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**LA THÈSE A ÉTÉ  
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Performance Impairment in Relation to Concomitant Physiological  
Vigilance Levels and Subjective States in Patients with  
Narcolepsy Compared to Matched Controls.

by Victoria Valley

Thesis submitted to the School of  
Graduate Studies of the University of  
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requirement for the Doctor of Philosophy  
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## Abstract

The degree and nature of performance impairment in narcoleptics was investigated in relation to concomitant physiological vigilance levels and subjective states. Ten narcoleptic patients off medication and 10 matched controls were tested individually in morning sessions (preceded by a practice morning). Two monotonous tasks (Wilkinson's 1 hr auditory vigilance task and the 10 minute four-choice serial reaction time task) and two stimulating tasks [paced auditory serial addition task (PASAT) and Digit Span] were administered in counter-balanced order. Self-ratings of drowsiness [Stanford Sleepiness Scale (SSS)] and effort were obtained for each test. Polygraphic recordings obtained during the vigilance task and the two stimulating tasks were scored by 40 sec epochs. To determine the relation between vigilance performance and physiological state, recordings during the auditory vigilance task were also scored by 3 and 3 + 10 sec periods preceding each signal and false positive response. Scoring categories comprised four stages: wakefulness; stage 1A (slowed and/or fragmented alpha rhythm); stage 1B (theta activity); stage 2.

In comparison with control subjects, the narcoleptic group exhibited significant performance deficits on the two monotonous tasks but not on the two stimulating tasks. The patients reported significantly greater effort expenditure on the PASAT and significantly higher drowsiness (SSS) ratings on all the tasks. Their SSS scores did not correlate significantly with performance on any of the tests. Narcoleptics spent significantly less time in wakefulness than controls

during the vigilance task and Digit Span but not during the PASAT.

Increased effort and increased wakefulness during the PASAT were attributed to its higher degrees of both stimulation and complexity. The narcoleptics' deficits were interpreted to be bivalent in nature, the decreased vigilance enhanced by a task of low stimulation resulted in performance deficits while a task of high stimulation and complexity counteracted performance deficits but required compensatory effort thereby stressing the patients. The more moderate levels of stimulation and demand, characteristic of Digit Span, did not result in such deficits and thus appeared more optimally suited for the narcoleptic.

The sequential epoch scoring of the vigilance task revealed an early occurring and continually fluctuating physiological state in which amounts of wakefulness (44%), stages 1A (28.5%) and 1B (26%) remained constant across the task (as did performance). Stage 2 occurred only briefly in four patients. Control subjects remained in wakefulness 99% of task time.

Analysis of vigilance performance in relation to physiological state revealed that narcoleptics' performance during wakefulness was significantly better than that during stage 1A, but poorer than the performance of control subjects during wakefulness. Deficits consisted of an increase in both false positive responses and lapses (errors of omission) relative to hits. Narcoleptics also made significantly more false positive responses for the time spent in wakefulness than controls. Performance during stages 1B and 2 were characterized almost entirely by lapses. The narcoleptics' poor performance during wakefulness was attributed to the inability to sustain wakefulness. Performance

during periods of sustained wakefulness was significantly better than performance during wakefulness immediately preceded by decreased vigilance levels (fragmented wakefulness), and did not differ from performance of control subjects. These deficit patterns demonstrated, in narcoleptics, the insufficiency of the lapse-microsleep formulation which indicates that poor performance in conditions of decreased vigilance is characterized solely by lapses associated with microsleeps (i.e., stages 1B or 2).

## Curriculum Studiorum

Vicki L. Valley was born February 27, 1950 in Prairie du Chien, Wisconsin. She received the Bachelor of Arts degree in Psychology and French Area Studies from the University of Wisconsin, Madison, Wisconsin in 1973. She received the Master of Arts degree in Clinical Psychology from the State University of New York; Plattsburgh, New York in 1976. The title of her Master's thesis was The Stress Reducing Effect of Perceived Control Over Noise.



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## CHAPTER 1

### INTRODUCTION

Over the past 25 years sleep research has focused on elucidating normative sleep patterns and on investigating the functions of sleep by various manipulations of these patterns. Recently there has been an upsurge of interest in the pathologies of sleep. This trend has resulted not only in providing more accurate diagnoses and more appropriate therapies for those afflicted, but has also contributed valuable knowledge about the nature of sleep and wakefulness.

Narcolepsy, an early recognized sleep disorder, was first described as a discrete disease entity by Gelineau in 1880 as "a rare, little known neurosis characterized by an imperative need to sleep of sudden onset and short duration, recurring at more or less close intervals" (p.1156). Today, with the increased interest in sleep disorders, this truly debilitating syndrome is becoming more widely recognized, although its incidence, estimated at about .1% (Bruhova & Roth, 1972; Guilleminault & Dement, 1974) is greater than that of a number of better known neurological conditions such as multiple sclerosis.

Yoss and Daly (1957) first established the criteria for diagnosis of narcolepsy by four major symptoms which they termed the narcoleptic tetrad. These include irresistible sleep attacks which are usually the first symptoms to appear, and three auxiliary symptoms; cataplexy, sleep paralysis and hypnagogic hallucinations, of which one or more usually

appears as the disease progresses (Carskadon, 1976; Guilleminault & Dement, 1974; Sours, 1963). The symptoms tend to be unremitting once they occur. The majority of investigations of narcolepsy have concentrated on the pathophysiological mechanisms and treatment of the tetrad of symptoms.

Most patients, however, also have a major complaint of chronic daytime drowsiness which may be the basis of further symptoms regarding poor mental functioning. In the view of numerous investigators (Broughton & Ghanem, 1976; Daniels, 1934; Guilleminault, Billiard, Montplaisir, & Dement, 1975a; Guilleminault & Dement, 1977; Ganado, 1958; Sours, 1963) the quality of a narcoleptic's life is greatly eroded by difficulties in performing daily tasks, problems which appear to be related particularly to excessive and persistent drowsiness. While there has been recent increasing recognition of drowsiness as a most pervasive and disabling aspect of narcolepsy (Dement, 1976; Dement, Guilleminault, Zarcone, Wilson & Carskadon, 1974; Roth, Bruhová & Lehovsky, 1969; Sours, 1963), the nature of this symptom and its effects on daily life are still only vaguely understood and have received almost no experimental attention (Broughton & Ghanem, 1976; Dement, 1979). Moreover drowsiness is the symptom most refractory to medication (Guilleminault & Dement, 1974) which indicates a need for better understanding of this symptom in the interest of more efficient treatment. The purpose of the present study is to provide a more specific and comprehensive understanding of this state of lowered vigilance in narcoleptics by investigating its effects on the narcoleptic's daytime perfor-

mance abilities and subjective experience, as well as its electrophysiological correlates.

### Characteristic Symptoms and Pathophysiology

#### The Narcoleptic Tetrad

Narcoleptics generally complain of an enduring though fluctuating drowsiness which is punctuated by actual sleep episodes and auxiliary symptoms. As the narcoleptic succumbs intermittently to the mechanisms of the sleep state, response to the outer world is completely interrupted for a temporary period.

Two types of sleep attacks have been delineated and are associated with two different categories of narcolepsy (Dement, Rechtschaffen & Gulevich, 1966; Roth et al., 1969). Independent narcolepsy (characterized by sleep attacks alone) involves NREM sleep attacks in which the patient gradually drifts from drowsiness to NREM sleep, while compound narcolepsy (characterized by auxiliary symptoms of cataplexy, sleep paralysis, and/or hypnagogic hallucinations) most often involves sleep onset REM periods (SOREMP) which tend to be more abrupt in onset. Sleep attacks normally last from 10-20 minutes but can vary from a few seconds to a few hours, depending on the circumstances. Specifically, if the patient is intent on doing something or is in an uncomfortable position, they will tend to be brief. Though asleep, patients sometimes report being vaguely aware of what goes on around them. REM sleep attacks are more likely to occur than are NREM attacks when patients are in a comfortable position (Hishikawa et al., 1968). The former can be associated

with sleep paralysis (muscle atonia) and hypnagogic hallucinations (dream-like experiences), particularly frightening experiences caused by dissociated REM mechanisms occurring prematurely during semi-consciousness (Hishikawa et al., 1978). Sleep paralysis and hallucinations may also occur at sleep onset or awakening from nocturnal sleep. Extreme drowsiness and these resultant sleep attacks and auxiliary symptoms all occur most frequently during monotonous work, periods of physical inactivity (Daniels, 1934; Ganado, 1958; Sours, 1963), and when the person is in a physically comfortable position (Hishikawa et al., 1968).

Cataplexy, the most commonly occurring auxiliary symptom (Sours, 1963), is initiated by emotional excitement and associated with a more or less full level of consciousness. Cataplectic attacks are more prone to occur, as are the other symptoms, when the person is feeling drowsy. Attacks usually last only a few seconds and involve partial to complete muscle atonia caused by dissociated REM mechanisms. In longer lasting attacks, patients can advance to REM sleep.

As only compound narcolepsy is clearly associated with REM related sleep attacks and auxiliary symptoms, the validity of independent narcolepsy as "true" narcolepsy rather than a form of hypersomnia, is questioned (Dement, 1976; Dement et al., 1966), though it may represent compound narcolepsy in the early stages (Carskadon, 1976). Presently, diagnosis of narcolepsy is confirmed by the presence of SOREMP (cf. Raynal, 1976). However, since SOREMP has been observed 100% of the time in patients with cataplexy (Guilleminault, 1976) which is a symptom unique to narcolepsy (Association of Sleep Disorders Centers, 1979), it

has been concluded that if sleep attacks and cataplexy are presenting symptoms, no sleep recording is necessary for clear diagnosis of narcolepsy (Guilleminault & Dement, 1977).

