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A SIGNAL DETECTION ANALYSIS OF SLEEP-WAKE PERCEPTION IN NORMAL SLEEP AND THE ALTERATION OF THAT PERCEPTION BY A PRIORI SLEEP AND A PRIORI WAKE INSTRUCTION SETS

City University of New York PH.D. 1982

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by

Deborah E. Sewitch

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Abstract

A SIGNAL DETECTION ANALYSIS OF SLEEP-WAKE PERCEPTION IN NORMAL SLEEP AND THE ALTERATION OF THAT PERCEPTION BY A PRIORI SLEEP AND A PRIORI WAKE INSTRUCTION SETS

by

Deborah E. Sewitch

Adviser: Professor John S. Antrobus

Previous work in the field has alluded to discrepancies between the polygraphic criteria used to define sleep as currently standardized and subjective reports of sleep and wakefulness for normal sleepers. In two experiments, a Signal Detection Theory framework was used to systematically assess the extent of this discrepancy in normal sleepers. The main hypothesis was that polygraphic criteria are an external, recordable index of an internal "state" that is _detected_ by subjects and _used_ by them to decide whether they have been awake or asleep.

Eleven normal sleepers (20-35 years old) spent six nonconsecutive nights, one adaptation night and five experimental nights, in the laboratory. An average of twelve trials were studied per experimental night: eight during polygraphically defined sleep (Stage 2 or REM) and four during wakefulness. For each sleep or wake trial, the subject was alerted by a telephone ring and asked to state whether he was "awake" or "asleep" just before hearing the ring. The subject was then asked to rate how confident he

was of that answer on a three-point scale: 1) positive, 2) pretty sure, or 3) not so sure.

Six of the original eleven subjects were asked to participate in a second condition (an additional five experimental nights) of study. They were assigned, in a counterbalanced order, to one or two a priori instruction set conditions. The subject was specifically told each night that the telephone would ring eight times during sleep and only four times during wakefulness (a priori sleep instruction set) or the subject was told that the telephone would ring eight times during wakefulness and only four times during sleep (a priori wake instruction set). In addition, subjects in both instruction set conditions were given feedback following their answers to the first three trials during the night (two wake trials, one Stage 2 trial) and they were told how many errors they had made the next morning.

Sleep-wake discrimination out of stage 2 sleep was significantly poorer than sleep-wake discrimination out of REM sleep, $\underline{t}(10)=4.10$, $\underline{p}<.01$. The response bias associated with EEG wake - EEG stage 2 sleep discrimination was significantly greater than the response bias associated with EEG wake - EEG REM sleep discrimination, $\underline{t}(10)=5.54$, $\underline{p}<.001$. A priori instruction set and limited performance feedback did significantly affect the subjects' abilities to discriminate between polygraphic wakefulness and stage 2 or REM sleep, $\underline{F}(1,4)=9.69$, $\underline{p}<.05$. Sleep-wake discrimination out of REM

sleep was affected significantly more by a priori instruction set and limited performance feedback than sleep-wake discrimination out of stage 2 sleep, $\underline{F}(1,4)=14.9$, $\underline{p}<.025$. A priori instruction set and limited feedback did significantly affect the response bias associated with discrimination of EEG wakefulness from EEG stage 2 or REM sleep, $\underline{F}(1,4)=6.89$, $\underline{p}<.10$.

The hypothesis that polygraphic data are closely correlated with internal signals that are <u>detected</u> by subjects and <u>used</u> by them to decide whether they have been awake or asleep was supported only in part. Normal sleepers do not detect polygraphic stage 2 sleep as being sleep fifty-five percent of the time and they do not detect REM sleep as being sleep twenty-seven percent of the time. The significant bias associated with all subject responses toward reporting 'awake' regardless of polygraphic criteria demonstrates that the sleep-wake decision process of normal sleepers is strongly dependent on factors independent of the conventional polygraphic criteria. These results seriously question the adequacy of conventional polygraphic criteria to decide whether or not someone has been asleep.

This study is dedicated to my father whose wisdom I hope I will one day have and to my mother whose love, strength, and determination are unequaled by anyone I have ever known.

ACKNOWLEDGEMENTS

I wish to express my deepest gratitude to the Sleep-Wake Disorders Center (SWDC) and the Department of Neurology at Montefiore Hospital under the leadership of Dr. Elliot D. Weitzman, Chairman of the Department and Director of the SWDC and Dr. Charles P. Pollak, Co-Director of the SWDC. This entire study was carried out at the SWDC using the Center's equipment, supplies, and facilities. The Center even went so far as to finance the design and construction of an intercom system specifically for this work. Dr. Charles Pollak has been enthusiastic and completely supportive of this work since its conception and is probably the single person most responsible for its completion to this point.

To my parents who totally financed all direct costs for this work over the last year, including subject and technician fees, I owe a debt, not only in financial support, but also in emotional support, that I can never repay. Had they not backed this project it would have died and a three-year dream along with it. Even my grandmother contributed financially towards this work. One could say that it became a family project.

I wish to express my sincere thanks to the technician/experimenters, Ruth Reinsel, Miriam Wollman, and Bob Stein, who did an excellent job collecting a total of 40 out of the 73 nights of experimental data.

I would like to acknowledge the computer services extended to me for the PSG analyses through the MHCRC grant to the Psychiatric Institute of New York from NIMH, MH30906-03 and the sleep analysis program made available to me through Drs. Neil B. Kavey and Joaquin Puig-Antich.

In addition, I am grateful to the C.U.N.Y. College Work/Study Program, funded by the Department of Health, Education, and Welfare, who supplied me with an excellent keypunch operator who ran the PSG data through the computer and two undergraduates who patiently recorded the reaction time data, heart rate data and respiration rate data. Steven Gidro-Frank scored 18 PSG records for me and Ken Tucker scored another ten. Without the concerted effort of all these people, this study would have taken considerably longer than it did.

To Dr. Crawford Clark who has given so much of his time discussing the results of this work and their implications with me, I owe a particular debt of gratitude.

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I. INTRODUCTION

Research has firmly established the fact that sleep is not a steady state, first noted by Loomis, Harvey and Hobart (1937), and that the sleep stages described by Dement and Kleitman (1957a) follow an orderly cyclical pattern. The sleep stages as they are presently standardized (Rechtschaffen and Kales, 1968) emphasize the electrical changes in the electroencephalogram (EEG). They are:

STAGE W	(wakefulness) which is distinguished by alpha activity and/or low voltage, mixed frequency activity in the EEG;
STAGE 1	which is distinguished by a relatively low voltage, mixed frequency activity devoid of any rapid eye movements;
STAGE 2	consisting of sleep spindles and "K"-complexes on a background of relatively low voltage, mixed frequency activity in the EEG;
STAGE 3	consisting of moderate amounts of high amplitude, slow wave activity and
STAGE 4	consisting of large amounts of high amplitude, slow wave activity.

Stages 1,2,3, and 4 are known collectively as STAGE NREM or simply NREM as they describe stages of sleep that are distinctively different from the final stage of sleep. All four sleep stages discussed are devoid of the episodic rapid eye movements (REMs) that characterize the fifth stage of sleep. These eye jerks are associated with a relatively low voltage mixed frequency activity in the EEG and a low amplitude electromyogram (EMG) which is indicative of a general loss of muscle tonus. Thus, the final stage of sleep is distinguished as STAGE REM or simply REM. This sleep stage breakdown represents the standardized conventions used in categorizing the sleep of the adult human purely on the basis of electrical change recorded from surface electrodes around the head. Despite the fact that specific physiological and behavioral correlates of the various sleep stages have been described, subjective correlates and their relationship to the EEG or polygraphic sleep stages remain ambiguous and obscure. As early as 1937, Loomis, et al. attempted to compare and correlate electroencephalographic changes that occurred with the transition from wakefulness to sleep with subjective experience. They reported on one subject who moved and responded 'awake' following an auditory stimulus in the C state (Stage 2 sleep). Another early study by Davis, Davis, Loomis, Harvey and Hobart (1938) instructed subjects to signal, by squeezing a bulb, whenever they realized that they had just "drifted or floated off" or whenever they felt they had just awakened from "real sleep". Subjects signaled a "floating" or sleep state when there was a diminution of the alpha rhythm 75% of the time. The authors also noted that;

> Occasionally a period of one or two minutes of unquestionable sleep passed entirely unsignaled. This agrees with our experience in other experiments in which such changes have appeared in the records and in which the subjects have denied having fallen asleep. Akin to this is the situation toward the end of an experiment [frequently an afternoon nap] when the subject is asleep most of the time and often fails to signal when alpha waves appear for a few seconds on the record. (p. 31)

Dement and Kleitman (1957b) studied subjective experience in conjunction with different EEG sleep stages giving particular attention to Stage REM. When they awakened subjects from Stage 1, the subjects reported that they had not been asleep and described the same "floating" and "drifting" experiences that were "signaled" by the subjects in the Davis, et al. (1938) study in conjunction with the disappearance of the alpha rhythm.

Kamiya (1961) reported on a study of dreaming and its electrophysiological correlates. Subjects were awakened by a bell with the appearance of the first sleep spindle (Stage 2 sleep). They were asked first, if they had been awake or asleep and second, if they had been dreaming prior to the bell. Forty-seven judgements were obtained from 20 subjects. Nineteen or 40.4% of the judgements obtained from Stage 2 sleep were awake judgements with thinking mentation, 12 judgements (25.5%) expressed "uncertainty of the subjective stage, or drifting" (p. 159), and only 12 or 25.5% of all judgements made out of early Stage 2 sleep were asleep judgements. Several observations made by Kamiya (1961) are particularly interesting in light of their apparent loss over the years.

> In conclusion, it seems that the EEG is a fairly good indicator of sleep onset, in spite of its limited usefulness in the nonnormal conditions of extreme sleep deprivation and pharmacological or surgical intervention that produce dissociation between the EEG and behavior, and in spite of <u>its less than perfect relation to subjective reports at sleep onset</u>....Because of its general promise, and because it can provide a continuous measure over time without disturbing the arousal level of the

> subject, it is understandable that the EEG has come increasingly to be regarded as the criterion of sleep....However, we must be mindful that this usage <u>may be premature or not sufficiently specific</u>. What we need very much is a clearer picture of what specific behavioral and experiential attributes are associated with each differentiable EEG pattern, and under what conditions. (p. 160)

Foulkes and Vogel (1965) also studied mental activity at sleep onset. Nine subjects participated in a four-night (nonconsecutive) study of mentation during the first 2-4 hours of the sleep period. Subjects were alerted by name over an intercom and interviewed for anything that was being experienced just prior to being called. The second question asked of each subject involved a judgemental ranking of his subjective state prior to being called. The rankings were: "awake and reasonably alert; awake but drowsy; drifting off to sleep; in light sleep; in deep sleep" (p. 232). Awakenings were taken from a continuous alpha EEG record trace, a discontinuous alpha EEG record trace, descending Stage 1 sleep, and descending Stage 2 sleep. In all cases the subjects ranked themselves as having been 'awake' although the rankings showed a consistent progression from 'awake-alert' to 'drifting off to sleep' with the descent into EEG Stage 2 sleep.

In all of the research reviewed up to this point, the subject samples have been young adult, <u>normal</u> sleepers. Rechtschaffen (1968) reported on a study of the nocturnal mentation of "good" versus "poor" sleepers. In an experimental protocol that required five awakenings after sleep onset, three REM awakenings preceded and followed by a NREM awakening, the poor sleepers reported having been 'awake' prior to six out of their 22 (27.3%) early NREM awakenings. All early NREM awakenings were Stage 2 sleep defined by ten minutes after the first sleep spindle. The poor sleepers also reported more "thoughtlike" activity on the early NREM awakening.

Walker (1972) (cited by Agnew and Webb, 1972) studied the effectiveness of varying stimulus conditions on sleep onset in 74 adult subjects. Subjects were tested in a 45 minute, early afternoon session. Following the session, subjects were asked if they had fallen asleep during the session. Forty-five percent of the subjects who achieved Stage 1 or Stage 2 sleep reported that they had not fallen asleep during the testing session and two subjects who achieved <u>Stages 3-4 sleep</u> also reported that they had not slept. On the second day of testing only 31% of the subjects achieving Stage 1 or 2 sleep reported not sleeping.

In a study on delayed sleep onset as a function of disturbing presleep thought by Antrobus and Saul (1978), two groups of subjects were selected on the basis of self reported sleep onset latency recorded in a two week sleep log. Two ten subject samples were established with the shortest and longest reported mean sleep latencies. The protocol consisted of an uninterupted night's sleep in the laboratory and an experimental night during which subjects were awakened at two minutes after "lights out" and at intervals of 4,8,16 and 32 minutes following each preceding awakening. Subjects were asked three questions upon each awakening including "were you awake or asleep before I called you?" The awakenings continued until each subject "gave two consecutive 'asleep' responses, regardless of EEG-EOG criteria," (p. 4). Subjects with the longest reported mean sleep latencies reported having been 'awake' out of an EEG sleep state 25% of the time and subjects with the shortest reported mean sleep latencies reported having been 'awake' out of an EEG sleep state 19% of the time. The proportion of subjective/polygraphic discrepancies was highest out of Stage 2 sleep followed by slow wave sleep Stages 3-4. The discrepancy was least out of REM sleep. Generally, subjects reported having been 'asleep' out of REM sleep. Reaction times (verbal response to name) were shortest for the EEG awake/subjective response 'awake' category, longest for the EEG sleep/subjective response 'asleep' category and intermediate for the EEG sleep/subjective response 'awake' category.

Having reviewed what constitutes the literature on the "perception" of sleep during the beginning of the nocturnal sleep period or during an artificially structured afternoon "nap", it is striking that the relationship of EEG sleep stage to sleep perception has never been systematically assessed despite continuous anecdotal reports of the discrepancies between polygraphic descriptions of sleep and the individual's perception of sleep. The present study was undertaken to make a statistical, probabalistic assessment of the relationship of EEG sleep Stages 2 and REM to sleep perception. It was designed to delineate the decision process involved in sleep-wake discrimination during the entire nocturnal sleep period.

There is a second reason why the present study is so relevant to current issues in sleep research and sleep disorders medicine. Many people complain of difficulty initiating and/or maintaining sleep (insomnia). The complaint of insomnia arises in association with a number of medical, neurological, and psychiatric disorders including sleep apnea, hypnotic drug tolerance or withdrawal, gastroesophageal reflux, periodic movements during sleep ("nocturnal myoclonus"), and delayed phase of the circadian sleep-wake cycle. Psychopathology can often be demonstrated and is usually assumed to contribute to the insomnia complaint.

The pathophysiology of insomnia appears to be varied, as are its causes. It has been shown, for example, that caffeine administration and hypnotic drug withdrawal produce different kinds of sleep pattern disturbances (Brezinova, Oswald and Loudon, 1975). Sleep apnea causes insomnia by introducing short, frequent arousals into the sleep pattern. Periodic movements of the legs are sometimes associated with similar brief arousals. In delayed sleep phase, the circadian sleep-wake rhythm is displaced in time, preventing sleep onset until a late clock hour. In each of these disorders, both the patient's complaint and the objective basis for it seem clear. By contrast, however, roughly 25% of the patients who complain of insomnia fall into a category that is characterized by its absence of associated abnormal polygraphic and psychological findings. It is listed as a "Subjective Disorder Initiating and Maintaining Sleep (DIMS) Complaint without Objective Findings" in the current nosology of the Association of Sleep Disorders Centers and the Association for the Psychophysiological Study of Sleep (1979). This group of insomniacs is not restricted to any age group but does have a higher frequency of occurrence in women (1979). In addition, these patients typically believe that if they "perceived" themselves as sleeping, they would be able to function at a much higher level of alertness during the day, i.e. the fact that they do not feel they are sleeping is the source of their daytime alertness problems. Although several "reasons" have been advanced to account for this "subjective" insomnia or disparity between subjective estimates of sleep parameters and polygraphic sleep parameters, these explanations originate from clinical inference rather than empirical demonstration. Excessive mentation during sleep; micro-arousals too subtle to be detected or scored by current polygraphic and visual scoring techniques; very subtle emotional or cognitive pathologies; have all been advanced as explanations to account for the distorted perception of sleep in these patients (1979). To date, no attempt has been made to analyze the complaint or discrepancy itself.

When a sleeper is awakened at some point during the night and asked to evaluate his subjective state prior to the awakening, he is confronted with a decision between two alternatives, sleep or wakefulness. Consequently, it would seem very appropriate to consider the issue of perceiving sleep and wakefulness in the context of a decision problem. There are three elements essential to any decision problem. There must be two "states of the world" and in the case of deciding about one's subjective state during the sleep period, those two states are wakefulness versus sleep. There must be some "information transmitted" and in the case of the sleeper who is alerted out of EEG wakefulness or EEG sleep, the period immediately prior to being alerted is assumed to carry information in it that can be used by the sleeper in "making an observation." And finally, the sleeper responds with the third element, the "decision" which completes the cycle (Green and Swets, 1966). Having defined the sleeper's subjective judgements about state as problems of a decision, there is a powerful theory for analyzing the essential structure of the cognitive decision process. It is the general theory of signal detectability or signal detection theory (SDT). A derivative of "information theory" and originally derived from the communication engineering literature, it has been adopted by experimental psychology to replace the traditional "threshold" approach to perception which ignored the non-sensory stimulus influences of motivation, alertness, expectation, and personality, as well as the interactive effect of sensory and non-sensory stimuli on the process of perception. The power of the signal detection model is that it permits the isolation and mathematical quantification of both sensory or physiological and non-sensory stimulus components of the decision making process. In fact, this part of the model is "an almost direct translation of statistical decision theory, or of the theory of testing statistical hypotheses" (p. 1, Green and Swets, 1966). SDT has been a highly effective model for predicting experimental results in sensory perception and recognition memory (Snodgrass, 1972a), sensory physiology, reaction time and vigilance tasks, and time discrimination (Green and Swets, 1966). It may also be an effective model for predicting, describing, and interpreting, sleep-wake perception of EEG sleep and EEG wakefulness. Clearly, no empirically based model already exists in sleep research to explain or predict the disparity between subjective perception of sleep and wakefulness and the polygraphically defined sleep-wake states in normal sleep much less subjective insomnia. Therefore, any possibility of postulating a model that can effectively explain or predict this disparity needs to be explored fully. The present study is in large part a feasibility study to test the efficacy of the SDT model for sleep-wake perception and the subject population chosen is that of normal sleepers.

This is a study of the ability of normal sleepers to decide whether they were awake or asleep just prior to being questioned during each of a series of nocturnal sleep periods. Polygraphic variables, especially the EEG, are continuously monitored as objective criteria of sleep and wakefulness.

The main hypothesis, to be tested by signal detection theory techniques, is that polygraphic criteria are an external, recordable index of an internal "state" that is detected by subjects and used by them to decide whether they have been awake or asleep.

In this study, the polygraphic sleep-wake state defined by conventional criteria (Rechtschaffen and Kales, 1968) is considered the external and recordable manifestation of an "internal" signal that normal sleepers can detect and report with varying degrees of probability that they have been asleep or awake. To test the efficacy of the polygraphic sleep-wake state in defining normal sleepers′ judgements of having been asleep or awake, a series of requests is given to the subject during different time points along the continuous polygraphic sleep-wake process. An estimation by the subject of his behavioral state just prior to the request is obtained. The subject is also asked to give a confidence rating of the sleep-wake judgement.

SDT provides a quantitative assessment of two aspects of a decision as a function of a subject′s performance. The first aspect of performance - sensitivity or discriminability - specifies how well the subject is able to make accurate decisions about his behavioral state and avoid inaccurate ones. The second aspect of performance - response bias - specifies the extent to which the subject favors a particular decision independent of polygraphic "evidence".

The subjective state of wakefulness is a "perception" inferred by an individual presumably from an increased and sustained awareness of external stimuli. The "perception" of having been asleep is also likely to be an inference based in part on the diminished awareness of external stimuli interpreted as the absence of wakefulness, and/or the occurrence of internal percepts specific to the sleep process such as REM sleep-related or NREM sleep-related mentation. One object of this study is to assess subjective judgements about sleep and wakefulness during the actual nocturnal sleep period by requesting the subject to judge whether or not he considered himself awake or asleep at a time just prior to the request. A comparison of judgements made during the sleep period with judgements made in the morning about the previous night's sleep may provide insight regarding the decision process involved in the normal sleeper's waking judgements about sleep. It is known, for instance, that morning judgements about nocturnal sleep often overestimate sleep latency (Monroe, 1967; Rechtschaffen, 1968; Antrobus and Saul, 1978; Freedman, 1976; Hauri, 1978; Frankel, Buchbinder and Snyder, 1973) and underestimate total sleep time (Hartmann, 1967) and number of awakenings (Frankel, Buchbinder and Snyder, 1973; Monroe, 1967; Hauri, 1978) in insomniac patients. Might we observe similar discrepancies in normal sleepers but to a much smaller degree?

II. METHODS

EXPERIMENT 1

Subjects. Twelve subjects (10 male, 2 female) participated in a six night experimental protocol. Eleven of the subjects were paid volunteers and classified themselves as "normal" sleepers with subjective sleep onset latencies of twenty minutes or less. The age range for these subjects was 20-35 with a mean age of 26. The twelfth subject was a volunteer, male insomnia patient (45 years old) who had undergone a complete evaluation by the Montefiore Hospital Sleep-Wake Disorders Center. He had been diagnosed as having a psychophysiological insomnia with a strong subjective component, i.e. a subjective-polygraphic discrepancy of greater than sixty minutes.

All subjects were carefully screened for drug and alcohol injestion. None of the subjects were on any drugs at the time of the experiment including marijuana. None had taken any drugs for at least a year prior to the experiment. Alcohol injection was minimal to not-at-all for all but three subjects who drank regularly on week-ends (beer). One subject was a heavy smoker and asked to curtail his smoking the nights of the experiment.

All subjects kept a two-week sleep log prior to the start of the experiment and filled out a morning questionnaire (Appendix B) every morning for the same two-week period as well as every morning following an experimental night. The purpose of the two-week sleep log was to establish regular and stable sleep-wake patterns. All subjects filled out the Minnesota Multiphasic Personality Inventory (MMPI) to rule out any major psychopathology. None of the subjects took regular daytime naps, although during the experiment itself some subjects took a nap the day after an experimental night.

The group of normal sleepers was chosen with regard to the reported facility with which the members claimed they could return to sleep after being awakened during the night and the reported ability to sleep well in a new or unusual environment. None of the subjects had any history of brain damage, head injuries, or EEG abnormalities. One subject had a history of childhood insomnia but had no recent history of persistent insomnia. This subject's polysomnographic sleep onset latencies turned out to be the longest of all the normal sleepers (Appendix A, subject BS).

The subjects, with the exception of the insomniac, were all solicited through friends or through former subjects so that motivation to participate and complete the experiment was high.

Apparatus. Two Grass Instruments; Model 78, 20 channel polygraph machines, were used for the continuous sleep recordings (polysomnograms). The surface electrodes were placed at C_4 and O_2 on the scalp (EEG) both referenced to the contralateral and ipsilateral (tied) mastoids; on the right and left outer canthi (EOG), each referenced to tied mastoids and to each other for a "fast" (T.C. = 3-60) bipolar, eye channel; on the chin (EMG) referenced to each other; and on the right (RAT EMG) and left (LAT EMG) anterior tibialis muscles. In addition, respiration was continuously monitored by left and right nasal thermistors and, on the adaptation night, by a pneumograph (bellows) as well for thoracoabdominal movements. Heart rate (EKG) was monitored with a single lead II. The polygraphs ran at a paper speed of 15 mm/sec. Appendix B provides additional information on the electrode montage.

Subjects went through the experiment two at a time. They slept in adjoining bedrooms connected to a control room from which all monitoring took place. Subjects slept in complete privacy and communicated via an intercom with the two experimenters in the control room. Since the bedrooms were sound attenuated but not sound proof, very soft foam headphones (Senzheiser) were worn by each subject and served in place of speakers. In the control room the experimenters also wore headphones.

Subjects were alerted by a tape recording of a continuous ringing telephone bell. A standard bell was removed from a telephone and adapted to ring continuously. A five minute cassette tape recording was then made of the ring. In addition, the two questions - "were you awake or asleep just before the telephone began to ring" and "how sure are you of that decision on a scale of 1-3; are you 1) positive, 2) pretty sure, or 3) not so sure" - were also taped and played in directly through the subject's headphones each time a trial was taken. These questions were tape recorded to prevent inadvertently supplying the subjects with feedback from changes in vocal inflection. Finally, to ensure the complete suppression of any noise or speech between bedrooms and from the control room, a small "white noise" generator was placed in each subject's bedroom.

Procedure. All subjects were instructed to abstain from alcohol and coffee after noon the days of experimental nights.

1. Laboratory Protocol. Each subject reported to the Sleep-Wake Disorders Center (SWDC) about two hours before his usual bedtime, as established by the prior two-week sleep-wake log. Written consent was obtained and witnessed by one of the experimenters (Appendix B). The two subjects were then prepared for their polysomnograms by attachment of the non-invasive electrodes and sensors, already described, for continuous monitoring. Each subject, except one, was studied for six non-sequential nights (typically two per week); one adaptation/baseline night and five experimental nights. One subject was only studied five nights. Thus, subjects typically reported to the SWDC Sunday and Wednesday nights for a total of three weeks. The reason for running subjects on nonconsecutive nights was to control for potential sleep rebound effects that were expected to occur on the night immediately following an experimental night during which eight sleep interruptions were planned.

a. Adaptation night. On the adaptation night, the subject was prepared for continuous monitoring of: EEG, EOG, EMG, EKG, and nasal airflow. Thoracoabdominal movements and bilateral anterior tibialis muscle activity were added for continuous monitoring during the baseline night to rule out sleep apnea (periodic cessation of respiration) and periodic leg movements or jerks during sleep ("nocturnal myoclonus") which might be present despite the subject's subjective unawareness of such sleep disorders. The presence of either of these two sleep disorders was a disqualifying factor. Subjects slept undisturbed throughout the adaptation night with headphones and the "white noise" generator on. In the morning each subject filled out a morning questionnaire (Appendix B) regarding the previous night's sleep.

b. Experimental nights. On every experimental night, each subject was again prepared for polysomnography which included monitoring of: EEG, EOG, EMG, EKG, and nasal respiration. Upon awakening in the morning, subjects again filled out the morning questionnaire.

The sampling protocol for all subjects consisted of 12 trials on each of the five experimental nights. A trial was defined as a polygraphic sleep or wake interruption and a "request" that the subject verbally identify his perceived, "behavioral state" just prior to hearing a telephone ring. The behavioral state consisted of a six-point confidence scale comprised of two three-point scales for both awake and asleep.

Each subject was given the following description and instructions prior to bedtime:

> This is an experiment designed to investigate how an individual perceives himself as awake or asleep during the course of the night. You are going to hear a telephone ring a number of times during the night after you are in bed and the lights have been turned out. As soon as you hear the telephone ring, indicate by saying "Yes".
>
> Your task is to tell me first, whether you had been awake or asleep just before the telephone began to ring. And then I want you to tell me how confident you are of that answer on a scale of 1-3. Listen to each of the three possibilities before you give me your confidence rating.
>
> I will say to you, "Were you awake or asleep before the telephone began to ring? And how sure are you of that decision on a scale of 1-3?"
> "Are you: 1. Positive
> 2. Pretty Sure
> 3. Not So Sure
>
> Both of these questions have been previously recorded on cassette tape and it will be the recording of these two questions that you will respond to following each telephone ring. When you have completed your answers I will come on the intercom and repeat them back to you for an accuracy check. You will then be allowed to go to sleep.
>
> Do you have any questions?

In the morning after each experimental night, all subjects were requested to write down whatever they could verbalize concerning the criteria each set for making an "asleep" or "awake" decision. The following specific two questions were asked: "How did you go about deciding whether you were awake or asleep last night? Are you able to describe what factors influenced how certain you were about your decisions?" (Appendix B). There was no information of any type given to the subject as to *when* the telephone could be expected to ring during the night, and there was no feedback given as to the *accuracy* of the subject's decisions for the entire five experimental night period.

The 12 trials given to subjects each night were as follows: 4 trials from EEG Wake ("*Signal*") and 8 trials from EEG Sleep ("*Noise*"). The 8 trials from EEG Sleep ("*Noise*") were subdivided into 4 trials from EEG Stage 2 and 4 trials from EEG (polysomnographic) Stage REM.

EEG Wake was defined polygraphically by 60 seconds of predominent alpha activity, either before EEG Sleep Onset or following sleep. EEG Wake did not follow an arousal from a body movement unless there had been at least ten seconds of intervening Stage 1 between the actual movement and 60 seconds of predominent alpha. EEG Wake was *not* scored if a synchronous alpha rhythm was present simultaneously with sleep spindles, K-complexes or superimposed on delta wave (1-3 hz) activity.

EEG Sleep was defined polygraphically by 60 seconds of continuous Stage 2 or REM sleep according to conventions outlined by Rechtschaffen and Kales (1968).

To control for a time of night effect, one EEG Stage 2 and one EEG Stage REM trial was obtained during each of the first four NREM-REM short-term sleep cycles (each REM period was taken as the end of a cycle with at least

20 minutes of NREM sleep subtending any 2 consecutive REM sleep periods) so that NREM and REM trials were evenly spread across the night's sleep period.

EXPERIMENT 2

Subjects. Six of the original 11 normal sleepers were asked to participate in an additional condition consisting of 5 more nights to be spent in the laboratory (another 2 1/2 weeks).

Procedure. Subjects were told that they would go through the same procedure with one major exception: this time they would be given information prior to sleep concerning when the telephone would ring during the night. They would also receive feedback (cues) following the first three trials of the night (2 EEG Wake; 1 EEG Stage 2 sleep) as to the accuracy of their responses. The next morning, they would be told the number of decision errors made the previous night. In all other ways the procedure for these additional five experimental nights was identical with the procedure for the first five experimental nights.

The six subjects were assigned in a counterbalanced order (ABBA) to one of two information conditions and, with the exception of one subject, all subjects began the information condition during the fourth week. One subject took a week off between conditions.

1) A Priori Sleep Condition. The subject was given the following information prior to bedtime each night:

> For the next five nights that you spend in the laboratory, you are going to hear a telephone ring 12 times during the night. Eight of those times the telephone will ring while you are Asleep and only 4 times the telephone will ring while you are Awake.
>
> As soon as you hear the telephone ring, say "Yes." Once again, tell me whether you were awake or asleep just before the telephone began to ring and then how confident you are of that answer on a scale of 1-3: 1) Positive, 2) Pretty Sure, and 3) Not So Sure.
>
> Following the 1st 3 times that you hear the telephone ring tonight and give your answers, I will tell you whether your answers are right or wrong. The rest of the night, I will simply repeat your answers back to you for an accuracy check.
>
> Do you have any questions?

The experimenter gave the subject the following feedback after the subject responded to each of the first three trials: 1st trial (EEG Wake trial), the experimenter said, "You were Awake"; 2nd trial (EEG Wake trial), the experimenter said, "You were Awake"; 3rd trial (EEG Stage 2 sleep trial), the experimenter said, "You were Asleep".

The next morning, the experimenter counted up the number of times less than 8 the subject said Asleep and repeated that number back to the subject as errors made in the direction of calling what was Sleep wakefulness, i.e. ""X" times that you said you were awake, you were really Asleep."

2) A Priori Wake Condition. The subject was given the following information prior to bedtime each night:

> For the next five nights that you spend in the laboratory, you are going to hear a telephone ring 12 times

> during the night. Eight of those times the telephone will ring while you are Awake and only 4 times the telephone will ring while you are Asleep.
>
> As soon as you hear the telephone ring, say "Yes." Once again, tell me whether you were awake or asleep just before the telephone began to ring and then how confident you are of that answer on a scale of 1-3: 1) Positive, 2) Pretty Sure, and 3) Not So Sure.
>
> Following the 1st 3 times that you hear the telephone ring tonight and give your answers, I will tell you whether your answers are right or wrong. The rest of the night, I will simply repeat your answers back to you for an accuracy check.
>
> Do you have any questions?

The experimenter gave the subject the following feedback after the subject responded to each of the first three trials: 1st trial (EEG Wake trial), the experimenter said, "You were Awake"; 2nd trial (EEG Wake trial), the experimenter said, "You were Awake"; 3rd trial (EEG Stage 2 sleep trial), the experimenter said, "You were Awake".

The next morning, the experimenter counted up the number of times less than 8 the subject said Awake and repeated that number back to the subject as errors made in the direction of calling what was Wakefulness sleep, i.e. ""X" times that you said you were asleep, you were really Awake." (Note that this condition actually supplies the subject with false information.)

Table 1 presents a listing of all subjects tested in both Experiments 1 & 2 and the conditions each one completed. In addition, the age of each subject is recorded as well as the total number of nights recorded for that subject.

TABLE 1

EXPERIMENTAL PROTOCOLS

Ss	AGE	NO INFO. COND.	A PRIORI SLEEP	A PRIORI WAKE	# OF NIGHTS RECORDED
MD	26	X			6
SV	27	X			6
AA	35	X			6
BZ	27	X			6
BS	21	X	X		11
YR[a]	22	X		X	11
HG	27	X		X	11
PC	20	X	X		11
SB[a]	27	X			6
KS	29	X	X		11
DM	21	X		X	9
RB[b]	45	X			6
TOTAL		12	3	3	100

[a] Female Subjects

[b] Insomniac

The subject DM completed only nine nights; one adaptation and eight experimental nights. This was prearranged for two reasons. First, the SWDC facility was only reserved for a specified time period and an earlier subject, SB, left the experiment after completing only the "no information" condition. It was therefore necessary to screen an additional subject and schedule him within the nine night period remaining in the study. Second, it was of interest to know whether four nights, instead of five nights, in the no information and information conditions were enough to demonstrate a significant alteration in discrimination (sensitivity) and response bias. The subject DM did show significance and the predicted changes in both discrimination and response bias.

SDT: Data Analysis Techniques. Signal detection theory assumes that the independent variable or stimulus is imbedded in a continuum of sensations from which it must be extracted (detected). Two aspects of the subject's perceptual judgement are identified: a sensory or physiological factor designated as the subject's sensitivity to the stimulus and a non-sensory factor designated as the response bias.

In the present study the EEG sleep-wake state is an independent variable since changes in the polygraphic sleep-wake state, as defined by conventional criteria (Rechtschaffen and Kales, 1968), have been used traditionally for sleep/wake discrimination. As a hypothetical construct, EEG Wake is the "signal" and EEG Sleep is the "noise", since the focus of the study is the error of judging polygraphic sleep to be wakefulness. By definition (McNicol, 1972), "noise" may be any stimulus which can be confused with the signal stimulus. The judgement of interest mistakes sleep for wakefulness. Thus, the judgement of having been awake during polygraphic sleep is classified as a false alarm. There are four outcomes possible to the subject's judgements in the classification of SDT. They are expressed as conditional probabilities and represent all possible stimulus-response combinations. Figure 1 depicts the possible stimulus-response combinations in a 2X2 contingency table. All SDT calculations are generated from the "Hit" and "False Alarm" probabilities. A high number of false alarms indicates a strong tendency for the subject to respond on the basis of non-stimulus factors such as personality, vigilance, motivation, and expectations, independent of variation in sensory stimulation.

1) The Rating Scale Procedure. A rating scale incorporates varying criteria with each stimulus presentation. The subject must not only decide whether or not an actual signal has been presented, but also, give a confidence rating as to that final judgement. The rating scale procedure assumes that a subject instructed to rate his behavioral state, prior to hearing a telephone ring along a six-point confidence scale, establishes five criterion placements (C_1 - C_5) by which a sleep/wake discrimination is made on any given trial. The decision rule is presented in Figure 2. Hit and false alarm probabilities are generated for each of the criteria and each criterion becomes a point on a curve

Figure 1. The subject can say "awake" when in fact he was polygraphically awake (HIT); "asleep" when he was in fact polygraphically awake (MISS); "awake" when he was polygraphically asleep (FALSE ALARM); and "asleep" when polygraphically he was indeed asleep (CORRECT REJECTION).

Figure 2. The decision rule was adapted from Snodgrass (1972b) to describe what is assumed to be the decision process involved in the present study. The decision rule makes the assumption that the subject is able to order the evidence or sensory events according to the likelihoods that they belong to either an Awake or Asleep behavioral state as represented by the EEG.

