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Perception of Waking and Sleeping: Possible Implications for the Evaluation of Insomnia

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Summary: Perception of awakening, its connection to electroencephalogram (EEG), and its significance for morning recall were studied in insomniacs and normals. Fourteen insomniacs and 14 age- and sex-matched controls kept a sleep log for 1 week and slept once in the laboratory (standard polygraphy). In addition, actual perception of awakening was measured by a behavioral device. Results suggest that physiological arousal is necessary, but not sufficient, for perception of awakening. Many arousals that are not perceived occur during the first REM–NREM cycle. Insomniacs nearly exclusively perceive those arousals occurring after consolidated sleep (at least 15 min) and at the beginning of interrupted sleep intervals. It is suggested that insomniacs perceive these intervals as continuous wakefulness and have difficulty in perceiving short-lasting sleep, whereas controls often do not perceive wakefulness at all. The latter may be a sleep-protecting mechanism. Number and correlation suggest that recalled awakenings are exactly those perceived. The connection between physiological and experimental subjective data is discussed. **Key Words:** Insomnia—Perception of awakening—Behavioral sleep measure.

It is a well-known empiric result of polygraphic studies that insomniacs tend to overestimate sleep latency (SL) and duration of waking episodes during the night and underestimate the number of awakenings (1–3). Different reasons for such discrepancies could be stressed: Subjects (Ss) could have difficulties (a) in perceiving waking and sleeping accurately, (b) in estimating actual time periods (of waking) correctly, or (c) in recalling the existence and duration of waking time periods. If (a) holds, it is evident that (b) and (c) cannot be correctly analyzed, insofar as knowledge about perception is crucial.

Perception of wakefulness versus sleep has been mostly studied via an awakening paradigm in good sleepers: Ss are awakened during a predefined epoch and asked whether or not they have been asleep, and, if so, whether sleep was light or deep. At sleep onset, discrimination of waking and sleeping is poor for at least 5–10 min (4–7). Correctness and subjective certainty of sleep–wake differentiation seem to be proportional to duration of preceding continuous NREM sleep (8). Awakening from REM

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sleep enhances statements of preceding sleep (7,9), possibly due to dream recall. Insomniacs have been studied rarely in awakening paradigms. Most studies report a worse perception of sleep by insomniacs than by controls (5,10–12), but equal perception is also possible (13).

A different approach in comparing perception of wakefulness versus sleep is to let Ss signal episodes of perceived spontaneous wakefulness (14–16). These studies have shown that normal Ss can perceive wakefulness during the night and communicate these perceptions. Signalled awakenings are mostly consistent with electroencephalogram (EEG)-defined arousals (i.e., alpha waves), but a high amount of wakefulness episodes is not signalled. Insomniacs have not been studied with this paradigm so far.

In this study, it is hypothesized that the basic point for discrepancies between reported and recorded sleep is perception. There may be two reasons why polygraphically defined arousals are not perceived: (a) Ss may not perceive that they awake at all, or (b) Ss may not perceive that they have awakened from sleep. In detail, it is supposed that reason (b) holds true for insomniacs. They cannot perceive that they have awakened because they do not realize on awakening that they were asleep, instead thinking that they have been awake continuously. Therefore, in a sequence of short intervals of waking and sleeping, only the first awakening episode of a series would be perceived as such, and all the rest as continuous wakefulness. Good sleepers also remember a lower number of awakenings than are recorded by the polygraph. They are presumed to "smooth" their awareness of waking and sleeping in the direction of sleep. Perception processes could be particularly interesting during sleep onset and may be basic for the rationality of the recently proposed definition of SL in insomniacs by Hauri and Olmstead (17) (SL as onset of the first noninterrupted 15 min sleep period).

METHODS

Subjects

Twenty-eight Ss were studied, 14 chronic insomniacs (10 psychophysiological and 4 with depressive personality disorders) and 14 controls. Insomniacs were to take part in a therapy outcome study with one drug and two behavioral treatments (18). They had been suffering for an average of 12 years from their disorder, but had no severe psychiatric or organic disorder, including dependency. Before the study began, two patients had been taking sleep-inducing drugs (all relatively low dosages of benzodiazepines) daily, and four Ss sometimes. Controls were good sleepers, individually matched for age and sex (median age 43.5 years, range 39–53 years, 9 women, 5 men in each group).