### Nocturnal Sleep

Disrupted nocturnal sleep is also characteristic of compound narcolepsy and, in fact, considered central to the pathology (Broughton & Mamelak, 1979). Prolonged periods of irregular sleep are reported to precede the appearance of symptoms in 50 to 70% of cases (Broughton & Ghanem, 1976; Mitchell & Dement, 1968). This evidence suggests that a disrupted sleep schedule either brings on narcolepsy in sensitive individuals, or that disrupted sleep could be the first symptom of narcolepsy rather than a cause or contributing factor. Nocturnal disruptions include SOREMP, fragmented and dissociated REM, terrifying dreams, frequent awakenings, and in some instances less stages 3 and 4 sleep (cf. Montplaisir, Billiard, Takahashi, Bell & Guilleminault, 1978).

Though the overall amount of sleep is normal, these abnormalities render its recuperative value questionable. When sleep deprived, narcoleptics do not experience recuperative sleep as do normals (Berti-Ceroni, Passaglia, Mantovani & Sabattini, 1971). Though daytime naps are considered refreshing (Daniels, 1934; Ganado, 1958; Zarcone, 1977) and improve performance (Billiard, 1976), they have also been reported to further disrupt the narcoleptic's nocturnal sleep (Montplaisir et al., 1978). Moreover, while normal individuals experiencing fatigue and exhaustion from overwork or stress can be replenished by longer and

deeper sleep (Hartmann, 1973; Oswald, 1970), these factors result only in increased symptomatology in narcoleptics (Mamelak, Caruso, & Stewart, 1979). The diurnal symptoms and longstanding fragmentation of night sleep suggest that the narcoleptic is partially sleep deprived throughout his life. Certainly this element of chronicity increases the severity of the narcoleptic's experience, in comparison with a temporarily partially sleep deprived normal who is eventually able to obtain recuperative sleep.

#### Pathophysiology

The pathophysiological mechanisms of narcolepsy are not entirely understood, but appear to involve a lability in both the wakefulness and sleep systems, as neither can inhibit the other for any length of time. For this reason, Passouant (1968) has termed narcolepsy a dysomnia rather than a hypersomnia.

It is known that the waking state is maintained by a tonic discharge from the reticular activating system (RAS) (Moruzzi & Magoun, 1949). In addition to this intrinsic stimulation, extrinsic or sensory stimulation also contributes to producing arousal (Hebb, 1955; Heron, 1957). The reports that narcoleptics are particularly vulnerable in situations of reduced stimulation suggest that the intrinsic stimulation provided by the wakefulness system is weakened or lessened (Yoss & Daly, 1960). Rechtschaffen and Dement (1967, 1969) postulated that narcolepsy is due to the inability of the wakefulness system to inhibit the REM sleep mechanism. While the REM mechanism is certainly associated with the

auxiliary symptoms, the appearance of both NREM and REM sleep attacks in compound narcolepsy (Hishikawa et al., 1968; Meier-Ewert, Schöpfer & Rüther, 1975; Roth et al., 1969), and the appearance of both NREM and REM microsleeps (brief bursts of sleep intruding into wakefulness) (Guilleminault et al., 1975a) suggest that pressure from both sleep states can overpower the inhibitory action of the wakefulness system.

The symptom of drowsiness then, is likely to be due to pressure of sleep mechanisms causing an insufficiency in the action of the wakefulness system, which is particularly vulnerable in narcoleptics if unaided by external stimulation. After a certain threshold point, the wakefulness system is greatly overpowered, and sleep attacks and auxiliary symptoms appear. The fact that patients often feel refreshed after attacks, further suggests that the previous drowsiness was due to high pressure from the sleep mechanism which has been released and remains temporarily in a refractory state.

### Treatment

Central nervous system stimulants, mainly amphetamines and methylphenidate, are considered the drugs of choice for relieving drowsiness and sleep attacks, while a series of tricyclic antidepressants (imipramine, desipramine, and clomipramine) are drugs of choice for suppressing auxiliary symptoms (Akimoto, Honda, & Takahashi, 1960; Guilleminault, Carskadon & Dement, 1974; Hishikawa et al., 1966; Roth, Faber, Nevsimailova & Tosofsky, 1971).

Stimulants apparently work by activating the RAS (Yoss & Daly,

1958) resulting in more sustained alertness and an increased power of concentration (Ganado, 1958; Parkes, 1976). Nonetheless, in narcoleptics, drowsiness and sleep attacks are only incompletely controlled by these medications (Guilleminault et al., 1975a). Moreover, amphetamine is prone to the development of tolerance and can have cardiovascular side effects (e.g., palpitations, hypertension) and severe withdrawal effects such as depression, insomnia, anxiety, and hallucinations. These withdrawal effects have occasionally lead to the misdiagnosis of narcolepsy as schizophrenia (Zarcone & Fuchs, 1976). Although methylphenidate is not as effective as amphetamine, it is much less likely to result in adverse side effects and is therefore the more frequently prescribed stimulant (Guilleminault & Dement, 1974). Lack of any effective and harmless treatment for drowsiness indicates a need to better comprehend the pathophysiology of this symptom and to investigate new treatment modes.

In comparison, the tricyclics are more successful in controlling auxiliary symptoms (Guilleminault & Dement, 1974). The efficacy of these drugs seems to be due to their REM suppressant activity.

There is no report of the effects on performance of either type of medication, during treatment or withdrawal. Clinical observations regarding withdrawal suggest that after one week off medication, all symptoms have stabilized to pretreatment levels (Broughton, Note 1.). Studies documenting baseline variables in narcoleptics (e.g., Guilleminault et al., 1974; Raynal, 1976; Takahashi, 1976; Wyatt, Fram, Buchbinder & Snyder, 1971) including performance tasks (Billiard, 1976;

Guilleminault et al., 1975a) have used a two week withdrawal regimen without apparent complications. For patients using amphetamines, a precautionary gradual withdrawal previous to this period was successful in preventing severe side effects (Guilleminault et al., 1974; Gillin, Horowitz & Wyatt, 1976; Wyatt et al., 1971). This model was used in the current study. Unknown withdrawal effects could exist after two weeks. However, due to the reported success of the above studies, the lack of any other available information, and the great inconvenience of a longer withdrawal to the patient population, it would seem most reasonable to follow this established regimen.

#### The Symptom of Drowsiness and Its Effects on Performance

The sparsity of documentation specifically regarding the nature of drowsiness may be due to its more elusive and less tangible nature in comparison to the more clear cut episodic symptoms of the tetrad.

While sleep and waking are generally viewed as dichotomous, they are perhaps more correctly seen as two extremes of vigilance, with the drowsy state occurring as a transitional descent from wakefulness into sleep. This progression has been reported to be associated with the shift from secondary to primary process thinking, i.e., with the loss of rational, purposeful thought (Zilberg, 1978), and with loss of control over thoughts (Gibson, Perry, & Redington, in press). Similarly, Gastaut and Broughton (1965) described the major characteristic of sleep onset as "a progressive obscuring of consciousness"; as one drifts off to sleep, thoughts and sensations become liberated from higher cortical

control. During profound drowsiness or the "twilight state" hypnagogic imagery and physical and sensory phenomena can also occur. A normal individual usually experiences these phenomena only during nocturnal sleep onset and perceives drowsiness as a pleasurable succumbing to the state of sleep. Narcoleptics, however, generally complain of an "obscuring of consciousness" associated with lingering drowsiness while attempting to meet responsibilities throughout the day. Unable to "shake off the haze of drowsiness" they put great effort into fighting sleep in order to function. Terms such as "dopiness", "semi-stupor", and "daze" have been used by patients to describe their state (Ganado, 1958).

Narcoleptics are not only hindered by the negative state of drowsiness, but attempts to fight sleep during extreme drowsy episodes can result in several unpleasant physical sensations and reduced sensory awareness which further interfere with performance. Visual problems include blurred vision, burning eyes and ptosis (Broughton & Ghanem, 1976; Chee, 1968; Ganado, 1958; Keef, Yoss, Martens & Daly, 1960; Levin, 1943; Sours, 1963). Broughton and Ghanem (1976) additionally reported involuntary eye flickering. Dulled hearing, numbness (Daniels, 1934; Ganado, 1958; Sours, 1963), headache, neck pain, and hunger can also occur (Daniels, 1934). Hyperexcitable responses, sometimes to sensations such as falling, light flashes or a gun shot, have been reported in normals (Gastaut, & Broughton, 1965) and have been reported to be especially frequent in narcoleptics (Daniels, 1934).

The more continual drowsiness of the narcoleptic is in contrast

to the generally fleeting appearance of this condition in normals. Its characteristic chronicity provides an opportunity to investigate this state of lowered vigilance in detail, particularly with reference to performance ability. What is currently known about the performance consequences of drowsiness in these patients is, for the most part, based on patient reports. Essentially, complaints of difficulties in attention and alertness, poor concentration and forgetfulness were obtained from investigations of case histories of over 100 patients each by Daniels (1934) and Ganado (1958). Ganado also reported slowed thinking and inability to make quick decisions, suggesting a general slowing of information processing. Lack of initiative and apathy often resulted in cessation of ongoing activities in some. For those who persevered, performance was slowed and achievement lowered. Extreme drowsiness was associated with an increase in mistakes in ongoing activity. However, intellectual capacity is not affected (Ganado, 1958; Pond, 1952; Roy, 1976).

In a survey of 43 narcoleptics (Broughton, & Ghanem, 1976) a significantly greater number of narcoleptics in comparison to controls reported memory problems and job difficulties which they attributed mainly to an inability to concentrate. A significant number also reported decreased earning capacity and reduced job performance. Accidents such as making mistakes in recipes and leaving tea kettles to burn on the stove were cited in greater number by narcoleptic responders. These authors also noted a significant increase in automobile accidents, although others (Guilleminault & Dement, 1974; Sours, 1963) reported

that statistics are within the normal range for those properly treated and aware of their limitations.