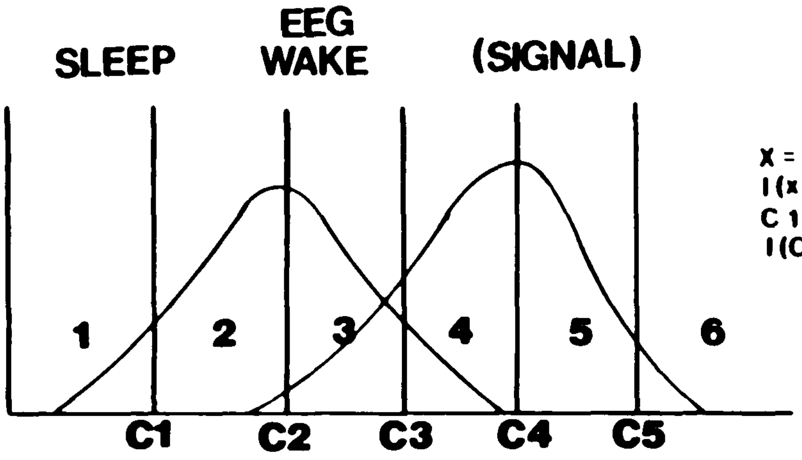
Figure 1.

CONDITIONAL PROBABILITIES

		SUBJECT'S RESPONSE	
		"AWAKE"	"ASLEEP"
POLYSOMNOGRAM	SIGNAL (WAKE)	HIT	MISS
	NOISE (SLEEP)	FALSE ALARM	CORRECT REJECTION

Figure 2.

ASSUMED DECISION RULE



X = EVIDENCE, "SENSATION"
$l(x)$ = LIKELIHOOD RATIO, "ODDS"
C 1-5 = CRITERIA
$l(C_1)-l(C_5)$ = CHOICE OF A PARTICULAR CRITERION VALUE

IF $l(C_5) < l(x)$	RESPOND "6" AWAKE (POSITIVE)
IF $l(C_4) < l(x) \leq l(C_5)$	RESPOND "5" AWAKE (PRETTY SURE)
IF $l(C_3) < l(x) \leq l(C_4)$	RESPOND "4" AWAKE (NOT SO SURE)
IF $l(C_2) < l(x) \leq l(C_3)$	RESPOND "3" ASLEEP (NOT SO SURE)
IF $l(C_1) < l(x) \leq l(C_2)$	RESPOND "2" ASLEEP (PRETTY SURE)
IF $l(x) \leq l(C_1)$	RESPOND "1" ASLEEP (POSITIVE)

ADAPTED FROM J.G. SNODGRASS. THEORY AND EXPERIMENTATION IN SIGNAL DETECTION: EXPERIMENTAL METHODS AND DATA ANALYSIS. LIFE SCIENCE ASSOCIATES. 1972. PART 2 p3.

known as a receiver-operating-characteristic (ROC). The ROC curve is generated by plotting the hit probability as a function of the false alarm probability at each criterion.

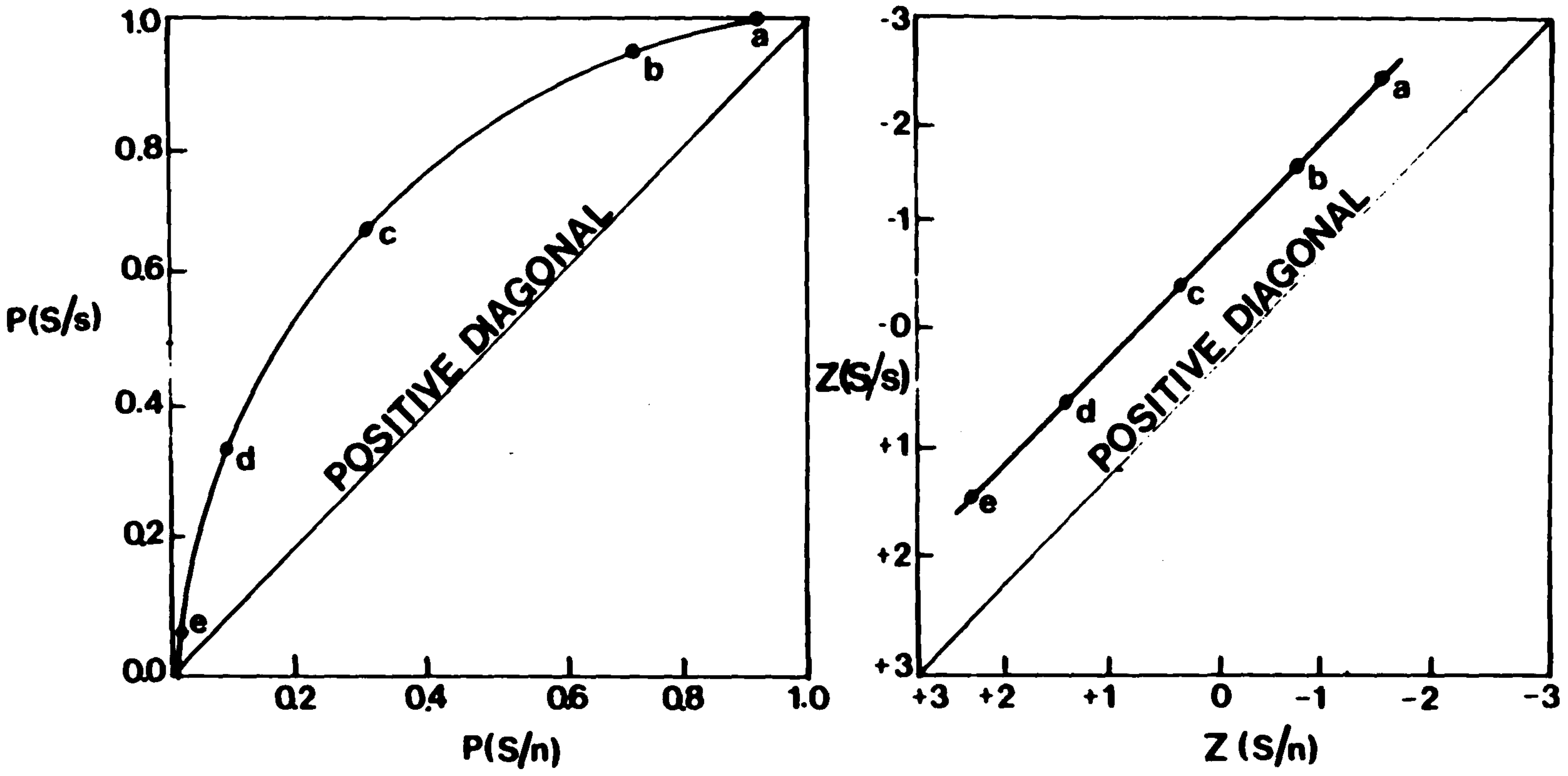
Figure 3 depicts a hypothetical ROC curve generated from a six-point rating scale so that there are five criteria or five sets of hit and false alarm probabilities. The hit and false alarm probabilities are plotted on linear coordinates and then on double probability coordinates. If the underlying Signal (+ noise) and Noise, i.e. EEG wake and EEG sleep, distributions are normally distributed (Gaussian), then the criteria will plot as a linear function on double probability coordinates. The slope of that line will equal one if the variances of the EEG wake and EEG sleep distributions are equal (McNicol, 1972). However, if the variance of the EEG wake distribution is greater than the variance of the EEG sleep distribution, then the slope will be less than one. If the EEG sleep distribution variance is greater than that of the EEG wake distribution, then the slope will be greater than one (McNicol, 1972).

2. <u>The Non-Parametric Measure of Sensitivity (Discriminability) P(A)</u>. "Sensitivity" is statistically defined as the distance between the mean of the signal (+ noise) distribution (EEG wake) and the mean of the noise (EEG sleep) distribution. This distance specifies a distinct ROC curve. The shape of and area under the ROC curve specify how sensitive a subject is to a given stimulus (polygraphic criteria of the sleep-wake state) by specifying the extent to

Figure 3. A theoretical ROC curve consisting of five criteria redrawn from McNicol (1972). The ROC curve is also known as an "isosensitivity" curve (Snodgrass, 1972a) because each criterion represents equal sensitivity but change in response bias.

Figure 3.

ROC CURVE AND ITS DOUBLE PROBABILITY PLOT



ADAPTED FROM D. McNICOL. A PRIMER OF SIGNAL DETECTION THEORY
GEORGE ALLEN & UNWIN LTD. 1972 pp 53, 54

which the signal (EEG wake) and noise (EEG sleep) distributions are separated.

For example, in Figure 4 there are three hypothetical ROC curves and their corresponding, inferred signal and noise distributions. Notice Curve C, it is the diagonal of the unit square. It encompases 0.50 of the total area (P(A)) of the square and it is associated with a distance (d′) of 0 between the means of the signal and noise distributions. Now look at Curve A in Figure 4, there is at this point a curvilinear function present that has a distinct increase in area associated with it as well as an increase "bulge" and it represents a distance of one standard deviation unit (d′=1) between the means of the signal and noise distributions. Curve B represents a distance of two standard deviation units (d′=2) between the signal and noise distribution means. It has an increased "curved" shape to it and it encompasses a greater proportion of the total area (P(A)) of the unit square. Consequently, the more sensitive a subject is to the polygraphic sleep-wake state, the more "curved" will be the ROC function, the greater will be the area (P(A)) under that function, and the greater will be the distance between the means of the EEG wake and EEG sleep distributions.

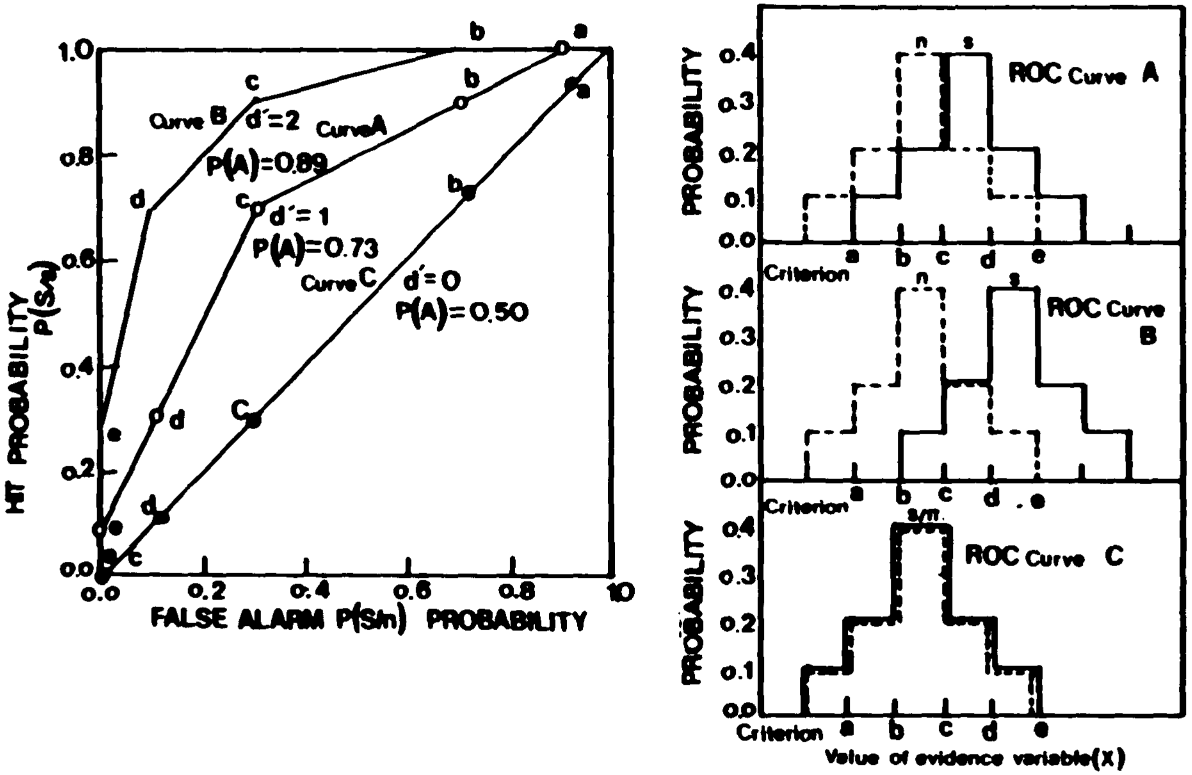
All SDT statistics, i.e. sensitivity and response bias, used in this study are non-parametric statistics because they make no assumptions on how the data are distributed and therefore are valid for the unequal variance case and, because the present study involves a low frequency of

Figure 4. Figure 4 depicts several hypothetical ROC curves and their inferred, underlying signal and noise distributions. The figure is adapted from (McNicol, 1972). It shows the relationship between area calculations (P(A)) of sensitivity and distance (d′) calculations, in standard deviation units, of sensitivity.

ROC curve C is a straight line and the diagonal of the graph. It corresponds to signal and noise distributions that are one in the same, i.e. no separation of their means, and indicates a minimal sensitivity to the signal stimulus. An area of 0.5 of the total area (1.0) lies below the diagonal. The increased "bulge" in ROC curve B as compared to ROC curve A is proportional to the increased distance between signal and noise distribution means for the two curves. Translated into a proportion of the total area beneath each curve, ROC curve B reflects 0.89 of the total area, while ROC curve A reflects only 0.73 of the total area.

Figure 4.

THEORETICAL ROC CURVES AND THEIR INFERRED DISTRIBUTIONS



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GEORGE ALLEN & UNWIN LTD. 1972 pp 20 & 22

observations. Generally, parametric SDT measures are not recommended for a low frequency of observations (McNicol, 1972).

The proportion of the total area beneath the ROC curve, P(A), is a non-parametric measure of sensitivity. It was used in this study to assess polygraphic wake-sleep discriminability. P(A) can be calculated geometrically by dividing up the area under the ROC curve according to the number of points (criteria) that define it. These component areas take the form of either triangles and/or trapezia. Figure 5 demonstrates the graphic calculation. The arithmetic formula for P(A) presented in McNicol (1972) was used for all calculations of sensitivity (discriminability).

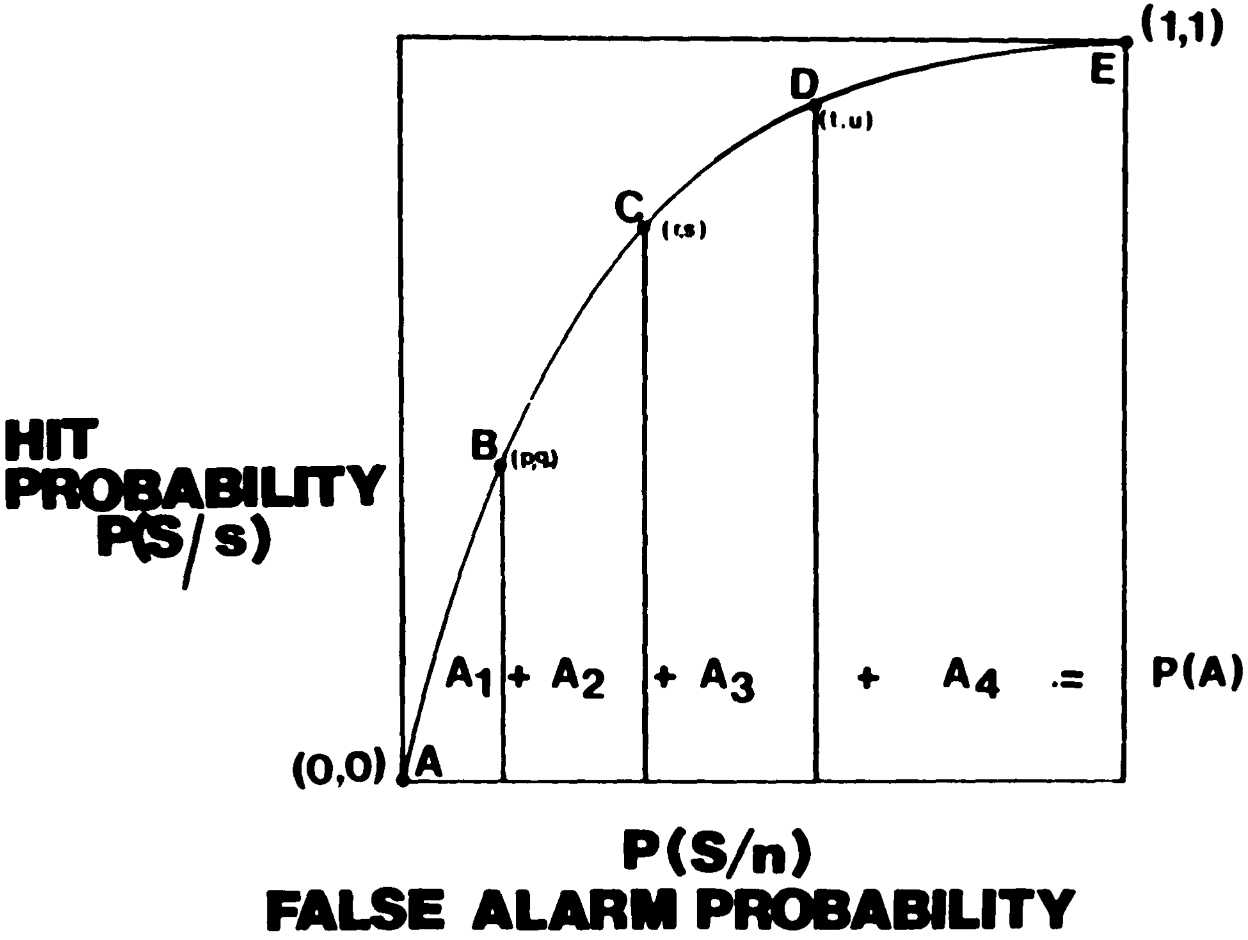
$$P(A)=1/2 \sum_{i=1}^{N+1} [P_i(S/n)-P_{i-1}(S/n)]\ [P_i(S/s)+P_{i-1}(S/s)].$$

3. Response Bias. Unfortunately, there is no equivalent, non-parametric measure that provides as much information as the parametric measure, L_x for response bias. L_x is the height of the signal distribution divided by the height of the noise distribution at a particular criterion. It will be recalled that the ROC curve is isosensitive, i.e. the sensitivity is equal at each criterion. However, the response bias is different at each criterion. L_x can be calculated at each criterion and used to demonstrate a change in bias as a function of changes in the stimulus independent of an unchanged sensitivity. This cannot be done with the non-parametric measure, "B", typically

Figure 5. Figure 5 is adapted from McNicol (1972). It shows the graphic determination of P(A). The areas under each component section of the ROC curve (A_1 - A_4) are summed to give the total area under the curve.

Figure 5.

GRAPHIC DETERMINATION OF P(A)



ADAPTED FROM D. McNICOL. A PRIMER OF SIGNAL DETECTION THEORY.
GEORGE ALLEN & UNWIN LTD. 1972. p 114.

used for response bias in experiments that use a rating or confidence scale because the measure only provides a single, general bias measure. The measure "B" is the rating scale category where the subject is equally disposed to giving awake and asleep reports. It is defined as the rating scale category at which the hit probability and the false alarm probability equal one (McNicol, 1972). In the data from the present study, there was no rating scale category at which the hit and false alarm probabilities equaled one, and therefore, there was no category for which the subjects were equally disposed to responding "asleep" as they were to responding "awake". They were always biased toward responding "awake".

The second non-parametric measure of response bias investigated was a graphic determination (Hodos, 1970) but its utilization was dependent on the ROC curve's criterion points lying symmetrically on either side of the <u>negative</u> diagonal. All ROC curve criteria generated from the present study are skewed to the right of the negative diagonal.

The measure of response bias finally chosen was simply the false alarm probability at a particular criterion (Dusoir, 1975) which would provide a gross estimate of bias for one ROC curve. The criterion chosen was Criterion 3. Referring back to Figure 2, it can be seen that Criterion 3, (C_3), specifies the interval between "Awake, not so sure" and "Asleep, not so sure". This is an arbitrary but reasonable criterion to choose, since it specifies the interval in which the subject's decisions change from "awake" to "asleep".

Since the hit and false alarm probabilities cumulate with each successive criterion, it was the cumulative false alarm probability at Criterion 3 that was used to specify the subject's bias in any particular polygraphic wake-sleep discrimination.

III. RESULTS AND DISCUSSION

Gross Analysis of Sleep Trial Assignment. A total of 375 sleep trials from eleven normal sleepers were collected from 54 experimental nights of study in Experiment 1. There were 210 from Stage 2 sleep, 165 from REM sleep, 185 from the first two NREM/REM sleep cycles, and 190 from the last three NREM/REM sleep cycles. Table 2 presents a breakdown of sleep trial assignment to either the "Awake" or "Asleep" categories by eleven normal sleepers. As a group, subjects assigned 43% of all sleep trials to the Awake categories (positive, pretty sure, and not so sure): 55% of all Stage 2 sleep trials, 27% of all REM sleep trials, 46% of all sleep trials in the first half of the night, and 40% of all sleep trials in the second half of the night.

An additional 204 sleep trials were collected in Experiment 2 during an additional 29 experimental nights of study. Thus, data from a total of 579 sleep trials were collected in Experiments 1 and 2.

Preparation for SDT Analysis. For each subject the data are pooled across all five experimental nights of a condition. For each condition, the following classes of the polygraphic sleep state ("noise") are considered: EEG Sleep (stages 2 and REM combined), EEG Stage (2 or REM), and Time into the sleep period (first two NREM/REM sleep cycles or last three NREM/REM sleep cycles).

1. EEG Sleep. The frequencies with which the EEG wake and EEG sleep trials are assigned to each category of the asleep/awake confidence scale are cumulated for each

TABLE 2

A DETAILED BREAKDOWN OF SLEEP TRIAL ASSIGNMENT BY 11 NORMAL SLEEPERS FOLLOWING THE "NO INFORMATION" CONDITION

	AWAKE CATEGORIES	ASLEEP CATEGORIES	
SLEEP	161 TRIALS (43%)	214 TRIALS (57%)	375 TOTAL
STAGE 2 SLEEP	116 TRIALS (55%)	94 TRIALS (45%)	210 TOTAL
REM SLEEP	45 TRIALS (27%)	120 TRIALS (73%)	165 TOTAL
NREM/REM CYCLES 1 & 2 (S2, REM)	85 TRIALS (46%)	100 TRIALS (54%)	185 TOTAL
NREM/REM CYCLES 3,4,5 (S2, REM)	76 TRIALS (40%)	114 TRIALS (60%)	190 TOTAL

condition. The SDT analysis was performed on an average of 18.5 (.517=SE) EEG wake trials and 34.1 (2.04=SE) EEG sleep trials collected per subject in the no information condition. In the a priori sleep condition, an average of 19.0 (1.23=SE) EEG wake trials and 34.0 (2.55=SE) EEG sleep trials were collected per subject for SDT analysis. In the a priori wake condition, an average of 17.0 (.708=SE) EEG wake trials and 29.7 (5.36=SE) EEG sleep trials were collected per subject. The subject DM, whose experimental series consisted of only four nights per condition, went through the a priori wake condition. Consequently, all of the trial means for the a priori wake condition are slightly lower and show a higher standard error than the no information and a priori sleep information conditions.

2. EEG Stage 2 or REM Sleep. The frequencies with which the EEG Stage 2 or the EEG REM sleep trials are assigned to each category of the asleep/awake confidence scale are cumulated separately to determine sleep-stage effects on the subjective asleep/awake discrimination. An average of 19.1 (.713=SE) EEG Stage 2 and 15.0 (1.46=SE) EEG Stage REM sleep trials were collected for each subject in the no information condition. A mean of 20.3 (.818=SE) EEG Stage 2 and 13.7 (2.86=SE) EEG Stage REM sleep trials were collected for each subject in the a priori sleep condition. In the a priori wake condition, a mean of 17.7 (1.78=SE) EEG Stage 2 and 12.0 (3.68=SE) EEG Stage REM sleep trials were collected from each subject.

3. Time into the Sleep Period. To assess a possible "time of night" effect on sleep perception, the EEG sleep (S2, REM) trials that occur during the first two NREM/REM cycles are combined, and the EEG sleep trials that occur during the third, fourth, and fifth NREM/REM cycles are combined for a separate SDT analysis. A mean of 16.8 (.968=*SE*) sleep trials from NREM/REM cycles 1 & 2 and 17.3 (1.36=*SE*) sleep trials from NREM/REM cycles 3,4 & 5 were collected for each subject in the no information condition. An average of 17.7 (1.47=*SE*) sleep trials per subject and 16.3 (2.28=*SE*) sleep trials per subject were collected from NREM/REM cycles 1 & 2 and NREM/REM cycles 3,4 & 5, respectively, in the a priori sleep condition. And, in the a priori wake condition, a mean of 13.7 (2.16=*SE*) sleep trials per subject and 16.0 (3.75=*SE*) sleep trials per subject were collected from NREM/REM cycles 1 & 2 and NREM/REM cycles 3,4 & 5, respectively.

4. The Five Classes of "Noise" (the Polygraphic Sleep State). The subjective assignment of the EEG wake trials to each of the six categories of the confidence scale, pooled over the five experimental nights of a condition, yields the cumulative HIT probabilities at each of five criteria. The subjective assignment of the EEG sleep, stage, or time trials, to each of the six categories of the confidence scale, pooled over the five experimental nights of a condition, yields the cumulative FALSE ALARM probabilities at each of five criteria. Table 3 presents the HIT and FALSE

TABLE 3

RECEIVER OPERATING CHARACTERISTICS (ROCs) DERIVED FROM EACH CONDITION FOR EACH SUBJECT

ROC CURVE	"SIGNAL (+ NOISE)"	"NOISE"
1	EEG Wake	EEG Sleep (Stages 2 & REM combined)
2	EEG Wake	EEG Stage 2 Sleep
3	EEG Wake	EEG Stage REM Sleep
4	EEG Wake	EEG Sleep NREM/REM Cycles 1 & 2 (S2 & REM)
5	EEG Wake	EEG Sleep NREM/REM Cycles 3,4 & 5 (S2 & REM)

ALARM combinations analyzed. For each subject in each condition, separate sensitivity (discrimination) and response bias calculations are generated for the following five categories of "noise": EEG sleep (S2 and REM), EEG Stage 2 sleep, EEG Stage REM sleep, EEG sleep NREM/REM cycles 1 & 2 (S2 and REM), and EEG sleep NREM/REM cycles 3,4 & 5 (S2 and REM). The same subjective assignment of the EEG wake trials is used as HITS for each class of the polygraphic sleep state (FALSE ALARMS). Group and individual (example) five-point ROC curves are constructed for each class of the polygraphic sleep state in each condition.

Mean P(A)s and Group ROC Curves for Each Condition. Table 4 presents the mean discriminability indices, P(A), for each condition and class of the polygraphic sleep state. Notice the very small standard error of the means for each condition but especially for the no information condition. The small standard errors stress the stability of the P(A) statistic across different subjects, i.e. the subjects used very similar strategies in discriminating EEG wakefulness from different classes of polygraphic sleep. Furthermore, EEG sleep-wake discriminations consistently changed in the predicted direction as a function of a priori instruction set and limited performance feedback, i.e. EEG sleep-wake discrimination improved with a priori sleep information for all classes of polygraphic sleep and deteriorated with a priori wake information for all classes of polygraphic sleep. There is probably a "floor" and "ceiling" to the change in discrim-

TABLE 4

THE ABILITY TO DISCRIMINATE BETWEEN SLEEP AND WAKEFULNESS - MEAN SENSITIVITY INDICES, P(A), FOR EACH INFORMATION CONDITION

	NO INFORMATION CONDITION				
	W-S	W-S2	W-REM	W-C1&2	W-C3,4,5
N = 11					
MEAN P(A)	0.86	0.82	0.91	0.84	0.87
STANDARD ERROR OF THE MEAN	0.01	0.01	0.02	0.02	0.02

	A PRIORI SLEEP INFORMATION CONDITION				
	W-S	W-S2	W-REM	W-C1&2	W-C3,4,5
N = 3					
MEAN P(A)	0.90	0.86	0.97	0.90	0.90
STANDARD ERROR OF THE MEAN	0.03	0.04	0.04	0.06	0.02

	A PRIORI WAKE INFORMATION CONDITION				
	W-S	W-S2	W-REM	W-C1&2	W-C3,4,5
N = 3					
MEAN P(A)	0.78	0.74	0.83	0.79	0.76
STANDARD ERROR OF THE MEAN	0.02	0.02	0.02	0.02	0.06

Note. W = wake; S = sleep (S2,REM); S2 = Stage 2 sleep; REM = REM sleep; C1&2 = NREM/REM cycles 1&2 (S2,REM); C3,4,5 = NREM/REM Cycles.3,4,5 (S2,REM).

ination that can be induced by a priori information in the normal sleeper as evidenced again by the small variability in individual subject P(A) measures.

Table 4A presents correlated _t_-tests on the mean P(A) measures in Table 4 for each condition. The correlated _t_-tests statistically analyze the significance of the obtained EEG sleep-wake discriminations from chance EEG sleep-wake discrimination. Prior to statistical testing, each P(A) measure was transformed by the angular transformation, 2 arcsin $\sqrt{P(A)}$ (McNicol, 1972; Kirk, 1968). The angular transformation is recommended for data expressed as proportions because proportional data tend to be skewed at the upper end of the distribution and this transformation normalizes that part of the distribution. Since the correlated _t_-test tests the difference of a mean of a group of scores from zero, the angular transformation for a P(A) = .500; a distance of zero (d′=0) or chance discrimination between the signal and noise distribution means (see Figure 4), was subtracted from each obtained and transformed, P(A) score before being entered into the equation. In other words, in the present situation the correlated _t_-test is being used to test the difference of the obtained mean P(A) scores from a P(A) = .500. As expected, all, except two, correlated _t_-tests show a significant ability to discriminate EEG sleep from EEG wakefulness in all conditions and for all classes of polygraphic sleep even though this discriminability has a moderate level of uncertainty built into it as well. The

TABLE 4A

CORRELATED T-TESTS TO TEST THE DIFFERENCE OF THE MEAN P(A) SCORES FROM CHANCE OR ZERO DISCRIMINATION

NO INFORMATION CONDITION

W-S	W-S2	W-REM	W-C1&2	W-C3,4,5
t=6.67	t=5.85	t=3.82	t=4.15	t=5.52
df=10	*df*=10	*df*=10	*df*=10	*df*=10
p<.0005	*p*<.0005	*p*<.005	*p*<.005	*p*<.0005

A PRIORI SLEEP

W-S	W-S2	W-REM	W-C1&2	W-C3,4,5
t=6.57	t=6.58	t=4.16	t=3.25	t=7.65
df=2	*df*=2	*df*=2	*df*=2	*df*=2
p<.025	*p*<.025	*p*<.05	*p*<.05	*p*<.01

A PRIORI WAKE

W-S	W-S2	W-REM	W-C1&2	W-C3,4,5
t=5.87	t=7.18	t=0	t=8.73	t=2.57
df=2	*df*=2	*df*=2	*df*=2	*df*=2
p<.025	*p*<.01	*n.s.*	*p*<.01	*n.s.*

Note. All alpha rejection levels are for a one-tailed test.

two cases where the correlated t-test does not reach significance are both in the a priori wake condition. Although EEG sleep-wake discriminability deteriorated in this condition, the obtained P(A)s still reflect a moderate degree of discriminability. The reasons for two of them not reaching statistical significance can be traced to the increased variability present between individual P(A) scores and the minimal degrees of freedom.

Although no systematic study of slow wave sleep (Stages 3-4) perception is formally designed into the rpesent study, it turns out that a total of thirteen slow wave sleep trials were collected from six normal sleepers in the no information condition (Experiment 1) as either errors or out of curiosity. Ten or 77% of the trials were assigned to the "Awake" categories while only 3 of the thirteen or 23% were assigned to the "Asleep" categories. All thirteen slow wave sleep trials came from the first two hours of the sleep period. A gross SDT analysis was performed on the data combining all of the EEG wake trials associated with the slow wave sleep trials, i.e. the EEG wake trials from six subjects. The P(A) thus generated equals 0.652 and the cumulative false alarm probability at criterion 3 is 0.769. Although the generated P(A) is considerably lower than the mean P(A) (Table 4) for the discrimination of EEG wake from EEG stage 2 sleep in the no information condition, it is closer to the perception (discrimination) out of NREM stage 2 sleep than to the perception out of REM sleep. Clearly, nothing more can be said about such a gross, unsystematic analysis of slow wave sleep perception except to sugget that it is poor and somewhat similar to stage 2 sleep perception in the first two hours of the sleep period.

Group ROC curves were generated for each condition to provide a general idea of the shapes of the curves. Figures 6-11 show the group ROC curves for each information condition and for each class of polygraphic sleep. Thus, there are five ROC curves for each condition. All curves were generated by taking the mean of the _z_-score for each hit and false alarm probability at each criterion; not by taking the mean of the hit and false alarm probabilities at each criterion which tends to underestimate the curve (McNicol, 1972). Notice that the ROC curves in Figures 6 and 7 for the no information condition cover less of an area in the unit squares than the ROC curves in Figures 8 and 9 from the a priori sleep condition. While the ara under the ROC curves in Figures 10 and 11 for the a priori wake condition is visually slightly less than the area under the ROC curves in Figures 6 and 7 from the no information condition. These area relationships are the same area relationships quantitatively expressed in Table 4 as mean P(A) scores and are here expressed graphically in the form of ROC curves.

<u>Mean P(S/n)s, Response Bias, for Each Condition</u>. Table 5 shows the mean, cumulative false alarm probabilities (P(S/n), at criterion 3 for each information condition. Criterion 3 specifies the decision interval between Categories

Figures 6 and 7. General shapes of the ROC curves for EEG wake and five classes of polygraphic sleep in the no information condition. The curves are based on a mean of eleven sets of hit and false alarm *z*-scores for each criterion. The final mean *z*-scores are then reconverted into probabilities so that they can be plotted.