Procedure and measurements

Before the beginning of therapy, insomniacs slept three times in the laboratory. They were to reduce the previous medication, at least after the first laboratory night. All Ss were drug-free on the second night, 2 weeks later, and on the third night, another week later. In patients with regular prior drug ingestion, data from night 3 are analyzed. In all other Ss, data of night 3 are preferred, although night 2 was sometimes analyzed for technical reasons. Controls slept once in the lab. Since the focus of interest was not group differences in sleep parameters but perception and recall of spontaneous awakenings, data of the first night of controls were analyzed in order to have at least some spontaneous awakenings.

Objective measure. A standard sleep polygraphy (1g) was conducted with central EEG, electrooculogram (EOG), and electromyogram (EMG). *Behavioral measure.* A microswitch was taped on the dominant hand. Ss were instructed to press it twice whenever they became aware of having just awakened. Signals were recorded on the polygraph. *Subjective measure.* During the entire week with the sleep laboratory night, all Ss kept a daily sleep log (time of going to sleep, final awakening and arising, sleep latency, and number and duration of waking intervals). In the evening, Ss were asked to prognosticate sleep quality, and in the morning, to estimate SL, awakenings, and sleep quality, and to compare the latter with the average of the preceding week.

Polygraphic recordings were scored visually in 30 s epochs according to the criteria of Rechtschaffen and Kales (19) by two independent raters. *Polygraphic sleep latency and awakenings* are defined in several ways: "SL" = traditional latency to stage 2, "consolidated SL" = latency to the first epoch of stage 2 followed by at least 15 min uninterrupted sleep (17), "arousals" = shifts to stage 0 (SSO), "awakenings" = SSO following at least one epoch of stage 2 since last epoch stage 0, and "awakenings after consolidated sleep" = SSO following at least 15 min uninterrupted sleep. Sleep log data are weekly means. Group differences are mostly analyzed with Mann–Whitney U tests or with Fisher's exact probability test. Correlations are Spearman rank correlations.

RESULTS

Sleep parameters

In their own view (sleep logs), insomniacs slept poorly, SL (insomniacs, median = 56 min, controls, 7.5 min) and total wake after sleep onset (insomniacs, median 48.6 min; controls, 3.5 min) lasting longer and total sleep time (TST) lasting shorter than in controls (insomniacs, median = 336.5 min; controls, median = 415 min). In addition, insomniacs woke up more often than controls (insomniacs, median = 2.5; controls, median = 0.9). Two insomniacs stated that they had not slept at all. As Table 1 shows, polygraphically, insomniacs had shorter TST, more total stage 0 after sleep onset, and smaller sleep efficiency than controls. Some qualitative differences are not reflected by the scoring in 30-s epochs because of their short duration: most insomniacs some-

TABLE 1. *Laboratory data, polygraphic and subjective*

Variable	Insomniacs		Controls		U test
	Median	Q3–Q1	Median	Q3–Q1	
Polygraphic					
Total sleep time (min)	352	63	388	44	*
Sleep latency (min)	23	41	17	14	NS
Total intervening wake (min)	30	36	17	19	*
Total slow wave sleep (min)	16	18	25	18	NS
Total REM (min)	16	30	68	33	NS
Shifts to stage 0	13.5	13	10.5	8	*
Sleep efficiency	83	13	95	4	**
Subjective					
Sleep latency (min)	60	30	25	21	**
Total intervening wake (min)	35	35	6	13	** (N = 12 each)
Awakenings	3.5	2.7	3.6	2.6	NS
Prognosis (rating 1–5)	3.8 (mean)	0.9 (sd)	2.2 (mean)	0.8 (sd)	*** (*t* test)
Sleep quality (rating 1–5)	3.7 (mean)	0.9 (sd)	2.9 (mean)	1.0 (sd)	* (*t* test)

Insomniacs: N = 14, controls: n = 14, *p < 0.05, **p < 0.01, ***p < 0.001.

times show short periods of alpha waves in all sleep stages; during sleep onset in the presence of sleep spindles, REMs sometimes do not disappear. Sometimes EEG and EOG suggest clear stage REM, but EMG is >5 μV. Occasionally, delta waves can be seen during stage REM.