Performance deterioration in narcoleptics has also been associated with a partial sleep state commonly termed "automatic behavior" (Daniels, 1934; Ganado, 1958; Guilleminault et al., 1975a; Guilleminault & Dement, 1977; Zorick, Salis, Roth & Kramer, 1979). In this state which is associated with periods of extreme drowsiness, the individual becomes less aware of his activity. Actions not requiring skill are performed satisfactorily, though in a semi-automatic way, whereas more complex tasks are often accompanied by errors and illogical behavior. The episode is associated with partial to complete amnesia and can last from a few minutes to a few hours.

The above mentioned observations provide valuable heuristic information regarding functional impairment in narcoleptics. Subjective reports, however, can be crude and unreliable predictors of performance, often overestimating the degree of the deficit. The necessity of objective measurement is exemplified by sleep deprivation research; performance tends to be resilient to deterioration and difficult to document, even though subjective drowsiness and complaints of difficulty in mental functioning prevail (Johnson & Naitoh, 1974).

Despite the pervasive reports of drowsiness and perceived performance dysfunction in narcoleptics, only two studies using objective performance measures have been published. Guilleminault et al. (1975a)<sup>1</sup>

---

1. Also described by Guilleminault and Dement (1977).

designed a study to investigate performance during the automatic behavior syndrome. In order to enhance drowsiness, which would favor the appearance of automatic behavior, patients were placed in potentially boring situations which consisted of performing lengthy monotonous tasks several times a day. Though narcoleptics were not statistically compared to control subjects, it was stated that the patients solved fewer additions on the Wilkinson Addition Task (WAT) and had more gaps (long periods of non-responding) on the Serial Alternation Task (SAT), a continuous key pressing task. Using the same tasks and protocol of repeated assessments, Billiard (1976) provided evidence that narcoleptic performance improved after naps containing NREM, and a combination of REM and NREM, while control subjects' performance did not change across naps. However, Billiard also failed to report statistical comparison between narcoleptic and control subjects. It is therefore not known from either study whether the narcoleptic's performance is significantly deteriorated.

#### Objective Indicators of Performance

The SAT and WAT were chosen by the above authors because these vigilance-type tasks had been previously shown to be sensitive to sleep deprivation (Lubin, Moses, Johnson, & Naitoh, 1974; Wilkinson, 1969). Since narcoleptics do express symptoms similar to sleep deprived subjects, in particular drowsiness, one might expect them also to exhibit a similar performance profile. According to Wilkinson (1965), the qualities of long-duration, monotony, and lack of incentive in vigilance

tasks are conditions favorable to performance decrement in sleep deprived subjects. The performance decrement is characterized by an increase in lapses or response omissions. The concept of lapses was first formulated by Williams, Lubin and Goodnow (1959), who stated that the absence of response, not the emitted response is the critical feature of performance decrement following sleep deprivation. While performance is normal between omitted responses, it is rendered progressively uneven by lapses. These lapses occur as missed signals on experimenter-paced tasks and as gaps (long periods of non-responding) on self-paced tasks.

Observations in the literature that performance deterioration in narcoleptics is more prone to occur in situations of monotony (Daniels, 1934; Ganado, 1958) as well as the preliminary performance evidence of slowed responses or gaps on self-paced vigilance tasks (Billiard, 1976; Guilleminault et al., 1975a) strongly suggest that narcoleptic performance would be most vulnerable to deterioration on a monotonous vigilance-type task.

In contrast, more stimulating tasks have generally been avoided by sleep researchers, as well as by these above authors assessing narcoleptics, since they have been relatively insensitive to performance deficits in sleep deprived subjects. These tasks involve increased response demands, briefer trials, and the incentive value of knowledge of results, aspects which minimize performance deficits in sleep deprived subjects (Wilkinson, 1964, 1969). Sensory stimulation during vigilance-type tasks also has been shown to prevent performance decrement subsequent

to sleep deprivation (Bergström, Gillberg, & Arnberg, 1973; Hockey, 1970; Wilkinson, 1963). Similarly the performance of narcoleptics would be expected to improve in situations of high stimulation which would increase arousal. However, Ganado (1958) indicated that narcoleptics sometimes experience drowsiness and performance difficulties even in stimulating situations. The ability of stimulating tasks to counteract poor performance has never been assessed in narcoleptics.

Thus, the preliminary performance evidence provided by Billiard (1976) and Guilleminault et al. (1975a) implies that performance difficulties do exist in very monotonous situations. However, due to lack of comparison to a control group in the above studies, it is not known whether performance is significantly impaired, even though it is subjectively experienced as such. Moreover, whether decrements would exist in briefer and less monotonous situations more similar to activities in daily life has not been considered.

#### Subjective Indicators of Performance

In the absence of objective measures, the ability to detect functional impairment from subjective ratings would be a valuable asset. Some evidence exists regarding the ability to predict performance in sleep deprived subjects from subjective drowsiness ratings using the Stanford Sleepiness Scale (SSS) (Hoddes, Dement, & Zarcone, 1972). This scale has been found to correlate highly with sensitive tasks during acute total sleep deprivation (Glenville & Broughton, 1979; Hoddes, Zarcone, Smythe, Phillips & Dement, 1973) but does not reflect the

capacity to function during long-term partial sleep deprivation (Friedmann, Globus, Huntley, Mullaney, Naitoh & Johnson, 1977; Herscovitch & Broughton, in press a). While it has been indicated in the "Diagnostic Classification of Sleep and Arousal Disorders" (Association of Sleep Disorders Centers, 1979) that the symptom of drowsiness may be quantitatively measured by subjective rating scales, the reliability of such ratings in reflecting the narcoleptic's capacity to function has not been demonstrated. As previously mentioned, subjective reports alone can be unreliable indicators and need to be validated with reference to actual performance. Therefore it would be valuable to assess the reliability of the SSS to determine whether it can be used to accurately and meaningfully measure the performance effects of drowsiness in narcoleptics.

The general discrepancy between subjective and objective measures can be attributed to the individual's ability to adapt despite his handicap. Stress theorists (Lazarus, 1966; McGrath, 1970) maintain that adaptation takes place when demands are not in balance with individual resources, and this usually takes the form of a change in strategy to cope with demands (Welford, 1973).

Increased effort is a particularly common adaptive strategy used by sleep deprived subjects to prevent performance deterioration (Malmo & Surwillo, 1960; Strausbaugh & Roessler, 1970; Wilkinson, 1962), especially during tasks of high incentive value (Wilkinson, 1961, 1964). Similarly, it is known that narcoleptics may attempt to overcome the effects of lowered vigilance by exerting extra effort (Ganado, 1958;

Zarcone, 1977). Zarcone and Fuchs (1976) added that the emotional difficulties reported by narcoleptics may be related to attempts to fulfill daily responsibilities while coping with drowsiness and other symptoms. For example, symptoms such as depression, low tolerance for frustration, and irritability (Broughton & Ghanem, 1976; Daniels, 1934; Sours, 1963) may be reactions to fatigue as a result of increased efforts put forth to meet daily demands adequately. Reports of similar psychological symptoms in long-term partially sleep deprived subjects who did not exhibit performance deterioration (Friedmann et al., 1977) support this implication.

In the assessment of performance then, the adaptive style of increased effort should be examined as it provides subtle information about strategies to mask potential deficits and also explains negative symptoms which could result from such strategies.

#### Electroencephalographic (EEG) Indicators of Drowsiness and Their Relation to Performance

The EEG manifestations of narcoleptic drowsiness during performance can provide more detailed information regarding the nature of this condition and in particular can reveal how the physiological states subsiding drowsiness affect performance.

The EEG pattern of drowsiness to light sleep is generally described as a slowing of alpha rhythm which often becomes fragmented, i.e., intermixed with medium voltage mixed frequencies. This pattern is gradually replaced by medium voltage 4-7 cps theta activity and sharp vertex

waves. Slow rolling eye movements may also occur during these states (Kiloh & Osselton, 1966; Oswald, 1962; Rechtschaffen & Kales, 1968; Simon & Emmons, 1956). These patterns were classified as stage A (slow alpha rhythm and mixed frequencies) and stage B (loss of alpha replaced by low voltage 4-7 cps theta activity) by Loomis, Harvey, and Hobart (1936) and as stages 1A and 1B by Gastaut and Broughton (1965). Oswald (1962) noted that vigilance does not steadily decline during sleep onset, but that stage 1A and 1B patterns alternate in a moment to moment interchange until alpha disappears.

Rechtschaffen and Kales (1968) classified the loss of alpha and the occurrence of theta activity with vertex waves and slow rolling eye movements as the first stage of sleep. However, Johnson (1973) asserted that it is only with the presence of sleep spindles (stage 2 sleep) that unambiguous sleep occurs. Similarly, Gastaut and Broughton (1965) indicated that a person does not normally perceive himself to be asleep in the states preceding stage 2. Thus, stages 1A and 1B may be more correctly viewed as transitional phases one passes through to enter into unambiguous sleep.

In narcoleptics, the frequent appearance of drowsiness and sleep patterns is a prominent feature of routine clinical EEGs (Gastaut & Roth, 1957; Pond, 1952; Roth, 1964; Yoss & Daly, 1957), even when the patients appear to be (Heyk & Hess, 1954) and perceive themselves to be (Hishikawa & Kaneko, 1965) awake. In particular, Pond (1952), Roth (1964), and Yoss and Daly (1957) have described drifting or vacillatory drowsy states which may reflect the alternating sleep onset pattern

described in normals by Oswald (1962). Unfortunately, the overall pattern of drowsiness was only very generally described in the above studies. Further, patients were not asked to perform mental tasks. Since a major difficulty of narcoleptics is the intrusion of drowsiness while attempting to work, it is of interest to know the characteristic temporal organization and levels or stages of physiological vigilance during performance, as well as how these patterns are specifically related to performance efficiency.

