MANOVA tests for the differences between REM and WO*

Increment due to TRC over TU	
TRC + TU	$F(1/29) = 39.87$
TU	$F(1/29) = 32.60$
Increment	$F(1/28) = 3.30$
Increment due to TU over TRC	
TRC + TU	$F(1/29) = 39.87$
TRC	$F(1/29) = 12.25$
Increment	$F(1/28) = 18.75^a$
Increment due to visual over TU	
Visual + TU	$F(1/29) = 37.92$
TU	$F(1/29) = 32.60$
Increment	$F(1/28) = 2.42$
Increment due to TU over alertness	
TU + alertness	$F(1/29) = 248.17$
Alertness	$F(1/29) = 209.17$
Increment	$F(1/28) = 4.585^b$
Increment due to TRC over alertness	
TRC + alertness	$F(1/29) = 247.67$
Alertness	$F(1/29) = 209.17$
Increment	$F(1/28) = 4.55^b$

WO, awake without external stimulation; MANOVA, multiple analysis of variance. Other abbreviations defined in Table 1.
[a] $p < 0.01$.
[b] $p < 0.05$.

Among the cognitive variables, TU was primary, accounting for 53% of the REM-W variance, and TRC accounted for 32% of the REM-W variance, with both of these measures higher during the W condition. The visual scale accounted for 15% of the variance, with the visual count being higher for REM than for W reports. Incremental

TABLE 4. *Differences between the WO and W conditions*

Variable	Source	*df*	SS	MS	*F*	p	r^2	Mean[a]
TRC	Model	1	0.10	0.10	1.29	0.266	0.042	−0.058
	Error	29	2.30	0.08				
	Total	30	2.41					
TU	Model	1	1.60	1.60	4.03	0.054	0.122	−0.23
	Error	29	11.51	0.40				
	Total	30	13.11					
Visual	Model	1	0.65	0.65	1.92	0.18	0.062	0.147
	Error	29	9.82	0.34				
	Total	30	10.47					
Auditory	Model	1	0.24	0.24	1.35	0.26	0.04	−0.089
	Error	29	5.10	0.18				
	Total	30	5.34					
Alertness	Model	1	18.99	18.99	8.10	0.008	0.218	−0.796
	Error	29	68.00	2.35				
	Total	30	86.98					

WO, awake without external stimulation; W, awake with external stimulation; SS, sum of squares; MS, mean square. Other abbreviations defined in Table 1.
[a] Positive mean indicates WO > W.

TABLE 5. *Differences between the REM and W conditions*

Variable	Source	*df*	SS	MS	*F*	p	r^2	Mean[a]
TRC	Model	1	3.99	3.99	13.32	0.001	0.32	−0.37
	Error	29	8.69	0.30				
	Total	30	12.63					
TU	Model	1	44.36	44.36	33.10	0.0001	0.53	−1.22
	Error	29	38.87	1.34				
	Total	30	83.23					
Visual	Model	1	4.22	4.22	5.14	0.03	0.151	0.38
	Error	29	23.81	0.82				
	Total	30	128.03					
Auditory	Model	1	0.13	0.13	0.24	0.63	0.008	0.06
	Error	29	15.48	0.53				
	Total	30	15.60					
Alertness	Model	1	2198.78	2198.78	261.6	0.0001	0.90	−8.56
	Error	29	243.75	8.41				
	Total	30	2442.53					

W, awake with external stimulation. Other abbreviations defined in Tables 1 and 4.
[a] Positive mean indicates REM > W.

MANOVA tests showed that no cognitive variable added significantly to the REM-W variance accounted for by TU (Table 6).

The alertness measure accounted for 90% of the REM-W variance. As might be expected, subjects reported their preinterruption alertness level as having been higher when interrupted from the waking condition than from REM. Both TU and TRC individually added significantly ($p < 0.05$ level) to the variance accounted for by alertness.

TABLE 6. *Incremental MANOVA tests for the differences between REM and W*

Increment due to TU over alertness	
TU + alertness	$F(1/29) = 335.77$
Alertness	$F(1/29) = 261.60$
Increment	$F(1/28) = 7.146$[a]
Increment due to TRC over alertness	
TRC + alertness	$F(1/29) = 353.75$
Alertness	$F(1/29) = 261.60$
Increment	$F(1/28) = 8.879$[a]
Increment due to TRC over TU	
TRC + TU	$F(1/29) = 37.28$
TU	$F(1/29) = 33.10$
Increment	$F(1/28) = 1.88$
Increment due to visual over TU	
Visual + TU	$F(1/29) = 39.82$
TU	$F(1/29) = 33.10$
Increment	$F(1/28) = 3.03$
Increment due to auditory over TU	
Auditory + TU	$F(1/29) = 37.55$
TU	$F(1/29) = 33.10$
Increment	$F(1/28) = 2.01$

MANOVA, multiple analysis of variance. Other abbreviations defined in Tables 1 and 4.
[a] $p < 0.05$.