Experimental effect of sleep lab on good sleepers

In insomniacs, subjective sleep parameters of the analyzed laboratory night did not differ from that of the week before. Good sleepers, however, felt that they had slept significantly worse in the lab than they had foreseen and they reported longer SL (21.5 min vs. 5.1 min, $p < 0.01$, t test for dependent samples) and more awakenings (3.5 vs. 0.7, $p < 0.01$) than during the rest of the week.

Signals

No S felt bothered by the switch. All controls gave at least one correct signal (pressing twice). Data of one insomniac night without signal are included in analysis. This S had only been drug-free for a sufficient length of time this night (night 3, 10 days), and he did signal in all preceding and succeeding nights. Polygraphically, he slept poorly; subjectively, he did not sleep at all. Single instead of two switch presses are regarded as casual and not analyzed. In sum, insomniacs gave 46 valid signals (range 0–7, mean 3.3 with, 3.5 without, the "nonresponder"); controls gave 49 valid signals (range 1–9, mean 3.5), mostly in stage 0 or movement time (MT) (Table 2). In both groups, most perceived awakenings followed epochs scored stage 2 or REM. As Table 2 shows, insomniacs signalled only in stage 0 or MT or after a short arousal without going back immediately to stage 2, which led to a stage 1 scoring; controls sometimes signalled in actual sleep stages (2–4, REM). In both groups the epochs following the signal epoch are scored stage 0 or 1. Thus, in this sample, cortical (alpha waves) or physical arousal (MT) is necessary for the perception of awakenings at night. However, it is not sufficient: many arousals and also awakenings as defined above were not signalled (insomniacs 71%: 108 of 157; controls 67%: 53 of 79). In the morning, no subject queried was aware of simply forgetting to signal when consciously being awake.

In the *first REM–NREM cycle*, the number of Ss who awoke at all is statistically the same in both groups (11 insomniacs and 9 controls), but significantly more insomniacs than controls did signal in this cycle (7 insomniacs and 2 controls, $p < 0.05$, Fisher test). Both control and three insomniac signals in the first NREM–REM cycle were given when ascending from stage REM. Four of the five remaining insomniac signals during the first cycle occur after stage 3 (or a longer period of stage 2) in a moment where a shift to stage REM could already be expected. After this, Ss are starting nearly a new

TABLE 2. *Sum of signals in relation to sleep stages*

		MT	0	1	2	SWS	REM	Sum
Signals in stage	I	18	26	2	0	0	0	46
	C	20	13	6	7	1	2	49
Signals following stage	I	0	12	7	15	1	11	46
	C	0	3	9	19	4	14	49
Stage after signalling	I	0	34	10	0	0	2	46
	C	3	17	19	7	0	3	49

I = insomniacs, C = controls, each N = 14.
MT, movement time; SWS, slow wave sleep (stages 3 and 4 combined); REM, rapid eye movement.

cycle before going to stage REM. Whereas polygraphically neither group shows more awakenings (as defined above) in the second (insomniacs, median = 2.5; controls, median = 1) than in the first cycle (insomniacs, median = 2; controls, median = 1), both signal significantly more often in the second than in the first cycle (insomniacs: first median = 0.5, second median = 1, $p < 0.05$; controls: first median = 0, second median = 1, $p < 0.05$, Wilcoxon test). In insomniacs, 31% of all awakenings that are not perceived are in the first cycle, and in controls 41%. Concerning *sleep latency*, not a single arousal or awakening between the two SL versions is perceived. The Hauri–Olmstead criterion prolongs SL in four insomniacs and six controls. Although in insomniacs mean consolidated SL is nearer to subjective SL than the usual SL measure, rank correlations of both polygraphical measures to subjective measures are very similar ($r = 0.61$ and $r = 0.67$, respectively). In controls, there is effectively no improvement by use of consolidated SL.