Figure 6.
GROUP AVERAGE ROC CURVES (N=11) FOR THE NO INFORMATION CONDITION

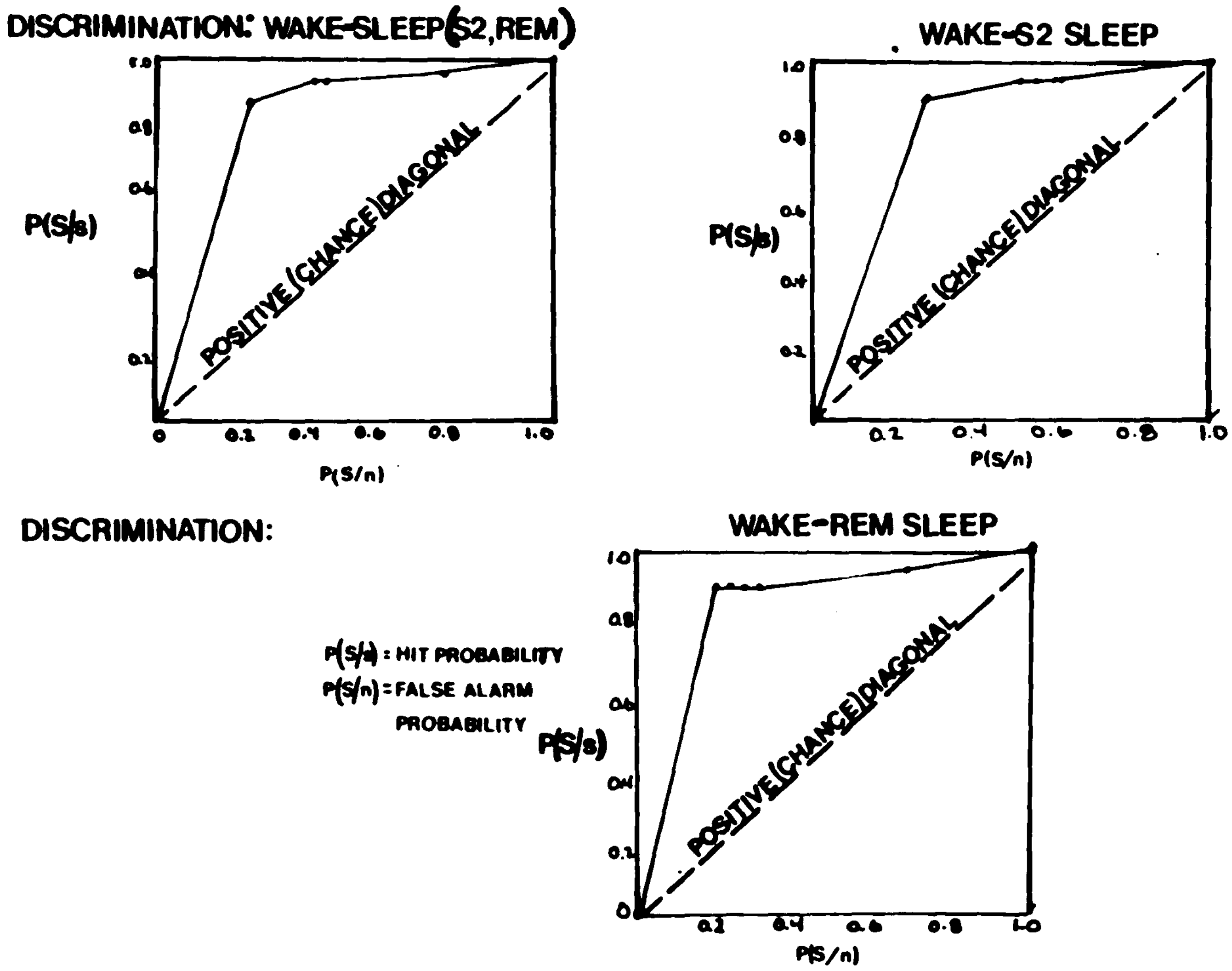
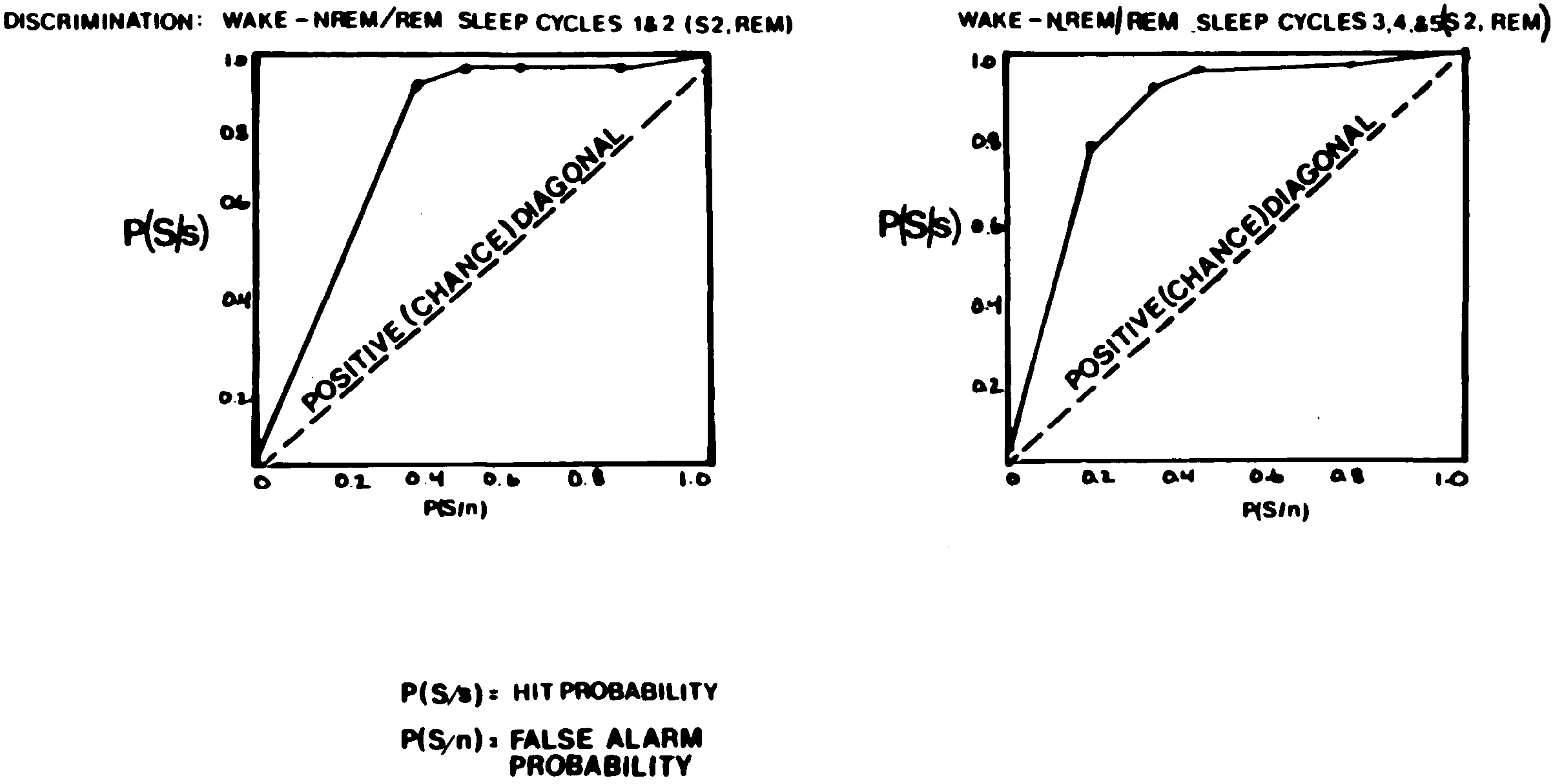


Figure 7.

GROUP AVERAGE ROC CURVES(N=11) FOR THE NO INFORMATION CONDITION



Figures 8 and 9. General shapes of the ROC curves for EEG wake and five classes of polygraphic sleep in the a priori sleep condition. The curves are based on a mean of three sets of hit and false alarm _z_-scores for each criterion. The final mean _z_-scores are then reconverted into probabilities so that they can be plotted.

Figure 8.

GROUP AVERAGE ROC CURVES(N=3)FOR THE A PRIORI SLEEP CONDITION

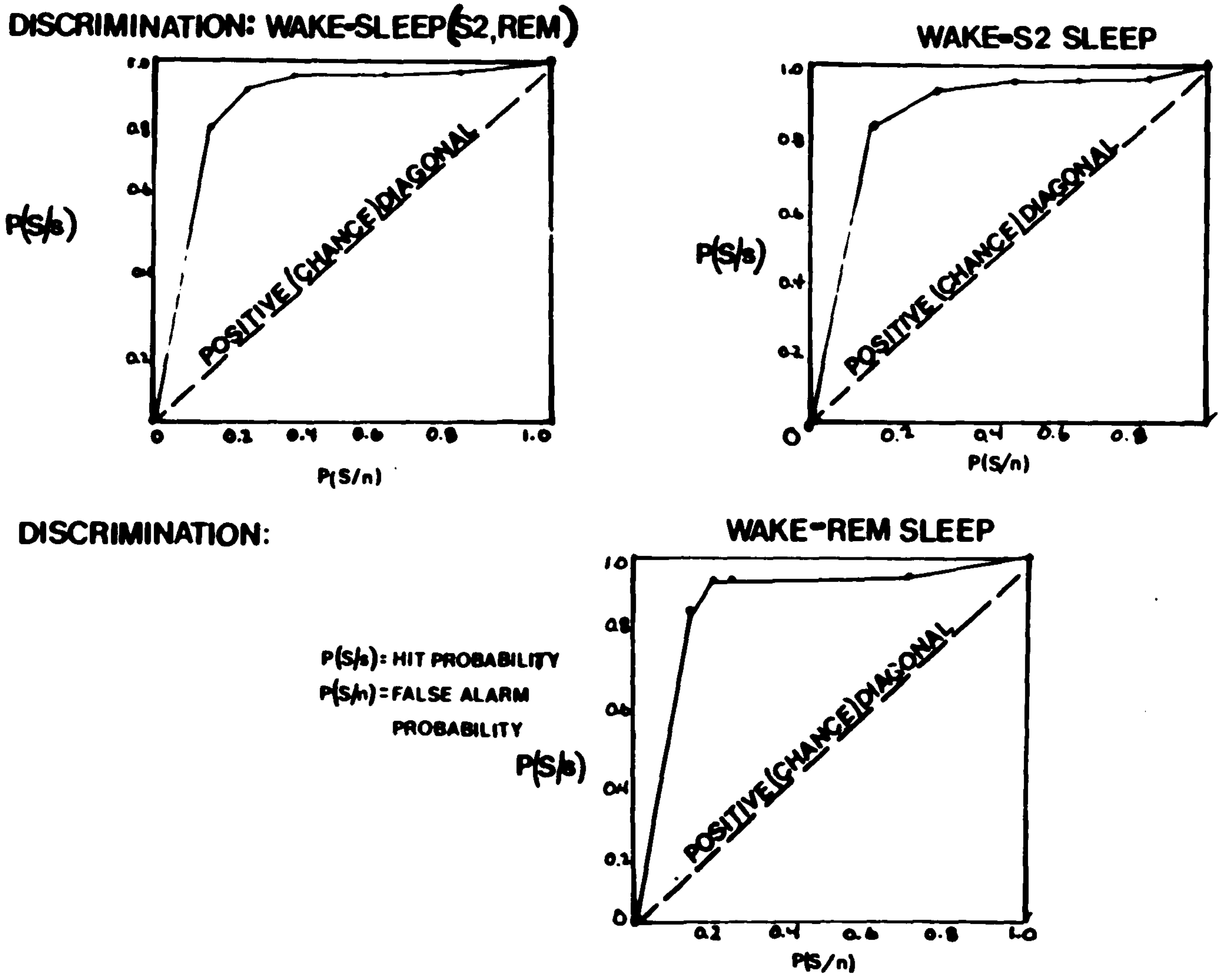
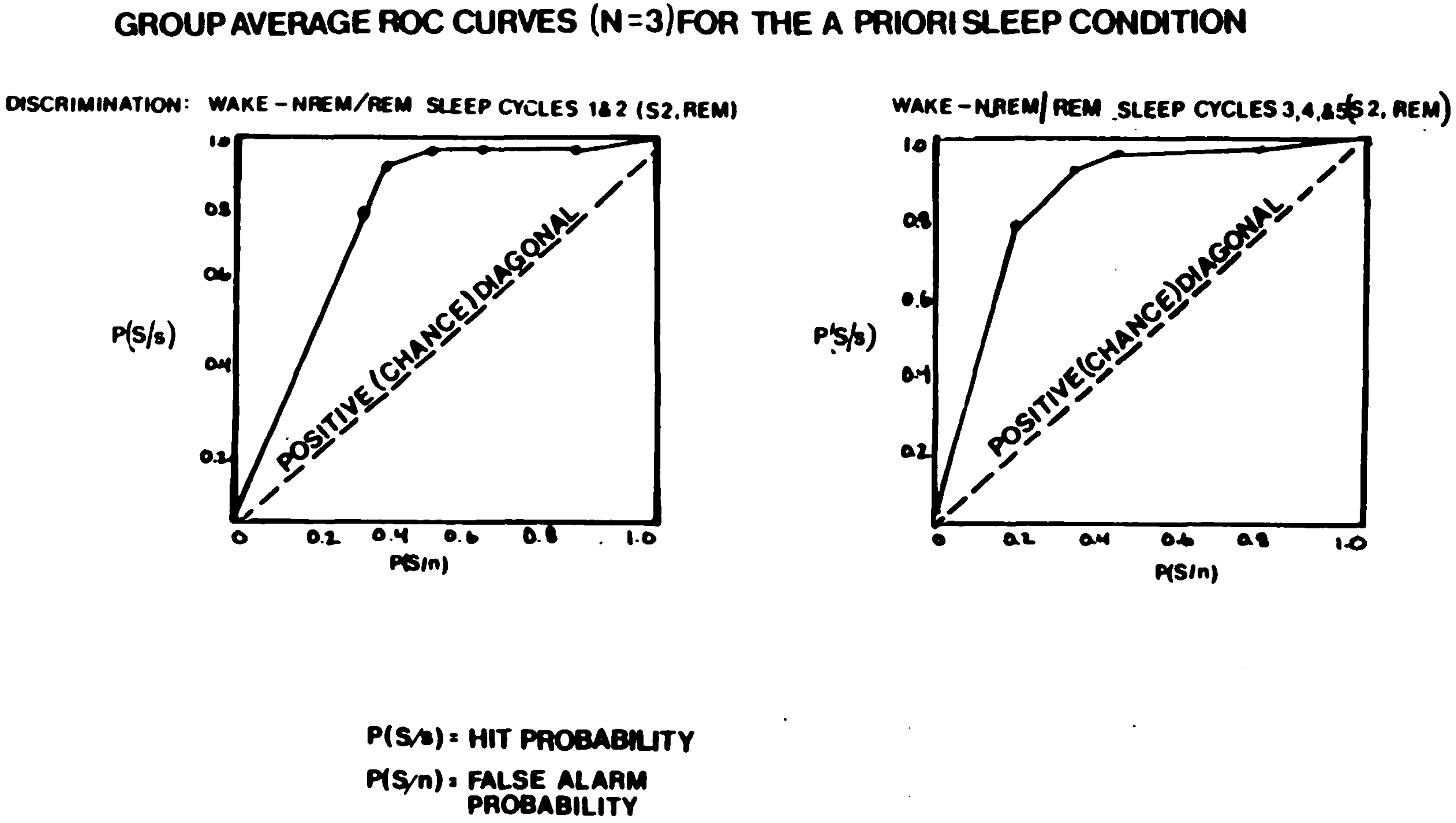
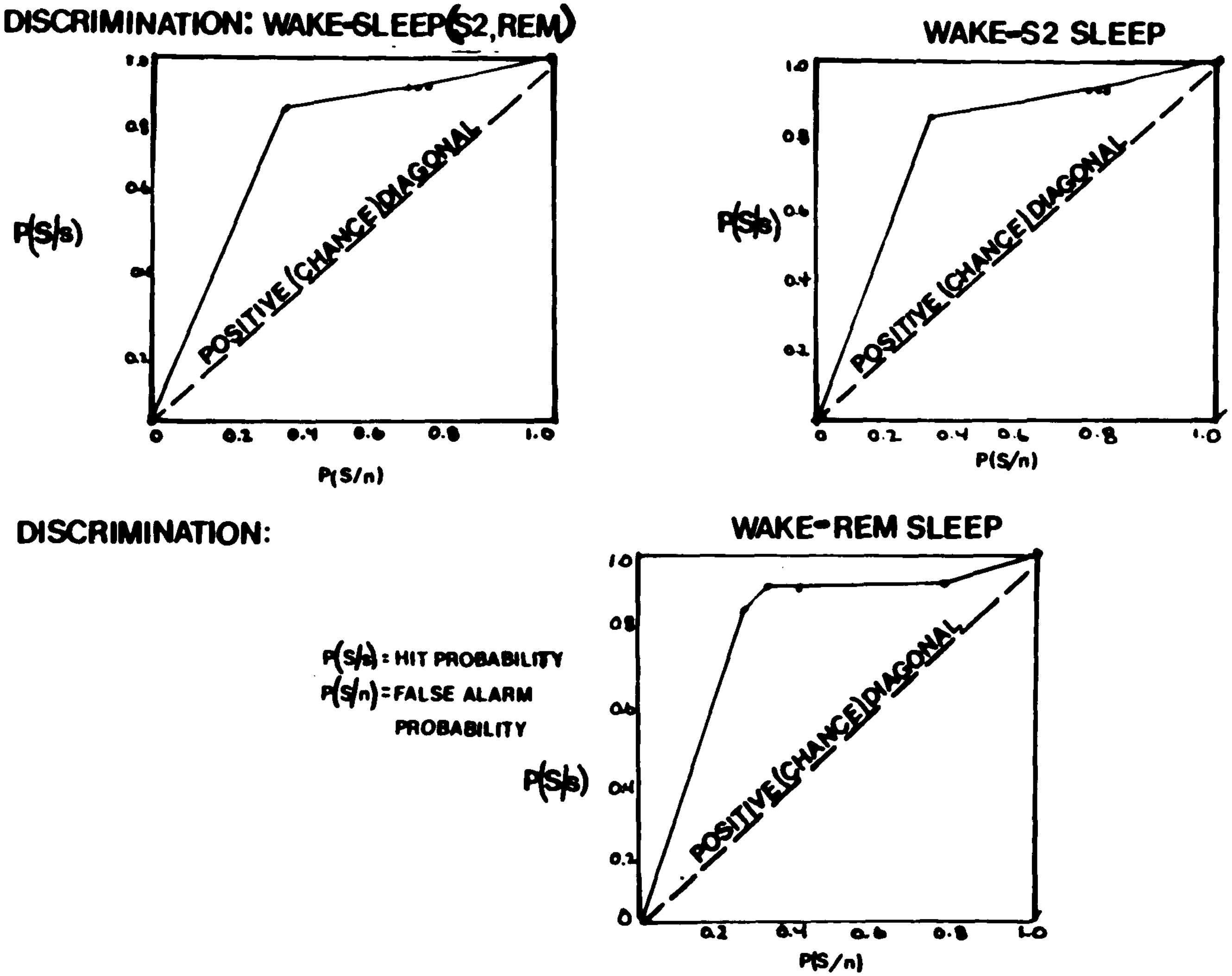


Figure 9.


GROUP AVERAGE ROC CURVES (N=3) FOR THE A PRIORI SLEEP CONDITION
DISCRIMINATION: WAKE-NREM/REM SLEEP CYCLES 1&2 (S2, REM)
WAKE-NREM/REM SLEEP CYCLES 3,4,&5 (S2, REM)
P(S/s)
P(S/n)
0
0.2
0.4
0.6
0.8
1.0
POSITIVE (CHANCE) DIAGONAL
P(S/s) = HIT PROBABILITY
P(S/n) = FALSE ALARM PROBABILITY

Figures 10 and 11. General shapes of the ROC curves for EEG wake and five classes of polygraphic sleep in the a priori wake condition. The curves are based on a mean of three sets of hit and false alarm *z*-scores for each criterion. The final mean *z*-scores are then reconverted into probabilities so that they can be plotted.

Figure 10.
GROUP AVERAGE ROC CURVES(N=3)FOR THE A PRIORI WAKE CONDITION



DISCRIMINATION: WAKE-SLEEP(S2,REM)

WAKE-S2 SLEEP

DISCRIMINATION: WAKE-REM SLEEP

Figure 11.

GROUP AVERAGE ROC CURVES (N=3) FOR THE A PRIORI WAKE CONDITION

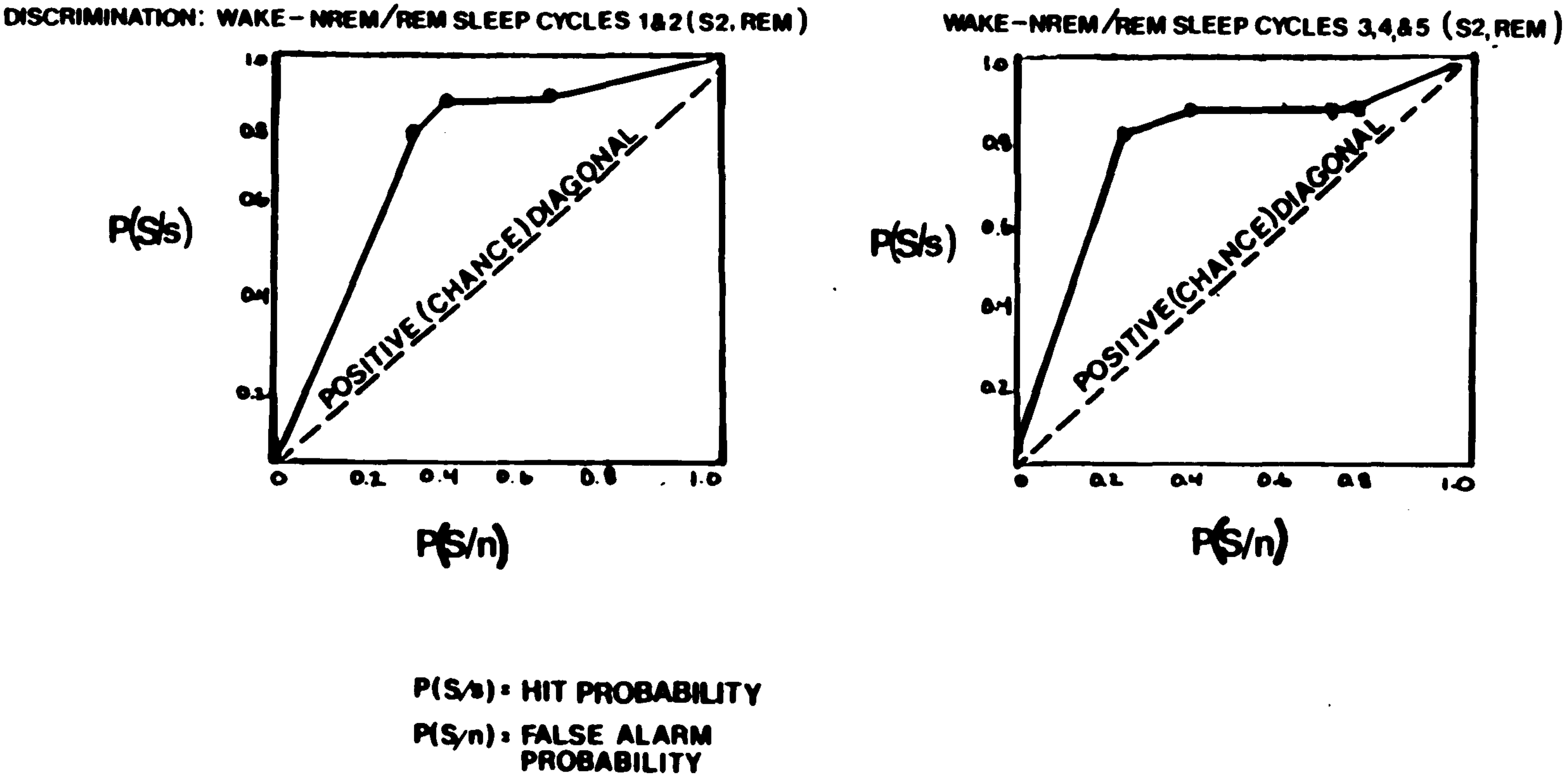


TABLE 5

RESPONSE BIAS INVOLVED IN SLEEP - WAKE DISCRIMINATIONS - MEAN P(S/n) FOR THE INTERVAL BETWEEN CATEGORIES 3 & 4

NO INFORMATION CONDITION

	W-S	W-S2	W-REM	W-C1&2	W-C3,4,5
N = 11					
MEAN P(S/n)	0.44	0.56	0.28	0.47	0.40
STANDARD ERROR OF THE MEAN	0.04	0.04	0.05	0.05	0.05

A PRIORI SLEEP INFORMATION CONDITION

	W-S	W-S2	W-REM	W-C1&2	W-C3,4,5
N = 3					
MEAN P(S/n)	0.38	0.58	0.10	0.37	0.40
STANDARD ERROR OF THE MEAN	0.08	0.07	0.13	0.07	0.14

A PRIORI WAKE INFORMATION CONDITION

	W-S	W-S2	W-REM	W-C1&2	W-C3,4,5
N = 3					
MEAN P(S/n)	0.55	0.62	0.44	0.53	0.58
STANDARD ERROR OF THE MEAN	0.16	0.16	0.14	0.12	0.20

Note. W = wake; S = sleep (S2,REM); S2 = Stage 2 sleep; REM = REM sleep; C1&2 = NREM/REM cycles 1&2 (S2,REM); C3,4,5 = NREM/REM Cycles 3,4,5 (S2,REM).

3 and 4 on the Rating Scale, i.e. "Awake, not so sure" and "Asleep, not so sure." The response bias measures, in the form of mean cumulative false alarm probabilities, show a consistent change in the predicted direction as a function of a priori instruction set in all but two cases. Both cases are from the a priori sleep information condition where the mean false alarm probability went up instead of down for the EEG wake - EEG stage 2 sleep discrimination and remained the same for the EEG wake - EEG sleep NREM/REM cycles 3,4, and 5 discrimination in comparison with the no a priori information condition. However, generally, as predicted the mean false alarm probabilities decreased in the a priori sleep information condition and increased in the a priori wake information condition. Unlike the sensitivity/discrimination data which are associated with very small standard errors of the means and, therefore, a small intersubject variability, the mean false alarm probabilities have higher standard errors and, therefore, higher variability between individual subject false alarm probabilities particularly for the a priori wake information condition.

<u>Individual P(A) scores for the No A Priori Information Condition, T-Tests for Related Measures, ROC Curves for One Normal Sleeper and A Posteriori Functions for Each Normal Sleeper in the No Information Condition</u>. Table 6 presents the individual P(A) scores for eleven normal sleepers and one insomniac. Only the P(A) scores of the normal sleepers are used in statistical tests. Following an angular trans-

TABLE 6

P(A) MEASURES FOR ALL SUBJECTS IN THE "NO INFORMATION" CONDITION

Ss	WAKE-SLEEP	WAKE-STAGE 2	WAKE-REM	WAKE-CYCLES 1,2	WAKE-CYCLES 3,4,5
MD	.86	.81	.89	.83	.87
SV	.80	.82	.79	.79	.82
YR	.88	.80	.98	.85	.91
BS	.87	.80	.94	.82	.93
PC	.92	.91	.94	.96	.88
HG	.89	.83	1.00	.90	.89
SB	.85	.83	.87	.81	.89
KS	.77	.75	.82	.82	.73
DM	.84	.77	.96	.73	.91
BZ[a]	.90	.86	.94	.89	.90
AA[a]	.86	.80	.92	.84	.87
RB(Insomniac)	.76	.56	.97	.75	.77

[a] P(A) point estimates at criterion 3.

formation, a t-test for related measures was performed on the discrimination out of REM sleep versus the discrimination out of Stage 2 sleep and on the discrimination out of the first two NREM/REM sleep cycles of the night versus the last three NREM/REM sleep cycles of the night. There was a significant effect on discrimination as a function of sleep stage but not as a function of time into the sleep period. EEG wake - EEG stage REM sleep discrimination is significantly better, $t(10) = 4.10$, $p<.01$, than EEG wake - EEG stage 2 sleep discrimination. However, EEG wake - EEG sleep NREM/REM cycles 1 and 2 discrimination does not differ significantly from EEG wake - EEG sleep NREM/REM cycles 3,4, and 5 discrimination, $t(10) = 1.17$, n.s.

Figures 12 and 13 depict the ROC curves of one normal sleeper for the discriminations between EEG wakefulness and the five classes of polygraphic sleep. Since the shapes of the ROC curves for all eleven of the normal sleepers are similar, one subject's curves were randomly selected as typical examples.

A double probability plot of the ROC curve for the discrimination of EEG wakefulness from EEG sleep (stage 2 and REM) is presented for two reasons. First, it shows whether the underlying EEG wake and EEG sleep distributions are Gaussian and second, it permits an analysis of the variance of the EEG wake distribution with respect to that of the EEG sleep distribution. The double probability plot of the EEG wake - EEG sleep discrimination for this subject

Figures 12 and 13. Individual ROC curves are presented for the normal sleeper, SB. The ROC curves depict the discriminability of EEG wakefulness from five clases of polygraphic sleep. Included in Figure 12 is the double probability plot of EEG wake - EEG sleep discrimination.

Figure 12.

INDIVIDUAL ROC CURVES FOR ONE SUBJECT FROM THE "NO INFORMATION" CONDITION

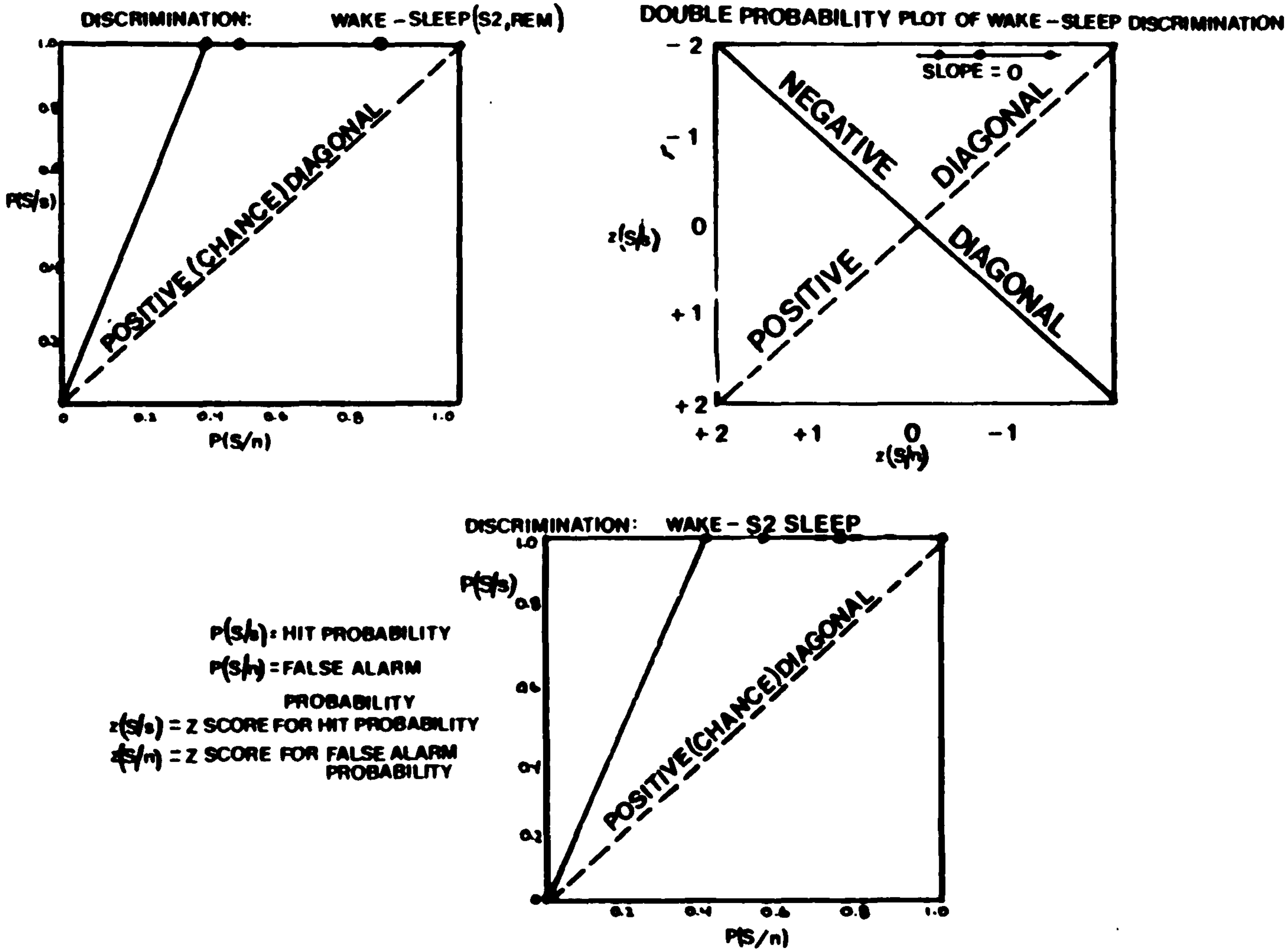
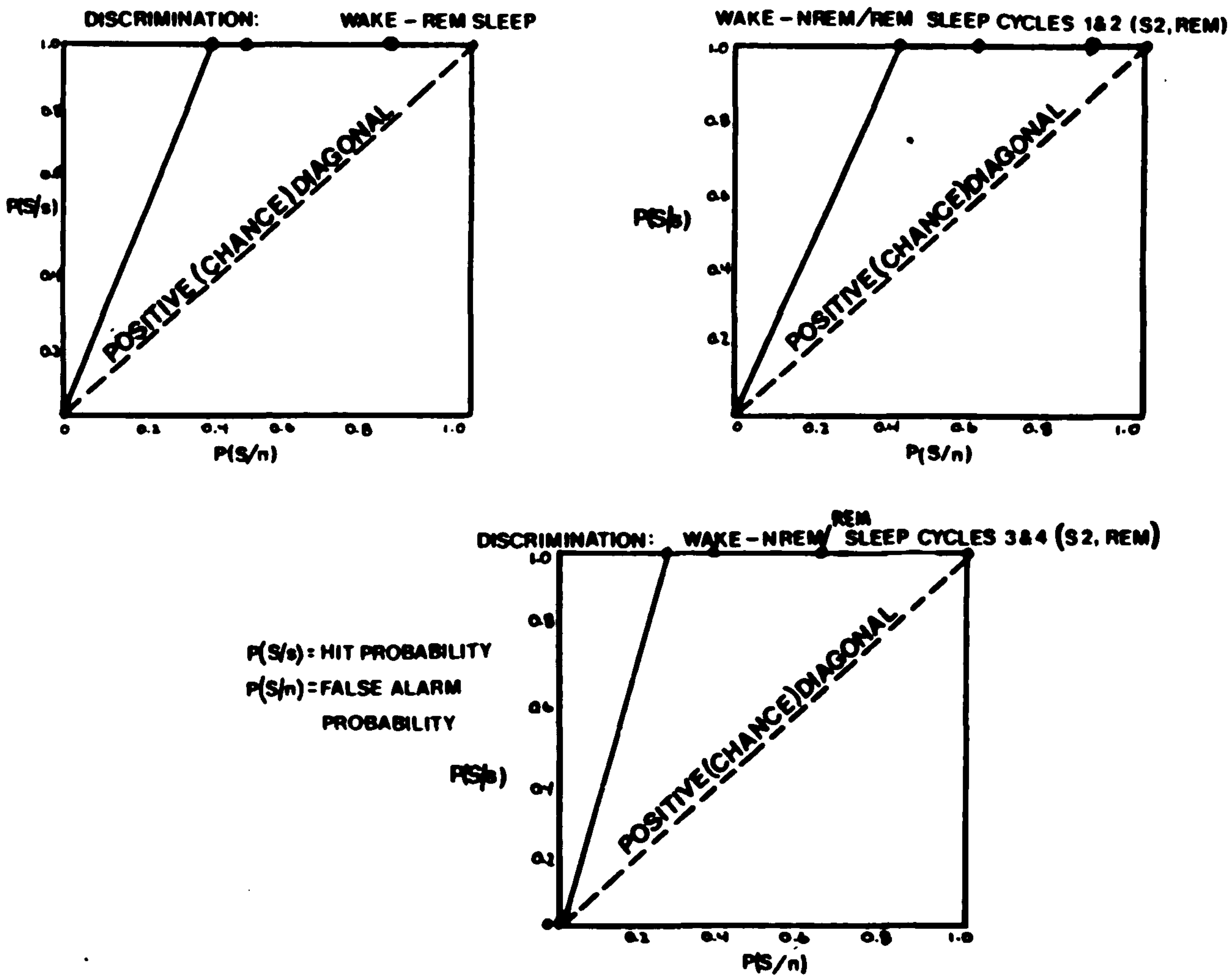


Figure 13.

INDIVIDUAL ROC CURVES FOR ONE SUBJECT FROM THE "NO INFORMATION" CONDITION



(Figure 12) is a straight, horizontal line with a slope of zero. The fact that the plot is linear demonstrates that the underlying EEG wake and EEG sleep distributions are normal (Gaussian). The slope of this line suggests no change or distance along the x-axis of the signal (EEG wake) distribution for every one standard deviation unit of distance along the x-axis of the noise (EEG sleep) distribution, i.e. zero increase in z(S/s) is related to an increase of one in z(S/n). Thus, there is no variance associated with the EEG wake distribution compared to a considerable variance associated with the EEG sleep distribution for this subject's discrimination process.

The eleven normal sleepers exhibit two types of linear double probability plots with slopes of zero (horizontal line) of a slope greater than one. Seven subjects have horizontal, double probability plots and one subject has a line, fitted by eye, witha slope greater than one. In both cases the underlying EEG wake and EEG sleep distributions are Gaussian and the variances are unequal with the variance of the EEG sleep distribution the only variance, in the case of a horizontal line, and the variance of the EEG sleep distribution greater than the variance of the EEG wake distribution in the case of the line with a slope greater than one. Three of the normal sleepers exhibit a third double probability plot which is linear (horizontal) except for one point. Examples of the alternate doublt probability plots can be found in Figures 19 and 21 to be discussed later.