Time of night effect

Dreams elicited from later REM sleep periods have been found to contain more activity than dreams elicited from earlier periods (10). It is possible (21) that awakenings made from later REM sleep periods are preceded by some REM sleep deprivation. REM sleep deprivation has been shown to increase "dreamlikeness" of REM mentation reports within the night (22). Cartwright (23) attempted to collect REM sleep mentation reports from early and late REM sleep periods without confounding later reports with the effects of some REM sleep deprivation. She found very little difference between the earlier and the later reports on the Foulkes DF Scale. However, the judges agreed that on eight of the 10 pairs she collected, the fourth REM period was "dreamier" than the first REM. In their review of the "time of night" question, Schwartz et al. (21) conclude that nothing conclusive can be said about the changes in mentation quality across the night.

In the present study, subjects were awakened and asked for reports from three different REM sleep periods during the night. The time-of-night effect was measured by having the report number correlated with the different content variables. In order to partial out subject variance, these correlations were performed on standardized scores. Each subject's mean score for each content variable was set to zero, and the standard deviation set to one.

The significant results are presented in Table 7. The TRC, visual, and auditory ratings all show significant positive relationships with report number, with later reports having more recall. All of the component visual and auditory scales showed significant positive relationships as well. The TU scale shows no relationship with report number, later reports having the same number of TUs as reports given earlier in the night. The alertness rating shows no relationship with report number.

DISCUSSION

The data presented here support the position that the auditory distraction characteristic of the waking environment continually interrupts what might otherwise be a continuous associative flow of cognitive events.

In a comparison of mentation reports of waking subjects with those subjects wakened from REM sleep, the major distinction was that the waking subject changes topic more frequently. When additional external stimulation was included in the waking environment, there were an even greater number of TUs. The increase in number of TUs approached significance with a p value of 0.054. TU was the best discriminator of

TABLE 7. *Relationship between report number and content variables*

Variable	p value
TRC	0.36[a]
TU	—
Visual	0.24[b]
Auditory	0.32[c]
Alertness	—

[a] $p < 0.001$.
[b] $p < 0.05$.
[c] $p < 0.01$.

the two waking conditions as well as the waking and REM conditions, using the variables tested. Although TRC is greater in waking than in REM sleep, it was the number of TUs that was the best discriminator of the two states.

By contrast, TU has been shown to make little distinction between REM and stage 2 sleep reports, despite the much greater length of the REM sleep reports (12). This similarity in TU number has been attributed to the similar auditory arousal thresholds in REM and Stage 2 sleep (24). Thus, REM sleep and waking mentation are distinguished from that of stage 2 sleep because of their greater cognitive activation with resultant increase in TRC, while REM is distinguished from waking mentation because of the elevated sensory thresholds and a resultant decrease in number of thought units.

APPENDIX: TU scale

The division of a mentation report into TUs is illustrated in the following two reports. The omission of punctuation is deliberate, so that the transcriber/typist does not impose his/her own ideas of verbal structure on the mentation sequence. In these examples, elicited after awakenings from REM sleep, individual TUs are separated by slash marks (/). Italicized words represent words included in the TRC.

The following two examples are mentation reports elicited after awakenings from REM sleep.

Example 1. Um about uh *5 minutes before you called me there was a guy in the room with me* and uh *I couldn't imagine what he was doing here* I had no thought that I might be dreaming or anything like that uh and *I had just made a request to him to go to the bathroom and he was* just kind of *joking with me* and talking and *he was* kind of like *your assistant* and *he worked just like a psychiatric resident* that works *at PI* / um also I had a dream in which *I was* just *having* just *a conversation* you know *a woman that I know out in New Jersey* just talking to her about *about* just *various things* about *about our work* / job that sort of thing let's let's see I was surprised that you called me because *I thought I was awake for the past 15 minutes* / or so uh that's about it

The previous mentation report contained three TUs, as indicated by the slash marks. The next report consists of only one thought unit.

Example 2. A dream with a baby oh yes I remember this what this was a strange adventure it was *someplace up in the country* and *I was with friends and some parts of my family* and *we were in what looked like a bungalow colony* you know what that is *and there was a fence that divided one bungalow colony from another and apparently the one that we were staying in was for a better class of people than the one on the other side of the fence* and *we had gone on a hike and* during the hike *it had rained very heavily and we were getting lost and when we returned because the roads were washed out we found that we had come down the hill on the other side of the fence and we were in eyesight of our own bungalow but we weren't able to get to it because of the rain and we came onto the porch of another bungalow from that group on the other side* and *the characters that lived in that bungalow reminded me of the Queen of Hearts* and the the *evil* Queen of Hearts and someone else *from Alice in Wonderland's mad tea party* they were people *they weren't dressed in costumes but that was the personality that I detected* and it was *that baby* who *was crying a lot and when I picked him up and held him he stopped crying but when his mother the evil Queen came* came *along and took the baby back she tended to abuse it* and I remember *my grandmother was along on the trip* she was the *the Queen was very hospitable to all of us* though she

wasn't *she didn't seem to mind us being there* and if you didn't wake me up I think *she was going to help us get back to our place* / that's all I can remember

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