Waking from Sleep at a Preselected Time

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Ten college students attempted to awaken themselves from normal sleep at home, at times selected by the experimenter. These times were randomly distributed through the night. The results were statistically significant, and indicate an ability to awaken at a preselected time. Further data on three of these subjects run in a sleep laboratory suggest that the phenomena can continue to occur in the laboratory, but the physiological data did not cast any light on the underlying mechanism in this brief series. This type of behavior may have considerable significance for our understanding of the process of time estimation, and of the nature of sleep.

It is a common belief that some people are able to awaken themselves from sleep at a preselected time without the use of artificial aids. Typical practical examples would be waking up quite early to go fishing or to catch a train. Anecdotal reports suggest that this behavior is often accurate to within a minute or less, that is, people will report waking themselves almost exactly at the desired time after many hours of sleep. This represents a very high level of accuracy of time estimation, considerably higher than that usually reported for time estimates in the waking state (Fraisse, 1963), as well as suggesting the possibility of highly discriminative behavior during a state of altered consciousness, sleep. It is, therefore, rather surprising to find that there have been no scientific studies of this phenomenon in 33 yrs. (excluding a one paragraph abstract [Elder, 1941] which simply mentions confirming earlier studies without providing any details), and only five studies of the phenomenon before that time. These five studies will be briefly reviewed below. The purpose of the present paper is to describe two new studies of the phenomenon: considering the tremendous increase in the number of studies of sleep in the past decade since Aserinsky and Kleitman's discoveries (1953, 1955), it is well to remind current sleep researchers of the existence of this intriguing phenomenon in order to en-

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courage research on it with today's powerful techniques.

Two of the old studies were of individual Ss, the author, in each case. Hall (1927) attempted to wake himself at random times in the latter half of the night on 100 different nights. He reported waking exactly on time in 18% of his trials, and within ± 15 min. in 53% of his trials, an obviously significant result (although neither Hall nor any of the four other authors applied statistical tests to their results). Brush (1930) also tried to wake up in the latter half of the night on 50 non-consecutive nights by repeating to himself the time selected ten times as he fell asleep. He reports that he woke within 20 min. of the set times in 68% of his trials.

Vaschide, as reported to Kleitman (1963, p. 126), worked with 33 Ss who believed they could wake up at a preselected time. Those Ss with a superior education showed an average error of 25 min., while the uneducated Ss showed an average error of only 7 min. Frobenius (1927) tested five Ss for a total of 135 nights under laboratory conditions, with E keeping the time. His results indicate an extremely high rate of success: 48% of the 134 awakenings (there was one failure to awaken in the graphed data Frobenius presents) occurred within ±10 min. of the target times, with the modal frequency of 42 cases occurring in the interval of 0-5 min. preceding the target times. Finally, Omwake and Loranz (1933) tested 20 college girls for 14 consecutive nights. Ten of these girls were confident they could wake at selected times, the others did not believe they could do so. For the confident group, 10% of the awakenings were exactly on time and 30% were within ±15 min. In the non-confident group, only 1% of the awakenings were exactly on time and 4% within ±15 min.

While these five studies leave little doubt that at least some Ss possess an accurate (and useful) ability to awaken themselves at preselected times, they tell us little about possible factors affecting this type of behavior and nothing about its modus operandi. Omwake and Loranz's girls felt they would have been more successful if they had had a real motivation to awaken at the specified times, rather than just showing they could do it, and Brush felt the same way. Frobenius reported that there was no evidence of improvement with practice. Ss seemed to awaken quite suddenly. Sometimes they recalled a dream, at other times they did not. In no case did the reported dream action seem to lead up to awakening at the

proper time; the dream just ceased suddenly, a finding analogous to Tart's (1966), in which Ss waking at the beginnings or ends of stage 1 dreams as a result of posthypnotic suggestion reported nothing in their dreams that seemed to lead up to awakening. The impression one gains from the above studies is that there must exist some sort of "timing process" that can be set for a specific time of the night, and that this process is dissociated from or outside of both waking consciousness and sleep consciousness (dreaming). This is all the more perplexing insofar as telling clock time is a conscious process.

Two studies were undertaken to investigate the phenomenon of awakening at preselected times. The first was to have Ss who believed they could do so actually try it for 6 nights at home. The second involved selecting some of the more successful Ss from the first study and seeing if the phenomenon could occur in a modern sleep laboratory in a short time and, if so, what light some physiological measurements of sleep could shed on the process.