Studies relating EEG state to performance generally measure the EEG state a few seconds immediately preceding each signal of the task (e.g., Gale, 1977; Groll, 1966; Townsend & Johnson, 1979). From this type of analysis, the concept of lapses in performance or periods of no response has been associated with microsleeps which consist of short bursts of stage 1 (loss of alpha), synchronized theta activity, or stage 2 sleep (e.g., Bjerner, 1949; Dement & Mitler, 1974; Mirsky & Cardon, 1962; Naitoh & Townsend, 1970; Oswald, 1962; Williams, Granda, Jones, Lubin & Armington, 1962). Microsleeps have traditionally been accepted as the major cause of the increased lapses in performance following sleep deprivation. Guilleminault et al. (1975a) also explained performance decrements in narcoleptics by this formulation. These authors concluded that performance impairment in narcoleptics takes the form of lapses accompanied by microsleeps and also by patterns considered to be "micro-REM" sleeps, while patients are apparently awake and able to perform normally between these brief bursts of sleep.

While the concept of lapses accompanied by microsleeps is by far the most influential explanation for the manner in which performance

deteriorates, it may be an inaccurate explanation. This formulation precludes the possibility that lapses as well as other types of deficits may also occur at higher levels of vigilance such as stage 1A or even wakefulness. Some writers (e.g., Kjellberg, 1977; Oswald, 1962) have criticized the lapse-microsleep interpretation stating that it represents only extreme low levels of vigilance and that deficits of a nature other than lapses occur previous to this level, resulting in a general deterioration.

Some support of this position has been provided by L. Morrell (1966) who indicated that in normals a stage 1A pattern was associated with slower responses than wakefulness, while a theta pattern (normally associated with microsleeps) was followed by lack of responding. Guilleminault, Phillips & Dement (1975b) reported similar patterns as L. Morrell (1966) with hypersonmics though they referred only to microsleeps in their discussion of the data. In an early study with normals, Simon and Emmons (1956) also noted partial recall of information input during a drowsy state preceding the loss of alpha, while the lack of recall was associated with theta activity. These authors also found that even awake subjects showed poor recall if they had recently been asleep. Whether such differentiated EEG-performance patterns also characterize narcoleptics has not been considered.

The method generally used to determine microsleeps, which involves analyzing EEG at the time of signals, provides an accurate determination of the relationship between performance and EEG state (Townsend & Johnson, 1979); but it does not indicate the overall temporal pattern or

amount of lowered vigilance. The pattern implied from this type of analysis is that physiological vigilance has a punctate pattern, shifting by brief "jumps" from wakefulness into stage 1 (loss of alpha) or 2 sleep. In contrast, above mentioned descriptions of an intermediate stage 1A, and EEG reports which describe both narcoleptic and normal drowsiness as "drifting" or "vacillating" infer a more gradual transition. This is supported by the subjective descriptions of narcoleptics' drowsiness in terms such as "dopiness" or "stupor" (Ganado, 1958) which imply a more continual nature.

Thus two major unanswered questions prevail regarding the physiological manifestations of drowsiness in association with performance in narcoleptics. First, it is not known whether narcoleptic's performance deficits can be explained solely by the undifferentiated punctate pattern of the lapse-microsleep formulation or whether a more general deterioration characterized by graduated and differentiated EEG-performance patterns may be the more correct pattern; that is, it is not clear whether poor performance occurs only as lapses (errors of omission) in association with microsleep patterns as has been previously suggested by sleep deprivation researchers and by Guilleminault et al. (1975a) with narcoleptics, or whether lapses and other types of deficits such as false positive responses (errors of commission) also impair performance at higher levels of vigilance. Secondly, the overall temporal pattern of drowsiness while a narcoleptic attempts to function is not clearly understood. Such information would help to clarify the physiological nature of drowsiness in narcoleptics and also shed some light

on the manner in which it affects performance. In this latter respect, the sufficiency of the lapse-microsleep formulation in explaining performance deterioration in narcoleptics could be determined.

#### Statement of the Problem and Hypotheses

While the episodic symptoms of the narcoleptic tetrad have received experimental attention, the more elusive symptom of drowsiness is a largely uninvestigated and only vaguely understood aspect of narcolepsy. The pervasive complaints of drowsiness by narcoleptics, the resistance of drowsiness to medication, and its association with further problems of poor performance indicate a need to investigate this symptom. This knowledge may be valuable in determining the manner and degree to which drowsiness interferes with the narcoleptic's daily functioning and in elucidating the nature of this condition for further study and treatment approaches.

Subjective accounts in the literature on narcolepsy indicate that drowsiness hinders performance ability. However, subjective reports are often unreliable and overestimate the degree of deficits found by objective measures. Since the two existing studies of performance in narcoleptics (Billiard, 1976; Guilleminault et al., 1975a) did not determine whether performance of narcoleptics differed significantly from that of controls it is also not known from these studies whether narcoleptic patients are, in fact, substantially impaired. Therefore the present study proposed to clarify the issue of whether performance in narcoleptics is significantly deteriorated when compared to that of

matched controls.

In addition to determining the degree of impairment, the present study used a protocol which would more fully explain the manner in which these patients might be impaired and also increase the applicability of its findings above those of the two previous performance studies. While the above mentioned studies involving performance in narcoleptics used a protocol which enhanced drowsiness, i.e., repeated assessments using monotonous tasks, the current study proposed to determine whether the narcoleptic's performance would be hindered in a situation more similar to that encountered in daily life. In this respect, subjects were tested only once (after training) in morning sessions as morning is considered the narcoleptic's most alert time of day (Richardson, Carskadon, Flagg, Van Den Hoed, Dement & Mitler, 1978). Secondly, stimulating as well as monotonous tasks were included to determine which parameters were most affected. The literature suggests that decreased attention and slowed information processing underlie the major performance complaints of narcoleptics. The test battery then consisted of four tasks which generally assess attentional abilities: 1) Wilkinson's 1 hr auditory vigilance task; 2) a 10 minute four-choice reaction time task; 3) Digit Span; 4) the paced auditory serial addition task (PASAT). The four-choice reaction time and PASAT which measure response speed, also reflect rate of information processing.

The 10 minute reaction time task has been shown to be sensitive to total sleep deprivation (Glenville, Broughton, Wing, & Wilkinson, 1978) and to shift work (Glenville & Wilkinson, 1980) but not to partial sleep

deprivation (Herscovitch & Broughton, in press b), while the 1 hr auditory vigilance task has been shown sensitive to both total and partial sleep deprivation (Glenville et al., 1979; Herscovitch & Broughton, in press b). The narcoleptics' performance efficiency on the four-choice reaction time then, would provide some evidence as to whether their deficits are severe enough to occur in a monotonous situation lasting only 10 minutes, as well as during the more lengthy auditory vigilance task. Secondly, the four-choice reaction time was included to determine its usefulness in future studies of narcolepsy. If this task were found sensitive to narcoleptic performance deficits, its added assets of brevity and portability would make it a most convenient tool for future appraisals of narcoleptic performance ability, particularly for the repeated assessments necessary to determine the efficiency of narcoleptic stimulant medications.

Regarding performance on these two tasks, the following hypothesis was made:

- I. Narcoleptics, in comparison with control subjects will exhibit a significant performance deficit on the auditory vigilance task, and on the four-choice serial reaction time task.

Digit Span, and the paced auditory serial addition task (PASAT) are characterized by brief trials and the incentive value of knowledge of results, aspects which minimize performance deficits in sleep deprived subjects. Digit Span is a simpler task involving the repetition of numbers in brief self-paced trials. In contrast, the PASAT is

decidedly more complex. It involves relatively longer trials requiring adding and complex tracking at increasing experimenter-paced speeds. Existing evidence implies that a low level of stimulation is the critical factor hindering performance in narcoleptics while increased stimulation serves to increase arousal thereby improving performance. If drowsiness is more profound, however, even stimulating work may be hindered. The degree to which stimulating tasks, even if complex, can counteract performance dysfunction has never been assessed in narcoleptics.

Regarding performance on these two stimulating tasks, it was hypothesized that:

- II. Narcoleptic performance will not differ significantly from that of controls on two short-duration, stimulating tasks; Digit Span and PASAT.

In addition, the sensitivity of the SSS to effects of drowsiness was investigated. The ability of this scale to accurately reflect performance efficiency in narcoleptics was judged important for determining its future use in the research and treatment of narcolepsy. Since a most common report in narcoleptics is drowsiness it is expected that their alertness ratings will be lower than those of controls. The ability of the SSS to predict performance is more speculative. The greater similarity of narcoleptic symptoms to long-term partial sleep deprivation for which the SSS is of poor reliability, than to acute total sleep deprivation for which the SSS has higher reliability, suggests that this scale would be of low predictive value for narcoleptics.

It was also proposed to determine by self-report, the amount of effort exerted during each task. The existence of increased effort exerted by narcoleptics in comparison to controls was judged important because this adaptive strategy can mask potential performance deficits. The existence of increased effort can also explain psychological difficulties which may be the result of energy depletion from compensatory effort.

Low initiative and lack of perseverance are considered characteristic of both narcoleptics and sleep deprived subjects. However, sleep loss is often reacted to as a challenge, particularly during tasks of high incentive, and this reaction results in the exertion of compensatory effort to maintain efficiency. It is therefore expected that narcoleptics might also expend compensatory effort. This adaptation would be more likely on the stimulating tasks which have a higher incentive value, though the stimulation itself may override any need to increase effort.