Arousal measures

Figure 1 shows means and SD of different arousal measures. Three are derived from the polygraphy; the other measures are switch signals and subjective morning recall. In both groups, most 30-s arousals belong to simple 0–1–0–1 sequences, and a significant number occur before sleep has consolidated since the last stage 0 (ANOVA with three measures and two groups, decline $p < 0.01$, interaction $p < 0.05$). In insomniacs, subjective morning recall is significantly lower than either polygraphic measure, whereas in controls, the number of recalled awakenings corresponds to awakenings after consolidated sleep. However, in both groups all rank correlations between recall and possible physiological awakening measures are low. In contrast, in both groups not only are subjectively recalled awakenings equal to means of signals, but rank correlations are highly significant (insomniacs $r = 0.90$, controls $r = 0.83$). Qualitatively, 11 insomniacs, but only 5 controls, signalled only awakenings after consolidated sleep, which is mostly the beginning of a "series" of stage shifts to 0 ($p < 0.05$, Fisher test). Thirteen insomniacs (i.e., all actual responders) and only 7 controls signalled mostly at awakenings after consolidated sleep (more than 50%, difference of groups $p < 0.05$, Fisher test).

DISCUSSION

It was hypothesized that reported wakefulness generally depends on its prior perception. In particular, it was supposed that insomniacs are not able to perceive arousals after short sleep intervals and therefore experience sleep periods as continuous wakefulness, whenever they are often interrupted.

The aim of this study was to compare perception of spontaneous arousals and not of sleep parameters themselves. Therefore, the slight first night effect in controls was necessary, because it led to a comparable stimulus frequency (subjective and probably objective awakenings) between groups. Nevertheless, controls' sleep parameters are still better than insomniacs', the latter showing typical values (1,20–22).

The experimental paradigm used in this study was a behavioral device Ss should use when they felt that they had awakened. Contrary to an awakening paradigm, this procedure does not disturb sleep experimentally. Results show that this device can supplement usual measures of wakefulness in insomniacs as well as in good sleepers.

Perception of spontaneous awakenings is particularly poor not only during the 15 min