STUDY 1

Method

Eighty-seven Ss (Stanford undergraduates and a few adults connected with the University community) were seen in two groups in the course of screening volunteers for an experiment on hypnosis. These Ss answered a questionnaire about their dreams, including the question, "Can you tell yourself to wake up at any time of the night and wake up at that time?" Forty-five percent answered yes or sometimes.[2] Three other Ss who believed they could awaken themselves at a present time were contacted through an advertisement in the Stanford student newspaper.

Instructions for attempting to wake up at six specified times were mailed to these 42 Ss. The times were randomly scattered through the night (1:30 A.M., 4:23 A.M., 12:15 A.M., 2:33 A.M., 3:17 A.M. and 5:04 A.M.) Ss were to try to wake up at *one* of the assigned times on a given night, in the order given (although the nights did not have to be consecutive). On waking, they were to record the time of waking, whether it was correct or not. Ss were asked to make their trials on nights when they could go to bed at their regular time and were not unduly fatigued.

The experimental manipulation thus consisted of the Ss' telling themselves to wake at the desired time and record. The control condition was implicit, i.e., it seems rather likely that the spontaneous rate of waking in the night and writing down the time of waking was essentially zero.

The timing of this study was poor as it came close to the Christmas vacation. Many Ss called or wrote explaining that they were not able to carry out the instructions because of losing the materials over vacation, too busy preparing term papers, etc. Response booklets were returned from 10 Ss, and the results of this first experiment are based on their responses.

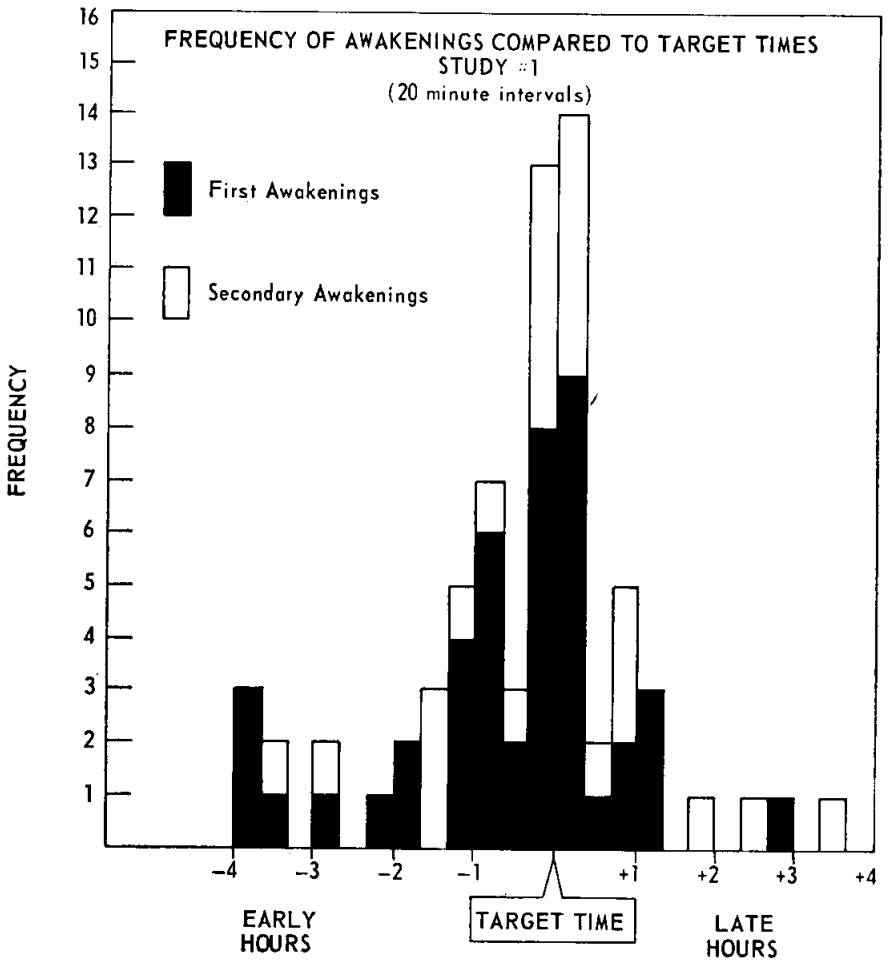
These 10 Ss completed their task during the period of November 14, 1964 to January 24, 1965, averaging 25 days each to complete their six nights.