Based on this information it is hypothesized that:

- III. In comparison with controls, narcoleptics will report significantly greater degrees of drowsiness and effort during performance. A significant increase in effort will occur in association with the stimulating tasks.
- IV. The SSS will not predict performance ability in the narcoleptic group.

The investigation was also designed to clarify the physiological nature of drowsiness in greater detail than what is known at present. With respect to the overall level of physiological vigilance, it was

proposed to determine what amounts of wakefulness and lowered vigilance exist during performance on the two stimulating tasks and on the monotonous auditory vigilance task. Existing evidence suggests that monotony is associated with drowsiness and poor performance while increased stimulation activates the RAS resulting in greater arousal.

Regarding this evidence, it was hypothesized that:

- V. Narcoleptics will spend significantly less time in wakefulness than control subjects during the 1 hr auditory vigilance task, but not during the two short-duration stimulating tasks; Digit Span and PASAT.

In addition, the study proposed to clarify the overall temporal organization of physiological vigilance during the 1 hr auditory vigilance task.

Finally, the study investigated the relationship between vigilance performance and the immediately preceding physiological state in an attempt to clarify the nature of performance as it relates to the levels of physiological vigilance. As mentioned, microsleeps are considered to be the cause of performance deficits which occur behaviorally as lapses or response omissions in both narcoleptics and sleep deprived individuals. The present study proposed that the lapse-microsleep formulation is an incomplete explanation for the predicted poor performance of narcoleptic patients. In particular, it was proposed that there are also deficits occurring above this low level of physiological vigilance, though they may be more subtle and/or of a different nature.

Regarding performance during the auditory vigilance task, it was hypothesized that:

- VI. In comparison with control subjects, the predicted poorer performance of narcoleptics will be associated with the vigilance level associated with microsleeps, i.e., stage 1B or stage 2, and will be characterized by an increase in lapses (errors of omission).
- VII. In comparison with control subjects, the predicted poorer performance of narcoleptics will also be associated with vigilance levels higher than that of microsleeps, i.e., stages 1A and wakefulness, and will be characterized by an increase in lapses and false positive responses (errors of commission).

## CHAPTER II

## METHOD

Subjects

Subjects consisted of 10 narcoleptics who were diagnosed by the co-existence of sleep attacks and cataplexy (according to the criteria of Guilleminault and Dement, 1977, refer to p. 5), and 10 "normal" control subjects. The groups were matched for sex and closely for age, occupational activity and educational attainment. Age of subjects ranged from 19 to 65 with the mean age being 43. Descriptions of individual subjects are detailed in Table 1 (matching of narcoleptic and control subjects) and Table 2 (descriptions of narcoleptic symptomatology, medication, and withdrawal regime).

Normal control subjects were referred by friends and hospital personnel, and were paid \$15 for their participation in the study. They were screened via questionnaire for any medication affecting central nervous system arousal, and to insure normal mental and physical health and sleep habits (see Appendix A).

Narcoleptic patients volunteered to participate in the study upon referral from a sleep disorders specialist who was also involved in the investigation.<sup>1</sup> Three patients (1, 3, and 6, refer to Table 2) were not taking medication at the time. Patients 5 and 8 were currently being

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Table 1

## Comparison of Narcoleptics and Matched Controls

| Subject <sup>a</sup> | Age      | Sex    | Education                             | Occupation <sup>b</sup>                            |
|----------------------|----------|--------|---------------------------------------|----------------------------------------------------|
| N 1<br>C 1           | 19<br>22 | M<br>M | 1 yr. university<br>2 yrs. university | unemployed<br>student                              |
| N 2<br>C 2           | 29<br>27 | F<br>F | R.N. diploma<br>M.A.                  | R.N., restaurant manager<br>graduate student       |
| N 3<br>C 3           | 32<br>32 | M<br>M | B.A.<br>B.A.                          | car salesman (former accountant)*<br>architect     |
| N 4<br>C 4           | 35<br>34 | F<br>F | R.N. diploma<br>B.A.                  | restaurant manager (previously RN)*<br>law student |
| N 5<br>C 5           | 41<br>41 | F<br>F | grade 10<br>grade 10                  | housewife<br>housewife                             |
| N 6<br>C 6           | 44<br>43 | F<br>F | grade 10<br>grade 10                  | maid (previously store clerk)*<br>secretary        |
| N 7<br>C 7           | 49<br>51 | F<br>F | high school<br>high school            | clerical worker<br>secretary                       |
| N 8<br>C 8           | 54<br>56 | F<br>F | R.N. diploma<br>high school           | housewife<br>housewife                             |
| N 9<br>C 9           | 59<br>59 | M<br>M | high school<br>B.A.                   | sales representative<br>civil service consultant   |
| N 10<br>C 10         | 65<br>65 | F<br>F | B.A.<br>B.A.                          | housewife<br>housewife                             |

Note. <sup>a</sup>N = narcoleptic patient, C = control, <sup>b</sup>\* = change in occupation due to narcolepsy

Table 2

## Description of Narcoleptic Symptomatology, Medication, and Withdrawal Regimen

| Patient | Age | Duration<br>(years) | Frequency of Symptoms<br>on usual medication |   |    |    |                 | Usual Daily Medication                          | Withdrawal<br>Regime (Days) | Comments                                                          |
|---------|-----|---------------------|----------------------------------------------|---|----|----|-----------------|-------------------------------------------------|-----------------------------|-------------------------------------------------------------------|
|         |     |                     | N                                            | C | HH | SP | ED <sup>a</sup> |                                                 |                             |                                                                   |
| N1      | 19  | 2                   | -                                            | = | -  | -  | +b              | none                                            |                             | son of N6                                                         |
| N2      | 29  | 6                   | -                                            | + | =  | =  | ++              | methylphenidate 60 mg<br>clomipramine HCL 75 mg | 3 partial<br>14 complete    | sister of N4                                                      |
| N3      | 32  | 20                  | -                                            | = | -  | -  | ++              | methylphenidate 10 mg<br>(taken irregularly)    | 28 complete                 | previously had<br>C(-), N(++); N<br>replaced by ED                |
| N4      | 34  | 18                  | =                                            | = | -  | +  | =               | gamma-hydroxy-butyrate<br>17.5 ml/night         | 14 complete                 |                                                                   |
| N5      | 41  | 21                  | ++                                           | + | =  | =  | ++              | methylphenidate 20 mg<br>clomipramine HCL 75 mg | 2 partial<br>14 complete    |                                                                   |
| N6      | 44  | 28                  | ++                                           | = | =  | =  | ++              | none                                            |                             | previously had<br>C(++) when raising<br>small children            |
| N7      | 49  | 27                  | =                                            | = | -  | -  | -               | methylphenidate 40 mg<br>desipramine HCL 100 mg | 1 partial<br>9 complete     | recently increased<br>medication, previously<br>had N(++), ED(++) |
| N8      | 54  | 15                  | ++                                           | = | =  | -  | -               | methylphenidate 20 mg<br>imipramine HCL 100 mg  | 3 partial<br>14 complete    |                                                                   |
| N9      | 59  | 33                  | +                                            | = | =  | +  | ++              | methylphenidate 10 mg                           | 14 complete                 |                                                                   |
| N10     | 65  | 28                  | ++                                           | + | +  | +  | ++              | methylphenidate 20 mg                           | 1 partial, 9 complete       |                                                                   |

Note. an = sleep attacks

C = cataplectic attacks

HH = hypnagogic hallucinations

SP = sleep paralysis

ED = episodes of extreme drowsiness

b++ = one or more times daily

+ = one or more times weekly

- = one or more times monthly

= = less than once a month

no sign = patient does not have symptom

withdrawn for a change of medication. All others voluntarily withdrew to aid in the research study. All patients undergoing withdrawal were completely free from medication for 9-15 days before testing. Those taking higher doses of tricyclic and stimulant medication underwent partial withdrawal for 1-3 days previous to this (see Table 2). The original withdrawal period was to be at least 14 days for all patients. However patients 7 and 10 were not able to remain off medication more than a 9 day period due to unforeseen life events. Patients undergoing withdrawal were contacted by phone during the withdrawal period to monitor any problems and to insure that they were following the procedure properly. Other than the expected increase in symptomatology, no serious problems were encountered. Informed consent was received by all patients who were withdrawn from medication.

Reports of hours of sleep (including naps) before each testing day did not reveal any increase or decrease beyond  $1\frac{1}{2}$  hours for any subjects. Average amount of sleep was 7.5 hours (range, 6-9 hours) for control subjects and 8 hours (range, 5.5-11 hours) for narcoleptics. As an additional control measure, subjects rated their alertness level just previous to the test session in comparison with their general level during other mornings of the past week. This 7-point scale ranged from 1 (much more alert) to 7 (much more drowsy) with the central rating of 4 representing "about the same" (see Appendix B). The mean ratings were 4.4 (narcoleptics) and 4.2 (controls). No subjects reported extreme ratings (i.e., 1 or 7). Thus it is reasonable to assume that alertness levels were within each individual's average range.

## Materials and Instrumentation

### Performance Tests

Wilkinson's Auditory Vigilance Task. During this 60 minute task, subjects wearing headphones were instructed to detect slightly shorter (375 msec) signals occurring randomly within an array of 500 msec signals occurring every 2 sec over a background of 85 dB white noise. A total of 40 signals occur in a pseudo-random fashion (approximately 10 signals for every 15 minute block) during the one hour period. Subjects pressed a response key to indicate that they had perceived the signal. The task is scored for number of hits (correct responses to shorter signals), and number of false positive responses (incorrect responses).

A 25 minute training tape for this task, administered on the practice day, contained instructions and practice runs. A one hour practice vigilance tape, administered on the same day, familiarized the subjects with the full task requirement.