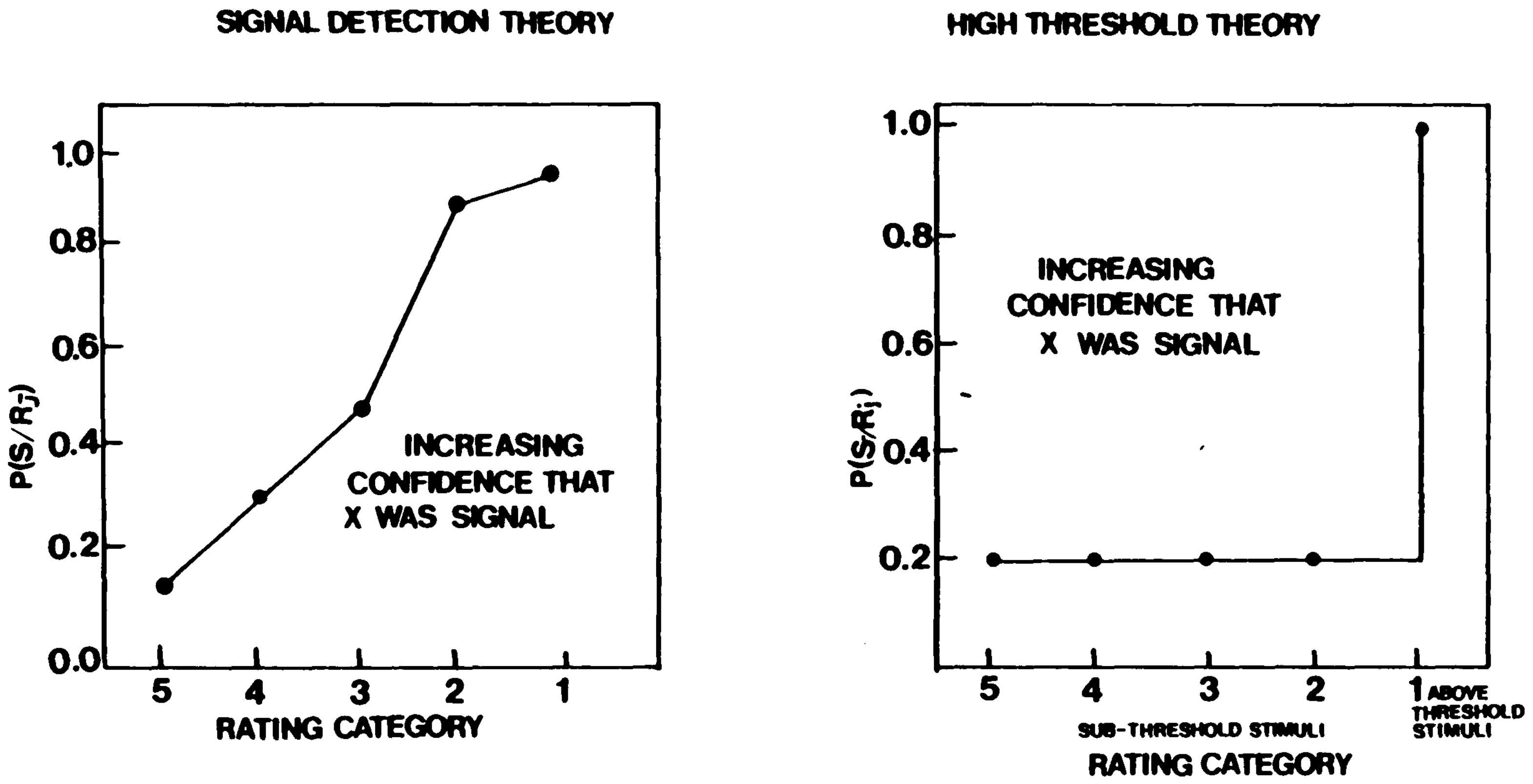
The a posteriori functions depicted by SDT versus high threshold theory are presented in Figure 14. SDT predicts that for each successive rating scale category, there should be an increased level of confidence that a stimulus is a signal, i.e. an increased probability. In terms of the present study, SDT predicts that the sleeper should show an increasing confidence with each successive rating scale category that a trial is EEG wakefulness. Thus, SDT predicts a monotonically increasing function with each successive rating scale category. In contrast, high threshold theory predicts that all rating scale categories except "signal, positive" are below threshold and, therefore, assignment to these categories should be random and low, while anything above threshold should be perceived 100% of the time, i.e. no false alarms.

The a posteriori functions generated by eleven normal sleepers in Experiment 1, the no information condition, are presented for the general discrimination of EEG wakefulness from EEG sleep (stage 2 and REM combined) in Figures 15-18. A glance through Figures 15-18 illustrates the close similarity of many of the a posteriori functions to the high threshold theory although, in no instance, are any of these functions exactly what is predicted by high threshold theory. None of the a posteriori functions generated by the normal sleepers in the present study contain a rating scale category devoid of false alarms which is exactly what is necessary to achieve a rating scale category with 100%

Figure 14. The a posteriori functions predicted by SDT versus high threshold theory are redrawn from McNicol (1972). P(s/Rj) is the probability of hits divided by the total number of responses assigned to a particular rating category.

Figure 14.

A POSTERIORI FUNCTIONS PREDICTED BY SIGNAL DETECTION VERSUS HIGH THRESHOLD THEORY



ADAPTED FROM D. McNICOL. A PRIMER OF SIGNAL DETECTION THEORY
GEORGE ALLEN & UNWIN LTD. 1972 pp 169 & 173

Figure 15. A posteriori functions for the subjects KS and DM from the _no_ a priori information condition.

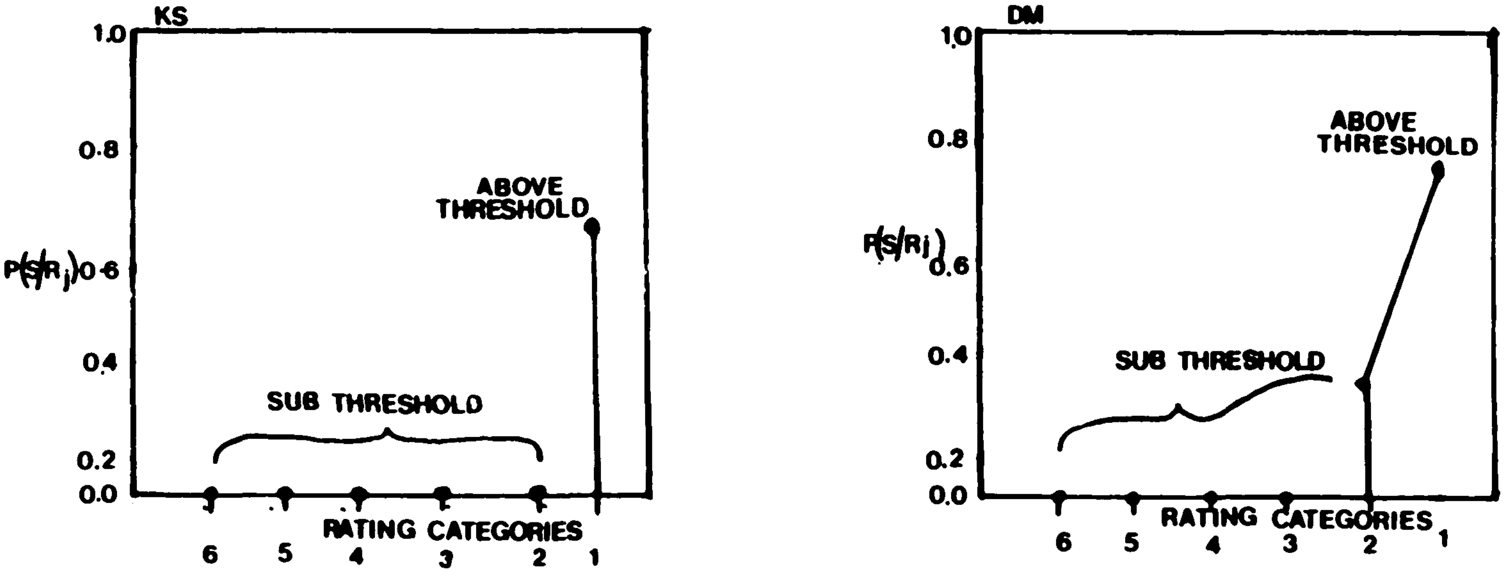
Figure 16. A posteriori functions for the subjects MD, SV, and BS, from the _no_ a priori information condition.

Figure 17. A posteriori functions for the subjects YR, BZ, and AA, from the _no_ a priori information condition.

Figure 18. A posteriori functions for the subjects HG, PC, and SB, from the _no_ a priori information condition.

Figure 15.

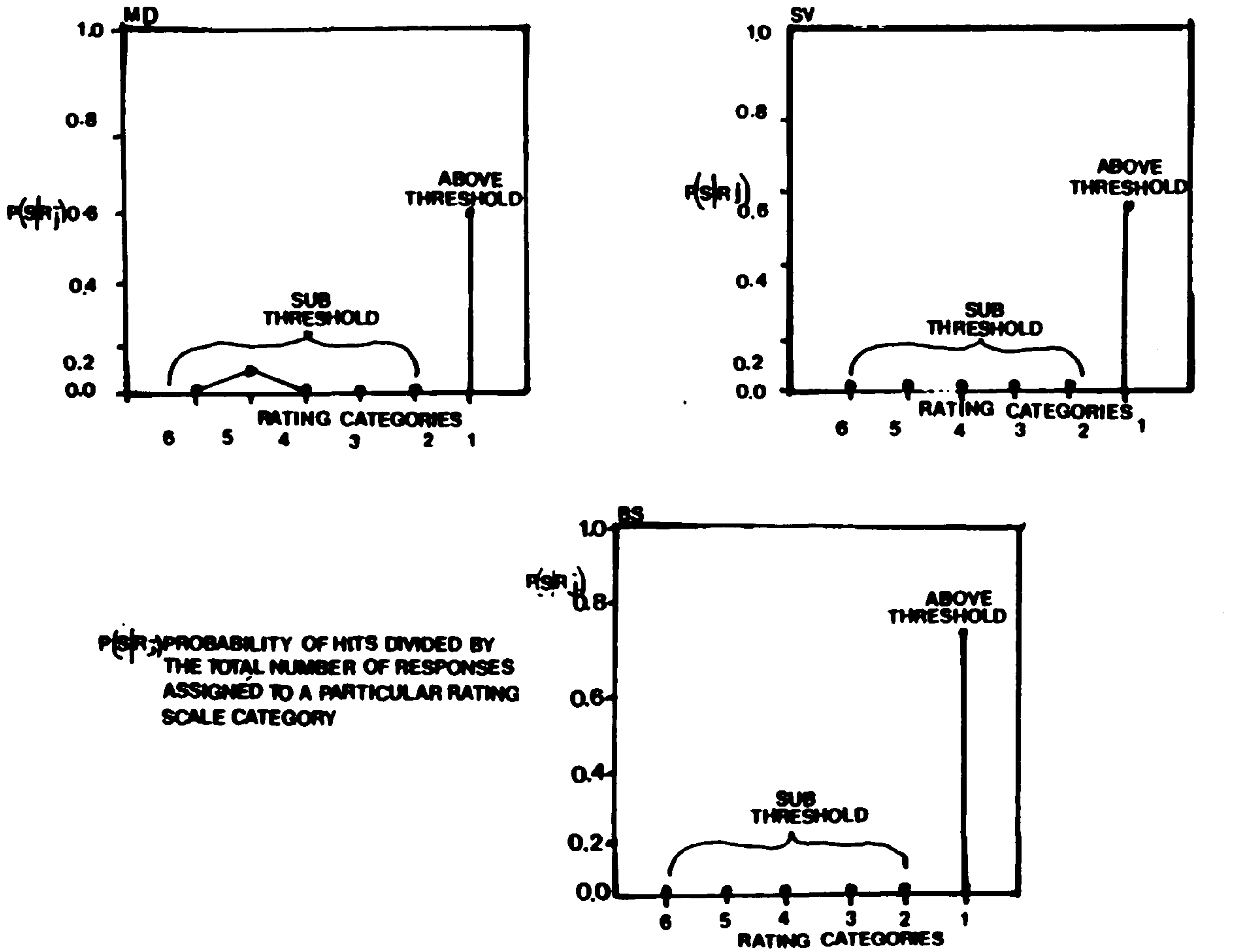
A POSTERIORI FUNCTION FOR EACH NORMAL SLEEPER DEPICTING THE DISCRIMINATION BETWEEN POLYGRAPHIC WAKEFULNESS AND SLEEP (S2, REM)



$P(S/R_j)$ PROBABILITY OF HITS DIVIDED BY THE TOTAL NUMBER OF RESPONSES ASSIGNED TO A PARTICULAR RATING SCALE CATEGORY

Figure 16.

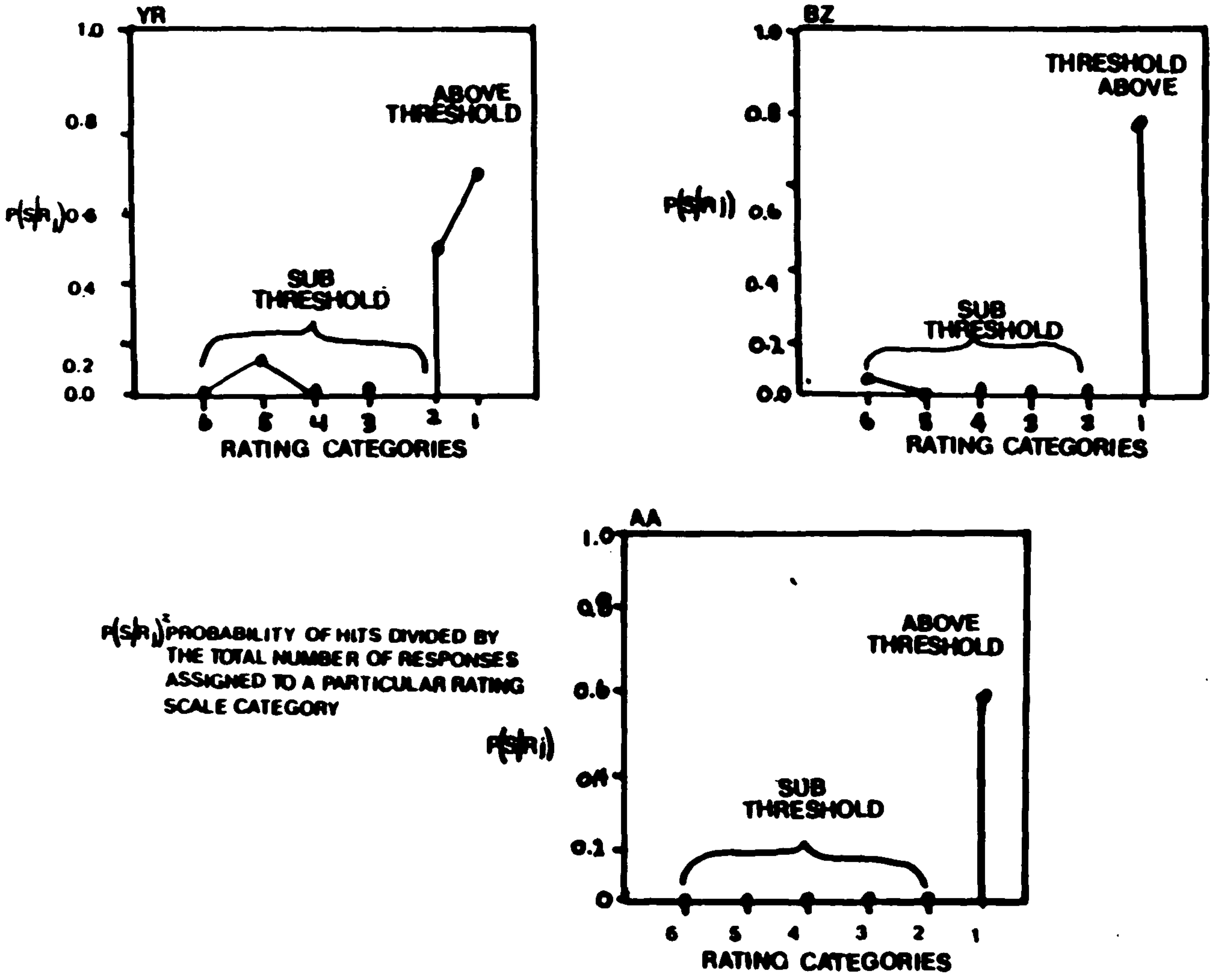
A POSTERIORI FUNCTION FOR EACH NORMAL SLEEPER DEPICTING THE DISCRIMINATION BETWEEN POLYGRAPHIC WAKEFULNESS AND SLEEP (S2, REM)



$P(S|R_j)$ PROBABILITY OF HITS DIVIDED BY THE TOTAL NUMBER OF RESPONSES ASSIGNED TO A PARTICULAR RATING SCALE CATEGORY

Figure 17.

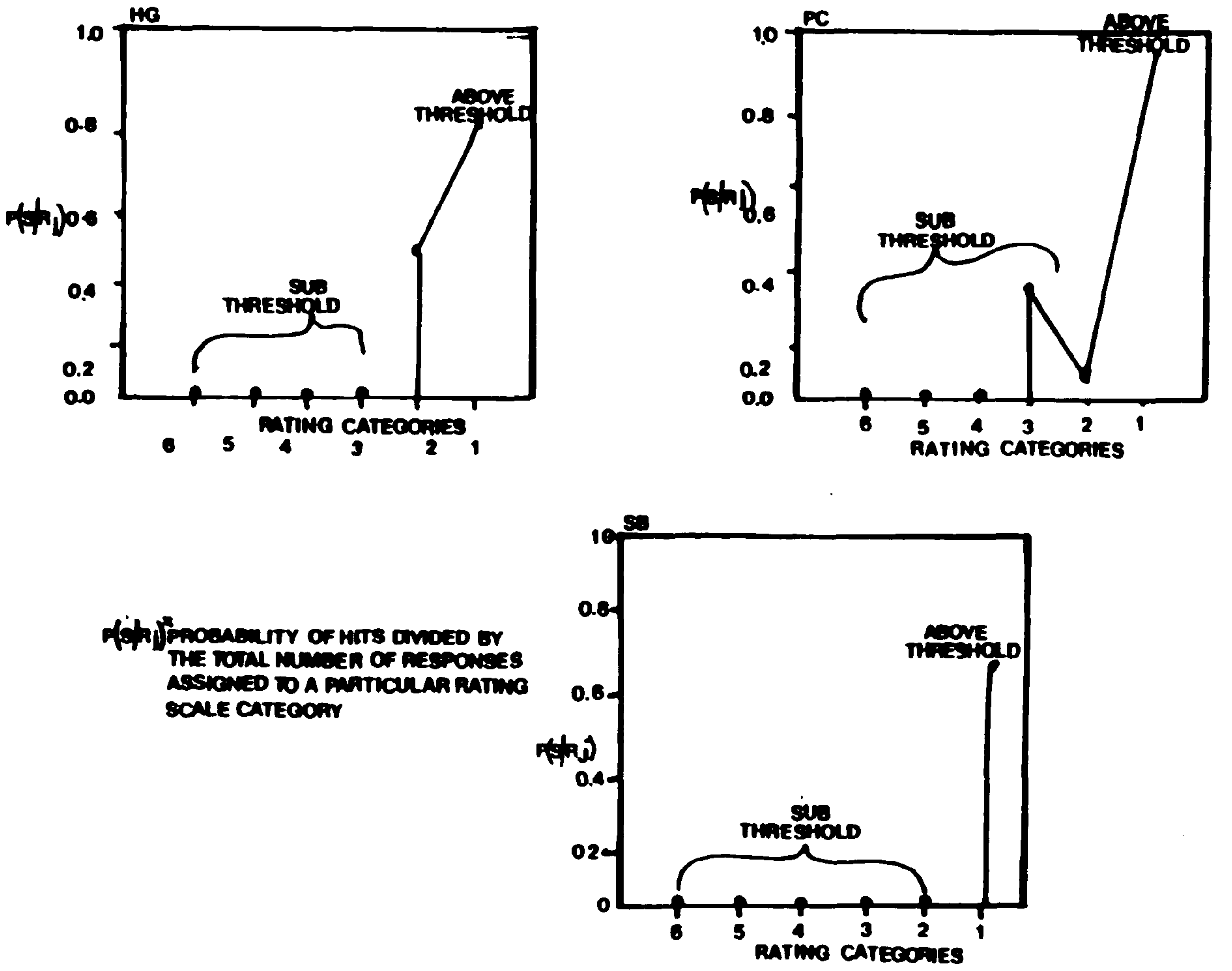
A POSTERIORI FUNCTION FOR EACH NORMAL SLEEPER DEPICTING THE DISCRIMINATION BETWEEN POLYGRAPHIC WAKEFULNESS AND SLEEP (S2, REM)



P(S/R$_i$) = PROBABILITY OF HITS DIVIDED BY THE TOTAL NUMBER OF RESPONSES ASSIGNED TO A PARTICULAR RATING SCALE CATEGORY

Figure 18.

A POSTERIORI FUNCTION FOR EACH NORMAL SLEEPER DEPICTING THE DISCRIMINATION BETWEEN POLYGRAPHIC WAKEFULNESS AND SLEEP (S2, REM)



$P(S/R_j)^*$ PROBABILITY OF HITS DIVIDED BY THE TOTAL NUMBER OF RESPONSES ASSIGNED TO A PARTICULAR RATING SCALE CATEGORY recognition of EEG wakefulness as wakefulness and no EEG sleep trials classified as wakefulness. Recall that P(s/Rj) is the probability of hits divided by the total number of responses assigned to a particular rating scale category. The only time that probability can equal one is when there are *only* hits. However, what the data do suggest is a strong physiological input into the EEG wake - EEG sleep discrimination process.

Cumulative False Alarm Probabilities by Subject; Response Bias for Experiment 1. Table 7 presents the response bias parameter for each subject in the no information condition. A *t*-test for related measures was performed on the response bias parameter associated with sleep-wake discrimination out of stage 2 versus stage REM sleep and on the response bias parameter associated with sleep-wake discrimination in the first half of the night versus the second half of the night. Since the response bias parameter is a proportion, i.e. the cumulative false alarm probability at Criterion 3, an angular transformation (2 arcsin $\sqrt{x}$) is performed on the data prior to statistical analysis. The response bias associated with sleep-wake discrimination out of stage 2 sleep is significantly higher than that associated with sleep-wake discrimination out of stage REM sleep, $t(10)=5.54$, $p<.001$. Whereas the response bias associated with sleep-wake discrimination in the beginning of the sleep period (NREM/REM cycles 1&2) does not differ significantly from that associated with sleep-wake discrimination at the

TABLE 7

FALSE ALARM PROBABILITIES (RESPONSE BIAS) FOR EACH SUBJECT IN THE "NO INFORMATION" CONDITION

Ss	SLEEP	STAGE 2	REM	CYCLES 1,2	CYCLES 3,4,5
MD	.36	.48	.25	.35	.36
SV	.44	.41	.47	.53	.36
BS	.50	.72	.25	.63	.33
YR	.29	.48	.06	.37	.21
HG	.31	.45	.08	.36	.28
PC	.46	.67	.18	.43	.50
SB	.42	.45	.38	.50	.33
KS	.55	.67	.36	.36	.73
DM	.70	.78	.56	.82	.62
AA	.45	.62	.26	.50	.40
BZ	.33	.44	.18	.35	.30
RB(Insomniac)	.69	.96	.41	.58	.77

end of the sleep period (NREM/REM cycles 3,4 & 5), _t_(10)= 1.36, _n.s._ The insomnia subject does not appear in any of the statistical analyses for Experiment 1. He is dealt with separately at the end of this chapter.

P(A) Measures as a Function of A Priori Information with Experiment 2. Table 8 displays the P(A) measures for six normal sleepers who each completed the no information condition and then completed one of two a priori information conditions with limited performance feedback. One subject in the a priori sleep condition shows a slight change in the opposite direction for the a priori sleep condition as compared to the no a priori information condition, i.e. the P(A)s decrease. Generally, however, the P(A) measures increase in the a priori sleep condition and decrease in the a priori wake condition. Following an angular transformation on all P(A) measures, a split-plot repeated measures analysis of variance (ANOVA) on one factor was performed on the difference scores for two discriminations; EEG wake - stage 2 sleep and EEG wake - stage REM sleep. Difference scores are computed between information conditions, i.e. no information - a priori sleep or a priori wake condition P(A)s. Table 9 presents the tabulated results. A priori information and limited performance feedback does significantly affect a normal sleeper's ability to discriminate EEG wake from EEG stages 2 or REM sleep, _F_(1,4)=9.69, _p_<.05. In addition, there is a significant interaction effect between sleep stage and a priori information condition, i.e. the effect of

TABLE 8

P(A) MEASURES FOR EACH SUBJECT IN THE "NO INFORMATION" CONDITION VERSUS EITHER THE "A PRIORI SLEEP" OR "A PRIORI WAKE" CONDITION

	CONDITION		CONDITION	
	NO INFORMATION	A PRIORI SLEEP	NO INFORMATION	A PRIORI WAKE
Wake - Sleep	.87	.94	.88	.81
Wake - Stage 2	.80	.90	.80	.77
Wake - REM	.94	1.00	.98	.85
Wake - Cycles 1,2	.82	.97	.85	.76
Wake - Cycles 3,4,5	.93	.91	.91	.85
Wake - Sleep	.92	.88	.89	.78
Wake - Stage 2	.91	.86	.83	.75
Wake - REM	.94	.92	1.00	.82
Wake - Cycles 1,2	.96	.90	.90	.81
Wake - Cycles 3,4,5	.88	.86	.89	.75
Wake - Sleep	.77	.87	.84	.74
Wake - Stage 2	.75	.81	.77	.71
Wake - REM	.82	1.00	.96	.81
Wake - Cycles 1,2	.82	.81	.73	.80
Wake - Cycles 3,4,5	.73	.93	.91	.67

TABLE 9

SPLIT-PLOT REPEATED MEASURES ANOVA ON P(A) MEASURES (SENSITIVITY) TO TEST THE EFFECTS OF A PRIORI INFORMATION

SOURCE	SS	df	MS	F
Total	2.47	11	--	--
Between Ss	1.77	5	--	--
A Priori Information Condition	1.26	1	1.26	9.69*
Error_b	.519	4	.130	--
Within Ss	.700	6	--	--
Wake-Sleep Stage (S2,REM)	.018	1	.018	.500
Sleep Stage X Info. Cond.	.537	1	.537	14.9**
Error_w	.145	4	.036	--

*$p < .05$
**$p < .025$

a priori information on discrimination differs significantly depending upon whether the sleep is stage 2 or stage REM, $F(1,4)=14.9$, $p<.025$. Sleep-wake discrimination out of REM sleep is affected significantly more by a priori information and limited performance feedback than sleep-wake discrimination out of stage 2 sleep.

Several issues regarding these particular results need further elaboration. Three separate types of information were supplied to each subject in the a priori information conditions intentionally. The question in the present study is whether any type of verbal information traditionally employed in SDT experiments can affect the normal sleeper's performance in this sleep-wake discrimination task. Consequently, a limited amount of three different types; information concerning a priori presentation of EEG wake and EEG sleep trials, trial-by-trial performance feedback for only the first three trials during the night, and morning performance feedback concerning the number of errors made the previous night, is combined in both a priori information conditions.

At this point a question may arise in the reader's mind concerning the significant change in the sensitivity measure, P(A), as a function of information condition since discrimination or "sensitivity" in SDT is the physiological/sensory component of the perceptual process. The answer involves integrating some basic conditioning principles with SDT. Schoeffler (1965) has described such an integration for psychophysics by using a computer simulation and referring to supportive literature. A number of studies in psychophysics have indeed demonstrated changes in sensitivity/discrimination as a function of practice, experimental instructions, motivation, and information (Swets and Green, 1961; Gundy, 1961; Lukaszewski and Elliot, 1962; Zwislocki, Maire, Feldman and Rubin, 1958; Swets and Sewall, 1963; and Schoeffler, 1962).

In his "Monte Carlo" computer simulation, Schoeffler (1965) also shows that "feedback" can be detrimental to performance in a psychophysical task" (p. 1124) when it is in conflict with the subject's own observation and when the subject has more confidence in his own observation. This is precisely what occurred in the present experiment for the one subject in the a priori sleep condition whose discrimination, not only did not improve, but also slightly deteriorated. He is the only subject out of the six subjects who participated in Experiment 2 who did not believe the trial-by-trial feedback he received for the first three trials of the night. Specifically, he did not believe that the third trial (EEG stage 2 sleep) was actually a sleep trial. He therefore decided to ignore the information he was receiving altogether and rely on his own observations instead. None of this was revealed until the subject was debriefed by the experimenter at the conclusion of the study.

Is there any evidence in the present study to suggest a dynamic (learning) process affecting sleep-wake discrimination as a function of the a priori information and limited performance feedback given to the subject? There is according to the subjects themselves although, curiously, they were not aware that their sleep-wake decisions were changing in comparison to the no information condition. In all post-experiment debriefings, subjects were amazed when confronted with the fact that their sleep-wake discriminations had clearly changed between conditions. The following answers, written by the subject BS, provide evidence of a learning process operating during the course of the experimental nights.

POST-EXPERIMENTAL NIGHT 3 IN THE
A PRIORI <u>SLEEP</u> CONDITION:

QUESTION: 1) How did you go about deciding whether you were awake or asleep last night?

> "I still maintain that I was awake when the machine said I was asleep. It was the third time it has happened, and all on the 3rd awakening. Last night I waited for the 3rd awakening, and I knew the machine was going to say I was asleep; I just don't believe it."

POST-EXPERIMENTAL NIGHT 4 IN THE
A PRIORI <u>SLEEP</u> CONDITION:

QUESTION: 1) How did you go about deciding whether you were awake or asleep last night?

> "For the 4th time, the machine said I was asleep on the 3rd awakening. I remember thoughts in my head jumping from one to the next, and me wondering why they did so. It was as this was going on that the phone rang."

POST-EXPERIMENTAL NIGHT 5 IN THE
A PRIORI SLEEP CONDITION:
QUESTION: 1) Describe what factors influenced how certain you were about your decisions?

> "Generally I said #3's [Not So Sure] when I was awake but I suspected (through previous experience and possibly an increased awareness of signs such as a dry mouth) that I might have been asleep."

The subject KS also provides evidence of a learning process operating during the course of the experimental nights in his morning answers.

POST-EXPERIMENTAL NIGHT 4 IN THE
A PRIORI SLEEP CONDITION:
QUESTION: 1) How did you go about deciding whether you were awake or asleep last night?

> "I noticed a certain feeling associated with falling asleep -- thus I got the Question #3 correct this time.

It is clear from the two subjects' excerpts that they are adjusting their decisions to conform with changes in their experience, i.e. they are learning. And, it is through this learning process that they are "sharpening" their awake-asleep discriminations in the a priori sleep condition.

The ROC curves of two subjects from Experiment 2 are chosen as examples to show the shapes of the curves generated by each condition. One subject, HG, is from the a priori wake condition and one subject, KS, is from the a priori sleep condition. Each subject was picked randomly from the subjects in his information condition.

Figures 19-22 show all of the ROC curves for the subject HG. The ROC curves generated by the no information condition

Figure 19. Individual ROC curves for the subject HG in the no information condition. Curves for two classes of the polygraphic sleep state are presented.

Figure 20. ROC curves for three classes of the polygraphic sleep state are presented from the no information condition (same subject - HG).

Figure 21. Individual ROC curves for the same subject, HG, in the a priori wake information condition. Two classes of the polygraphic sleep state are presented.

Figure 22. ROC curves for three classes of the polygraphic sleep state are presented from the a priori wake information condition (same subject - HG).

Figure 19.

INDIVIDUAL ROC CURVES FOR ONE SUBJECT FROM THE "NO INFORMATION" CONDITION

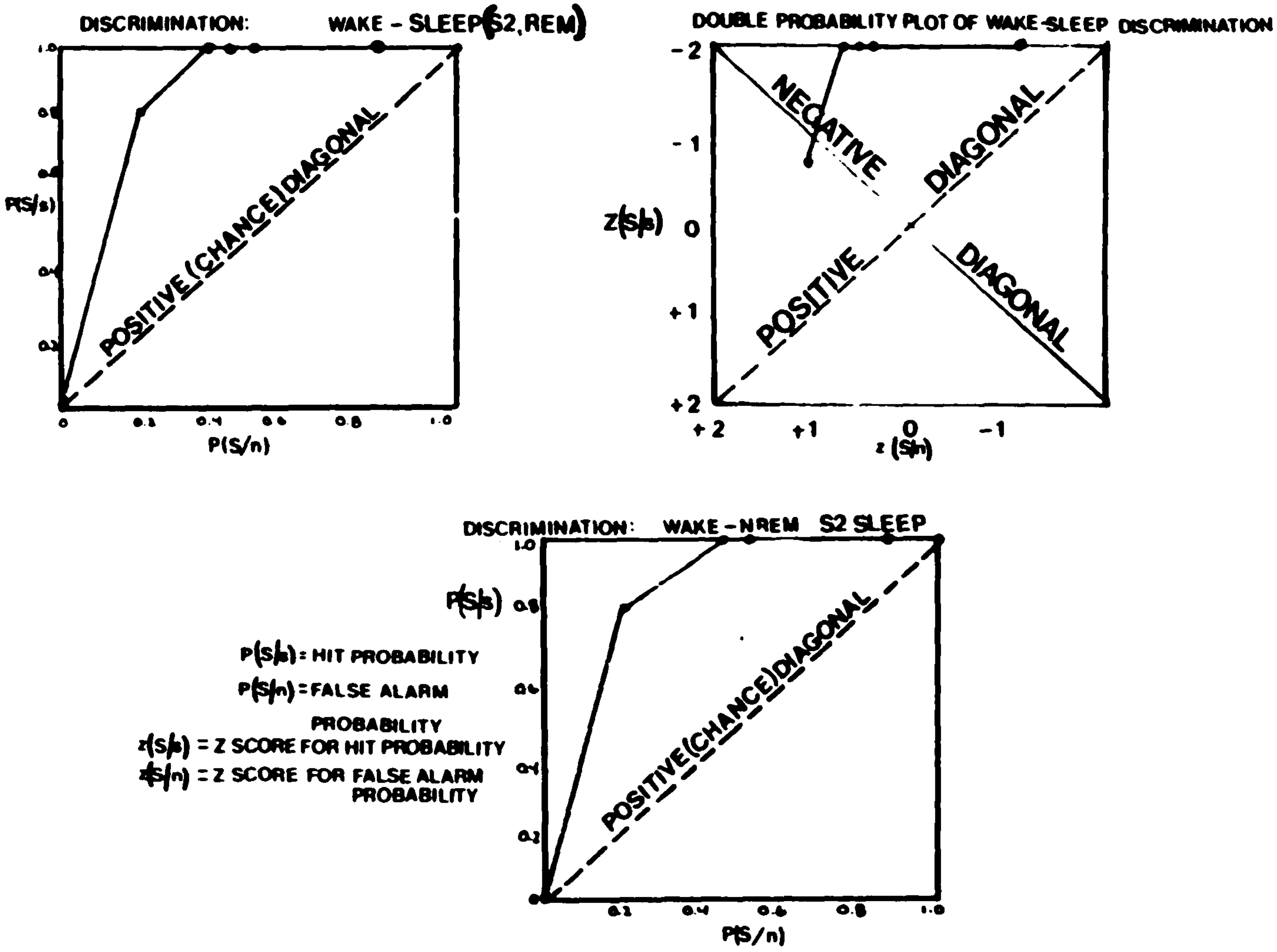


Figure 20.