Results

The first question of interest is whether the Ss' resolution to wake at a particular time significantly increased the frequency of the criterion behavior, viz. waking up and writing down the time. Although there were 60 possible trial nights for the 10 Ss, 4 of them reported they did not try for the 12:15 A.M. target time as it was too close to their normal bedtime. This leaves 56 nights: the Ss reported waking on 44 of these and failing to wake before normal rising time on 12 nights. Insofar as the assumed control condition, viz. that Ss almost never spontaneously wake up in the night and write down the time, is valid, the Ss' resolutions obviously increased the frequency of waking.

The second and more important question, given that Ss did wake from this procedure, is how *accurate* the Ss' waking behavior was. A problem arises in attempting to evaluate this, for six of the Ss reported one or more nights on which they awoke more than once. Some of these six Ss would thus awaken every hour or so until they awoke at or close to the assigned time.

Figure 1 shows the distribution of awakenings with respect to deviation from target time for all Ss and nights combined. The initial awakenings of the nights are graphed separately from the secondary awakenings. If Ss possessed no accuracy in their waking be-



havior, we would expect both the distributions to be essentially flat. The actual distribution shows a marked central peaking. Considering only initial awakenings, two-thirds of them (29 of 44) occur within ±1 hr. of the target times. Adding in the secondary awakenings does not change the basic shape of the distribution. There is some tendency for Ss to awaken early rather than late with respect to the target time.

Graphical analysis of the data obliterates individual differences between Ss, however, so the following statistical method was evolved

to objectively evaluate the accuracy of each S's reported performance.

The target times has been arbitrarily restricted during selection not to occur before midnight, this presumably being too close to some Ss' bedtimes, and not later than 6:00 A.M., this presumably being too close to normal rising time for some Ss. It was thus decided that awakenings before 11:30 P.M. or after 6:10 A.M.[3] would not be counted as experimental responses. This gave an experimental night of 400 min. length. By defining a "hit" as a reported awakening occurring within some arbitrarily small time of the target time, the probability of the obtained number of hits for each S could be evaluated from the binomial distribution.

Two analyses were carried out this way. For the first, it was arbitrarily decided that an awakening within ± 10 min. of target time was a hit. This gave a 20 min. wide slot in a 400 min. long continuum, and the probability of hitting it by chance alone is $20/400 = .05$. Because secondary awakenings changed the time base and P values on which an S was operating, this analysis was restricted to initial awakenings only.

Table 1 presents the initial awakening times of the Ss as deviations in min. from the assigned target times. The results of 3 Ss are significant by the binomial method (P values of .02, 5×10^{-4}, and 3×10^{-5}, one-tailed), and those of 3 others are suggestive (P values of .27, .27, and .14). In order to be sure these significant values are not chance fluctuations, the results for the 10 Ss as a whole were evaluated by combining the P values with the Stouffer (Stouffer *et. al.*, 1949, p. 45, footnote 15) technique, with a resultant $Z = 4.32$ $P = 2 \times 10^{-6}$ (one-tailed). Thus there is little doubt that some of the Ss exhibited a significant degree of accuracy in their waking.

For the second binomial analysis, only initial awakenings which were reported to be exactly on an assigned target time were considered hits. The probability of such an event by chance is 1/400. Three Ss each made one exact hit in 5, 3, and 4 trials, respectively, with associated P values for the observed or a greater number of hits of .01, .007, and .009. Combining these values with the other 7 P values of 1.00 by the Stouffer technique gives a $Z = 2.45$, $P = .007$ (one-tailed).