The Four-Choice Serial Reaction Time Task. (Wilkinson & Houghton, 1975). This 10 minute portable task consists of four lights arranged in a square below which are four similarly arranged keys. Subjects are instructed to press, as quickly as possible without error, the button corresponding to one of four illuminated lights. A response, correct or not, causes another or the same light to go on in a random sequence, thus causing the test to continue in a self-paced serial fashion. Results are cassette recorded for subsequent computer analysis which quantifies reaction times and differentiates correct and error responses.

The Paced Auditory Serial Addition Task. (PASAT) (6½ min.). In this

task, the subject is required to add in pairs series of orally presented, random single digits, with 60 digits in each trial (see Appendix C). Four trials were paced at 2.4, 2.0, 1.6, and 1.2 second rates (taped presentation). Initially, an unpaced series was administered to insure basic information processing ability and to allow the subject to become comfortable with the task. Subjects were instructed to add each new digit presented to the last one heard, e.g., if digits presented are 1, 3, 5, 2, responses would be 4, 8, 7. If a digit was missed, the subject waited for the next pair to be presented. The task was scored for per cent correct in each trial.

According to Gronwall and Wrightson (1977) rate of information processing is assessed. Performance of the PASAT has a low and insignificant correlation with intelligence, mathematical ability, and practice but a high positive correlation with selective attention (Gronwall, Note 2).

Digit Span. (Approximately 3½ min.). This Wechsler Adult Intelligence Scale subtest is a common indicator of short term attention, concentration, and memory. The subject is required to repeat, orally presented series of digits forward and in reverse order. In the present study, the digit series were tape recorded to insure uniformity of presentation (see Appendix D).

#### Self-Report (Subjective) Measures

Stanford Sleepiness Scale. (SSS) (Hoddes et al., 1972). This widely used scale, designed to quantify subjective sleepiness levels, consists of a 7-point equal interval scale ranging from 1 ("feeling active and vital; alert; wide awake") to 7 ("almost in reverie, sleep onset soon;

lost in struggle to remain awake") (see Appendix E).

Effort Rating Scale. To determine the potential influence of effort on performance, subjects rated how much effort each task demanded of them on 7-point scales ranging from 1 ("effortless") to 7 ("extremely frustrating") (see Appendix B).

#### Instrumentation for Polygraphic Recordings and Performance Tests

During the testing session, four channels of polygraphic recordings were monitored and recorded on magnetic tape (Vetter FM tape recorder). These included recordings of the electroencephalogram (EEG) ( $C_2-A_2$ ,  $O_2-A_1$ ); bipolar electro-oculogram (EOG), for which electrodes were placed 1 cm above and 1 cm lateral to the outer canthus of the left eye, and 1 cm below and 1 cm lateral to the outer canthus of the right eye; and bipolar submental electromyogram (EMG) for which electrodes were placed 2 cm apart overlying the right and left mylohyoid muscle. Gold cup 8 mm electrodes were used. Impedence was below 5 K ohms at the beginning of each recording. The polygraphic recordings were made on a Grass Model 6 apparatus at a paper speed of 15 mm/sec, and calibrated daily at 100  $\mu V/cm$  for EEG and EMG, and at 500  $\mu V/cm$  for EOG.

During the auditory vigilance task, PASAT and Digit Span, the stimuli and subject responses were simultaneously monitored on two additional channels of the polygraph.

#### Procedure

##### Test Sessions

Subjects were tested individually, with narcoleptics and control

subjects in interspersed order. Each subject spent two consecutive, two hour morning sessions in the testing laboratory. The first morning was a practice session though both days were believed by the subjects to be actual test days. Subjects were scheduled to arrive at the laboratory at 9 A.M. and testing began between 9 and 10 A.M. Coffee and tea were discouraged on these mornings but up to one cup was allowed before 8 A.M. All subjects reported that they complied with this request. The protocol and tests were described to subjects by standardized instructions (see Appendix F).

The practice session consisted of a half hour vigilance training tape, a PASAT training session followed by administration of the PASAT, and a one hour vigilance practice tape respectively. The four-choice reaction time test was administered in counterbalanced order across subjects.

On the test day, electrodes were placed on the subjects during the first half hour at the laboratory. Before the testing began a brief baseline EEG was taken (subjects were asked to close eyes and relax, open eyes, move head from right to left, blink, etc.), so the experimenter could become familiar with their EEG pattern and insure that equipment was properly functioning. Subjects then received the one hour auditory vigilance task, PASAT, and Digit Span, the order of which was counterbalanced across subjects while maintaining the same order for each narcoleptic and his/her matched control.

Testing took place in a small dimly lit, air conditioned soundproof room. Subjects sat at a desk in a hard back chair. Room temperature was recorded at the beginning of each session and averaged 61.7°F (wet

bulb) and 77.7°F (dry bulb) (range: 57-71°F, wet bulb; 71-79°F, dry bulb). Temperature was reported comfortable by all subjects.

During the vigilance task the experimenter was outside the room monitoring the polygraph and viewed the subject through an observation window. Subjects were asked to try to stay awake and to keep their eyes open during the vigilance task and were told they would be awakened by a buzzer if they fell asleep. During the practice day subjects were awakened if they showed behavioral signs of sleep and/or did not respond for a period longer than 7.5 minutes. Two patients were awakened (patient 6, twice; patient 9, once). During the test day they were awakened if they fell asleep (defined as stage 1B or 2, see p. 43) for a 90 sec period uninterrupted by any arousals, movements, or task responses. The PASAT and Digit Span were administered by the experimenter in the testing room. No subjects fell asleep during these two brief tests. Subjects were asked to "do their best" on each task. A five minute break was allowed between tests at which time subjects rated their alertness level during the previous test on an SSS form. The effort self-report scales were filled out as part of a post-test questionnaire at the end of the session (see Appendix B).

#### Analysis of the Data

For all tests an alpha level was set at .05 and where appropriate two tailed tests were conducted.

#### Performance Data

The number of hits (correct responses) and number of false positive responses obtained from the vigilance task were analyzed by two way

(2X4) analyses of variance with repeated measures on the factor of time. The task duration was divided into four 15 minute blocks for this analysis. The same analysis, with repeated measures on the factor of speed (four trials of increasing speed), was used to analyze per cent correct of the PASAT.

The four-choice reaction time (RT) task was analyzed for the following dependent measures: mean overall RT, mean RT for correct responses, mean RT for errors, percentage of errors, RT without gaps, and number of gaps (reaction times  $\geq 1$  sec). Due to slight variations in tape speed, a systematic but nonsignificant difference in total session time existed between groups ( $F < 1$ , range = 20 seconds). Analysis of covariance using total session time as a covariate was utilized to increase accuracy of all reaction time measures. Other measures utilized one way analysis of variance.

Digit Span was scored for number of digit sequences (combined forward and backward sequences) repeated correctly. These raw scores were converted to Wechsler scaled scores in order to be compared with the normal range for same age peers. Additionally, the difference scores between digits forward and backward were calculated and averaged for each group.

#### Self-Report (Subjective) Data

Pearson Product-Moment correlations compared SSS ratings obtained after each test with individual test scores for the narcoleptic group. Effort and SSS ratings during performance testing were compared between groups by Mann-Whitney U tests.

### Polygraphic Data

Scoring. From a preliminary 40 sec epoch analysis of all subject's records, four main EEG stages or levels of vigilance were determined: (1) Wakefulness; (2) stage 1A; (3) stage 1B; (4) stage 2. (No stages 3, 4, or REM were encountered). These patterns are representative of general descriptions of lowered vigilance described in the literature (refer to Introduction, p. 18) but were more specifically defined by the criteria below for reliable scoring. The stages, described below, are illustrated in Figures 1-5.

Wakefulness was scored when more than 50% of a 40 sec epoch contained one or more of the following patterns: (a) a low voltage (amplitude lower than 20  $\mu$ V) fast pattern (LVF); (b) 4-7 cps low voltage theta activity (amplitude greater than 20  $\mu$ V); or (c) 8-13 cps alpha rhythm (amplitude greater than 25  $\mu$ V) which may be primarily occipital or also diffused anteriorly onto the central channel, depending on the individual. Patterns were often intermixed, i.e., occurring in one record. The waking or baseline alpha rhythm frequency was measured during several 2 sec periods, usually during the pretest period and/or during the brief tasks, when alpha rhythm was most predominant because subjects had their eyes closed. Wakefulness was also characterized by rapid eye movements, particularly during the auditory vigilance when subjects were asked to keep their eyes open.

Stage 1A was characterized by more than 50% of an epoch containing one or more of the following EEG events: (a) slower alpha rhythm (defined as at least 1 cps slower than the individual's waking or baseline alpha rhythm), (b) alpha rhythm having an irregular or fragmenting

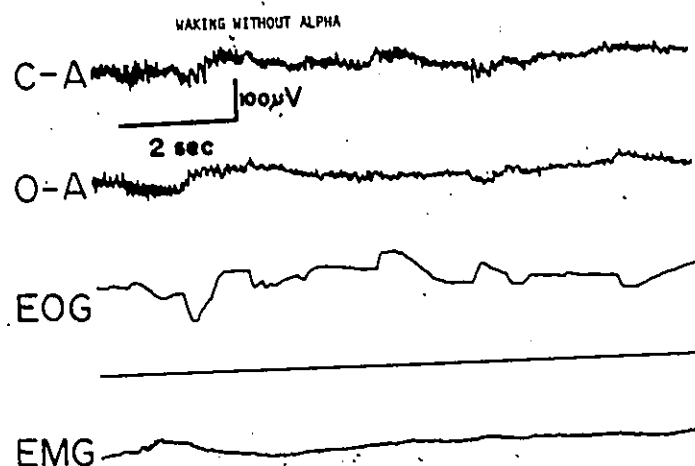


Figure 1. Polygraphic recording of patient 6 during wakefulness without alpha rhythm. Patient had her eyes open and rapid eye movements are seen on the third channel. Channels for the following figures 2-5 are the same as those indicated above. No recording was made on the fourth channel.