INDIVIDUAL ROC CURVES FOR ONE SUBJECT FROM THE "NO INFORMATION" CONDITION

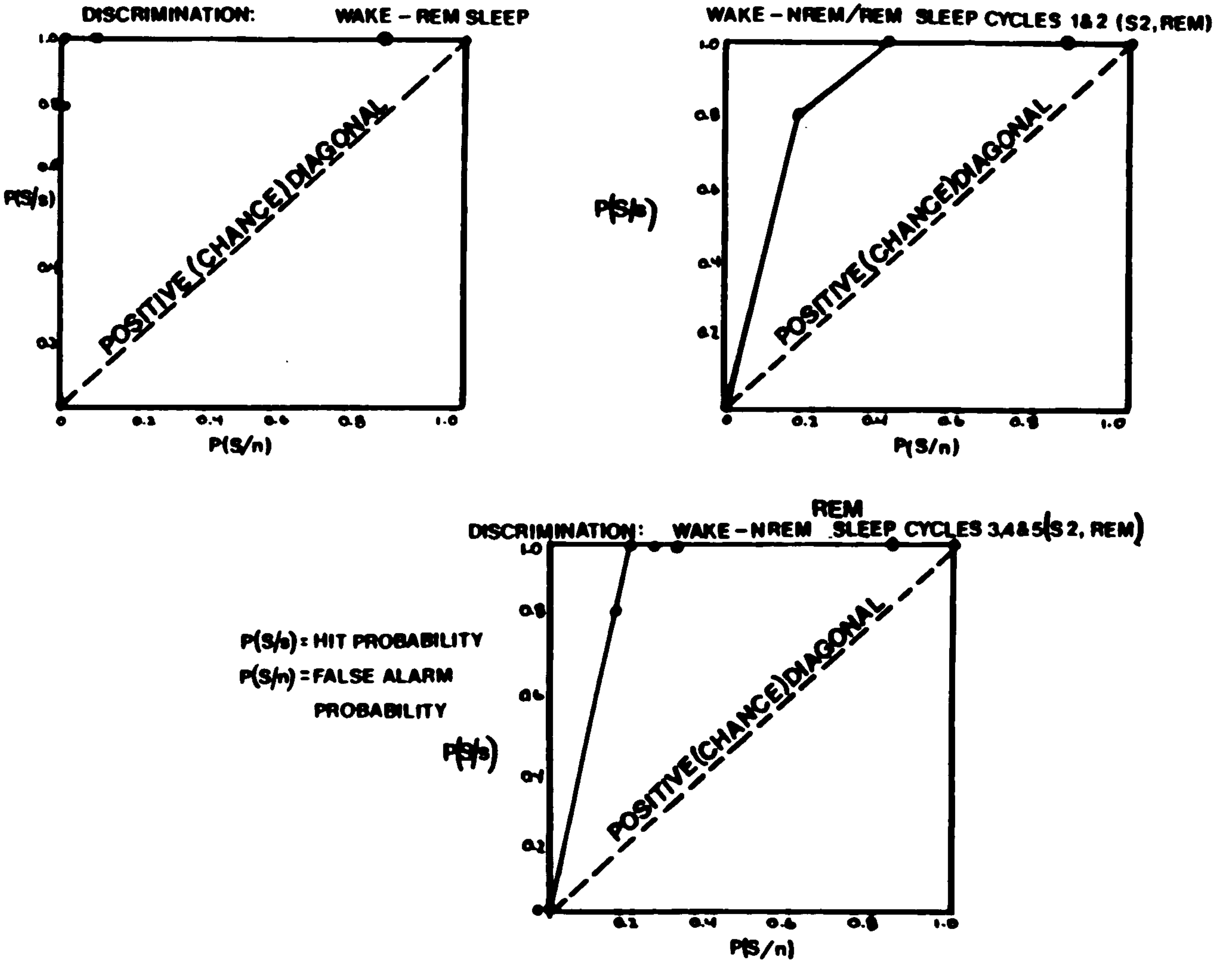
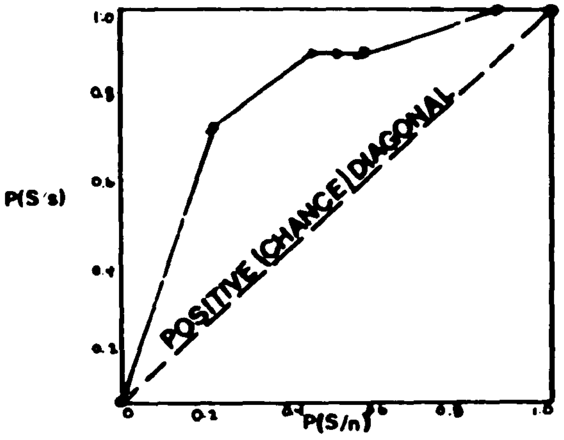


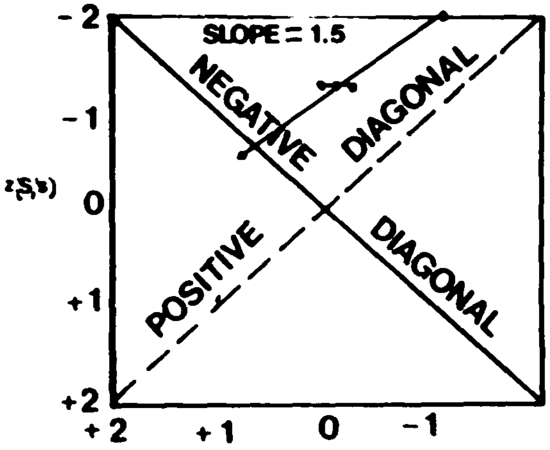
Figure 21.

INDIVIDUAL ROC CURVES FOR ONE SUBJECT FROM THE "A PRIORI WAKE" CONDITION

DISCRIMINATION: WAKE-SLEEP(S2, REM)



DOUBLE PROBABILITY PLOT OF WAKE-SLEEP DISCRIMINATION



DISCRIMINATION: WAKE S2 SLEEP

P(S/s): HIT PROBABILITY
P(S/n) = FALSE ALARM PROBABILITY
z(S/s) = Z SCORE FOR HIT PROBABILITY
z(S/n) = Z SCORE FOR FALSE ALARM PROBABILITY

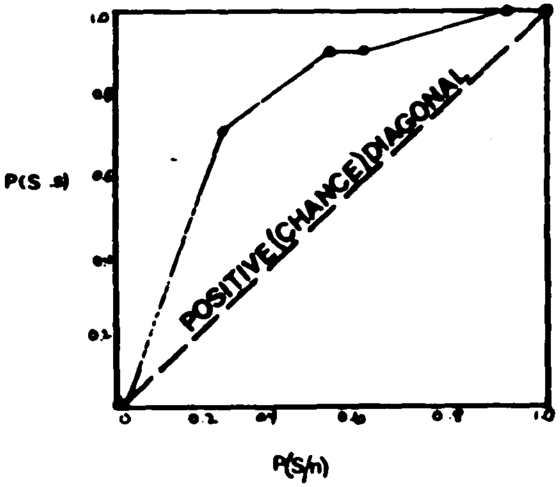
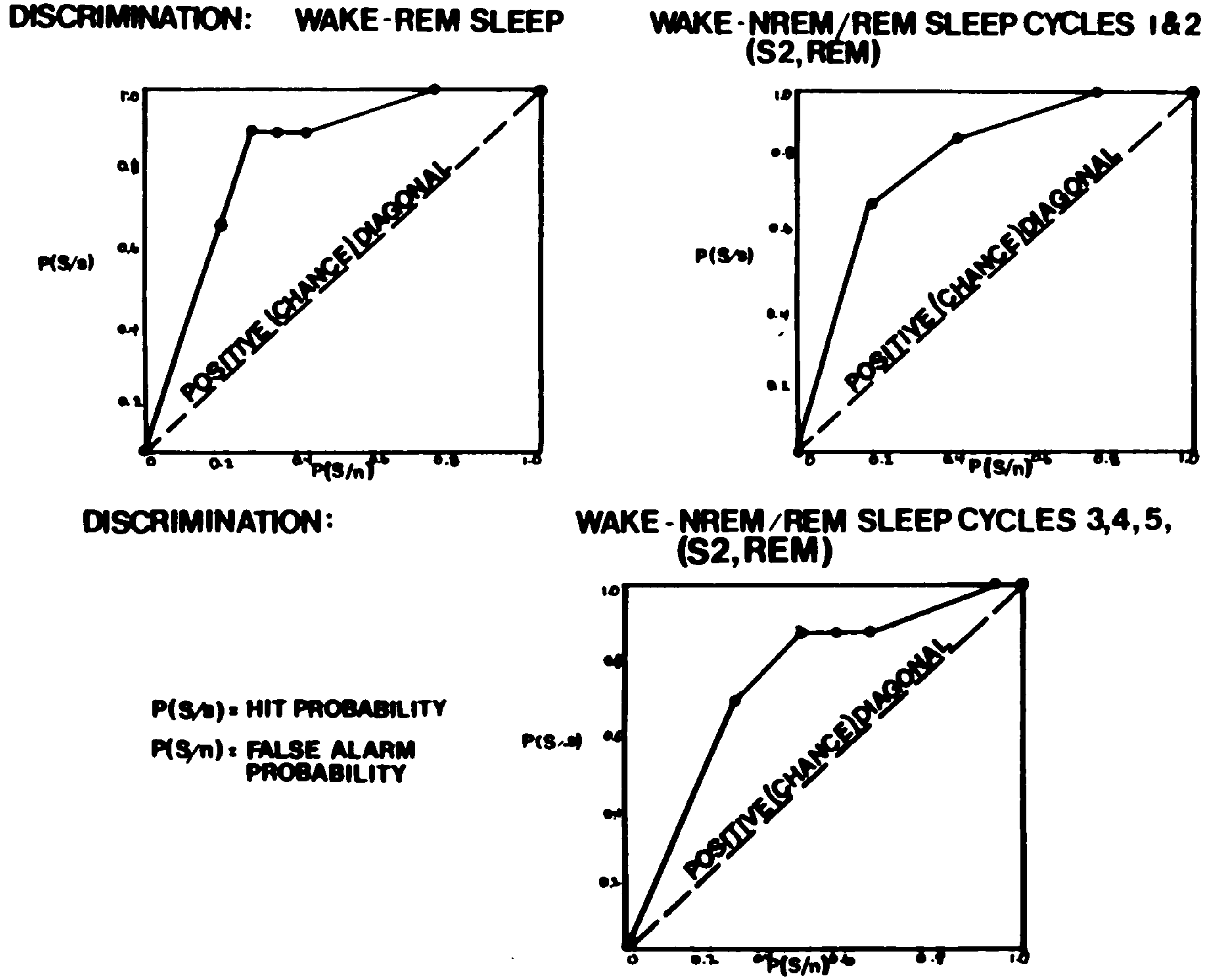


Figure 22.

INDIVIDUAL ROC CURVES FOR ONE SUBJECT FROM THE "A PRIORI WAKE" CONDITION



DISCRIMINATION: WAKE-REM SLEEP

WAKE-NREM/REM SLEEP CYCLES 1&2 (S2, REM)

DISCRIMINATION: WAKE-NREM/REM SLEEP CYCLES 3,4,5, (S2, REM)

P(S/s) = HIT PROBABILITY

P(S/n) = FALSE ALARM PROBABILITY

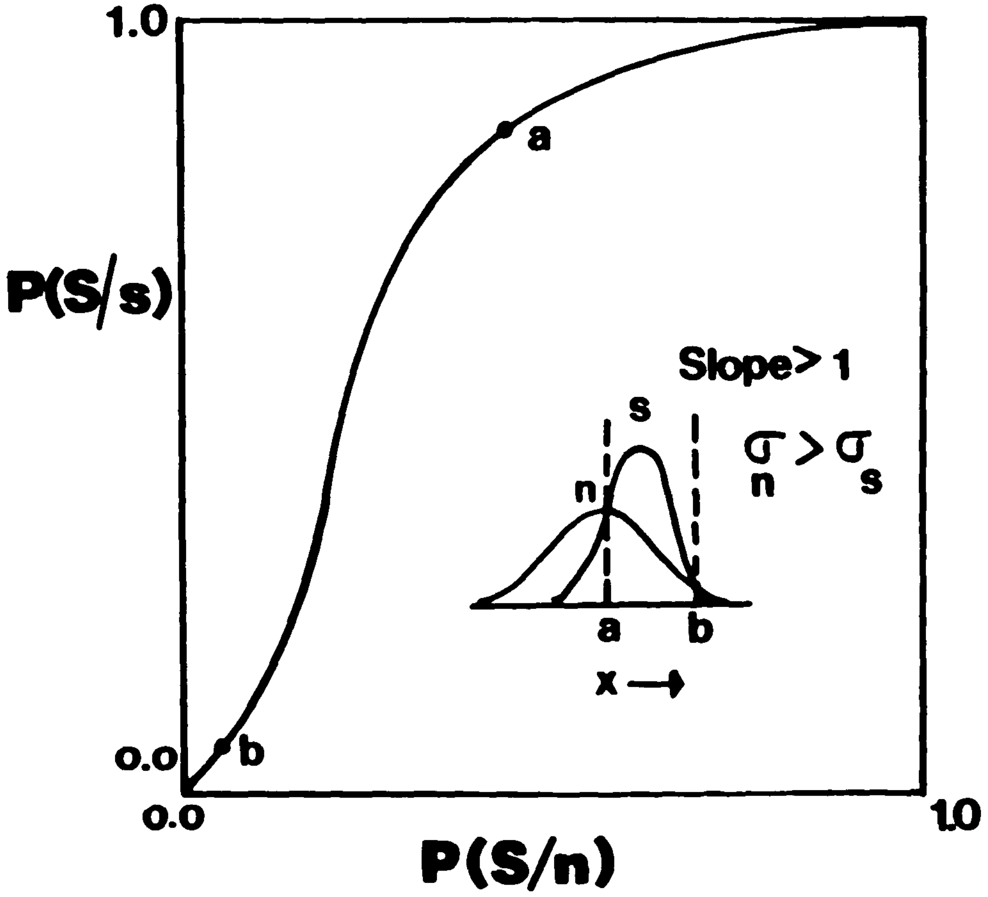
are presented first followed bythose generated by the a priori wake condition. The double-probability plot of his EEG wake-sleep (S2 and REM) discrimination (Figure 19) is an example of the third function generated by the data in the no information condition. It is made up of two line segments that form an obtuse angle. All points, except one, lie on the upper horizontal limb of the angle. Figures 21 and 22 show the ROC curves generated by the same subject for the a priori wake condition. Notice the dramatic change in the curves and the decrease in their areas associated with the a priori wake condition. Clearly the subject's discrimination has deteriorated. The double-probability plot of his EEG wake-sleep discrimination in the a priori wake condition is a linear function (fitted by eye to the points) with a slope of 1.5. A slope greater than one indicates that the underlying EEG wake (signal) distribution has a smaller variance than the underlying EEG sleep (noise) distribution since for every one standard deviation unit of change along the x-axis in this double-probability plot, there is only about .68 of a standard deviation unit of change up on the y-axis. The shape of the ROC curves in Figures 21 and 22 is similar to the idealized schematic redrawn from McNicol (1972) in figure 23. This is the general shape of the ROC curve when the variance of the underlying noise distribution is greater than the variance of the underlying signal distribution. Thus, Figure 24 presents the inferred underlying EEG sleep and EEG wake distributions. Note, that in the case of the double

Figure 23. The general shape of the ROC curve when the underlying noise distribution has a greater variance than the underlying signal distribution. The curve is redrawn from McNicol (1972).

Figure 24. The inferred underlying EEG sleep and EEG wake distributions when the variance of the EEG sleep distribution is greater than the variance of the EEG wake distribution.

Figure 23.

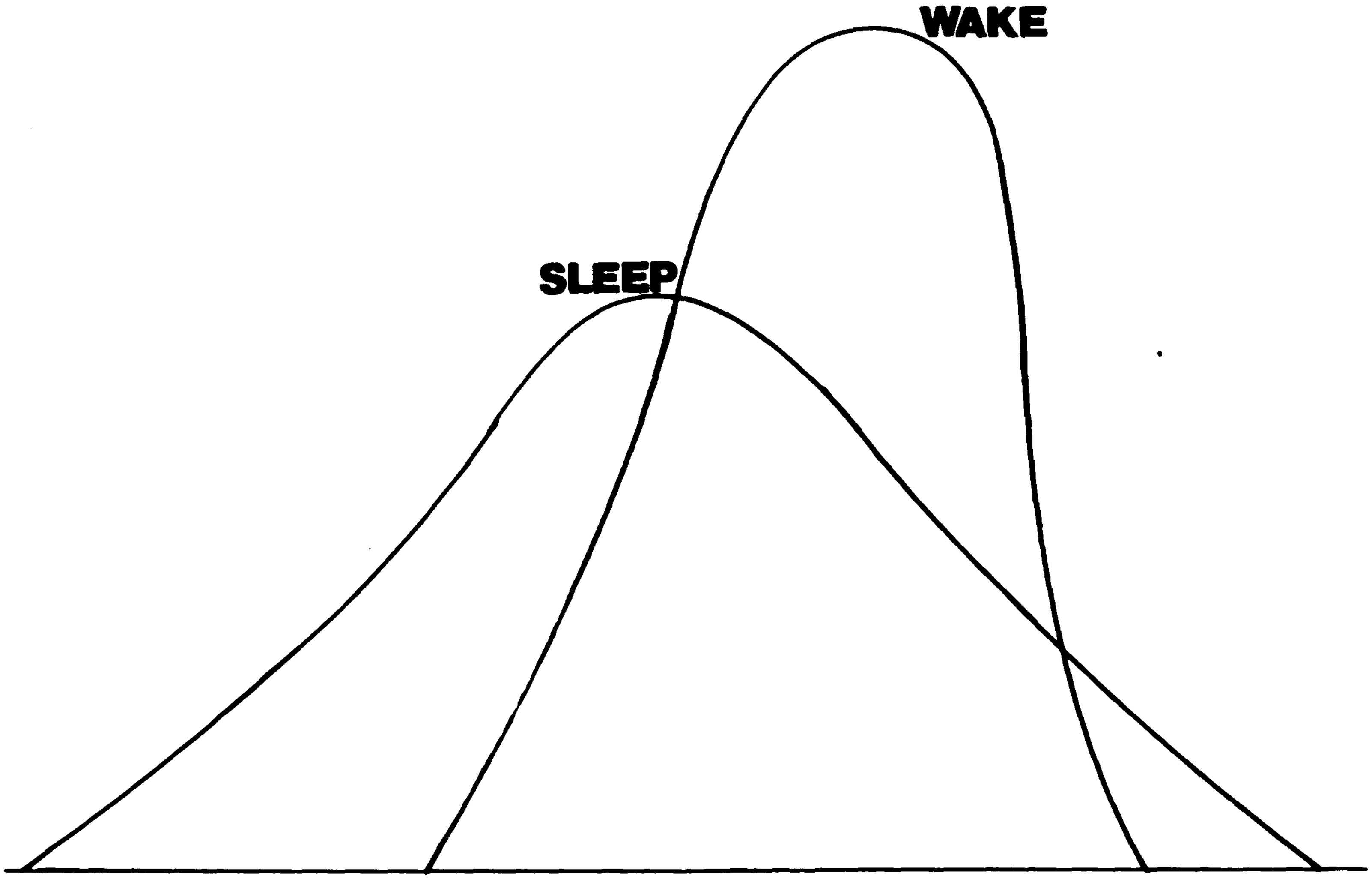
GENERAL SHAPE OF THE ROC CURVE



ADAPTED FROM D. McNICOL. A PRIMER OF SIGNAL DETECTION THEORY
GEORGE ALLEN & UNWIN LTD. 1972 p 80.

Figure 24.

INFERRED DISTRIBUTIONS FROM THE SHAPE OF THE ROC CURVES



probability plot of the ROC curve in the form of a horizontal line, the inferred EEG wake (signal) distribution would be an extremely leptokurtic distribution.

The ROC curves for the subject KS who was assigned to the a priori sleep condition are depicted in Figures 25-28. The ROC curves have been generated for both the no information and a priori sleep information conditions. Note the increase in the areas associated with the ROC curves from the a priori sleep condition (Figures 27 and 28) compared to the areas associated with the ROC surves from the no information condition. The increase in area is particularly dramatic for the EEG wake-REM sleep discrimination and the EEG wake-NREM/REM sleep cycles 3&4 discrimination. This subject, like one other subject assigned to the a priori sleep information condition, achieves perfect EEG wake-EEG REM sleep discrimination.

Response Bias Parameter for Experiment 2. Table 10 presents the cumulative false alarm probabilities at Criterion 3 for each subject in Experiment 2. Once again, false alarm probabilities, like the P(A) scores, are compared between information conditions. They are transformed by an angular transformation and then subtracted to yield difference scores (no information condition - a priori sleep or a priori wake condition) which are then entered into a split-plot repeated measures ANOVA on one factor. Table 11 shows the resulting tabulated analysis. A priori information and limited performance feedback does significantly and systematically manipu-

Figure 25. Individual ROC curves for the subject KS in the no information condition. Two classes of the polygraphic sleep state are presented.

Figure 26. ROC curves for three classes of the polygraphic sleep state are presented from the no information condition (same subject - KS).

Figure 27. Individual ROC curves for the same subject, KS, in the a priori sleep information condition. Two classes of the polygraphic sleep state are presented.

Figure 28. ROC curves for three classes of the polygraphic sleep state are presented from the a priori sleep information condition (same subject - KS).

Figure 25.

INDIVIDUAL ROC CURVES FOR ONE SUBJECT FROM THE "NO INFORMATION".CONDITION

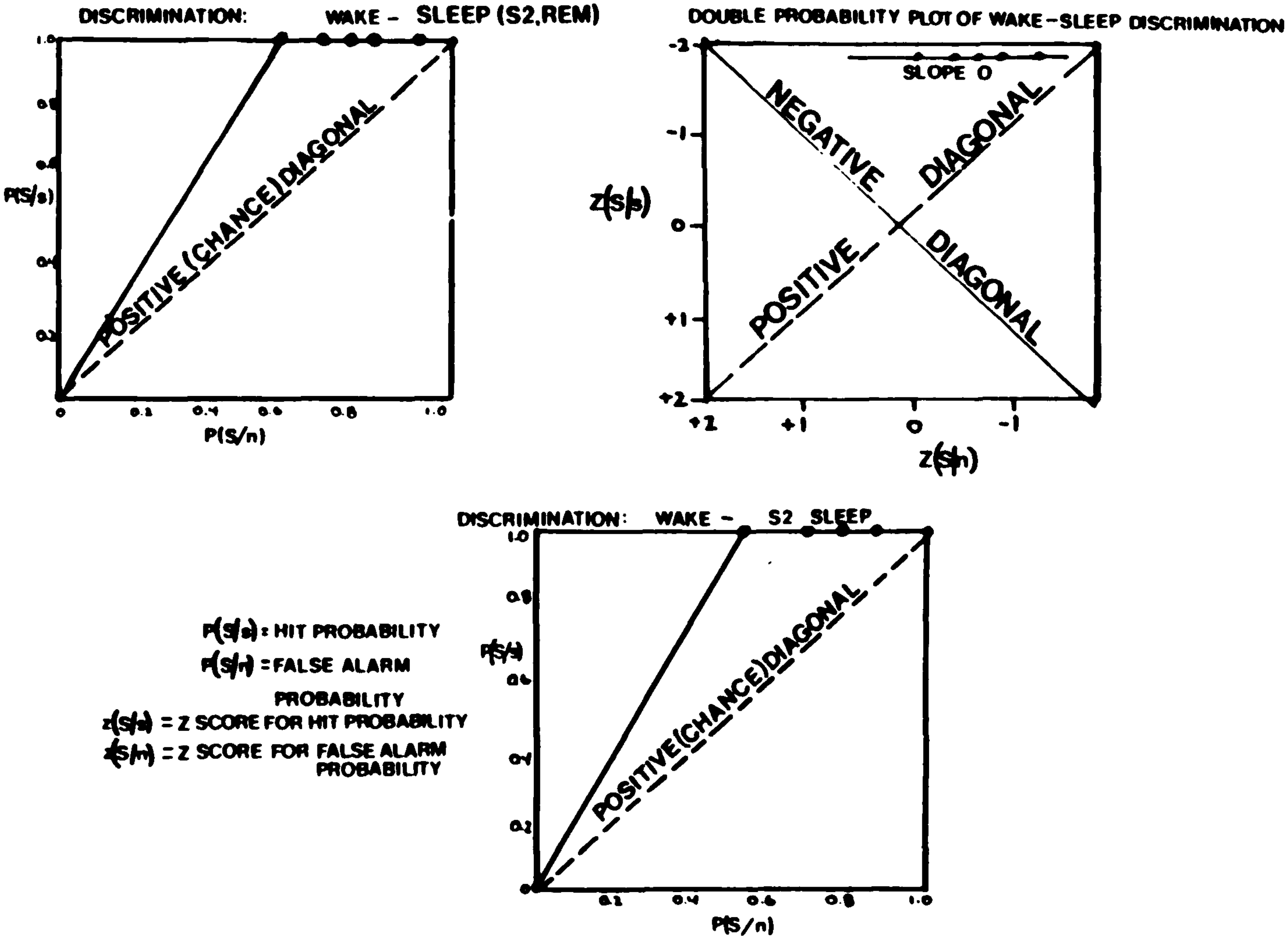


Figure 26.

INDIVIDUAL ROC CURVES FOR ONE SUBJECT FROM THE "NO INFORMATION" CONDITION

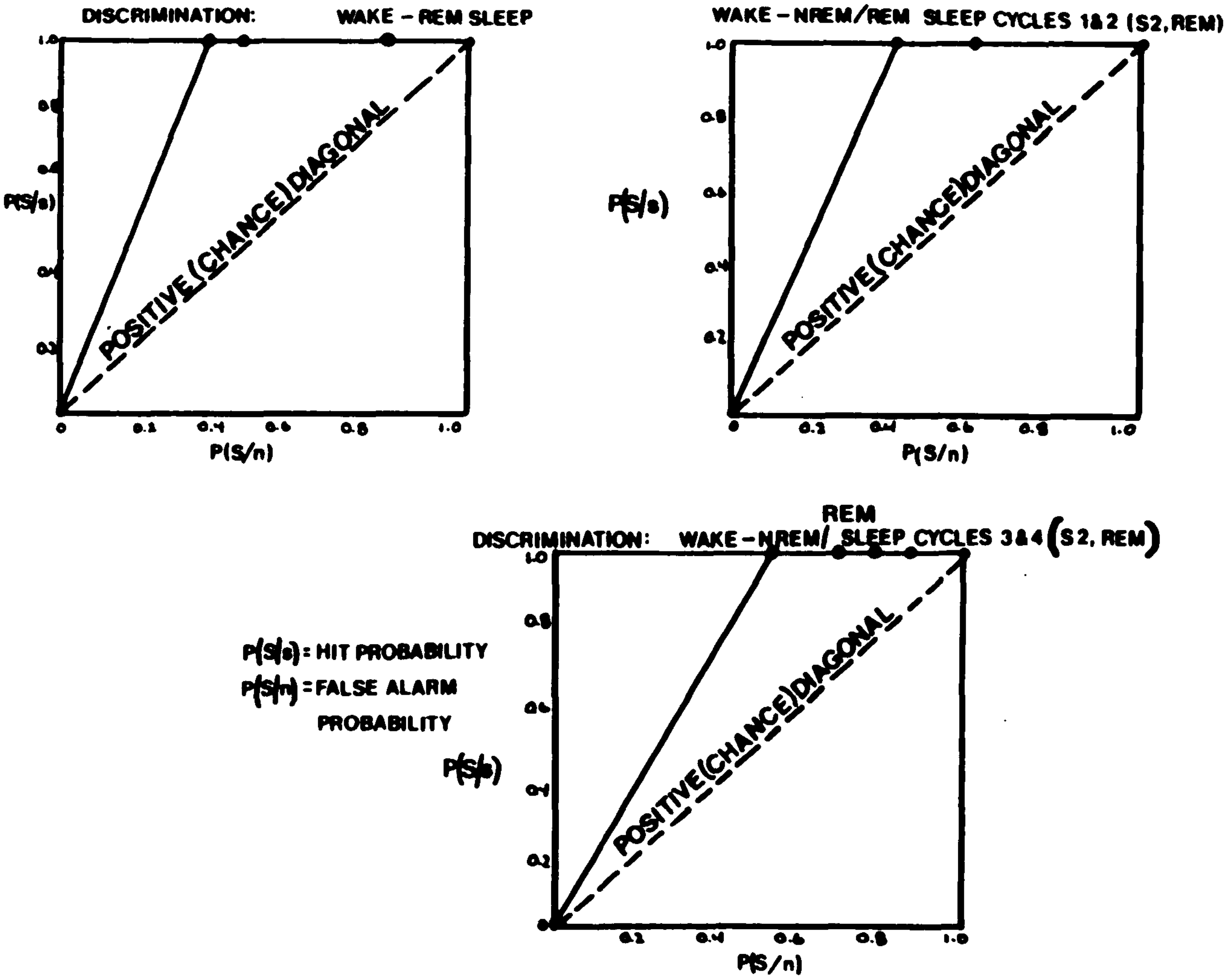
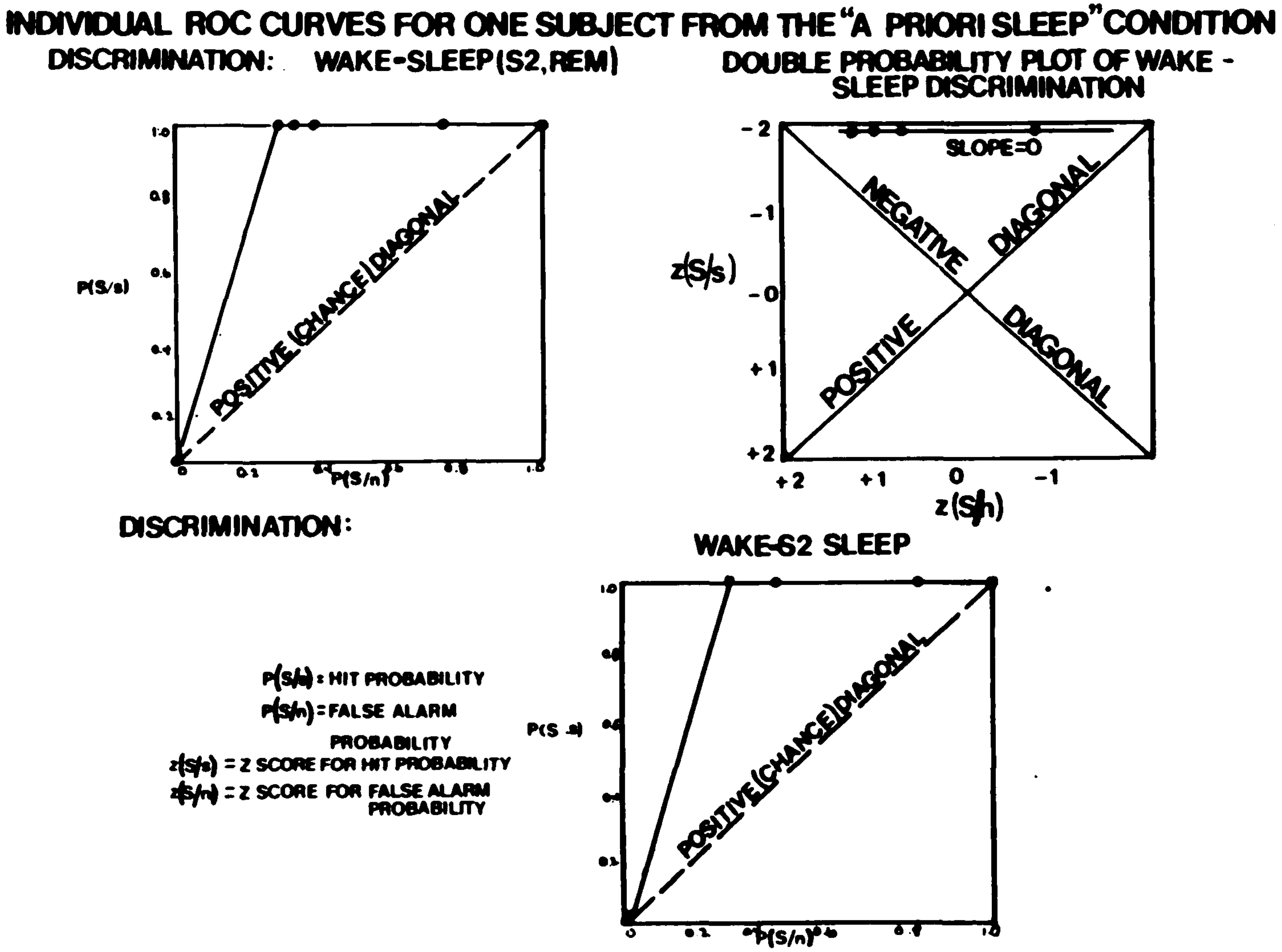


Figure 27.



INDIVIDUAL ROC CURVES FOR ONE SUBJECT FROM THE "A PRIORI SLEEP" CONDITION

DISCRIMINATION: WAKE-SLEEP (S2, REM)

DOUBLE PROBABILITY PLOT OF WAKE - SLEEP DISCRIMINATION

DISCRIMINATION: WAKE-S2 SLEEP

Figure 28.

INDIVIDUAL ROC CURVES FOR ONE SUBJECT FROM THE A PRIORI SLEEP CONDITION

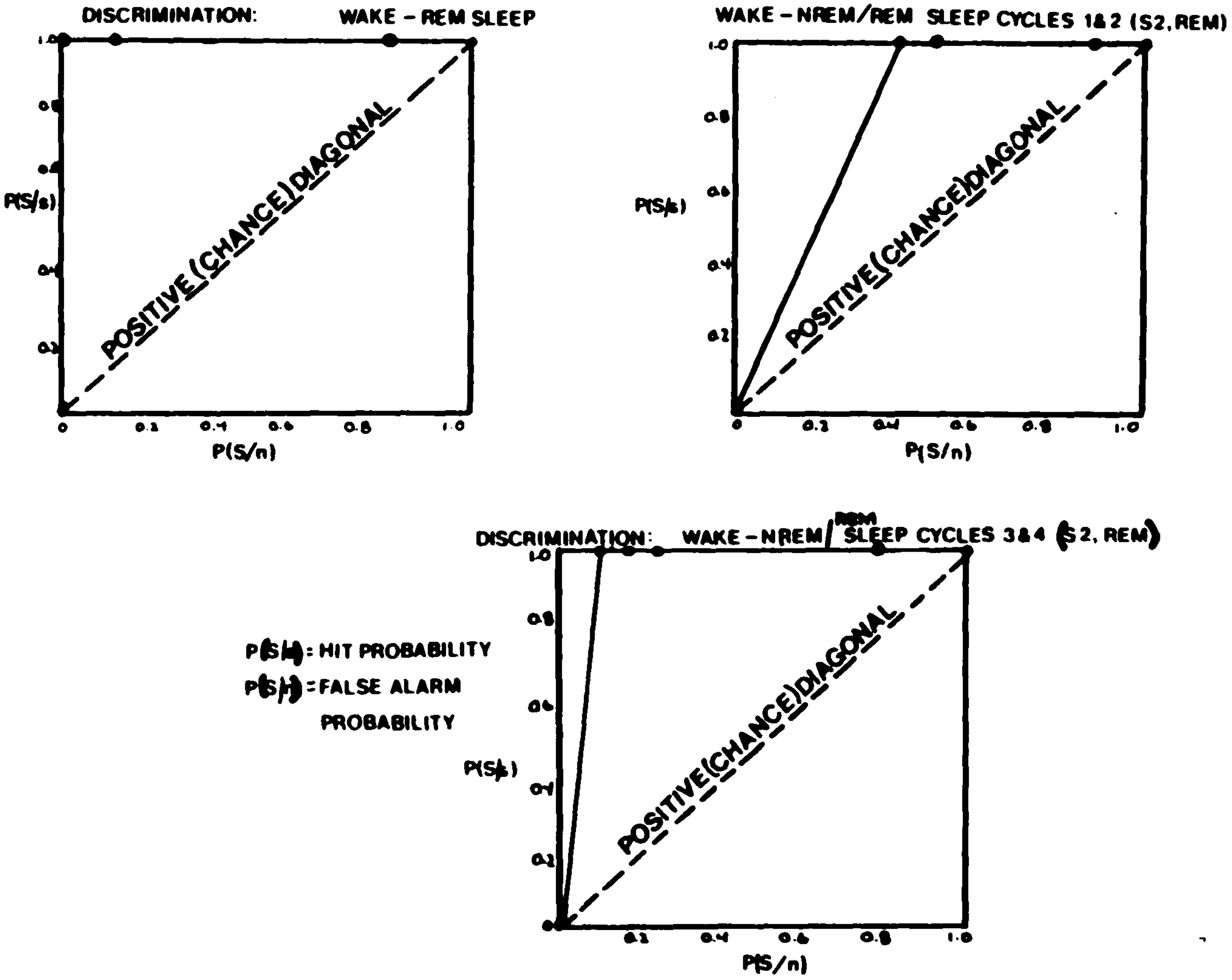


TABLE 10

FALSE ALARM PROBABILITIES FOR EACH SUBJECT IN THE "NO INFORMATION" CONDITION VERSUS EITHER THE "A PRIORI SLEEP" OR "A PRIORI WAKE" CONDITION

	CONDITION		CONDITION	
	NO INFORMATION	A PRIORI SLEEP	NO INFORMATION	A PRIORI WAKE
SLEEP	.50	.31	.29	.39
STAGE 2	.72	.58	.48	.44
REM	.25	0	.06	.33
CYCLES 1,2	.63	.25	.37	.46
CYCLES 3,4,5	.33	.40	.21	.35
SLEEP	.46	.51	.31	.46
STAGE 2	.67	.67	.45	.55
REM	.18	.31	.08	.33
CYCLES 1,2	.43	.41	.36	.41
CYCLES 3,4,5	.50	.60	.28	.50
SLEEP	.55	.33	.70	.81
STAGE 2	.67	.48	.78	.87
REM	.36	0	.56	.67
CYCLES 1,2	.36	.44	.82	.73
CYCLES 3,4,5	.73	.21	.62	.90

TABLE 11

SPLIT-PLOT REPEATED MEASURES ANOVA ON FALSE ALARM PROBABILITIES (RESPONSE BIAS) TO TEST THE EFFECTS OF A PRIORI INFORMATION

SOURCE	SS	df	MS	F
Total	2.61	11	--	--
Between Ss	1.96	5	--	--
A Priori Information Condition	1.24	1	1.24	6.89*
Error_b	0.722	4	.180	--
Within Ss	0.645	6	--	--
Wake-Sleep Stage (S2,REM)	0.043	1	0.043	0.500
Sleep Stage X Info. Cond.	0.259	1	0.259	3.01
Error_w	0.343	4	0.086	--

*$p<.10$

late the subjects' response bias parameters in discriminating between polygraphic wakefulness and stage 2 or stage REM sleep, $\underline{F}(1,4)=6.89$, $\underline{p}<.10$. The alpha rejection level is set slightly higher in the case of the bias parameter because the statistical power of the split-plot repeated measures ANOVA, with only six subjects, is minimal and the utilization of a cumulative false alarm probability as the bias parameter is a weak index of response bias.