Inspection of the results of the individual Ss indicated another

Table 1

Initial Awakening Times as Deviation from Assigned Target Times

Subject	Target Times 12:15 A.M.	1:30 A.M.	2:33 A.M.	3:17 A.M.	4:23 A.M.	5:04 A.M.	P (hits)[1] (±10 mn)	r_s
CW	NW	+70	NW	NW	—60	NW	1.000	+1.00
JS	NW	—20	—4	0	—3	—3	$3x10^{-5}$	+1.00
PW	DT	+15	NW	NW	+67	NW	1.000	+1.00
NH	0	+180	NW	NW	—33	NW	.143	+.50
JP	DT	+17	—67	+72	—176	—239	1.000	—.50
MH	DT	—1	—7	0	—58	NW	$5x10^{-4}$	+1.00
LS	+5	—65	+17	—107	—233	—234	.265	+.50
KS	+15	—60	—48	—22	—43	—79	1.000	+.99
NR	+53	—80	—113	+4	—43	—219	.265	+.66
RP	DT	—10	—2	—137	+32	+56	.023	+.71

NW=no awakening that night. DT=didn't try to awaken that night.

[1]P of the observed or a greater number of hits.

way in which some Ss' behavior seemed affected by the target times which did not show up in the binomial analysis of hits, viz. their awakenings over the nights were highly correlated order-wise with the target times, even though they may not have come close enough to the actual times to score any hits. The final column of Table 1 shows the rank order correlations for the Ss. As the Ns for these correlations were low, varying from 2 to 6, significance levels of the correlation coefficients were not worth computing, but it should be noted that 9 of the 10 correlation coefficients were positive, with the mean correlation coefficient being +.686.

Looking at the performances of the individual Ss, 3 of them never awoke within ±10 min. of the target times, even counting secondary awakenings, while at the opposite extreme 1 S reported waking within −5 min. of the target times 4 of the 6 times that he tried. Two Ss, who were father and son, recorded 27 awakenings altogether, approximately 2 to 3 per night, in such a fashion as to gradually approximate the target time (making 7 successes by the ±10 min. criterion, although only 1 of these was on an initial awakening).

Inspection of the data revealed no tendency for any target time to be clearly associated with more successes than any other. As in Frobenius' data, Ss reported more awakenings within the 5 min. preceding the target times than following them (5 reported instances before, 1 after, not counting the 3 awakenings right on time). The significance of this is not clear.

Since the data in this first study depend on the Ss' report, the possibility of a sampling error exists, viz. that Ss who tried and did not do well were discouraged and so did not mail back their report booklets. The results reported above might then be a biased selection of actual performance. A number of the Ss wrote or phoned to say that they had been unable to try the experiment due to exams, term papers, vacations, etc., but this did not account for all. Thus to further check the possibility of the results being due to biased returns, it was assumed that another 10 Ss had tried the experiment and had failed completely for the total 60 nights in terms of accuracy. These presumed failures were added into the S group and a Stouffer combination done for an N of 20 instead of 10, evaluating hits by the ±10 min. criterion. The obtained Z was 3.055, still

significant (P=.001, one-tailed), so it was concluded that biased returns could not account for the results.

STUDY 2

Method

The 6 most successful Ss were asked to participate in a laboratory study. Three of them were able to participate the required 5 (non-consecutive) laboratory nights. Subject A, a female, 19 yr. old college senior had shown 4 first awakenings, 1 failure to awaken, and 1 second awakening on the 5 nights she tried at home. Three of the first awakenings were successes by the ±10 min. criterion. Subject B, a 17 yr. old high school senior, had shown a total of 12 awakenings over 6 nights, of which 2 of the second awakenings and the 1 third awakening had been successes. Subject C, an 18 yr. old freshman, had shown 2 successes in his 5 first awakenings and single second awakening.

The first 2 nights were for adaptation to the laboratory, (Dement, 1955; Dement, Kahn, & Roffwarg, 1965; Rechtschaffen & Verdone, 1964; Snyder, 1963) with nothing asked of S. On the last three nights, Ss were given randomly selected times to awaken. Discarding one night on which the S apparently misunderstood the instructions, Ss A and C tried to awaken at stated times for 3 nights each, and S B twice.

On each laboratory night a technician attached electrodes for measuring basal skin resistance (palm to forearm, with silver-silver chloride electrodes, as described by O'Connell & Orne, 1960) for electroencephalogram (frontal-to-vertex and vertex-to-occipital, Grass disc electrodes), and for rapid eye movements [semiconductor strain gage on one eye, as described by Baldridge (1963) and Tart (1963)]. Recording was continuous on a Grass model VII polygraph, at 10 mm/sec. The technician and equipment were in a separate room, with an intercom system for communication. The technician did not disturb S in any way after he (or she) went to sleep. When S awoke and called out, the technician noted it but did not inform S as to the actual time or degree of success. Ss were paid $5/night.