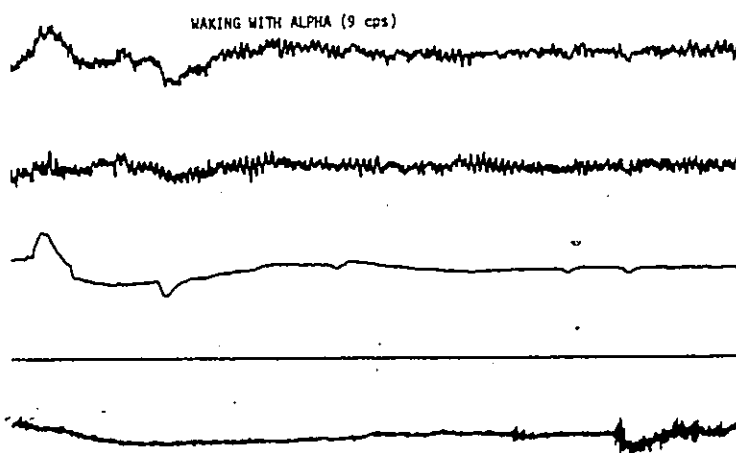


Figure 2. Polygraphic recording of patient 6 with eyes closed during wakefulness. Baseline alpha is 9 cps.

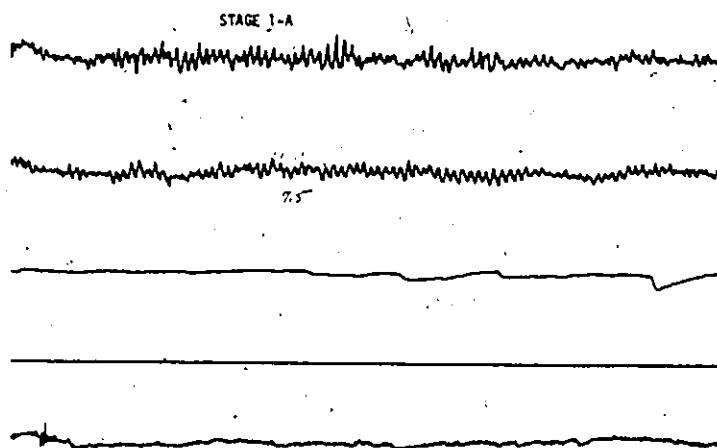


Figure 3. Polygraphic recording of patient 6 during stage 1A. A slowed alpha rhythm and medium voltage mixed frequency background activity are seen. Partially slowed eye movements are seen on the third channel.

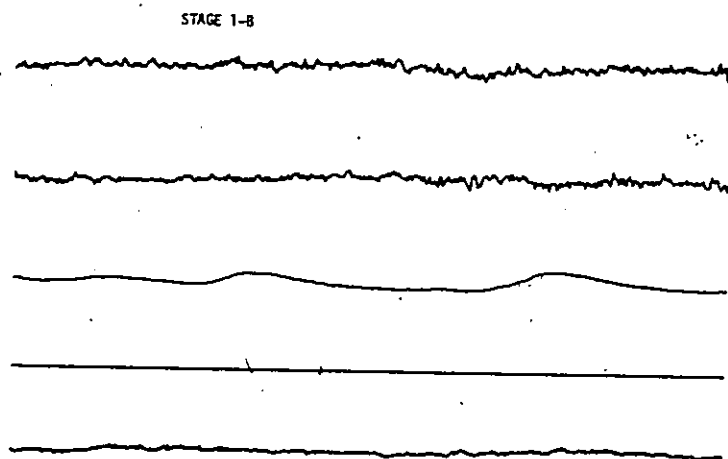


Figure 4. Polygraphic recording of patient 6 during stage 1B. Note the loss of alpha rhythm. Theta activity with medium voltage mixed frequencies are seen. Slow rolling eye movements are illustrated on the third channel.

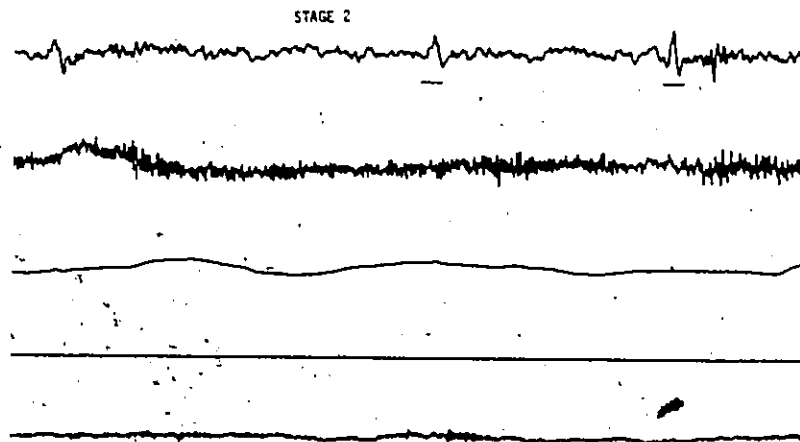


Figure 5. Polygraphic recording of patient 6 during stage 2. K complexes on the central (first) channel are underlined. The occipital (second) channel became artifacted when the patient dropped her head forward.

appearance, i.e., intermixed with a medium voltage mixed frequency pattern. Both patterns could occur in an individual's record. Eye movements during stage 1A were important cues for scoring. They often occurred as partial or definite slow "rolling" eye movements (lasting at least 2 sec defined from peak to peak).

Stage 1B and 2 were defined in a manner similar to the standardized scoring procedure for sleep stages 1 and 2 (Rechtschaffen & Kales, 1968). Stage 1B epochs were defined by the presence of more than 50% 4-7 cps theta activity (amplitude higher than 20  $\mu$ V) or other medium voltage mixed frequencies and the presence of less than 20% alpha rhythm. This stage could also be accompanied by slow rolling eye movements or little or no ocular movement and the presence of sharp vertex waves on the central channel. The background activity of stage 1B was generally slower than that of wakefulness or stage 1A.

Stage 2 epochs were defined by the presence of one or more "sleep spindles" (11-15.5 cps sigma rhythm lasting longer than  $\frac{1}{2}$  sec and greater than 25  $\mu$ V in amplitude) and/or K complexes (sharp waves occurring at the vertex, lasting longer than  $\frac{1}{2}$  sec, and associated with a slow wave and/or spindle). More than 50% of the background activity of stage 2 consisted of medium voltage mixed frequencies such as that occurring during stage 1B, and less than 20% delta waves (with frequencies of less than 2.5 cps). Some individuals showed a progressive decrease in submental EMG with the descent from wakefulness to stages 1A, 1B, and 2.

All records were scored blind. EEG during the auditory vigilance task, Digit Span and PASAT tests were scored by 40 second epochs.

Additionally to determine the relationship between auditory vigilance task performance and physiological state, the EEG stage for 3 sec preceding each signal (and in the 10 sec preceding this for those signals following 3 sec wakefulness) were scored by the same criteria as above.

Interjudge reliability was established with an experienced rater for 85% of the records (17/20). Based on 30 epochs (slightly more than a quarter of each recording), chosen pseudo-randomly to include epochs of all stages and some of low confidence, an overall 94.6% agreement was reached (narcoleptics: 89.7%, range 83-97%; controls: 99.6%, range 97-100%).

Analysis. Because of extreme deviations from normality and heterogeneity of variance between groups non-parametric statistical tests were used. These consisted of Mann-Whitney U tests and Wilcoxon matched pairs signed ranks tests for between and within group comparisons respectively. Since control subjects were predominantly in the waking state during recordings, statistical comparisons with narcoleptics' records were confined to this stage. Also, only performance following stage 1A and wakefulness was compared by statistical tests in narcoleptics because of the sparsity of responses following stage 1B (8 responses by 2 patients) and lack of responding following stage 2.

From the epoch scoring the auditory vigilance task was analyzed for: (1) group differences in level of physiological vigilance by comparing the percentage of time in wakefulness between groups; (2) the percentage of time narcoleptics spent in each of the lower stages; (3) the percentage of time spent in each stage between the first and

second half hour of the vigilance test to determine possible time related change; (4) the overall amount of stage changes by counting the number of shifts from one stage to another; (5) the degree of ability to maintain an EEG state before shifting, by comparing the percentage of time each stage was maintained for a period of 6 or more epochs to the time it was maintained for only 1-5 epochs.

During the auditory vigilance task, performance in relation to the EEG stage for 3 sec prior to each signal was determined by obtaining the hit rate, defined as the number of hits in proportion to total signals (hits/hits + misses), and hit-response rate defined as the number of hits in proportion to total responses (hits/hits + false positive responses) for each stage. These data were analyzed to determine differences in performance efficiency regarding both errors of omission and commission between stages and groups.

In addition, for each stage the number of responses (hits + false positives) and number of false positive responses in proportion to the amount of time (percentage of epochs) spent in the respective stage were obtained to determine differences in frequency of overall responding and of false-positive responding between stages.

For Digit Span and PASAT, group differences in level of physiological vigilance were determined by comparing percentage of time in wakefulness between groups. These two brief tasks were not amenable to comparison of performance with the immediately preceding EEG state because of irregular and very brief time spans between signals and responses. However, some indication of this relationship was obtained by Pearson-Product Moment correlations between percentage of time in wakefulness and test scores.

## CHAPTER III

## RESULTS

Performance

Narcoleptics performed significantly worse than controls on the vigilance and reaction time tasks. Performance test results are summarized in Table 3.