Learning. Tables 12-14 demonstrate the effects of practice and learning on the subject's performance, i.e. sleep trial assignment to either the awake or asleep categories, by experimental nights in each information condition. Table 12 depicts the sleep trial (stage 2 and REM combined) assignment for the no information condition. The first three nights of the no information condition show a progressive performance deterioration which stabilizes on the third night. Following the third night of the no information condition, there is no further decrement in performance.

Table 13 shows the sleep trial assignment for the a priori wake condition. Here there is an immediate learning effect as a function of the a priori wake instruction set and limited performance feedback on the second night but that effect is highly unstable and transient. It retrogresses on the third and fourth nights. Depite the regression of the learning effect, on night 5 of the a priori wake condition, a clear shift in the assignment of sleep trials to the awake categories has occurred forming a sharp contrast to night 5

TABLE 12

SLEEP TRIAL (STAGE 2 & REM) ASSIGNMENT BY NIGHTS IN THE "NO INFORMATION" CONDITION

	AWAKE CATEGORIES	ASLEEP CATEGORIES
NIGHT #1	37%	64%
NIGHT #2	42%	58%
NIGHT #3	46%	54%
NIGHT #4	46%	54%
NIGHT #5	46%	54%

Note. Data are combined across 11 subjects.
Total number of sleep trials = 375.

TABLE 13

SLEEP TRIAL (STAGE 2 & REM) ASSIGNMENT BY NIGHTS IN THE "A PRIORI WAKE" CONDITION

	AWAKE CATEGORIES	ASLEEP CATEGORIES
NIGHT #1	32%	68%
NIGHT #2	67%	33%
NIGHT #3	53%	47%
NIGHT #4	50%	50%
NIGHT #5	56%	44%

Note. Data are combined across 3 subjects.
Total number of sleep trials = 89.

of the no information condition.

Table 14 shows the sleep trial assignment for the a priori sleep condition. Once again, there is an immediate learning effect evident on night 2 which shows only a slight retrogression on nights 3 and 4 but then disappears altogether on night 5; reverting right back to the original sleep trial assignment on night 1 of the a priori sleep condition.

The finding that the learning effect is transient and unstable in the a priori information and limited performance feedback conditions designed for the present study is not surprising considering the infrequent and "mixed" nature of the information given to the subject. The question in this study is whether sleep-wake discriminatory learning is possible as a function of information. It was not the intention of the present study to induce a lasting, stable change in the normal sleep subject's EEG wake-sleep discriminatory process for ethical reasons.

Tables 15 and 16 present a detailed breakdown of sleep (all five polygraphic classes) and wake trial assignment to the awake and asleep categories for both the no information and a priori information conditions for one subject assigned to the a priori wake condition and one subject assigned to the a priori sleep condition, respectively. The important feature to notice in these two tables is the higher responsiveness of sleep trial assignment out of REM sleep to a priori instruction sets and limited performance feedback.

Reaction Time Data. For each EEG wake and EEG sleep

TABLE 14

SLEEP TRIAL (STAGE 2 & REM) ASSIGNMENT BY NIGHTS IN THE "A PRIORI SLEEP" CONDITION

	AWAKE CATEGORIES	ASLEEP CATEGORIES
NIGHT #1	50%	50%
NIGHT #2	32%	68%
NIGHT #3	33%	67%
NIGHT #4	35%	65%
NIGHT #5	50%	50%

Note. Data are combined across 3 subjects.
Total number of sleep trials = 102.

TABLE 15

A DETAILED BREAKDOWN OF SLEEP AND WAKE TRIAL ASSIGNMENT FOR A SUBJECT ASSIGNED TO THE A PRIORI WAKE CONDITION

	NO INFORMATION CONDITION		A PRIORI WAKE CONDITION	
$\underline{S}_1$	AWAKE CATEGORIES	ASLEEP CATEGORIES	AWAKE CATEGORIES	ASLEEP CATEGORIES
WAKE TRIALS	94.5%	5.6%	88.2%	11.8%
SLEEP (S2 & REM)	29%	71%	39.4%	60.6%
STAGE 2 SLEEP	47.6%	52.1%	44.5%	55.5%
REM SLEEP	5.9%	94.1%	33.3%[a]	66.7%
CYCLES 1,2	36.8%	63.1%	46.2%	53.9%
CYCLES 3,4,5	21.1%	79%	35%	65%

[a] The perception out of REM sleep showed a greater sensitivity to the A Priori Wake Instruction Set.

TABLE 16

A DETAILED BREAKDOWN OF SLEEP AND WAKE TRIAL ASSIGNMENT FOR A SUBJECT ASSIGNED TO THE A PRIORI SLEEP CONDITION

$\underline{S}_1$	NO INFORMATION CONDITION		A PRIORI SLEEP CONDITION	
	AWAKE CATEGORIES	ASLEEP CATEGORIES	AWAKE CATEGORIES	ASLEEP CATEGORIES
WAKE TRIALS	100%	0%	100%	0%
SLEEP (S2 & REM)	50%	50%	31.4%	68.5%
STAGE 2 SLEEP	72.3%	27.9%	57.8%	42.1%
REM SLEEP	24.9%	75%	0%[a]	100%
CYCLES 1,2	63.1%	36.8%	25%	75%
CYCLES 3,4,5	33.3%	66.7%	40%	60.1%

[a] The perception out of REM sleep showed a greater sensitivity to the A Priori Sleep Instruction Set.

trial, the reaction time to vocal response was obtained. In all cases, the response criterion, vocal response to a continuous telephone ring, was preceded by a K-complex and a persistent alpha rhythm in the EEG. The reaction time scored was the time interval between the start of the telephone ring and the vocal response of the subject, not the electroencephalographic changes indicative of some minimal level of arousal.

Table 17 presents the mean reaction times for ten normal sleepers and one insomniac in Experiment 1 as a function of sleep trial assignment to either the awake or asleep categories. The grand mean of the reaction times for the sleep trials assigned to the "asleep" categories is almost twice as long as the grand mean of the reaction times for the sleep trials assigned to the "awake" categories. This difference is significant, $\underline{t}(9)=2.79$, $\underline{p}<.05$. A $\underline{t}$-test for related measures was used to test for significance following a reciprocal transformation of the reaction time data. A reciprocal transformation is recommended for reaction times prior to statistical analysis (Kirk, 1968) because the square of the treatment means and standard deviations tend to be proportional. Table 18 shows the same relationship between reaction time and assignment to either the awake or asleep categories for the thirteen slow wave sleep trials collected, however, the data are so limited in the case of slow wave sleep trials that no firm statement can be made without further data collection.

TABLE 17

MEAN REACTION TIMES TO VOCAL RESPONSE AND SLEEP TRIAL (S2 & REM) ASSIGNMENT

S	AWAKE CATEGORIES	ASLEEP CATEGORIES
AA	3.4 SECONDS	4.1 SECONDS
BZ	4.0	25.1
DM	2.2	4.2
KS	3.4	7.3
SB	7.8	12.9
PC	3.7	5.2
HG	2.2	4.7
BS	1.9	2.2
SV	5.7	6.2
YR	8.6	4.3
GRAND MEAN	4.3	7.6
STANDARD ERROR OF THE GRAND MEAN	0.79	2.3
RB (INSOMNIAC)	2.4	3.5

TABLE 18

MEAN REACTION TIMES TO VOCAL RESPONSE AND SLOW WAVE SLEEP TRIAL ASSIGNMENT

AWAKE CATEGORIES	ASLEEP CATEGORIES
(N = 10) 14.3 SECONDS	(N = 3) 23.3 SECONDS

Table 19 displays the mean reaction times to vocal response as a function of polygraphic state. Following a reciprocal transformation, a one-way, repeated measures ANOVA was performed on the data. Reaction time varies as a function of polygraphic state and sleep stage, $\underline{F}(2,18)=17.4$, $\underline{p}<.001$. Polygraphic wake trials are associated with the shortest reaction times, polygraphic REM sleep is associated with the longest reaction times, and polygraphic stage 2 sleep is associated with reaction times intermediate between the two extremes.

Other Physiological Data. Heart rate and respiratory rates were taken sixty seconds prior to a vocal response to an EEG sleep or EEG wake trial and sixty seconds following the vocal response. The data were scanned for any systematic relationships to the subject's assignment of the trial to either the awake or asleep categories. No systematic changes in heart rates or respiratory rates prior-to versus immediately-following the subject's vocal response could be discerned. Therefore, no heart and respiratory rate comparisons could be made to the subject's assignment of trials.

PSG Data. A complete and detailed polysomnographic (PSG) analysis on every subject from both Experiments 1 and 2 appears in Appendix A. All PSG records ran at a paper speed of 15 mm/sec. Thus, each epoch was 20 seconds in duration. All records were scored by a 20 second epoch criterion according to the standardized sleep-stage scoring criteria outlined by Rechtschaffen and Kales (1968) for the normal,

TABLE 19

MEAN REACTION TIMES TO VOCAL RESPONSE BY STAGE

S	EEG WAKE TRIALS	EEG STAGE 2 TRIALS	REM TRIALS
YR	2.6 SECONDS	7.1 SECONDS	3.6 SECONDS
HG	2.1	2.9	5.6
SB	3.2	9.5	12.4
AA	2.6	2.6	5.3
SV	8.2	6.0	5.9
PC	1.9	3.6	5.9
KS	2.5	3.5	7.5
DM	1.8	2.8	2.5
BZ	2.2	5.7	34.1
BS	1.0	1.6	2.5
GRAND MEAN	2.8	4.5	8.5
STANDARD ERROR OF THE GRAND MEAN	0.66	0.82	3.1
RB (INSOMNIAC)	2.0	2.6	3.5

young adult subject. There were three scorers involved in the scoring of the 100 PSG records generated by Experiments 1 and 2. One scorer scored 72 of the records which included all of Experiment 2 - both the no information and the a priori wake or sleep conditions - one scorer scored 18 of the records, and the remaining scorer scored 10 of the records. There was good interscorer agreement.

Table 20 presents the mean Sleep Efficiency (sleep time/ time in bed) for each of the eleven normal sleepers who went through the no information condition in Experiment 1. The table is presented to show that the subject's sleep was not severely compromised by the large number of sleep trials (8) taken each experimental night. The grand mean of the Sleep Efficiency percentages is 80.5% (2.65%=SE).

In Experiment 2, there are two independent variables that could conceivably affect the dependent variable, sleep-wake perception. One is of course the a priori information and performance feedback given and the second is variation in polysomnographic parameters between the no information condition and the a priori wake or sleep conditions. Having already demonstrated that EEG sleep-wake discrimination does vary significantly as a function of a priori information and limited performance feedback, it is now necessary to demonstrate that this change is independent of any changes that occurred in polysomnographic parameters between conditions. Table 21 presents an overall PSG analysis for all three information conditions. Generally, in the a priori wake

TABLE 20

MEAN SLEEP EFFICIENCY FOR EACH SUBJECT IN THE NO INFORMATION CONDITION

MD	89.5%
SV	88.3%
SB	87.5%
AA	76.3%
BZ	81.6%
YR	87.8%
HG	78.5%
BS	61.5%
KS	84.1%
DM	74.2%
PC	76.0%
GRAND MEAN	80.5%
STANDARD ERROR OF THE GRAND MEAN	2.65%

TABLE 21

POLYSOMNOGRAPHIC ANALYSIS AND COMPARISON UNDER EACH INFORMATION CONDITION

	NO INFORMATION		A PRIORI WAKE		A PRIORI SLEEP	
	GRAND[a] MEAN		GRAND[b] MEAN		GRAND[c] MEAN	
Time in Bed (mins.)	398.97	(11.36)	421.4	(6.36)	414.7	(29.5)
Total Sleep Time (mins.)	320.14	(13.24)	365.7	(3.80)	319.6	(11.5)
Sleep Period Time (SPT)	361.81	(11.92)	393.3	(1.92)	374.1	(19.8)
Sleep Efficiency % (sleep time/time in bed)	80.48	(2.65)	86.8	(2.07)	77.7	(6.42)
Sleep Latency[d] (mins.)	37.16	(7.49)	28.1	(6.43)	40.6	(12.3)
Minutes Awake	39.38	(6.45)	26.5	(3.55)	53.5	(21.4)
Awake Time %	10.76	(1.70)	6.76	(.926)	14.1	(5.25)
# of Awakenings for the Whole Sleep Period	25.54	(1.99)	27.7	(5.51)	29.2	(2.70)
# of REM Periods	3.04	(.296)	3.13	(.779)	2.53	(.455)
REM Latency (mins.)	72.71	(9.47)	94.3	(37.3)	87.3	(21.6)
REM % (SPT)	13.39	(1.94)	12.2	(2.36)	12.4	(.432)
Stage 1% (SPT)	7.15	(.868)	6.03	(1.20)	6.61	(1.73)
Stage 2% (SPT)	46.60	(2.30)	52.9	(2.13)	45.3	(8.81)
Stages 3&4% (SPT)	21.39	(2.05)	22.5	(2.82)	21.2	(6.67)

Note. The Standard Error of the Grand Mean appears in the parentheses.

[a] N=11.

[b] N= 3.

[c] N= 3.

[d] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

condition, PSG parameters improved, while in the a priori sleep condition, PSG parameters generally deteriorated compared to the no information condition. This then is variability in the opposite direction of the sleep-wake discrimination changes exhibited by the subjects which clearly vary with the a priori information and performance feedback given. Therefore, variability in the subjects' sleep-wake discriminations is independent of the variability in PSG parameters between information conditions. This independence is further amplified by Tables 22-24 which depict mean Sleep Efficiency percentages by subject and information condition, mean Stage 2 percentages (sleep period time) by subject and information condition, and mean Stage REM percentages (sleep period time) by subject and information condition, respectively.

Morning Questionnaire Data. Table 25 presents a comparison between mean morning estimates of awakenings and recorded mean PSG awakenings during the experimental nights for eleven subjects in Experiment 1. The recorded mean PSG awakenings are three times as great as the reported mean awakenings according to the grand means. This difference is significant according to a *t*-test for related measures, $t(10)=8.57$, $p<.001$. No transformation was applied to the data prior to statistical analysis.

It is interesting to note that in only six cases, the mean morning estimates of awakenings during the night are eight or greater. Despite the fact that subjects in the no

TABLE 22

POLYSOMNOGRAPHIC COMPARISON BY SUBJECT OF MEAN SLEEP EFFICIENCY UNDER DIFFERENT INFORMATION CONDITIONS

	CONDITIONS	
Ss	NO INFORMATION	A PRIORI SLEEP
BS	61.5 (8.35)%	67.3 (17.2)%
KS	84.1 (3.84)%	83.8 (4.36)%
PC[a]	76.0 (10.2)%	82.1 (8.28)%
	NO INFORMATION	A PRIORI WAKE
DM	74.2 (14.6)%	84.9 (4.15)%
YR	87.8 (2.95)%	90.2 (2.73)%
HG	78.5 (7.04)%	85.4 (5.91)%

Note. The Standard Error of the Mean appears in the parentheses.

[a] A Priori Information and feedback did not alter this subject's decisions.

TABLE 23

POLYSOMNOGRAPHIC COMPARISON BY SUBJECT OF MEAN STAGE 2% (SPT) UNDER DIFFERENT INFORMATION CONDITIONS

	CONDITIONS	
Ss	NO INFORMATION	A PRIORI SLEEP
BS	35.5 (9.57)%	33.2 (9.78)%
KS	45.0 (3.97)%	44.6 (3.73)%
PC[a]	51.1 (4.41)%	58.1 (8.71)%
	NO INFORMATION	A PRIORI WAKE
DM	49.0 (7.46)%	53.6 (2.60)%
YR	54.9 (4.23)%	55.5 (4.85)%
HG	50.4 (6.62)%	49.6 (4.25)%

Note. The Standard Error of the Mean appears in the parentheses.

[a] A Priori Information and feedback did not alter this subject's decisions.

TABLE 24

POLYSOMNOGRAPHIC COMPARISON BY SUBJECT OF MEAN REM % (SPT) UNDER DIFFERENT INFORMATION CONDITIONS

	CONDITIONS	
Ss	NO INFORMATION	A PRIORI SLEEP
BS	6.94 (4.20)%	11.9 (6.11)%
KS	13.8 (1.66)%	13.1 (1.26)%
PC[a]	6.52 (3.69)%	12.3 (4.52)%
	NO INFORMATION	A PRIORI WAKE
DM	4.18 (1.97)%	8.5 (.712)%
YR	17.1 (1.48)%	15.0 (2.78)%
HG	11.6 (3.66)%	13.1 (3.92)%

Note. The Standard Error of the Mean appears in the parentheses.

[a] A Priori Information and feedback did not alter this subject's decisions.

TABLE 25

MEAN NUMBER OF AWAKENINGS DURING THE NIGHT

	MORNING QUESTIONNAIRES	PSG
MD	9.8	22.4
SV	6.8	25.8
SB	6.6	26.2
AA	14.0	21.0
BZ	6.0	18.0
YR	10.4	38.0
HG	4.8	28.8
BS	11.6	30.0
KS	3.2	25.0
DM	8.0	15.5
PC	9.0	30.2
GRAND MEAN	8.2	25.5
STANDARD ERROR OF THE GRAND MEAN	.996	1.99

information condition were not told how many times they would be awakened each night during the experimental period, prior to entering the experiment, each subject signed a consent form which did stipulate the number of times the telephone bell would ring during the entire sleep period. Many of the subjects did not recall the consent form having stated a specific number and were surprised when confronted with their original, signed consent forms at the conclusion of the study. Clearly, both scheduled and spontaneous PSG awakenings are greatly underestimated by all of the subjects. The criterion used in scoring PSG awakenings was a persistent alpha rhythm lasting longer than ten seconds.

Table 26 presents mean morning estimates of awakenings and total sleep for the subjects in Experiment 2. The data are contradictory and, because of the small number of subjects, difficult to interpret with any degree of confidence. Generally, it appears the subjects' morning estimates of total sleep reflect the recorded improvement in PSG sleep parameters for the a priori wake condition, while the increase in the number of awakenings reported may reflect the influence of the a priori wake instruction set and limited feedback on morning estimates as well as on EEG sleep-wake perception. In the a priori sleep condition, a different pattern emerges. Here, the total sleep reported in the morning increases in comparison with the no information condition which contradicts the recorded PSG sleep parameters but is consistent with the improvement of EEG sleep-wake perception in the a priori

TABLE 26

MORNING QUESTIONNAIRE DATA ON MEAN AWAKENINGS AND MEAN TOTAL SLEEP

	CONDITIONS	
	NO INFORMATION	A PRIORI WAKE
YR	10.4 (2.66) awakenings 6.9 (.647) hrs.	12 (1.37) awakenings 6.1 (.274) hrs.
HG	4.8 (.652) awakenings 6.5 (.250) hrs.	6.2 (.224) awakenings 7.2 (.224) hrs.
DM	8 (2.06) awakenings 6 (.354) hrs.	10 (.471) awakenings 6.4 (.276) hrs.

	CONDITIONS	
	NO INFORMATION	A PRIORI SLEEP
BS	11.6 (1.04) awakenings 4.7 (.652) hrs.	9.6 (.447) awakenings 5.8 (.742) hrs.
KS	3.2 (.224) awakenings 5.8 (.274) hrs.	4 (.500) awakenings 6.2 (.224) hrs.
PC[a]	9 (.867) awakenings 6.2 (.137) hrs.	9.2 (.418) awakenings 6.8 (.285) hrs.

Note. The Standard Error of the Mean appears in the parentheses.

[a] A Priori Information and feedback did not alter this subject's decisions.

sleep condition.

Table 27 describes the morning reflections of subjects on the determining factors to their sleep-wake discriminations in both Experiments 1 and 2. The two most frequent determining factors given are reaction time to the bell and type of mentation experienced. What is interesting about these contemplated factors is the fact that they do not change across conditions despite the fact that clearly, EEG sleep-wake discriminability does change significantly as a function of condition.

The Insomniac's Data. A total of 20 EEG wake trials and 45 EEG sleep trials were collected on the insomnia subject. The breakdown of EEG sleep trials is as follows: 23 from stage 2 sleep, 22 from stage REM sleep, 19 from the first two NREM/REM sleep cycles, and 26 from the last three NREM/REM sleep cycles. Of the total EEG sleep trials collected, 31 (69%) were assigned by the subject to the awake categories. Of all the EEG stage 2 sleep trials, 22 (_96%_) out of 23 were assigned to the _awake_ categories. Of all the EEG stage REM sleep trials, 9 (41%) of them were assigned to the awake categories. Eleven (58%) of all EEG sleep trials collected in the first half of the night were assigned to the awake categories. Finally, 20 (77%) of all EEG sleep trials collected in the second half of the night were assigned to the awake categories.

Table 28 presents the insomnia subject's SDT analysis. The outstanding feature of this analysis is the subject's EEG

TABLE 27

MORNING REFLECTIONS BY SUBJECTS ON THE DETERMINING FACTORS FOR THEIR DECISIONS THE NIGHT BEFORE

1. Reaction Time, i.e. how fast they were able to respond to the telephone bell
2. Type of Mentation, i.e. thoughts versus sensory images
3. Interruption of ongoing mentation by telephone bell
4. How alert or foggy--how coherent they were when the bell stopped
5. Heaviness or Lightness of state
6. Awareness of a Change in Consciousness
7. Ability to Control Speech and Actions
8. Ability to Process what was heard
9. Level of Confusion that the telephone bell caused
10. Time into the Night--Early; positively Awake
    Later; Uncertainty about state
11. "Dreaming" versus the Absence of "Dreaming"
12. Dry Mouth

TABLE 28

A SIGNAL DETECTION ANALYSIS OF THE DATA GENERATED BY ONE INSOMNIAC SUBJECT WHO COMPLETED THE NO INFORMATION CONDITION

Discrimination:	Wake & Sleep (Stage 2 & REM)
P(A)	0.763
P(S/n)	0.69
Discrimination:	Wake & Stage 2 Sleep
P(A)	0.561
P(S/n)	0.96
Discrimination:	Wake & REM Sleep
P(A)	0.971
P(S/n)	0.41
Discrimination:	Wake & NREM/REM Cycles 1&2 (Stage 2 & REM)
P(A)	0.750
P(S/n)	0.58
Discrimination:	Wake & NREM/REM Cycles 3,4,5 (Stage 2 & REM)
P(A)	0.770
P(S/n)	0.77

sleep-wake discrimination out of stage 2 sleep; P(A)=.561, false alarm probability at Criterion 3 = .96. This is virtually chance discrimination between EEG wakefulness and EEG stage 2 sleep for this subject.

The percentile ranks of this subject's P(A) and false alarm probability scores were calculated in comparison to the eleven normal sleepers who also went through the no information condition. The mean P(A) score, when the insomnia subject is added to the sample, for the no information condition is .795 with <u>SD</u> = .088 and <u>SE</u> = .025. The percentile rank of the insomniac's P(A) score is 8.33 which means that only 8.33% of all the sleepers had lower P(A) scores.

The mean false alarm probability, when the insomniac is added to the eleven normal sleepers, for the no information condition is .594 with <u>SD</u> = .179 and <u>SE</u> = .052. The percentile rank of the insomniac's false alarm probability is 100 which means that 100% of the sleepers had lower false alarm probabilities.

Figures 29 and 30 show the ROC curves generated by this insomniac. The feature to note is the ROC curve for EEG wake - EEG stage 2 sleep discrimination. The ROC curve is almost the positive diagonal itself.

Table 29 presents the insomniac's PSG analysis. Considering the large number of awakenings in the present experimental protocol, the integrity of this insomniac's sleep was not too severely compromised. The fact that his PSG sleep does not deteriorate too badly suggests that such a protocol

Figure 29. ROC curves for one insomniac in the no a priori information condition. The ROC curves for the discrimination of EEG wake and three classes of the polygraphic sleep state are shown.

Figure 30. ROC curves for one insomniac are presented for the discrimination of EEG wake and two classes of the polygraphic sleep state. In addition, a double-probability plot of the EEG wake - EEG sleep (S2 and REM) discrimination is included.

Figure 29.

ROC CURVES FOR ONE SUBJECTIVE INSOMNIAC SUBJECT

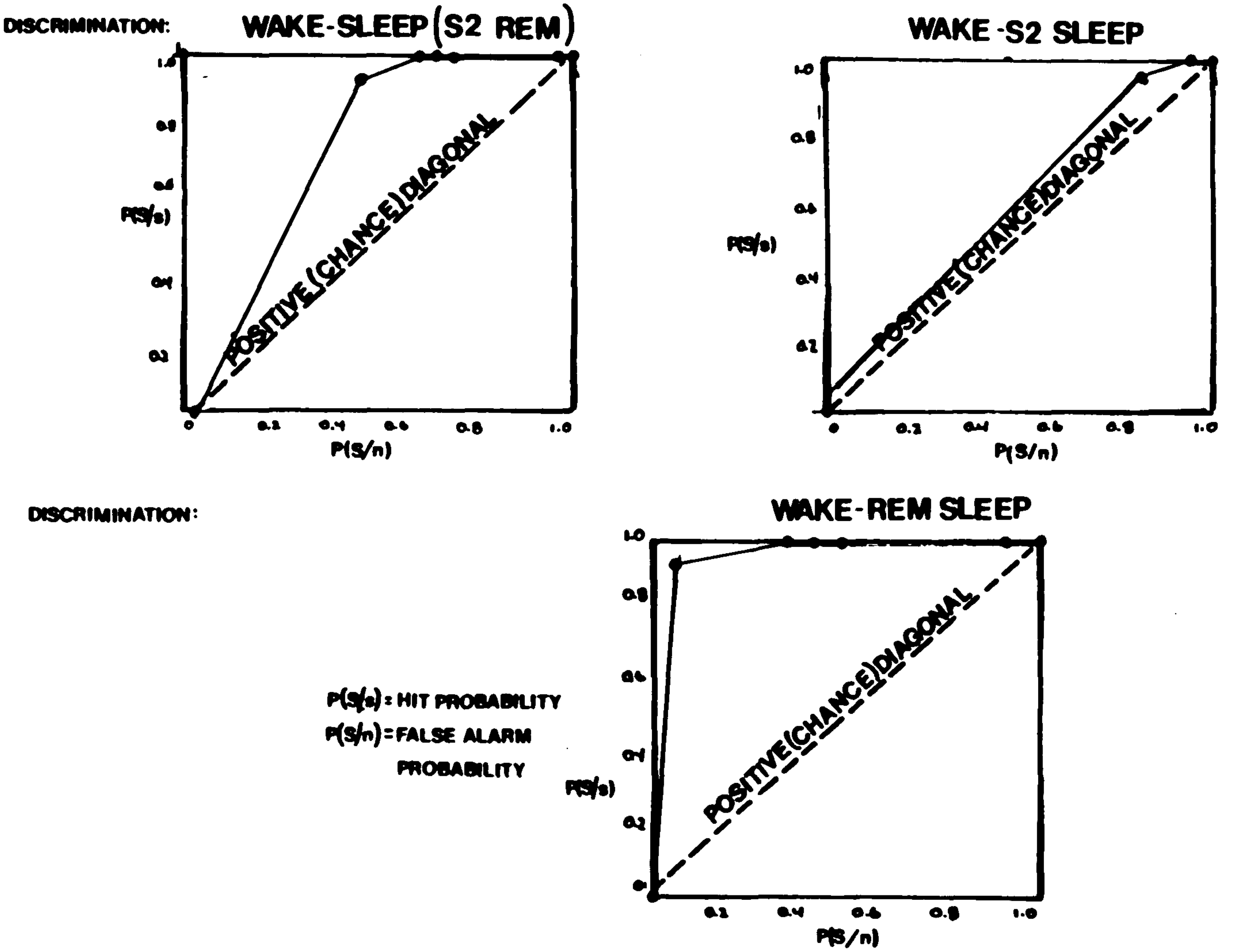


Figure 30.

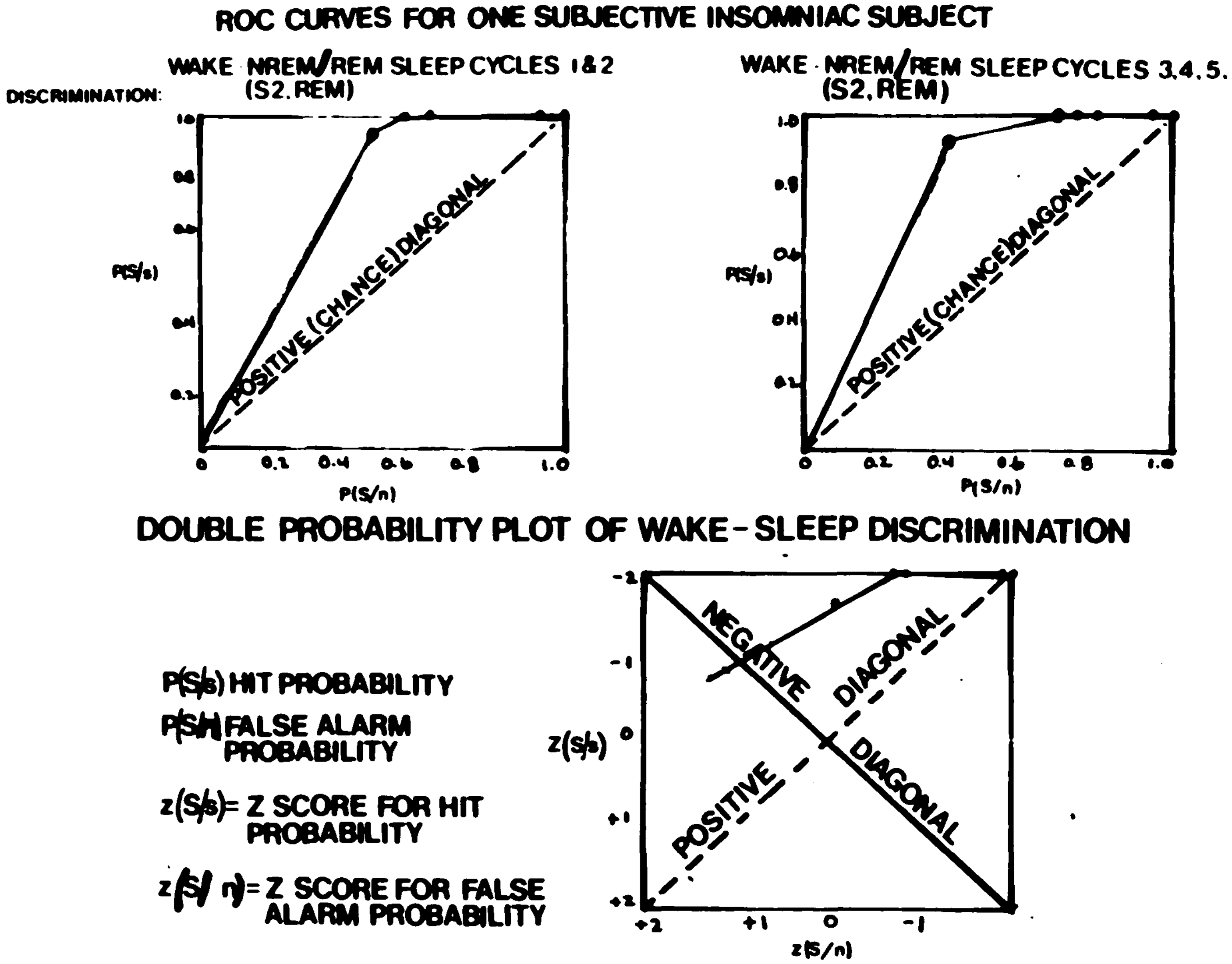

ROC CURVES FOR ONE SUBJECTIVE INSOMNIAC SUBJECT
DISCRIMINATION:
WAKE NREM/REM SLEEP CYCLES 1&2
(S2.REM)
WAKE NREM/REM SLEEP CYCLES 3,4,5.
(S2.REM)
P(S/s)
1.0
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
1.0
P(S/n)
POSITIVE (CHANCE) DIAGONAL
DOUBLE PROBABILITY PLOT OF WAKE-SLEEP DISCRIMINATION
P(S/s) HIT PROBABILITY
P(S/n) FALSE ALARM PROBABILITY
z(S/s)= Z SCORE FOR HIT PROBABILITY
z(S/n)= Z SCORE FOR FALSE ALARM PROBABILITY
z(S/s)
-2
-1
0
+1
+2
+2
+1
0
-1
z(S/n)
NEGATIVE DIAGONAL
POSITIVE DIAGONAL

TABLE 29

POLYSOMNOGRAPHIC ANALYSIS FOR ONE INSOMNIAC SUBJECT (AGE = 45)

	MEAN[a]	
Time in Bed (mins.)	514.1	(7.16)
Total Sleep Time (mins.)	377.7	(13.0)
Sleep Period Time (SPT)	420.2	(13.4)
Sleep Efficiency % (sleep time/time in bed)	73.4	(2.24)
Sleep Latency[b] (mins.)	93.9	(12.6)
Minutes Awake	35.5	(3.8)
Awake Time %	8.5	(.984)
# of Awakenings for the Whole Sleep Period	29	(4.47)
# of REM Periods	5.2	(.179)
REM Latency (mins.)	82.4	(21.5)
REM % (SPT)	14.3	(1.25)
Stage 1% (SPT)	9.7	(.716)
Stage 2% (SPT)	56.6	(2.15)
Stages 3&4% (SPT)	9.2	(.984)

Note. The Standard Error of the Mean appears in the parentheses.

[a] Mean of the 5 experimental nights only.

[b] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

can be readily executed using an insomniac sample without fear of detrimental physiological consequences.

Finally, mention needs to be made of an unexpected and potentially illuminating post-experiment impression expressed by the insomniac. The following excerpt is from a group of tape recorded impressions by the insomnia subject following experimental night 5 but prior to being debriefed by the experimenter.

> "Also, there is for me a state which may be technically sleep to you but is wakefulness to me and --uhh...it's an intermediate state -- it's very hard to define --uhh--but I definitely felt that it's there --and uhh... uhh...none of the questions precisely examined this situation."

Atkinson (1963) has proposed a theory of detection that also incorporates learning theory. He suggests that there are three states to any detection problem; a detect state, a non-detect state, and a state of uncertainty which is amenable to conditioning. Conditioning determines whether stimuli falling into the uncertain state will shift into the detect or non-detect states. In his model (Atkinson, 1963), the conditioning is in accordance with past performance so that the detection process is constantly modifying itself.

Could it be that the third state described by the insomniac as an "intermediate state" between wakefulness and sleep is precisely that uncertain state that is amenable to conditioning techniques? It is quite probable that for this particular insomniac, most of EEG stage 2 sleep falls into that "intermediate" category or is for him an uncertain state highly responsive to being shifted over into the sleep state by conditioning strategies such as trial-by-trial performance feedback and a priori instruction sets.

Summary of Significant Results.