Results

Two to three nights each in the laboratory for the Ss showed the following results: 17 awakenings altogether, 8 of which were first awakenings. There were no successes by the ± 10 min. criterion on first awakenings, but for S B there was a second awakening 2 min. after the target time, and for S C there was a second awakening exactly on the target line. In addition, on S B's last night, when the target time was 1:23, he was heard to mumble "Wake at 2:23" in his sleep and woke a min. later at 2:22 A.M.: this was a very intriguing response, but as it indicated the S may have misunderstood the target time this night was discarded from the analyses.

The occurrence of 17 awakenings on experimental nights versus none on the baseline nights again indicates that instructions to awaken and call out at a set time clearly increase the frequency of awakening. This result also increases the credibility of the assumed control in the first experiment, viz. that Ss normally wake up and write down the time with a base frequency of zero.

The accuracy of the awakening behavior may be evaluated in the same manner as the initial study, although it is possible here to consider the initial and secondary awakenings together: as the Ss were never informed what time it actually was when they awoke, the P values for a hit were not affected by multiple awakenings. Again defining a reasonable hit as waking ±10 min. of the target time, Ss A and C have 1 hit each in 7 and 3 trials, respectively, with P values of .26 and .14: combining these by the Stouffer technique gives $Z=1.46$, $P=.07$ (one-tailed). By the exact hit criterion, A's 1 hit has a P value of .017, and the Stouffer combination gives $Z=1.38$, $P=.08$ (one-tailed). The correlational analysis is not applicable here when multiple awakenings are counted.

With regard to the physiological measures taken, Ss, by and large, showed the normal sleep patterns one would expect. The success which was exactly on time took place as a sudden awakening from a stage 1 EEG pattern; the EEG pattern was obscured by 60-cycle artifact in the other instance. However, many incorrect awakenings took place from stage 1 sleep, as well as from other stages of sleep. Thus all that can be concluded about possible physiological concomitants of waking at a preselected time from this exploratory study is that they are not obvious ones.

DISCUSSION

Three main conclusions may be drawn from the present results, confirming the old literature: (1) instructing the Ss to awaken at selected times produced a very large increase in the frequency of awakening; (2) this behavior is accurate in a general sense insofar as there was a positive correlation between awakening times and target times; and (3) this behavior was extremely accurate for some Ss who reported awakening at or very close to the target times in a significant number of instances.

The results of the second study were not particularly significant in themselves but: (1) were consistent with the first study; and (2) indicate that this accurate awakening behavior can occur in the modern sleep laboratory. The physiological data collected in this later study merely indicated that there were no obvious correlates of this awakening behavior for the 3 Ss tested.

The data also suggest that there may be two kinds of successful S, one type who awakens once per night, at the preselected time and another type who awakens fairly regularly through the night and finally approximates the preselected time. The old published studies did not report any comparable findings.

In terms of over-all level of success, the present studies were not as successful as some of the earlier ones, particularly that of Frobenius (1927). This may be largely a matter of the subject population. This population of Stanford undergraduates seems most comparable to Vaschide's "educated" group, which was the least successful of his groups.

The process by which Ss manage to awaken at the proper time is completely unknown. External cues can be disregarded for the trials were spread randomly over many weeks and times of night. There are rather stable physiological rhythms during a normal night's sleep (reviewed in Kamiya, 1961; Kleitman, 1963; Oswald, 1964; Snyder, 1963) which could form the basis for a physiological clock. For example, knowledge of the basal temperature curve or the basal skin resistance curve for some sleepers would allow one to predict the amount of time spent sleeping to within an hour or so (Tart, in press) but not to an accuracy measured in *minutes*. There are circadian rhythms which could also constitute a physiological clock (see Brozek, 1964 for a recent review), but we are still com-

pletely ignorant as to what brain processes (1) constitute a far more reliable clock than currently known rhythms and (2) link a conscious resolve to wake at a certain time with this clock and the needed effectors to bring about arousal.

A related study should also be mentioned which further complicates the question of the nature of the awakening process. Bleksley (1963) reports a series of 149 trials in which a selected S attempted to awaken at times randomly selected by E. But E and S were 1,000 miles apart, so S would have to employ some form of ESP in order to be successful. Evaluating those awakenings by S (who recorded 1 awakening each night and mailed the results to E) which fell within ±1 min. of the target time, Bleksley reports 8 such successes, with an associated P value of less than 10^{-5}.