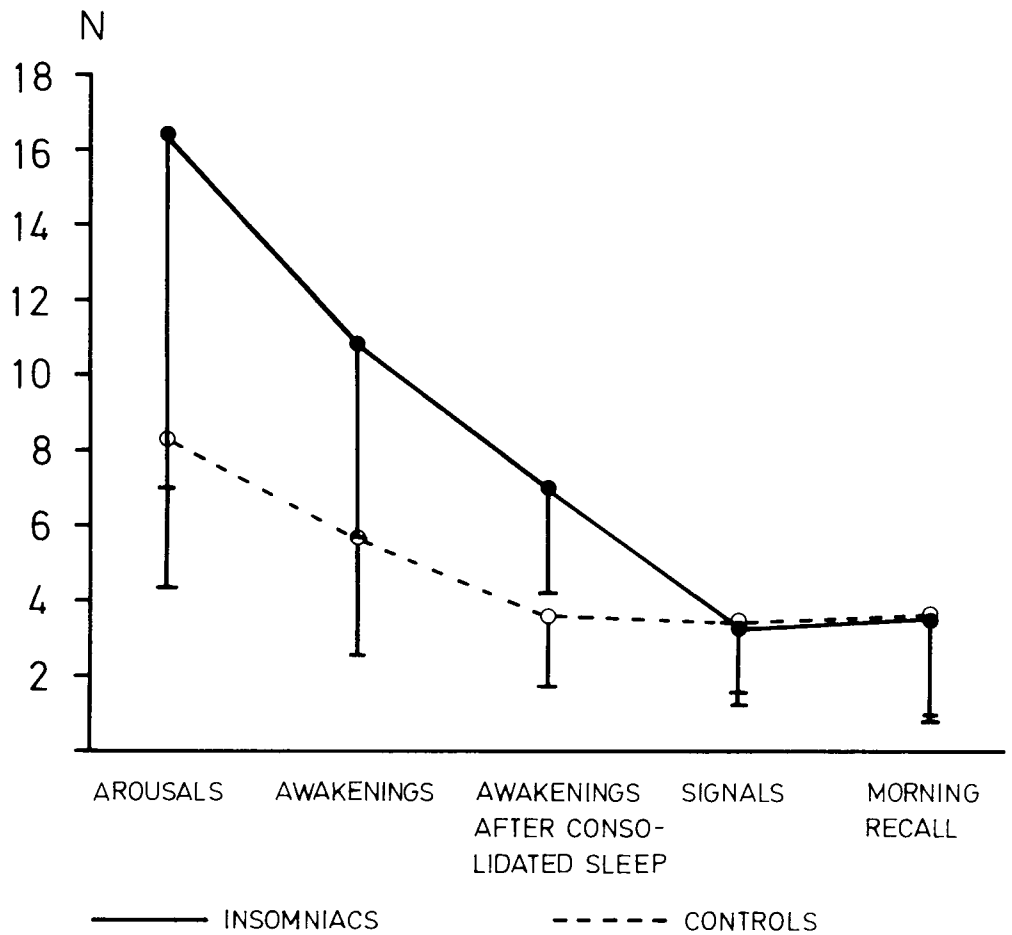

FIG. 1. Means and SD of awakenings according to different measurements and definitions. "Arousal" = all shifts to stage 0. "Awakenings" = shifts to stage 0 following at least one epoch of stage 2 since last epoch stage 0. "Awakenings after consolidated sleep" = shifts to stage 0 following at least 15 min uninterrupted sleep. "Signals" = behavioral switch signals. "Morning recall" = subjectively recalled awakenings. Insomniacs: N = 14; controls: N = 14.

following the first spindle (17), but during the whole NREM period of the first REM–NREM cycle. This rather lengthy perceptual uncertainty of waking and sleeping seems to be universal, since it occurs also with experimental waking procedures in good sleepers (7,8). Therefore, theoretically it must be assumed that there is a sleep-onset period instead of a fixed moment, as was discussed in the early days of sleep laboratory research (23,24). Defining a moment of sleep onset must remain in some way artificial.

In contrast to comparable studies (14–16), in these two samples some short physiological arousal seems to be necessary to perceive awakening. Two instructional reasons may account for this clearer connection between physiology and awareness and for the relatively low signal frequency: first, an instruction to signal twice tends to rule out casual signalling. Second, the decision criterion to signal correctly after "waking up" is clearer than "when being awake." On the other hand, both groups actually miss not only most arousals, but more than one-half of the awakenings. Beyond the theoretical possibility that they sometimes might have simply forgotten to signal, equating alpha

and wakefulness, therefore, does not reflect conscious experience as Campbell and Webb have discussed earlier (15). This is also known from alpha–delta sleep (25) and reports of "lucid dreams" after experimental awakenings from alpha during REM (26,27).

Concerning both means and correlations, the number of reported arousals does not correspond to any polygraphic arousal measure, but it is connected in a highly systematic way to the number of behavioral signals. Thus, actually perceived awakenings may reasonably be assumed to be the remembered ones. In both groups, recall for awakenings is good, if they are perceived, and it is independent from the duration of arousal. Differentially, the quality of signalled awakenings is most interesting. In normal Ss, signals do not occur systematically in connection with any sort of polygraphically defined arousal. This result is not subject to interpretation, so that we must assume that unsignalled awakenings usually are not perceived. In contrast, insomniacs almost consistently signal only awakenings after consolidated sleep (although not all of them). They seem almost unable to perceive awakenings after sleep intervals shorter than 15 min. Most plausibly, this is explained by assuming that they cannot perceive awakening because they have no feeling of having slept during these previous short intervals. Thus, their perception seems to be biased in the direction of "wakefulness" unless sleep has been lengthy, in which case they perceive awakenings much better and rather consistently.

Generally, it may be a sleep-protecting phenomenon to barely perceive accelerations of the EEG, in particular during the first 60–90 min of sleep. Moreover, EEG measures for SL and awakenings reflect experience and therefore recall only incompletely. Both must be defined in their own right. Stage 2 being undoubtedly sleep, it is reasonable to define alpha frequencies following stage 2 as physiological awakenings. A substantial part of those, however, will not reach consciousness and memory.

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