1. EEG wake - EEG stage 2 sleep discrimination is significantly poorer than EEG wake - EEG stage REM sleep discrimination, $t(10)=4.10$, $p<.01$.
2. The response bias associated with EEG wake - EEG stage 2 sleep discrimination is significantly greater than the response bias associated with EEG wake - EEG stage REM sleep discrimination, $t(10)=5.54$, $p<.001$.
3. A priori information and limited performance feedback does significantly affect the subjects' abilities to discriminate between polygraphic wakefulness and stage 2 or REM sleep, $F(1,4)=9.69$, $p<.05$.
4. The effect of a priori information and limited performance feedback on discrimination differs significantly depending upon whether the sleep is stage 2 or REM, $F(1,4)=14.9$, $p<.025$. Sleep-wake discrimination out of REM sleep is affected significantly more by a priori information and limited performance feedback than sleep-wake discrimination out of stage 2 sleep.
5. A priori information and limited feedback does significantly affect the response bias associated with discrimination of EEG wakefulness from EEG

stage 2 or REM sleep, $F(1,4)=6.89$, $p<.10$.

6. Mean reaction times to vocal response are significantly shorter for sleep trials assigned to the awake categories than for sleep trials assigned to the asleep categories, $t(9)=2.79$, $p<.05$.
7. Mean reaction times show a significant differentiation by EEG state and stage of sleep, i.e. reaction times for EEG wake trials are shortest, reaction times for EEG REM sleep trials are longest, and reaction times for EEG stage 2 sleep trials are intermediate, $F(2,18)=17.4$, $p<.001$.
8. Mean reported morning estimates of awakenings during the sleep period significantly <u>underestimate</u> recorded PSG awakenings, $t(10)=8.57$, $p<.001$.

IV. GENERAL DISCUSSION

As early as 1937, Loomis, Harvey and Hobart attempted to compare and correlate electroencephalographic changes that occurred with the transition from wakefulness to sleep with subjective experience. They reported on one subject who moved and responded 'awake' following an auditory stimulus in the C state (Stage 2 sleep). Another early study by Davis, Davis, Loomis, Harvey and Hobart (1938) instructed subjects to signal, by squeezing a bulb, whenever they realized that they had just "drifted or floated off" or whenever they felt they had just awakened from "real sleep". Subjects signaled a "floating" or sleep state when there was a diminution of the alpha rhythm only 75% of the time.

Dement and Kleitman (1957b) studied subjective experience in conjunction with different EEG sleep stages giving particular attention to Stage REM. When they awakened subjects from Stage 1, the subjects reported that they had not been asleep and described the same "floating" and "drifting" experiences that were "signaled" by the subjects in the Davis, et al. (1938) study in conjunction with the disappearance of the alpha rhythm.

Kamiya (1961) reported on a study of dreaming and its electrophysiological correlates. Subjects were awakened by a bell with the appearance of the first sleep spindle (Stage 2 sleep). They were asked first, if they had been awake or asleep and second, if they had been dreaming prior to the bell. Forty-seven judgements were obtained from 20 subjects. Nineteen or 40.4% of the judgements obtained from

Stage 2 sleep were awake judgements with thinking mentation, 12 judgements (25.5%) expressed "uncertainty of the subjective stage, or drifting" (p. 159), and only 12 or 25.5% of all judgements made out of early Stage 2 sleep were asleep judgements.

Foulkes and Vogel (1965) also studied mental activity at sleep onset. Nine subjects participated in a four-night (nonconsecutive) study of mentation during the first 2-4 hours of the sleep period. Subjects were alerted by name over an intercom and interviewed for anything that was being experienced just prior to being called. The second question asked of each subject involved a judgemental ranking of his subjective state prior to being called. The rankings were: "awake and reasonably alert; awake but drowsy; drifting off to sleep; in light sleep; in deep sleep" (p. 232). Awakenings were taken from a continuous alpha EEG record trace, a discontinuous alpha EEG record trace, descending Stage 1 sleep, and descending Stage 2 sleep. In all cases the subjects ranked themselves as having been 'awake' although the rankings showed a consistent progression from 'awake-alert' to 'drifting off to sleep' with the descent into EEG Stage 2 sleep.

Rechtschaffen (1968) reported on a study of the nocturnal mentation of "good" versus "poor" sleepers. In an experimental protocol that required five awakenings after sleep onset, three REM awakenings preceded and followed by a NREM awakening. The poor sleepers reported having been 'awake' prior to six out of their 22 (27.3%) early NREM awakenings. All early NREM awakenings were Stage 2 sleep defined by ten minutes after the first sleep spindle. The poor sleepers also reported more "thoughtlike" activity on the early NREM awakening.

Walker (1972) (cited by Agnew and Webb, 1972) studied the effectiveness of varying stimulus conditions on sleep onset in 74 adult subjects. Subjects were tested in a 45 minute, early afternoon session. Following the session, subjects were asked if they had fallen asleep during the session. Forty-five percent of the subjects who achieved Stage 1 or Stage 2 sleep reported that they had <u>not</u> fallen asleep during the testing session and two subjects who achieved <u>Stages 3-4 sleep</u> also reported that they had <u>not</u> slept. On the second day of testing only 31% of the subjects achieving Stage 1 or 2 sleep reported not sleeping.

In a study on delayed sleep onset as a function of disturbing presleep thought by Antrobus and Saul (1978), two groups of subjects were selected on the basis of self reported sleep onset latency recorded in a two week sleep log. Two ten subject samples were established with the shortest and longest reported mean sleep latencies. The protocol consisted of an uninterupted night's sleep in the laboratory and an experimental night during which subjects were awakened at two minutes after "lights out" and at intervals of 4,8,16 and 32 minutes following each preceding awakening. Subjects were asked three questions upon each awakening including "were you awake or asleep before I called you?" The awakenings continued until each subject "gave two consecutive 'asleep' responses, regardless of EEG-EOG criteria," (p. 4). Subjects with the longest reported mean sleep latencies reported having been 'awake' out of an EEG sleep state 25% of the time and subjects with the shortest reported mean sleep latencies reported having been 'awake' out of an EEG sleep state 19% of the time. The proportion of subjective/polygraphic discrepancies was highest out of Stage 2 sleep followed by slow wave sleep Stages 3-4. The discrepancy was least out of REM sleep. Generally, subjects reported having been 'asleep' out of REM sleep. Reaction times (verbal response to name) were shortest for the EEG awake/subjective response 'awake' category, longest for the EEG sleep/subjective response 'asleep' category and intermediate for the EEG sleep/subjective response 'awake' category.

It is striking that the relationship of EEG sleep stage to sleep perception has never been systematically assessed despite continuous anecdotal reports of the discrepancies between polygraphic descriptions of sleep and the individual's perception of sleep. The present study was undertaken to make a statistical, probabalistic assessment of the relationship of EEG sleep Stages 2 and REM to sleep perception.

The results are consistent with previous, essentially anecdotal reports, of polygraphic/perceived sleep discrepancies in normal sleepers, suggesting that they are not artifactual. Furthermore, the present work demonstrates this discrepancy to be much more extreme and specifically stage related than heretofore reported in the literature. A total of 375 sleep (Stage 2 and REM) trials were sampled from eleven normal sleepers in the "no information" condition; 210 of those trials were Stage 2 and 165 were REM, producing a substantial data base from which to generalize about the polygraphic/perceived sleep discrepancy. Normal sleepers do not detect polygraphic stage 2 sleep as being sleep fifty-five percent of the time and they do not detect REM sleep as being sleep twenty-seven percent of the time. These results demonstrate that the sleep-wake decision process of normal sleepers is significantly influenced by factors independent of conventional polygraphic criteria and may challenge the use of polygraphic data as the sole criterion of sleep.

Probably the most unexpected finding of the present study is that the _normal_ sleepers underestimate recorded PSG awakenings by sixty-six percent. It has been demonstrated that morning judgements about nocturnal sleep underestimate number of awakenings (Frankel, Buchbinder and Snyder, 1973; Monroe, 1967; Hauri, 1978) in insomniac patients. However, such a finding has never previously been reported for normal sleepers. This is the first and only cognitive sleep study that has compared morning estimates of nocturnal arousals and recorded PSG arousals from _normal_ sleepers. The finding clearly demonstrates that underestimates, by conventional polygraphic criteria, of nocturnal arousals are not restricted to insomniacs but are also found in normal sleepers.

When a sleeper is awakened at some point during the night and asked to evaluate his subjective state prior to the awakening, he is confronted with a decision between two alternatives, sleep or wakefulness. Consequently, it would seem very appropriate to consider the issue of perceiving sleep and wakefulness in the context of a decision problem. There are three elements essential to any decision problem. There must be two "states of the world" and in the case of deciding about one's subjective state during the sleep period, those two states are wakefulness versus sleep. There must be some "information transmitted" and in the case of the sleeper who is alerted out of EEG wakefulness or EEG sleep, the period immediately prior to being alerted is assumed to carry information in it that can be used by the sleeper in "making an observation." And finally, the sleeper responds with the third element, the "decision" which completes the cycle (Green and Swets, 1966). Having defined the sleeper's subjective judgements about state as problems of a decision, there is a powerful theory for analyzing the essential structure of the cognitive decision process. It is the general theory of signal detectability or signal detection theory (SDT).

SDT provides a quantitative assessment of two aspects of a decision as a function of a subject's performance. The first aspect of performance - sensitivity or discriminability - specifies how well the subject is able to make accurate decisions about his/her behavioral state and avoid inaccurate ones. The second aspect of performance - response bias - specifies the extent to which the subject favors a particular decision independent of polygraphic "evidence". What the present study tests is the extent to which the decision a sleeper makes regarding sleep or wakefulness reflects the same "signals" indexed or represented by the conventional polygraphic criteria currently employed to define the sleep-wake state. The advantage to the signal detection model is that it permits the isolation and quantification of both sensory or physiological and non-sensory stimulus components of the decision making process. SDT has been a highly effective model for predicting experimental results in sensory perception and recognition memory (Snodgrass, 1972a), sensory physiology, reaction time and vigilance tasks, and time discrimination (Green and Swets, 1966). The present study demonstrates that it is also an effective model for predicting, describing, and interpreting, sleep-wake perception of EEG sleep and EEG wakefulness. No empirically based model exists in sleep research to explain or predict the disparity between subjective perception of sleep and wakefulness and the polygraphically defined sleep-wake states in normal sleep much less subjective insomnia.

The main hypothesis, tested by signal detection theory techniques, was that polygraphic criteria are an external, recordable index of internal "signals" that are detected by subjects and used by them to decide whether they have been awake or asleep. To test the efficacy of the polygraphic sleep-wake state in defining normal sleepers' judgements of having been asleep or awake, a series of requests was given to the subject during different time points along the continuous polygraphic sleep-wake process. An estimation by the subject of his/her behavioral state and a confidence rating just prior to the request was obtained.

The results only partially support the hypothesis that polygraphic signals are a close corollary of an internal signal that is detected by subjects and used by them to decide whether they have been awake or asleep and even contradict it in one important respect. According to all of the ROC curves generated by every subject, all decision criteria are skewed to the right of the negative diagonal, demonstrating that normal sleepers show a strong bias toward reporting 'awake' (the signal) regardless of the polygraphic criteria.

The sensitivity or discrimination factor, P(A), shows a significant sleep stage relationship. Normal sleepers discriminate sleep from wakefulness when awakened out of PSG stage 2 sleep to a significant (correlated *t*-test) but very limited degree classifying fifty-five percent of all PSG stage 2 sleep arousals as being periods of prior wakefulness. Although sleep-wake discrimination out of PSG REM sleep is significantly better than out of PSG stage 2 sleep, twenty-seven percent of all PSG REM arousals are also classified as periods of prior wakefulness.

The standard deviations are small, demonstrating the stability of the discrimination process across different subjects. The small standard deviations also argue against considering the limited sleep-wake discrimination out of PSG stage 2 sleep as a serendipitous or artifactual finding.

The response bias factor also shows a significant sleep stage dependency. Motivational/personality factors play a significantly greater role in the sleep-wake discrimination process out of PSG stage 2 sleep than out of PSG REM sleep. Furthermore, as already mentioned, there is an overall bias towards reporting 'awake' (the signal) regardless of polygraphic wave patterns according to the skew in all ROC curves generated that cannot be explained by the conventional PSG criteria used to describe and differentiate sleep and wakefulness.

The subjective state of wakefulness is an inference made by an individual possibly from an increased and sustained perception of external stimuli. The inference of having been asleep is likely to be based in part on the _diminished_ awareness of external stimuli interpreted as the _absence of wakefulness_, and/or the occurrence of internal percepts specific to the sleep process such as REM sleep-related or NREM sleep-related mentation.

Subjects often claimed that the cognitive act of dreaming suggested that they had in fact been asleep prior to being alerted by the telephone ring. There are two reasons why this criterion for making an asleep decision oversimplifies the decision process that actually takes place. First, several subjects claimed that they did not "dream" during the night, yet they did generate 'asleep' decisions. Those subjects who claimed to use "dreaming" as the criterion for giving an 'asleep' decision still gave 'awake' responses twenty-seven percent of the times they were alerted out of REM sleep during which time this type of mentation is most likely to occur. The converse was also true in that out of stage 2 sleep during which this type of sensory oriented, affective mentation is least likely to occur, subjects reported having been 'asleep' forty-five percent of the time. The second reason ongoing mentation is too simple a criterion by which to explain the generated sleep-wake decisions is the very fact that these decisions were significantly altered by a priori information and limited performance feedback, i.e. subjects gave more 'awake' decisions particularly out of REM sleep during the a priori wake condition and no 'awake' decisions out of REM sleep during the a priori sleep condition compared to the no information condition. Ongoing mentation, specifically "dreaming", probably contributes to the sleep-wake decision process but only insofar as it is consistent with other information that the subject has about his/her internal state.

The fact that a priori information and limited performance feedback does significantly affect discriminability and response bias demonstrates the powerful role of non-sensory, psychological factors in the sleep-wake decision process. Furthermore, it demonstrates that sleep-wake discrimination can be learned. Sleep-wake discrminability significantly improves with a priori sleep information and limited performance feedback and the response bias towards reporting 'awake' decreases, while sleep-wake discriminability significantly deteriorates with a priori wake information and limited performance feedback and the response bias towards reporting 'awake' increases. Sleep-wake discrimination out of REM sleep is much more responsive to a priori information and limited performance feedback suggesting an "acquired" component to the discrimination and reinforcing the importance of psychological, motivational factors on the discrimination process.

A very interesting finding, in light of what subjects reported on post-experimental night questioning, is the significant relationship between reaction time to vocal response and sleep trial assignment. Subjects often claimed that the speed with which they were able to coherently respond to the telephone ring determined whether they felt they had been awake or asleep. If they were able to respond quickly, they felt that they had been awake prior to the bell. Statistically, those sleep trials assigned to the awake categories had a significantly shorter reaction time associated with them than those assigned to the sleep categories. Despite the tendency to explain sleep trial assignment by reaction time to vocal response, it must be remembered that a priori information and limited performance feedback significantly altered sleep trial assignment over the no information condition suggesting that reaction time reflects an <u>effect</u> rather than a cause.

Finally, what sort of conceptual construct can be proposed that is consistent with the findings of the present study? The significant discrepancy evinced by all normal subjects between sleep-wake judgements and polygraphic wakefulness and sleep stages indicates that, whatever the underlying internal signals that are detected and used by subjects to report whether they have been awake or asleep, they are not necessarily the same signals that are indexed by polygraphic data. What the subject attends to in making a sleep-wake decision is to a significant extent <u>independent</u> of what is presently defined polygraphically as sleep and wakefulness. In terms of SDT, the polygraphic data in current use are only a <u>weak</u> index of the underlying internal signals detected and used by normal sleepers in making an awake or asleep decision.

The remainder of this final chapter is devoted to <u>speculation</u> as to what may account for the sleep-wake decisions generated by normal sleepers. The first part discusses the complex nature of polygraphic stage 2 sleep and suggests some speculations as to why it is so often mistaken for wakefulness even by a normal sleeper. The second part presents a discussion of cognitive, perceptual discrimination learning relying heavily on some basic concepts of information theory as a theoretical framework in which to view the results of the present study. The third part provides some speculation on circadian factors as major physiological input into the sleep-wake discrimination process.

The sleep EEG recorded from scalp electrodes is an extremely complex signal. However, the conventional criteria employed to discretely break it down into simpler components (referred to as stages of the sleep state) may be too crude. Stage 2 sleep is characterized by spindles and K-complexes superimposed on a background of relatively low voltage, mixed-frequency (predominantly theta) activity. Generally, evoked and spontaneous K-complexes during sleep are regarded as phasic, "excitatory" events (Davis, Davis, Loomis, Harvey and Hobart, 1939; Roth, Shaw and Green, 1956; Ackner and Pampiglione, 1957; Sassin and Johnson, 1968; Raynal, Montplaisir and Dement, 1974; Naitoh, Antony-Baas, Muzet and Ehrhart, 1982). Research on the sleep spindle is contradictory. Although the function of sleep spindles during sleep is still unknown, the majority of studies suggest the "inhibitory" nature of sleep spindles and their sleep preserving function (Ackner and Pampiglione, 1957; Hongo, Kubota and Shimizu, 1963; Rhodes, 1969; Yamadori, 1971; Johnson, Hanson and Bickford, 1976; Ehrhart, Ehrhart, Muzet, Schieber and Naitoh, 1981; Naitoh, et al., 1982). However, other research suggests that the sleep spindle may be excitatory (Moruzzi, Brookhart, Niemer and Magoun, 1950; Herz, 1965; Anderson, Anderson and Lomo, 1967; Church, Johnson and Seales, 1978).

In a very recent study, Naitoh, et al. (1982) have demonstrated an inverse relationship (antagonism) between sleep spindles and spontaneous K-complexes and an "antagonism" between sleep spindles and delta wave activity. Loomis, Harvey and Hobart (1938) postulated that K-complexes and delta waves might be related. Gaillard and Tissot (1975) suggested that K-complexes and the delta wave activity of slow wave sleep share a common synchronizing mechanism. Naitoh, et al. (1982) hypothesize an "antagonism" between a "sleep-spindle-generating mechanism" and "the mechanisms which generate the vertex sharp waves, K-complexes and delta waves" (p. 69) such that both mal repertoire, of which the song <u>O pri Pershtine</u> may be taken as an example (Antoni, 1977: 200-201). Here we find an equivalent dependence on the second, and even the use of parallel seconds at the beginning of the 2nd, 3rd, 4th, and 5th lines of echanisms cannot function simultaneously. The authors even go so far as to suggest that sleep should be categorized as spindle-dominant, delta-dominant, and REM rather than the current and arbitrary five-stage categorization of Rechtschaffen and Kales (1968). Insofar as stage 2 sleep is a neurophysiologically complex and even paradoxical state, it should come as no surprise that its discriminability from wakefulness involves considerable error. Complexity and contradiction generate ambiguity which results in an unstable percept that oscillates between "awake" and "asleep" judgements.

In the present study all stage 2 sleep trials are "phasic", i.e. there are at least two K-complexes present in a sixty second period. Consequently, every stage 2 sleep trial contained highly contradictory information or evidence from which the subject had to make a sleep-wake discrimination. Borrowing from Gestalt psychology the principle of conflict or opposition in the organization of a percept, the organization of stage 2 sleep for the perceiver is unstable and its discrimination by the sleeper may therefore oscillate between "awake" and "asleep" decisions. What determines the probability of an awake or asleep response may very well be the past history of that response, i.e. if a subject says "awake" to an EEG stage 2 sleep trial, the likelihood of his saying "awake" to the next stage 2 sleep trial increases. By the same token, if a subject says "awake" to a stage 2 sleep trial and is told by the experimenter that he is wrong, presuming that he has an increased confidence in what the experimenter tells him, he should adjust his criterion and the probability of his saying "awake" to the next stage 2 sleep trial should decrease (Schoeffler, 1965). Note that the same response history applies to sleep-wake discrimination out of REM sleep. Consequently, if a subject responds "asleep" out of a REM sleep trial, the probability increases that he will respond "asleep" out of the next REM sleep trial.

Information theory began at the Bell Telephone Laboratories with the papers of Nyquist (1924) and Hartley (1928). It began "as a way of conceptualizing and quantifying the process of communication" (p. 277, cf. Bourbon, 1978). With the publication of Cybernetics by N. Wiener (1948) and the paper entitled "A Mathematical Theory of Communication" by C.E. Shannon also in 1948, parallels were quickly acknowledged between information transmission in electronic systems and information processing in living organisms. Thus, the information processing approach to psychology came into being (Miller and Frick, 1949).

Central to the theory of information is the quantification of uncertainty. Information and uncertainty are quantitatively the same, i.e. the amount of information gained is detemined by the amount by which uncertainty has been reduced (Garner, 1962). Uncertainty about the outcome of any event is related to the number of possible outcomes that exist. The amount of uncertainty involved in any discrimination is the logarithm of the number of possible outcomes. "The amount of the uncertainty effect [in any discrimination problem] is directly related to the amount of response conflict (response uncertainty), but in the sense that the subject is not sure which response should be used on a given occasion," (p. 51, Garner, 1962). In the present study reaction time varied significantly as a function of EEG state and stage of sleep. It also varied significantly as a function of assignment to either the awake or asleep categories. Another way of interpreting the variance in reaction time is as a function of response uncertainty or response conflict, i.e. there is a greater response uncertainty associated with an "asleep" response than with an "awake" response.

Any discrimination problem by virtue of its involvement of two or more alternatives generates uncertainty. Information gained through performance feedback and/or a priori information reduces uncertainty. In discrimination learning, then, practice, performance feedback, and a priori information, modify discrimination in the direction of reducing uncertainty. In the present study, a priori information and limited performance feedback, not only acted on response bias, but also acted on the subject's ability to discriminate between two alternatives, sleep and wakefulness, by reducing the uncertainty involved in the discrimination task. If the information is believed by the subject and it is not redundant, then it should modify the discrimination process by reducing the uncertainty with regard to possible outcomes, i.e., reducing the number of outcomes.

Roughly 25% of the patients who complain of insomnia fall into a category of insomnia that is characterized by an absence of associated abnormal polygraphic and psychological findings. It is listed as a "Subjective Disorder Initiating and Maintaining Sleep (DIMS) Complaint without Objective Findings" in the current nosology of the Association of Sleep Disorders Centers and the Association for the Psychophysiological Study of Sleep (1979). This group of insomniacs is not restricted to any age group but does have a higher frequency of occurrence in women (1979). Several explanations have been advanced for this form of insomnia, all based on clinical inference rather than empirical demonstration. Excessive mentation during sleep, micro-arousals too subtle to be detected or scored by current polygraphic and visual scoring techniques, very subtle emotional or cognitive pathologies, have all been advanced as explanations to account for the distorted perception of sleep in these patients (1979). To date, no attempt has been made to analyze the complaint or discrepancy itself. The present work was designed to provide a methodology and potential model to be used in the evaluation of the subjective insomniac's complaint, i.e. polygraphic/subjective discrepancy. What was not expected was the finding that this discrepancy is not restricted to the subjective insomniac but is a feature of sleep-wake perception in normal sleepers.

Sleep-wake perception must be the selective, filtering-out of the critical features which differentiate the two states rather than relate the two states. Since the underlying psychophysiology of EEG sleep stages (both mentation and physiological correlates) is complex and often contradictory for stages REM and 2 sleep (particularly stage 2 sleep), sleep-wake perception is a slow, developmental process dependent on practice, conducive environmental stimulation, and reinforcement for training. When environmental reinforcement for the development of sleep-wake perceptual differentiation, it is reasonable to hypothesize that subjective insomnia is the result. Thus, the reversal of subjective insomnia should be possible by "teaching" or training sleep-wake discrimination through trial-by-trial performance feedback and error performance feedback. The "payoff" or reward for the subjective insomniac is the ability to perceive sleep and, according to most of these patients, that is the only reward they need or want. The present study makes it clear that some of the discrepancy found between subjective report and PSG recordings in subjective insomnia can be explained by cognitive factors independent of pathology.

The final section of this chapter speculates on the nature of the physiological input in terms of a circadian factor that seems to play an important role in sleep-wake perception in the *absence* of a priori information and performance feedback according to the a posteriori functions. It has been known for some time that an individual's performance and vigilance levels roughly parallel the circadian core-body temperature rhythm (Kleitman, 1963; Hockey and Colquhoun, 1972). When body temperature is normally high during the 24-hour day, performance, efficiency and vigilance are also high, and when body temperature is low during the 24-hour day, performance, efficiency, and vigilance are also low. Observational notes from an underground cave study designed to study circadian period modification by Kleitman (1963) indicated that a subjective feeling of sleepiness was strongly coupled to a low phase of the rectal, body temperature rhythm curve, while a subjective, alert feeling was strongly coupled to a high phase of the body temperature curve.

Typically, core-body temperature rises in the morning, reaches its peak in the afternoon, drops in the evening just before sleep, continues to slowly decrease reaching its nadir at about 4:00 AM, assuming an 11:30PM-midnight bedtime, and then starts to rise again. By morning awakening, body temperature is rising but is still lower than at sleep onset. This constant relationship is only altered in the face of physiological or psychological stress (Kleitman, 1963) and "free-running" conditions (Czeisler, 1978). The core-body temperature rhythm has a constant 24-hour periodicity and serves as a marker for a number of other circadian rhythms in the normal entrained sleeper (Hockey and Colquhoun, 1972; Czeisler, Weitzman, Moore-Ede, Zimmerman and Knauer, 1980). It may also represent an easily monitored reflection of circadian factors influential in sleep-wake discrimination. At sleep onset, the core-body temperature rhythm shows a steep drop which amounts to 1.00^{o}-2.00^{o}F over a fifteen to twenty minute period in the normal sleeper (Czeisler, 1978) which then tapers off to a slow, continual drop over the next several hours. It is reasonable to hypothesize that the perception of sleep reflects a substantial biological input from the drop in a number of circadian rhythms over the course of the first few hours of the polygraphic sleep period. This role is probably contradictory in the sense that these circadian factors are slowly but continually changing making their interpretation by the perceptual process unstable. Indeed, the unstable but influential role of circadian factors in the perceptual process as well as the contradictory nature of the EEG sleep information (K-complexes, vertex sharp wave and delta wave activity) may help to explain the poor sleep discrimination out of slow wave sleep during the first two hours of the sleep period. Performance feedback and a priori information probably act to reinforce those aspects of the circadian, biological rhythm fluctuations during the sleep period which are consistent with the information and feedback given to the subject in the same way that they focus or direct attention to those neurophysiological correlates of the polygraphic sleep stages which are consistent with the information and feedback given to the subject. The rest of the "contradictory" input is probably rated lower in information value and has a minimal influence on the final discrimination response. It is possible that, under certain psychiatric conditions (depression) and schedule disturbances (shift-work) when biological rhythms including the sleep-wake cycle alter in relative phase relationship or in other properties, the polygraphic/subjective sleep discrepancy may become greatly exaggerated.

In the final analysis, the present study provides a demonstration of the value of a SDT/information processing approach to the discrimination of EEG wake from EEG sleep for the normal sleeper. Furthermore, a cogent argument, with supportive data from the present study, has been made for considering EEG sleep-wake discrimination in the context of a perceptual discrimination problem where the discrimination involves a learned, set of principles by which input from internal/ external and psychological/physiological sources are organized into meaningful representations of "sleep" or "wakefulness" by the sleeper. The completion of this study is, I hope, its beginning.

> No fairer destiny could be alloted to any physical theory, than that it should of itself point out the way to the introduction of a more comprehensive theory, in which it lives on as a limiting case. (p. 77, Einstein, 1961)

V. APPENDICES

APPENDIX A: COMPLETE, INDIVIDUAL PSG ANALYSES FOR ALL SUBJECTS STUDIED IN BOTH EXPERIMENTS 1 & 2

NO INFO. CONDITION

NAME MD

AGE 26

	NIGHTS							
	ADAPT	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	304.3	479	330.3	326	309.7	331	355.2	69.7
Total Sleep Time (mins.)	300.3	435	301	296.7	272.3	287.3	318.5	66.1
Sleep Period Time (SPT)	303	470.7	320	314	290.7	310.7	341.2	73.2
Sleep Efficiency % (sleep time/time in bed)	98.7	90.8	91.1	91	87.9	86.8	89.5	2
Sleep Latency^a (mins.)	1.3	8.3	10.3	12	19	20.3	14	5.4
Minutes Awake	0	35.3	19	17	18	21.3	22.1	7.5
Awake Time %	0	7.5	5.9	5.4	6.2	6.9	6.4	.8
# of Awakenings for the Whole Sleep Period	1	34	19	20	22	17	22.4	6.7
# of REM Periods	2	5	3	3	3	3	3.4	.9
REM Latency (mins.)	88	62	60.3	73.7	92.3	74	72.5	12.8
REM % (SPT)	14.9	17	17.9	10.7	10.9	20.8	15.5	4.5
Stage 1% (SPT)	2.1	8.2	4.8	5.4	5.3	6.1	6	1.3
Stage 2% (SPT)	52.5	49	37.5	43.9	49.5	38.1	43.6	5.7
Stages 3&4% (SPT)	29.7	18.2	33.8	34.4	28	27.5	28.4	6.5

Note. The Adaptation night was not included in the Mean and S.D. calculations.

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

NO INFO. CONDITION

NAME SV

AGE 27

			NIGHTS					
	ADAPT	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	345	397.7	443	413	480.3	384.7	423.7	38.4
Total Sleep Time (mins.)	317.7	338.3	373.3	367.3	439.3	352.3	374.1	38.9
Sleep Period Time (SPT)	333.3	367.3	411	401.7	472.7	377.3	406	41.3
Sleep Efficiency % (sleep time/time in bed)	92.1	85.1	84.3	88.9	91.5	91.6	88.3	3.4
Sleep Latency[a] (mins.)	11.7	30.3	32	11.3	7.7	7.3	17.7	12.4
Minutes Awake	.7	27	32	23.7	21.3	19.3	24.7	5.0
Awake Time %	.2	7.4	7.8	5.9	4.5	5.1	6.1	1.4
# of Awakenings for the Whole Sleep Period	1	34	31	30	11	23	25.8	9.2
# of REM Periods	3	3	4	4	5	5	4.2	.8
REM Latency (mins.)	73	33.7	41.3	64.3	0	0	27.9	27.8
REM % (SPT)	13.7	18.5	23.8	27.2	24.7	22.5	23.3	3.2
Stage 1% (SPT)	4.5	11.3	13.8	6.1	7.9	10.7	10	3.0
Stage 2% (SPT)	53.3	49.9	51	43.7	52.1	48.9	49.1	3.3
Stages 3&4% (SPT)	23.8	12.5	2.2	14.4	8.2	11.2	9.7	4.8

Note. The Adaptation night was not included in the Mean and S.D. calculations.

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

NO INFO. CONDITION

NAME AA

AGE 35

			NIGHTS					
	ADAPT	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	399.3	413.0	421.0	421.0	349.0	382.7	397.3	35.0
Total Sleep Time (mins.)	367.0	353.0	364.0	318.7	289.0	195.3	304.0	75.5
Sleep Period Time (SPT)	393.7	401.7	408.3	411.3	326.3	366.3	382.8	40.6
Sleep Efficiency % (sleep time/time in bed)	91.9	85.5	86.5	75.7	82.8	51.0	76.3	16.5
Sleep Latency[a] (mins.)	5.7	11.3	12.7	9.7	22.7	16.3	14.5	5.78
Minutes Awake	26.7	48.7	44.0	68.3	37.3	171.0	73.9	62.1
Awake Time %	6.8	12.1	10.8	16.6	11.4	46.7	19.5	17.2
# of Awakenings for the Whole Sleep Period	18	20	23	27	18	17	21.0	4.54
# of REM Periods	4	5	4	4	4	3	4.0	.791
REM Latency (mins.)	88.0	42.0	66.3	64.3	54.7	64.3	58.3	11.4
REM % (SPT)	16.4	27.1	18.6	24.1	19.6	9.5	19.8	7.49
Stage 1% (SPT)	4.2	7.4	8.4	10.0	12.6	8.6	9.4	2.25
Stage 2% (SPT)	48.2	29.5	48.2	30.0	38.8	23.4	34.0	10.8
Stages 3&4% (SPT)	24.4	23.8	13.9	13.4	17.6	11.9	16.1	5.34

Note. The Adaptation night was not included in the Mean and S.D. calculations.

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

NO INFO. CONDITION

NAME BZ

AGE 27

	NIGHTS							
	ADAPT	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	260.0	352.7	344.3	358.0	350.0	271.7	335.3	40.2
Total Sleep Time (mins.)	236.7	232.0	298.7	311.0	285.0	236.7	272.7	40.5
Sleep Period Time (SPT)	243.3	249.0	327.0	337.0	324.3	254.7	298.4	47.9
Sleep Efficiency % (sleep time/time in bed)	91.0	65.8	86.7	86.9	81.4	87.1	81.6	10.2
Sleep Latency[a] (mins.)	16.7	103.7	17.3	21.0	25.7	17.0	36.9	41.9
Minutes Awake	6.0	17.0	25.3	26.0	38.3	18.0	24.9	9.54
Awake Time %	2.5	6.8	7.7	7.7	11.8	7.1	8.22	2.28
# of Awakenings for the Whole Sleep Period	11	18	21	17	21	13	18.0	3.71
# of REM Periods	2	2	3	3	3	2	2.6	.612
REM Latency (mins.)	82.3	60.3	112.3	60.3	92.3	60.7	77.2	26.8
REM % (SPT)	32.2	16.5	21.8	23.1	16.9	15.6	18.8	3.82
Stage 1% (SPT)	4.4	3.9	4.6	8.0	8.2	4.2	5.78	2.38
Stage 2% (SPT)	25.5	42.6	40.9	38.7	45.8	47.1	43.0	3.86
Stages 3&4% (SPT)	35.2	30.3	24.0	22.5	17.0	26.1	24.0	5.46

Note. The Adaptation night was not included in the Mean and S.D. calculations.

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

NO INFO. CONDITION

NAME SB

AGE 27

	NIGHTS							
	ADAPT	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	344.7	386.0	422.3	429.0	432.0	388.0	411.5	25.3
Total Sleep Time (mins.)	316.7	339.7	364.0	375.7	373.7	346.0	359.8	18.2
Sleep Period Time (SPT)	333.0	361.3	383.3	409.7	411.0	366.0	386.3	26.2
Sleep Efficiency % (sleep time/time in bed)	91.9	88.0	86.2	87.6	86.5	89.2	87.5	1.35
Sleep Latency[a] (mins.)	11.7	24.7	39.0	19.3	21.0	22.0	25.2	8.90
Minutes Awake	16.3	16.7	16.3	34.0	37.0	20.0	24.8	11.1
Awake Time %	4.9	4.6	4.3	8.3	9.0	5.5	6.34	2.42
# of Awakenings for the Whole Sleep Period	29	19	21	29	39	23	26.2	9.03
# of REM Periods	2	3	2	4	3	2	2.8	.935
REM Latency (mins.)	103.0	117.0	58.3	82.0	83.3	83.3	84.8	23.40
REM % (SPT)	7.6	8.1	14.1	13.8	6.2	6.7	9.78	4.33
Stage 1% (SPT)	3.5	3.0	3.5	5.8	3.8	4.5	4.12	1.21
Stage 2% (SPT)	56.7	60.1	54.4	68.7	43.7	57.7	56.9	10.2
Stages 3&4% (SPT)	27.3	22.8	22.9	3.5	37.2	25.6	22.4	13.5

Note. The Adaptation night was not included in the Mean and S.D. calculations.

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

NO INFO. CONDITION

NAME BS

AGE 21

	NIGHTS							
	ADAPT	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	382.3	449.0	433.7	412.3	463.3	413.7	434.4	24.8
Total Sleep Time (mins.)	267.0	237.7	237.3	291.7	301.3	264.7	266.5	33.2
Sleep Period Time (SPT)	340.7	285.3	278.7	347.7	415.0	383.0	341.9	66.8
Sleep Efficiency % (sleep time/time in bed)	69.8	52.9	54.7	70.7	65.0	64.0	61.5	8.35
Sleep Latency[a] (mins.)	41.7	163.7	155.0	64.7	48.3	30.7	92.5	69.6
Minutes Awake	70.3	40.0	55.0	55.0	112.3	105.3	73.5	36.8
Awake Time %	20.6	14.0	12.8	15.8	27.1	27.5	19.4	8.11
# of Awakenings for the Whole Sleep Period	31	25	27	30	31	37	30.0	5.12
# of REM Periods	2	2	2	3	2	3	2.4	.612
REM Latency (mins.)	152.3	51.3	58.0	57.0	75.0	74.7	63.2	4.20
REM % (SPT)	14.9	4.7	8.7	5.1	3.5	12.7	6.94	4.20
Stage 1% (SPT)	7.6	13.4	11.1	9.1	6.3	12.8	10.5	3.24
Stage 2% (SPT)	36.8	43.8	37.4	42.9	28.5	24.7	35.5	9.57
Stages 3&4% (SPT)	19.1	21.4	27.9	26.8	34.3	18.9	25.9	6.72

Note. The Adaptation night was not included in the Mean and S.D. calculations.