It is clear that at least some Ss possess a highly accurate ability to awaken themselves from sleep at preset times, and further laboratory investigation of the nature of this ability should have important implications for understanding the nature of sleep consciousness and the process of time estimation.

REFERENCES

Aserinsky, E., & Kleitman, N. Regularly occurring periods of eye motility and concomitant phenomena during sleep. **Science,** 1953, 118, 273-274.

Aserinsky, E., & Kleitman, N. Two types of ocular motility occurring in sleep. **J. appl. Physiol.,** 1955, 8, 1-10.

Baldridge, B., Whitman, R., & Kramer, M. A simplified method for detecting eye movements during dreaming. **Psychosom. Med.,** 1963, 25, 78-82.

Bleksley, A. An experiment on long-distance ESP during sleep. **J. Parapsychol.,** 1963, 27, 1-15.

Brozek, J. Psychorhythmics: a special review. **Psychophysiol.,** 1964, 1, 127-141.

Brush, E. Observations on the temporal judgment during sleep. **Amer. J. Psychol.,** 1930, 42, 408-411.

Dement, W. Dream recall and eye movements during sleep in schizophrenics and normals. **J. nerv. ment. Dis.,** 1955, 122, 263-269.

Dement, W., Kahn, E., & Roffwarg, H. The influence of the laboratory situation on the dreams of the experimental subject. **J. nerv. ment. Dis.,** 1965, 140, 119-131.

Elder, J. A study of the ability to awaken at assigned hours. **Psychol. Bull.,** 1941, 38, 693. (Abstract)

Fraisse, P. **The psychology of time.** New York: Harper & Row, 1963.

Frobenius, K. Uber die zeitliche Orientierung im Schlaf und einige Aufwachphanomene. **Z. f. ges. Psychol.,** 1927, 103, 100-110.

Hall, W. The time sense. **J. ment. Science,** 1927, 73, 421-428.

Kamiya, J. Behavioral, subjective, and physiological aspects of drowsiness and sleep. In D. Fiske & S. Maddi (Eds.), **Functions of varied experience.** Homewood, Illinois: Dorsey Press, 1961. Pp. 145-174.

Kleitman, N. **Sleep and Wakefulness.** Chicago: University of Chicago Press, 1963.

O'Connell, D., Tursky, B., & Orne, M. Electrodes for the recording of skin potential: an evaluation. **Arch. gen. Psychiat.,** 1960, 3, 252-258.

Omwake, K., & Loranz, M. Study of ability to wake at a specified time. **J. appl. Psychol.,** 1933, 17, 468-474.

Oswald, I. Physiology of sleep accompanying dreaming. In **Scientific Basis of Medicine Annual Reviews 1964.** London: Athelone Press, University of London, 1964. Pp. 102-124.

Rechtschaffen, A., & Verdone, P. Amount of dreaming: effect of incentive, adaptation to laboratory, and individual differences. **Percept. mot. Skills,** 1964, 19, 947-958.

Snyder, F. The new biology of dreaming. **Arch. gen. Psychiat.,** 1963, 8, 381-391.

Stouffer, S., **et. al. The American soldier. Vol. 1, Adjustment during army life.** Princeton: Princeton University Press, 1949.

Tart, C. Technical note: use of strain gage to measure REMs. Paper presented to the Assoc. Psychophysiol. Study of Sleep in New York, 1963.

Tart, C. Toward the experimental control of dreaming: a review of the literature. **Psychol. Bull.,** 1965, 64, 81-91.

Tart, C. Some effects of posthypnotic suggestion on the process of dreaming. **Int. J. clin. exp. Hypnosis,** 1966, 14, 30-46.

Tart, C. Patterns of basal skin resistance during sleep. **Psychophysiology,** in press.

FOOTNOTES

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[2]This is quite similar to Clauser's finding (reported in Fraisse, 1963, p.44) that 52% of 1,080 people reported on a questionnaire that they could sometimes wake up at a preselected time.

[3]The 10 minutes were added after 6:00 AM to make the experimental night exactly 400 minutes long for convenience in statistical calculation.