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

A PRIOR SLEEP

NAME BS

AGE 21

	NIGHTS						
	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	427	447.7	480.3	467	464	457.2	22.9
Total Sleep Time (mins.)	247	363.7	233.7	395.7	298.7	307.8	79.3
Sleep Period Time (SPT)	353.7	399.7	392	426.0	411.0	396.5	30.3
Sleep Efficiency % (sleep time/time in bed)	57.8	81.2	48.6	84.7	64.4	67.3	17.2
Sleep Latency[a] (mins.)	73.3	48.0	88.3	41.0	53.0	60.7	21.9
Minutes Awake	106.7	30.7	158.3	30.0	112.0	87.5	62.5
Awake Time %	30.2	7.7	40.4	7.0	27.3	22.5	16.4
# of Awakenings for the Whole Sleep Period	45	28	30	33	28	32.8	7.96
# of REM Periods	2	4	3	3	3	3.0	.791
REM Latency (mins.)	45.3	61.0	182	90.3	49.7	85.7	63.3
REM % (SPT)	6.6	18.5	7.7	16.9	9.6	11.9	6.11
Stage 1% (SPT)	13.1	7.3	8.0	6.8	8.6	8.76	2.82
Stage 2% (SPT)	23.6	36.6	24.3	38.2	43.1	33.2	9.78
Stages 3&4% (SPT)	26.5	28.5	19.6	31.0	11.5	23.4	8.83

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

NO INFO. CONDITION

NAME YR

AGE 22

	NIGHTS							
	ADAPT	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	292.7	409.0	434.7	572.0	458.0	384.3	451.6	81.3
Total Sleep Time (mins.)	269.7	350	393.3	513.0	386.7	340.7	396.7	77.0
Sleep Period Time (SPT)	277.3	378.7	422.0	547.7	428.7	365.3	428.5	80.5
Sleep Efficiency % (sleep time/time in bed)	92.1	85.6	90.5	89.7	84.4	88.6	87.8	2.95
Sleep Latency[a] (mins.)	15.3	30.3	12.7	24.3	29.3	19.0	23.1	8.23
Minutes Awake	2.7	22.3	27.0	33.0	33.7	19.0	27.0	7.22
Awake Time %	1.0	5.9	6.4	6.0	7.9	5.2	6.28	1.12
# of Awakenings for the Whole Sleep Period	9	33	41	44	49	23	38.0	11.4
# of REM Periods	4	4	5	6	5	4	4.80	.935
REM Latency (mins.)	37.0	46.7	56.0	56.0	48.7	48.7	51.2	4.96
REM % (SPT)	19.6	19.4	16.2	16.6	16.9	16.3	17.1	1.48
Stage 1% (SPT)	2.4	5.5	9.2	9.7	11.9	5.9	8.44	3.02
Stage 2% (SPT)	47.2	53.9	56.7	60.3	50.2	53.6	54.9	4.23
Stages 3&4% (SPT)	28.0	13.8	11.1	7.2	11.2	17.4	12.1	4.21

Note. The Adaptation night was not included in the Mean and S.D. calculations.

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

A PRIORI WAKE

NAME YR

AGE 22

	NIGHTS						
	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	383.0	385.3	400.3	452.7	438.0	411.9	35.5
Total Sleep Time (mins.)	339.0	340.3	371.7	420.3	387.3	371.7	38.2
Sleep Period Time (SPT)	356.7	364.3	389.7	444.3	416.0	394.2	40.7
Sleep Efficiency % (sleep time/time in bed)	88.5	88.3	92.8	92.9	88.4	90.2	2.73
Sleep Latency[a] (mins.)	26.3	21.0	10.7	8.3	22.0	17.7	8.67
Minutes Awake	17.7	19.3	17.7	22.7	28.0	21.1	4.89
Awake Time %	5.0	5.3	4.5	5.1	6.7	5.32	.923
# of Awakenings for the Whole Sleep Period	34	28	34	39	40	35.0	5.36
# of REM Periods	4	4	4	4	5	4.2	.500
REM Latency (mins.)	37.7	41.0	58.0	70.3	50.3	51.5	14.8
REM % (SPT)	13.2	13.2	19.1	14.0	15.7	15.0	2.78
Stage 1% (SPT)	6.0	7.1	8.5	7.7	9.1	7.68	1.35
Stage 2% (SPT)	53.0	59.4	49.5	59.7	56.0	55.5	4.85
Stages 3&4% (SPT)	22.9	13.7	28.3	13.2	12.3	18.1	7.99

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

NO INFO. CONDITION

NAME HG

AGE 27

	NIGHTS							
	ADAPT	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	386.3	479.0	399.7	374.0	402.7	415.3	414.1	43.9
Total Sleep Time (mins.)	358.0	333.3	320.0	287.3	317.0	361.7	323.9	30.2
Sleep Period Time (SPT)	366.0	366.3	359.7	307.0	351.0	386.3	354.1	32.8
Sleep Efficiency % (sleep time/time in bed)	92.7	69.6	80.1	76.8	78.7	87.1	78.5	7.04
Sleep Latency[a] (mins.)	20.3	112.7	40.0	67.0	51.7	29.0	60.1	36.5
Minutes Awake	7.7	33.0	39.7	19.7	34.0	23.7	30.2	8.89
Awake Time %	2.1	9.0	11.0	6.4	9.7	6.4	8.5	2.29
# of Awakenings for the Whole Sleep Period	16	28	40	17	29	30	28.8	9.13
# of REM Periods	1	4	3	2	3	2	2.8	.935
REM Latency (mins.)	74.0	52.0	61.3	46.0	58.7	87.0	61.0	17.6
REM % (SPT)	8.4	11.4	7.0	15.5	10.3	13.8	11.6	3.66
Stage 1% (SPT)	2.5	7.0	6.3	5.1	5.1	4.5	5.6	1.14
Stage 2% (SPT)	55.1	54.7	51.3	49.5	40.8	55.7	50.4	6.62
Stages 3&4% (SPT)	31.9	17.9	24.4	23.5	34.1	19.7	23.9	7.03

Note. The Adaptation night was not included in the Mean and S.D. calculations.

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

A PRIORI WAKE

NAME HG

AGE 27

	NIGHTS						
	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	421.7	430.3	359.7	452.0	449.0	422.5	41.8
Total Sleep Time (mins.)	325.7	392.7	307.7	382.3	398.0	361.3	46.5
Sleep Period Time (SPT)	366.3	411.0	333.7	401.7	438.3	390.2	45.6
Sleep Efficiency % (sleep time/time in bed)	77.2	91.2	85.5	84.6	88.6	85.4	5.91
Sleep Latency[a] (mins.)	55.3	19.3	26.0	50.3	10.7	32.3	21.8
Minutes Awake	33.7	18.0	26.0	19.3	40.3	27.5	10.6
Awake Time %	9.2	4.4	7.8	4.8	9.2	7.08	2.62
# of Awakenings for the Whole Sleep Period	35	25	19	30	34	28.6	7.44
# of REM Periods	5	2	2	3	4	3.2	1.46
REM Latency (mins.)	40.0	114.0	65.0	86.7	85.0	78.1	30.8
REM % (SPT)	17.9	9.4	13.3	10.0	14.8	13.1	3.92
Stage 1% (SPT)	8.2	5.7	3.7	6.3	6.8	6.14	1.84
Stage 2% (SPT)	46.5	44.8	52.2	53.8	50.5	49.6	4.25
Stages 3&4% (SPT)	16.3	35.7	23.0	25.0	18.6	23.7	8.42

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

NO INFO. CONDITION

NAME PC

AGE 20

	NIGHTS							
	ADAPT	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	372.3	351.0	349.3	331.7	403.0	412.3	369.5	40.0
Total Sleep Time (mins.)	304.7	286.3	228.3	292.3	279.3	311.0	279.4	34.6
Sleep Period Time (SPT)	313.0	310.0	281.3	315.7	359.7	350.0	323.3	35.5
Sleep Efficiency % (sleep time/time in bed)	81.8	81.6	65.4	88.1	69.3	75.4	76.0	10.2
Sleep Latency[a] (mins.)	59.3	41.0	68.0	16.0	43.3	62.3	46.1	22.9
Minutes Awake	8.3	23.7	50.0	23.3	80.3	39.0	43.3	26.3
Awake Time %	2.7	7.6	17.8	7.4	22.3	11.1	13.2	7.36
# of Awakenings for the Whole Sleep Period	12	22	25	20	43	41	30.2	12.2
# of REM Periods	3	3	2	2	2	1	2.0	.791
REM Latency (mins.)	67.0	95.3	59.0	76.0	275.3	216.7	144.5	107.2
REM % (SPT)	14.1	12.0	5.9	6.7	3.6	4.4	6.52	3.69
Stage 1% (SPT)	3.6	7.0	9.5	4.4	18.4	15.0	10.9	6.43
Stage 2% (SPT)	55.8	54.8	54.1	49.3	45.2	52.3	51.1	4.41
Stages 3&4% (SPT)	23.8	18.5	11.6	32.3	10.4	17.1	18.0	9.70

Note. The Adaptation night was not included in the Mean and S.D. calculations.

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

A PRIORI SLEEP

NAME PC

AGE 20

	NIGHTS						
	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	440.7	401.3	420.7	410.0	393.3	413.2	20.6
Total Sleep Time (mins.)	311.7	323.0	344.0	361.0	351.3	338.2	22.8
Sleep Period Time (SPT)	399.0	361.7	386.3	386.0	382.0	383.0	15.1
Sleep Efficiency % (sleep time/time in bed)	70.7	80.5	81.8	88.0	89.3	82.1	8.28
Sleep Latency[a] (mins.)	41.7	39.7	34.3	24.0	11.3	30.2	14.1
Minutes Awake	87.3	38.7	39.3	22.0	30.7	43.6	28.4
Awake Time %	21.9	10.7	10.2	5.7	8.0	11.3	6.99
# of Awakenings for the Whole Sleep Period	41	25	24	26	32	29.6	7.93
# of REM Periods	1	3	4	3	3	2.8	1.22
REM Latency (mins.)	337.0	64.3	53.7	53.3	84.0	118.5	137.3
REM % (SPT)	7.5	12.3	15.9	16.6	9.0	12.3	4.52
Stage 1% (SPT)	9.0	5.6	7.0	6.5	7.5	7.12	1.41
Stage 2% (SPT)	48.0	63.0	51.5	64.9	63.3	58.1	8.71
Stages 3&4% (SPT)	13.6	8.4	14.6	5.6	12.2	10.9	4.22

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

NO INFO. CONDITION

NAME KS

AGE 29

	NIGHTS							
	ADAPT	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	350.7	370.3	377.0	390.7	393.0	345.7	375.3	21.3
Total Sleep Time (mins.)	288.0	319.7	295.7	337.3	327.7	298.0	315.7	20.5
Sleep Period Time (SPT)	299.7	340.0	338.0	370.0	360.0	317.0	345.0	23.1
Sleep Efficiency % (sleep time/time in bed)	82.1	86.3	78.4	86.3	83.4	86.2	84.1	3.84
Sleep Latency[a] (mins.)	51.0	30.3	39.0	20.7	33.0	28.7	30.3	7.45
Minutes Awake	11.0	19.7	42.0	25.7	31.3	19.0	27.5	10.6
Awake Time %	3.7	5.8	12.4	6.9	8.7	6.0	7.96	3.06
# of Awakenings for the Whole Sleep Period	11	14	31	22	32	26	25.0	8.22
# of REM Periods	3	2	2	3	2	3	2.4	.612
REM Latency (mins.)	67.0	77.7	57.0	68.0	56.0	48.7	61.5	12.7
REM % (SPT)	10.8	15.7	14.0	11.7	14.4	13.2	13.8	1.66
Stage 1% (SPT)	1.6	2.9	4.5	2.8	6.8	3.8	4.16	1.82
Stage 2% (SPT)	51.6	40.1	44.1	49.0	43.9	47.9	45.0	3.97
Stages 3&4% (SPT)	32.2	35.2	24.8	27.7	25.9	29.0	28.5	4.55

Note. The Adaptation night was not included in the Mean and S.D. calculations.

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

A PRIORI SLEEP

NAME KS

AGE 29

	NIGHTS						
	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	417.3	400.0	386.3	368.0	296.7	373.7	52.2
Total Sleep Time (mins.)	326.3	348.3	339.3	302.3	248.3	312.9	44.8
Sleep Period Time (SPT)	374.3	372.0	363.0	339.7	264.3	342.7	51.3
Sleep Efficiency % (sleep time/time in bed)	78.2	87.1	87.8	82.2	83.7	83.8	4.36
Sleep Latency[a] (mins.)	43.0	28.0	23.3	28.3	32.3	31.0	8.32
Minutes Awake	47.7	22.7	23.3	37.3	16.0	29.4	14.4
Awake Time %	12.7	6.1	6.4	11.0	6.1	8.46	3.53
# of Awakenings for the Whole Sleep Period	26	29	24	24	23	25.2	2.67
# of REM Periods	2	2	2	2	1	1.8	.50
REM Latency (mins.)	60.3	42.7	66.3	59.0	59.7	57.6	9.86
REM % (SPT)	12.7	12.2	12.0	14.6	13.9	13.1	1.26
Stage 1% (SPT)	4.4	3.1	3.4	3.4	5.4	3.94	1.06
Stage 2% (SPT)	41.1	46.6	45.9	48.3	41.0	44.6	3.73
Stages 3&4% (SPT)	29.0	29.5	32.2	22.7	33.6	29.4	4.70

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

NO INFO. CONDITION

NAME DM

AGE 21

	NIGHTS						
	ADAPT	EXP.#1	EXP.#2	EXP.#3	EXP.#4	MEAN	S.D.
Time in Bed (mins.)	450.7	425.3	397.7	411.7	448.3	420.8	24.9
Total Sleep Time (mins.)	419.3	312.3	341.0	332.7	255.0	310.2	44.8
Sleep Period Time (SPT)	431.7	390.7	370.0	370.0	358.7	372.4	15.4
Sleep Efficiency % (sleep time/time in bed)	93.0	73.4	85.8	80.8	56.9	74.2	14.6
Sleep Latency[a] (mins.)	19.0	34.7	27.7	41.7	89.7	48.4	32.4
Minutes Awake	12.3	78.3	29.0	34.3	103.7	61.3	41.4
Awake Time %	2.9	20.1	7.8	9.3	28.9	16.5	11.4
# of Awakenings for the Whole Sleep Period	16	18	15	14	15	15.5	2.0
# of REM Periods	2	2	2	3	1	2.0	.943
REM Latency (mins.)	187.0	53.7	186.7	86.3	64.0	97.7	70.3
REM % (SPT)	8.3	5.3	4.4	5.3	1.7	4.18	1.97
Stage 1% (SPT)	2.3	4.5	3.8	4.0	2.7	3.75	.877
Stage 2% (SPT)	59.6	48.0	56.0	51.5	40.7	49.0	7.46
Stages 3&4% (SPT)	26.9	22.1	27.9	29.1	26.1	26.3	3.53

Note. The Adaptation night was not included in the Mean and S.D. calculations.

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

A PRIORI WAKE

NAME DM

AGE 21

	NIGHTS					
	EXP.#1	EXP.#2	EXP.#3	EXP.#4	MEAN	S.D.
Time in Bed (mins.)	479.3	408.3	443.7	387.7	429.8	46.6
Total Sleep Time (mins.)	383.3	358.0	388.0	327.7	364.2	32.0
Sleep Period Time (SPT)	418.7	384.7	413.0	365.3	395.4	28.8
Sleep Efficiency % (sleep time/time in bed)	80.0	87.7	87.5	84.5	84.9	4.15
Sleep Latency[a] (mins.)	60.7	23.7	30.7	22.3	34.4	20.7
Minutes Awake	35.3	26.7	25.0	37.0	31.0	6.96
Awake Time %	8.4	6.9	6.1	10.1	7.88	2.04
# of Awakenings for the Whole Sleep Period	25	15	18	20	19.5	4.85
# of REM Periods	1	2	2	3	2.0	.943
REM Latency (mins.)	190.3	96.0	178.3	148.7	153.3	48.5
REM % (SPT)	8.6	8.5	9.2	7.7	8.5	.712
Stage 1% (SPT)	5.0	4.3	3.6	4.2	4.28	.662
Stage 2% (SPT)	52.5	53.5	56.7	51.5	53.6	2.60
Stages 3&4% (SPT)	25.4	26.8	24.5	26.4	25.8	1.19

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

INSOMNIAC

NAME RB

AGE 45

	NIGHTS							
	ADAPT	EXP.#1	EXP.#2	EXP.#3	EXP.#4	EXP.#5	MEAN	S.D.
Time in Bed (mins.)	424	493.7	523	532	501.3	520.7	514.1	16
Total Sleep Time (mins.)	265.3	362.7	364	381.7	353.7	426.3	377.7	29
Sleep Period Time (SPT)	274.7	415	408.7	420	388	469.3	420.2	30
Sleep Efficiency % (sleep time/time in bed)	62.6	73.5	69.6	71.7	70.5	81.9	73.4	5
Sleep Latency[a] (mins.)	149.3	78.7	114.3	112	113.3	51.3	93.9	28.1
Minutes Awake	8.7	48	40.3	31	29.7	28.7	35.5	8.4
Awake Time %	3.2	11.6	9.9	7.4	7.6	6.1	8.5	2.2
# of Awakenings for the Whole Sleep Period	18	40	35	19	33	18	29.0	10
# of REM Periods	3	5	5	5	5	6	5.2	.4
REM Latency (mins.)	29	160.7	72.7	90	39.3	49.3	82.4	48
REM % (SPT)	18.9	9.9	14.2	14.6	15	17.8	14.3	2.8
Stage 1% (SPT)	6.6	7.2	9.2	10.5	11.1	10.7	9.7	1.6
Stage 2% (SPT)	58.7	63	56.7	58.3	55.6	49.6	56.6	4.8
Stages 3&4% (SPT)	12.4	7.3	9	7.5	9.5	12.9	9.2	2.2

Note. The Adaptation night was not included in the Mean and S.D. calculations.

[a] Criterion used for scoring Sleep Onset = 10 Minutes of at least Stage 1 sleep.

APPENDIX B: ELECTRODE MONTAGE, MORNING QUESTIONNAIRES, AND CONSENT FORMS

ELECTRODE MONTAGE - ADAPTATION NIGHT

CHANNEL	PIN #	ELECTRODE DERIVATION		SENS.	T.C.
	G	FOREHEAD GROUND			
1	5	$C_4 - A_1 + A_2$	(EEG)	7.5	0.3
2	6	$O_2 - A_1 + A_2$	(EEG)	7.5	0.3
3	1,3	ROC - LOC	(EOG)	7.5	3.0
4	1	ROC - $A_1 + A_2$	(EOG)	7.5	0.1
5	3	LOC - $A_1 + A_2$	(EOG)	7.5	0.1
6	9,10	CHIN EMG	(EMG)	1.5	3.0
7	11,12	RAT EMG	"	1.5	3.0
8	13,14	LAT EMG	"	1.5	3.0
9	7,8	EKG	(RHYTHM STRIP)	$\frac{MV}{CM}$	0.3
10	15,16	RNA - LNA	(THERMISTORS)	$\frac{MV}{CM}$	0.1
11	EXT.	TAM	D.C. EXT.		

STANDARD CALIBRATIONS

All Channels 50 uV 60 cycle filter in Sens. = 7.5 mm

T.C. = 0.3 paper speed = 15 mm/sec.

ELECTRODE MONTAGE - EXPERIMENTAL NIGHTS

CHANNEL	PIN #	ELECTRODE DERIVATION	SENS.	T.C.
	G	FOREHEAD GROUND		
1	5	$C_4 - A_1 + A_2$ (EEG)	7.5	0.3
2	6	$O_2 - A_1 + A_2$ (EEG)	7.5	0.3
3	PLUG IN BACK OF POLYGRAPH J_5 or J_6	MARKER +/or ROC-LOC - (T.C. = 3)		
4	1	ROC - $A_1 + A_2$ (EOG)	7.5	0.1
5	3	LOC - $A_1 + A_2$ (EOG)	7.5	0.1
6	9,10	CHIN EMG (EMG)	1.5	3.0
7	7,8	EKG (RHYTHM STRIP)	$\frac{MV}{CM}$	0.3
8	15,16	RNA - LNA (THERMISTORS)	$\frac{MV}{CM}$	0.1

STANDARD CALIBRATIONS

All Channels 50 uV 60 cycle filter in Sens. = 7.5 mm

T.C. = 0.3 paper speed = 15 mm/sec.

Sleep-Wake Disorders Center
Montefiore Hospital and Medical Center

PATIENT'S MORNING QUESTIONNAIRE

PLEASE COMPLETE THIS QUESTIONNAIRE WITHIN 1/2 HOUR
OF THE TIME THAT YOU AROSE

CIRCLE THE LETTER OF YOUR ANSWER OR FILL IN THE BLANK

NAME________________________________ TODAY'S DATE____________

TIME RIGHT NOW:_____AM OR _____PM

1. From the time you began to try, how long did it take to fall asleep last night?

   a. Fell asleep right away
   b. Fell asleep in ___ minutes (FILL IN)
   c. Fell asleep in ___ hours (FILL IN)
   d. Didn't fall asleep at all

2. Compared to the time it usually takes you to fall asleep at home, this was:

   a. Much longer than usual
   b. Longer than usual
   c. Same as usual
   d. Shorter than usual
   e. Much shorter than usual

3. How light or deep was your sleep?

   a. Much lighter than usual
   b. Lighter than usual
   c. Same as usual
   d. Deeper than usual
   e. Much deeper than usual

4. How restless or restful was your sleep?

   a. Much more restless than usual
   b. More restless than usual
   c. Same as usual
   d. More restful than usual
   e. Much more restful than usual

5. How much did you dream?

   a. Didn't dream at all
   b. Dreamed less than usual
   c. Dreamed same as usual
   d. Dreamed more than usual
   e. Dreamed much more than usual

6. How many times do you recall waking up?

   _________ times

7. Compared to the number of times you usually wake up this was:

   a. Much more than usual
   b. More than usual
   c. Same as usual
   d. Less than usual
   e. Much less than usual

8. How did you awaken just now?

   a. Spontaneously (of your own accord) at _____ AM or _____ PM
   b. Some disturbance (such as noise) woke you at _____ AM or _____ PM
   c. Alarm clock woke you at _____ AM or _____ PM
   d. Technician woke you at _____ AM or _____ PM

9. Altogether, how much sleep do you think you got?

   a. _____ hours of sleep (FILL IN)
   b. _____ minutes of sleep (FILL IN)
   c. No sleep at all

10. Compared to the amount of sleep you usually get at home, this was:

   a. Much more than usual
   b. More than usual
   c. Same as usual
   d. Less than usual
   e. Much less than usual

11. How long after awakening did you get up and out of bed?

   a. Immediately after awakening
   b. _____ minutes after awakening (FILL IN)
   c. _____ hours after awakening (FILL IN)

12. How did you feel immediately after awakening?

    a. Alert. Wide awake. Energetic.
    b. At high level, but not at peak.
    Able to concentrate
    c. Awake, but not fully alert
    d. A little foggy, let down
    e. Foggy
    f. Sleepy. Preferred to be lying down. Woozy

13. Compared to the way you usually feel immediately after awakening, you felt:

    a. Much more awake & alert than usual
    b. More awake & alert than usual
    c. Same as usual
    d. Less awake & alert than usual
    e. Much less awake & alert than usual

14. How much longer could you have slept?

    a. Couldn't have slept longer
    b. Could have slept ____ minutes longer (FILL IN)
    c. Could have slept ____ hours longer (FILL IN)

15. Do you have any physical complaints (pain, headache, nausea, others) right now?

    a. No
    b. Yes. Explain: ________________________________

    ____

16. All in all, the way you just slept was:

    a. Much better than usual
    b. Better than usual
    c. Same as usual
    d. Worse than usual
    e. Much worse than usual

17. Please explain your answer to the last question or add any other comments or information:

    ____

    ____

    ____

    ____

NAME_________________________________ DATE ___________________

(Normal Control, Insomniac Subject)

MORNING POST-EXPERIMENTAL NIGHT #_____

Please write down whatever you can verbalize concerning how you made an <u>asleep</u> or <u>awake</u> decision.

Specifically ----

1) How did you go about deciding whether you were awake or asleep last night?

2) Describe what factors influenced how certain you were about your decisions.

CONSENT FORM

A Study of Sleep-Wake "Perception"

I, ____________________________, hereby consent to participate as a (Normal Control, Insomniac) research subject in a study of sleep-wake perception. The following procedures have been explained to me and I have been given the opportunity to ask any questions I wish regarding these procedures and the purposes of this study.

In the evening, various devices will be attached to the skin of my head, face, chest, and legs. These will be used to record my sleep, heart activity, breathing and leg activity, for 8 or more hours. This involves no significant discomfort or risk.

The study will be conducted during six complete nights of sleep. I will participate on two non-consecutive nights each week for a total period of three weeks.

On the first night of the study, I will be allowed to sleep undisturbed through the night. On each of the remaining five nights, I will be aroused by a telephone ring twelve times during the course of the night and asked by tape recording to rank along a six point scale whether I was asleep or awake just before I heard the telephone ring. After each ranking, I will be allowed to return to sleep.

I have been told that I may refuse to participate or discontinue my participation in this study at anytime and that my refusal to participate will not prejudice in any way my further treatment or my future relations with the hospital and its doctors.

Signed, (subject) ________________	Signed, (witness) ________________
	Date ________________

VI. REFERENCES

Ackner, B. and Pampiglione, G. Some relationship between peripheral vasomotor and EEG changes. Journal of Neurology, Neurosurgery and Psychiatry, 1957, 20, 58-61.

Agnew, H.W. and Webb, W.B. Measurement of sleep onset by EEG criteria. American Journal of EEG Technology, 1972, 12(3), 127-134.

Anderson, P., Anderson, S.A., and Lomo, T. Nature of thalo-mocortical relation during spontaneous barbiturate spindle activity. Journal of Physiology (London), 1967, 192, 283-307.

Antrobus, J.S. and Saul, H.N. Insomnia and presleep affect. Unpublished manuscript, 1978.

Association of Sleep Disorders Centers. Diagnostic Classification of Sleep and Arousal Disorders, First Edition, prepared by the Sleep Disorders Classification Committee, H.P. Roffwarg, Chairman, Sleep, 1979, 2, 1-137.

Atkinson, R.C. A variable sensitivity theory of signal detection. Psychological Review, 1963, 70, 91-106.

Bourbon, W.T. Psychophysics and perception. In Anderson and Borkowski (Eds.), Experimental psychology: research tactics and their applications. Oakland, N.J.: Scott, Foresman and Company, 1978, 248-306.

Brezinova, V., Oswald, I., and Loudon, J. Two types of insomnia: too much waking or not enough sleep. British Journal of Psychiatry, 1975, 126, 439-445.

Bruning, J.L. and Kintz, B.L. Computational handbook of statistics. Oakland, N.J.: Scott, Foresman and Co., 1968, 12-17, 43-47, 54-61.

Church, M.W., Johnson, L.C., and Seales, D.M. Evoked K-complexes and cardiovascular responses to spindle-synchronous and spindle-asynchronous stimulus clicks during NREM sleep. Electroencephalography and Clinical Neurophysiology, 1978, 45, 443-453.

Czeisler, C.A. Human circadian physiology: internal organization of temperature, sleep-wake and neuroendocrine function in an environment free of time cues. Ph.D. dissertation, Stanford University, 1978.

Czeisler, C.A., Weitzman, E.D., Moore-Ede, M.C., Zimmerman, J.C., and Knauer, R.S. Human sleep: its duration and organization depend on its circadian phase. Science, 1980, 210, 1264-1276.

Davis, H., Davis, P.A., Loomis, A.L., Harvey, E.N., and Hobart, G. Human brain potentials during the onset of sleep. Journal of Neurophysiology, 1938, 1, 24-38.

Davis, H., Davis, P.A., Loomis, A.L., Harvey, E.N., and Hobart, G. Electrical reactions of the human brain to auditory stimulation during sleep. Journal of Neurophysiology, 1939, 2, 500-514.

Dement, W.C. and Kleitman, N. Cyclic variations in EEG during sleep and their relation to eye movements, body motility, and dreaming. Electroencephalography and Clinical Neurophysiology, 1957a, 9, 673-690.

Dement, W.C. and Kleitman, N. The relation of eye movements during sleep to dream activity: an objective method for the study of dreaming. Journal of Experimental Psychology, 1957b, 53, 339-346.

Dusoir, A.E. Treatments of bias in detection and recognition models: a review. Perception and Psychophysics, 1975, 17(2), 167-178.

Ehrhart, J., Ehrhart, M., Muzet, A., Schieber, J.P., and Naitoh, P. K-complexes and sleep spindles before transient activation during sleep. Sleep, 1981, 4, 400-407.

Einstein, A. Relativity: the special and the general theory. New York: Crown Publishers, 1961, 77.

Foulkes, D. and Vogel, G. Mental activity at sleep onset. Journal of Abnormal Psychology, 1965, 70, 231-243.

Frankel, B.L., Buchbinder, R. and Synder, F. Ineffectiveness of electrosleep in chronic primary insomnia. Archives of General Psychiatry, 1973, 29, 563-568.

Freedman, R. Psychological and physiological characteristics of sleep-onset insomniacs. Abstract. Sleep Research, 1976, 170.

Gaillard, J.M. and Tissot, R. EEG sleep studies of insomniacs under flunitrazepam treatment. International Pharmacopsychiatry, 1975, 10, 199-207.

Garner, W.R. Uncertainty and structure as psychological concepts. New York: Wiley, 1962, 1-19, 138-213, 338-345.

Green, D.M. and Swets, J.A. Signal detection theory and psychophysics. New York: Wiley, 1966, 5-30.

Gundy, R.F. Auditory detection of an unspecified signal. Journal of the Acoustical Society of America, 1961, 33, 1008-1012.

Hartmann, E. *The biology of dreaming*. Springfield, Il.: Thomas, 1967, 99-100.

Hartley, R.V.L. Transmission of information. *Bell System Technical Journal*, 1928, *7*, 535-563.

Hauri, P. Biofeedback techniques in the treatment of serious, chronic insomniacs. *Proceedings of the Biofeedback Society of America*, 1978, *9*, 206-208.

Herz, A. Cortical and subcortical auditory evoked potentials during wakefulness and sleep in the cat. In Akert, Bally, and Schade (Eds.), *Sleep mechanisms*. Amsterdam: Elsevier, 1965, 63-69.

Hockey, G.R.J. and Colquhoun, W.P. Diurnal variation in human performance: a review. In Colquhoun (Ed.), *Aspects of human efficiency: diurnal rhythm and loss of sleep*. London: The English Universities Press, 1972, 1-24.

Hodos, W. Nonparametric index of response bias for use in detection and recognition experiments. *Psychological Bulletin*, 1970, *74(5)*, 351-354.

Hongo, T., Kubota, K., and Shimizu, H. EEG spindle and depression of gamma motor activity. *Journal of Neurophysiology*, 1963, *26*, 568-580.

Johnson, L.C., Hanson, K., and Bickford, R.G. Effect of flurazepam on sleep spindles and K-complexes. *Electroencephalography and Clinical Neurophysiology*, 1976, *40*, 67-77.

Kamiya, J. Behavioral, subjective, and physiological aspects of drowsiness and sleep. In Fiske and Maddi (Eds.), *Functions of varied experience*. Homewood, Il: Dorsey Press, 1961, 145-175.

Kirk, R.E. *Experimental design: procedures for the behavioral sciences*. Belmont, California: Brooks/Cole Publishing Co., 1968, 63-67.

Kleitman, N. *Sleep and wakefulness*. Chicago: The University of Chicago Press, 1963, 53-67, 148-161, 172-184.

Loomis, A.L., Harvey, E.N. and Hobart, G.A. Cerebral states during sleep, as studied by human brain potentials. *Journal of Experimental Psychology*, 1937, *21(2)*, 127-144.

Loomis, A.L., Harvey, E.N. and Hobart, G.A. Distribution of disturbance-patterns in the human electroencephalogram, with special reference to sleep. *Journal of Neurophysiology*, 1938, *1*, 413-430.

Lukaszewski, J.S. and Elliott, D.N. Auditory threshold as a function of forced-choice technique, feedback, and motivation. Journal of the Acoustical Society of America, 1962, 34, 223-228.

McNicol, D. A primer of signal detection theory. London: George Allen & Unwin Ltd., 1972, 3-130.

Miller, G.A. and Frick, F.C. Statistical behavioristics and sequences of responses. Psychological Review, 1949, 56, 311-324.

Monroe, L.J. Psychological and physiological differences between good and poor sleepers. Journal of Abnormal Psychology, 1967, 72(3), 255-264.

Moruzzi, G., Brookhart, J.M., Niemer, W.T., and Magoun, H.W. Augmentation of evoked electrocortical activity during spindle bursts. Electroencephalography and Clinical Neurophysiology, 1950, 2, 29-31.

Naitoh, P., Antony-Baas, V., Muzet, A. and Ehrhart, J. Dynamic relation of sleep spindles and K-complexes to spontaneous phasic arousal in sleeping human subjects. Sleep, 1982, 5(1), 58-72.

Nyquist, H. Certain factors affecting telegraph speed. Bell System Technical Journal, 1924, 3, 324-346.

Raynal, D., Montplaisir, J., and Dement, W.C. K-alpha events in hypersomniacs and normals. Sleep Research, 1974, 3, 144.

Rechtschaffen, A. Polygraphic aspects of insomnia. In Gastaut, Lugaresi, Berti-Ceroni, and Coccagna (Eds.), The abnormalities of sleep in man. Proceedings of the XVth European meeting on electroencephalography, Bologna, 1967, Bologna: Aulo Gaggi, 1968, 109-125.

Rechtschaffen, A. and Kales, A. (Eds.), A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects. Washington, D.C.: Public Health Service, U.S. Government Printing Office, 1968.

Rhodes, J.M. Electrical activity of the brain as a reflection of inhibitory phenomena. Neuropsychologia, 1969, 7, 209-216.

Roth, M., Shaw, J. and Green, J. The form, voltage distribution and physiological significance of the K-complex. Electroencephalography and Clinical Neurophysiology, 1956, 8, 385-402.

Runyon, R.P. and Haber, A. Fundamentals of behavioral statistics, 2nd edition. Reading, MA.: Addison-Wesley Publishing Company, 1972, 46-52.

Sassin, J.F. and Johnson, L.C. Body motility during sleep and its relation to the K-complex. Experimental Neurology, 1968, 22, 133-144.

Schoeffler, M.S. Probability learning and the discrimination of two durations. Unpublished manuscript presented to The Psychonomic Society, 1962.

Schoeffler, M.S. Theory for psychophysical learning. Journal of the Acoustical Society of America, 1965, 37(6), 1124-1133.

Shannon, C.E. A mathematical theory of communication. Bell System Technical Journal, 1948, 27, 379-423, 623-656.

Snodgrass, J.G. Theory and experimentation in signal detection. New York: Life Science Associates, 1972a, 1-5.

Snodgrass, J.G. Theory and experimentation in signal detection: experimental methods and data analysis. New York: Life Science Associates, 1972b, 1-4.

Swets, J.A. and Green, D.M. Sequential observations by human observers of signals in noise. In Cherry (Ed.), Information theory, fourth London Symposium. London: Butterworths Scientific Publications, Ltd, 1961, 177-195.

Swets, J.A. and Sewall, S.T. Invariance of signal detectability over stages of practice and levels of motivation. Journal of Experimental Psychology, 1963, 66, 120-126.

Walker, P.M. Sleep onset as a function of auditory stimulation rates, response requirements, and novelty of the environment. University of Florida Ph.D. dissertation, 1972 (unpublished). (cited in Agnew and Webb, 1972.)

Wiener, N. Cybernetics. New York: Wiley, 1948. (Out of print.)

Yamadori, A. Role of the spindles in the onset of sleep. Kobe Journal of Medical Science, 1971, 17, 97-111.

Zwislocki, J., Maire, F., Feldman, A.S., and Rubin, H. On the effect of practice and motivation on the threshold of audibility. Journal of the Acoustical Society of America, 1958, 30, 254-262.