Auditory Vigilance Task

Results of a repeated measures ANOVA indicate a significant main effect between groups in number of hits on the vigilance task,  $F(1,18) = 18.71$ ;  $p < .001$ , with narcoleptics performing more poorly than control subjects. No difference was found in number of false positive responses between groups. Change in number of hits or false positives as a function of time on task (four 15 min. blocks) did not reach significance. Group-time interaction was also nonsignificant.

Four-Choice Reaction Time (RT)

Narcoleptic patients' performance contained significantly more gaps  $F(1,18) = 5.59$ ,  $p < .05$ , and longer mean RT for errors  $F(1,17) = 4.57$ ,  $p < .05$ . Mean RT overall, mean RT for correct, and mean RT without gaps all approached significance at .06 level of probability [ $F(1,17) = 3.97$ , 3.99 and 3.90 respectively]. A large proportion of within variance was attributable to one narcoleptic (patient 8) of whom the mean RT overall was 5.6 standard deviations (428 msec) longer than the group

Table 3

Mean ( $\pm$  SD) Performance Test Scores  
and Significant Group Differences

| Performance Measures                    | Narcoleptics      | Controls           |
|-----------------------------------------|-------------------|--------------------|
| <u>Vigilance</u>                        |                   |                    |
| Hits                                    | 10.3 $\pm$ 6.7    | 23.0 $\pm$ 6.3 *** |
| False Positives                         | 20.0 $\pm$ 11.3   | 17.8 $\pm$ 15.3    |
| <u>PASAT</u>                            |                   |                    |
| % correct                               | 54.2 $\pm$ 17.1   | 65.2 $\pm$ 18.7    |
| <u>Digit Span</u>                       |                   |                    |
| Scaled Score                            | 12.3 $\pm$ 4.3    | 11.7 $\pm$ 4.2     |
| Forward (raw score)                     | 6.8 $\pm$ 1.2     | 6.5 $\pm$ 1.4      |
| Backward (raw score)                    | 4.7 $\pm$ 1.8     | 4.6 $\pm$ 1.0      |
| <u>Four-Choice Serial Reaction Time</u> |                   |                    |
| N = 20                                  |                   |                    |
| RT overall                              | 822.7 $\pm$ 186.2 | 699.6 $\pm$ 102.6  |
| RT correct                              | 820.4 $\pm$ 178.3 | 701.9 $\pm$ 102.2  |
| RT errors                               | 794.3 $\pm$ 280.3 | 585.9 $\pm$ 95.5 * |
| RT without gaps                         | 717.0 $\pm$ 79.0  | 663.9 $\pm$ 74.1   |
| no. of gaps                             | 107.1 $\pm$ 69.7  | 47.4 $\pm$ 39.0 *  |
| % error                                 | 2.8 $\pm$ 3.2     | 2.0 $\pm$ 1.9      |
| N = 18                                  |                   |                    |
| RT overall                              | 784.4 $\pm$ 75.9  | 684.7 $\pm$ 96.6 * |
| RT correct                              | 768.8 $\pm$ 75.8  | 686.8 $\pm$ 95.8 * |
| RT errors                               | 714.5 $\pm$ 129.9 | 577.7 $\pm$ 97.4 * |
| RT without gaps                         | 697.4 $\pm$ 51.9  | 652.7 $\pm$ 69.0   |
| no. of gaps                             | 87.1 $\pm$ 31.1   | 43.8 $\pm$ 39.6 *  |
| % error                                 | 1.9 $\pm$ 0.8     | 2.1 $\pm$ 1.9      |

Note. SD = standard deviation.

N = number of subjects included in analysis.

RT = reaction time.

Gaps = RT  $\geq$  1 sec.

\*p < .05.

\*\*\*p < .001.

mean of the other patients. After deleting the scores for this patient and her matched control, a second analysis revealed that the narcoleptic group yielded significantly longer mean RTs for responses overall  $F(1,15) = 4.94, p < .05$ , for correct responses  $F(1,15) = 4.82, p < .05$ , and for error responses,  $F(1,15) = 5.81, p < .05$ .

Narcoleptics also had significantly more gaps  $F(1,16) = 6.67, p < .05$ . Mean RT without gaps and percent errors were nonsignificant in both analyses.

Thus, for the narcoleptic group slowed response speed, characterized by gaps, occurred during both correct and error responses. Performance deficits were therefore reflective of speed rather than errors.

#### PASAT

Results of a repeated measures ANOVA for the PASAT trials showed no significant difference between groups. As speed of trials increased on this task, both groups showed a significant and virtually linear decline in performance  $F(1,18) = 106.3, p < .001$ . Group-speed interaction was nonsignificant.

#### Digit Span

When raw scores were compared to Wechsler scaled scores for same age peers, all subjects scored within the average range of 7-13. Mean scaled scores were 12.3 (narcoleptics) and 11.7 (controls). These were slightly above the Wechsler average mean of 10. The mean difference score between digits forward and backward was small and nearly identical for both groups; 2.1 (narcoleptics), 1.9 (controls).

### Subjective Ratings

Mean group ratings and significant findings for the Effort and SSS scales are presented in Table 4.

#### SSS Ratings

Pearson correlations of the narcoleptic group's SSS ratings obtained during performance testing, and test scores were not significant on any of the tests. However, SSS scores reported by the narcoleptics were significantly lower than those of the control group for all the tasks;  $U=17$  (vigilance),  $U=19$  (PASAT),  $U=15$  (four-choice RT),  $U=21$  (Digit Span)  $p < .05$ .

#### Effort Ratings

Group comparison of Effort scale scores indicated that narcoleptics rated the PASAT as demanding significantly more effort to perform than did controls,  $U=2$ ,  $p < .005$ . No group differences for effort expenditure were found on any of the other tests.

### Polygraphic Recordings During the Vigilance Task

In comparison with the polygraphic recordings of control subjects obtained during the 1 hr vigilance task, those of narcoleptics were characterized by significantly less time in wakefulness, and by frequent shifts of EEG stages resulting in a waxing and waning pattern. Analysis of the relationship of vigilance performance to the immediately preceding EEG state revealed that narcoleptic patients had performance deficits during all stages of physiological vigilance. In addition, a

Table 4  
Group Comparison of Mean Subjective Ratings

|                           | Wigilance | RT  | PASAT | Digit Span |
|---------------------------|-----------|-----|-------|------------|
| <u>Alertness (SSS)</u>    |           |     |       |            |
| Narcoleptics              | 4.7       | 3.0 | 3.6   | 3.6        |
|                           | *         | *   | *     | *          |
| Controls                  | 2.3       | 1.8 | 1.8   | 1.7        |
| <u>Effort Expenditure</u> |           |     |       |            |
| Narcoleptics              | 2.9       | 5.3 | 1.6   | 4.3        |
|                           |           |     | **    |            |
| Controls                  | 1.8       | 5.0 | 2.8   | 3.2        |

Note. Low scores represent high levels.

RT = four-choice reaction time task.

\* $p < .05$ .

\*\* $p < .005$ .

unique pattern and degree of deficit was associated with each stage.

### Epoch Analyses

Stage Distribution. Results of the epoch scoring of polygraphic records yielded a significant difference in percentage of time in wakefulness between groups ( $U=0$ ,  $p < .005$ ). All 10 narcoleptic patients' recordings contained wakefulness, stages 1A and 1B, and four patients entered stage 2 briefly. Stages 3, 4, or REM were not encountered. Mean percentage of time in wakefulness was  $43.9 \pm 10.4$ , stage 1A;  $28.5 \pm 17.4$ , stage 1B;  $26 \pm 19.8$ , and stage 2;  $2.5 \pm 1.9$ . In comparison, control subjects remained awake for  $98.9 \pm 1.5\%$  of time on task with the remaining  $1.1 \pm 1.5\%$  being occupied by stage 1A. Only five control subjects entered stage 1A, all briefly (1-4 epochs).

There were no significant differences in percentage of any EEG stages between the first and second half of the test. However, individual differences in ability to ~~maintain wakefulness~~ at task onset were noted. While one patient (no. 4) was able to maintain wakefulness for the first 50 of 90 epochs, the remaining nine patients were able to maintain wakefulness for an average of only 7 epochs or slightly more than 4½ minutes (range 1-18 epochs). The five patients who had the greatest amount of wakefulness overall were able to remain in wakefulness longer at task onset (range 12-50 epochs) than the other five (range 1-5 epochs).

Stage Lability. During the 1 hr vigilance task the narcoleptic group had a mean of  $36 \pm 10.2$  shifts from one stage to another indicating a fluctuating or oscillatory pattern of physiological vigilance.

The five control subjects for whom stage shifts existed had a mean of only  $3.6 \pm 1.3$  shifts. The numerous stage shifts and decreased wakefulness in the narcoleptic group can be appreciated by comparing the sample histograms of a patient (see Figure 6) and control subject (see Figure 7).

For the narcoleptic group, the degree of lability or fluctuation characteristic of each stage was quantified by comparing the amount of each stage that was sustained for  $\geq 6$  epochs to the amount sustained for briefer periods (1-5 epochs). All stages were predominated by the briefer time period of 1-5 epochs: wakefulness; 63.4%, Stage 1A; 97.6%, stage 1B; 73%. Stage 1A was the most transitory of the three states. Only one patient was able to maintain it for  $\geq 6$  epochs, while six patients were able to maintain stage 1B and seven patients were able to maintain wakefulness for this length of time. Stage 2 (which existed sparsely in four patients) ranged from 1-3 epochs in length.

These data are minimally affected by the fact that patients were awakened if they maintained stage 1B or 2 for a 90 sec period uninterrupted by responses or momentary arousals. Only two patients required awakening (patient 9, twice during stage 2 and once during stage 1B; patient 8, three times during stage 1B). Hence the majority of fluctuations and stage amounts occurred spontaneously.

Only three patients reported themselves to have fallen asleep during the vigilance test. These were three of the four patients who had entered stage 2.

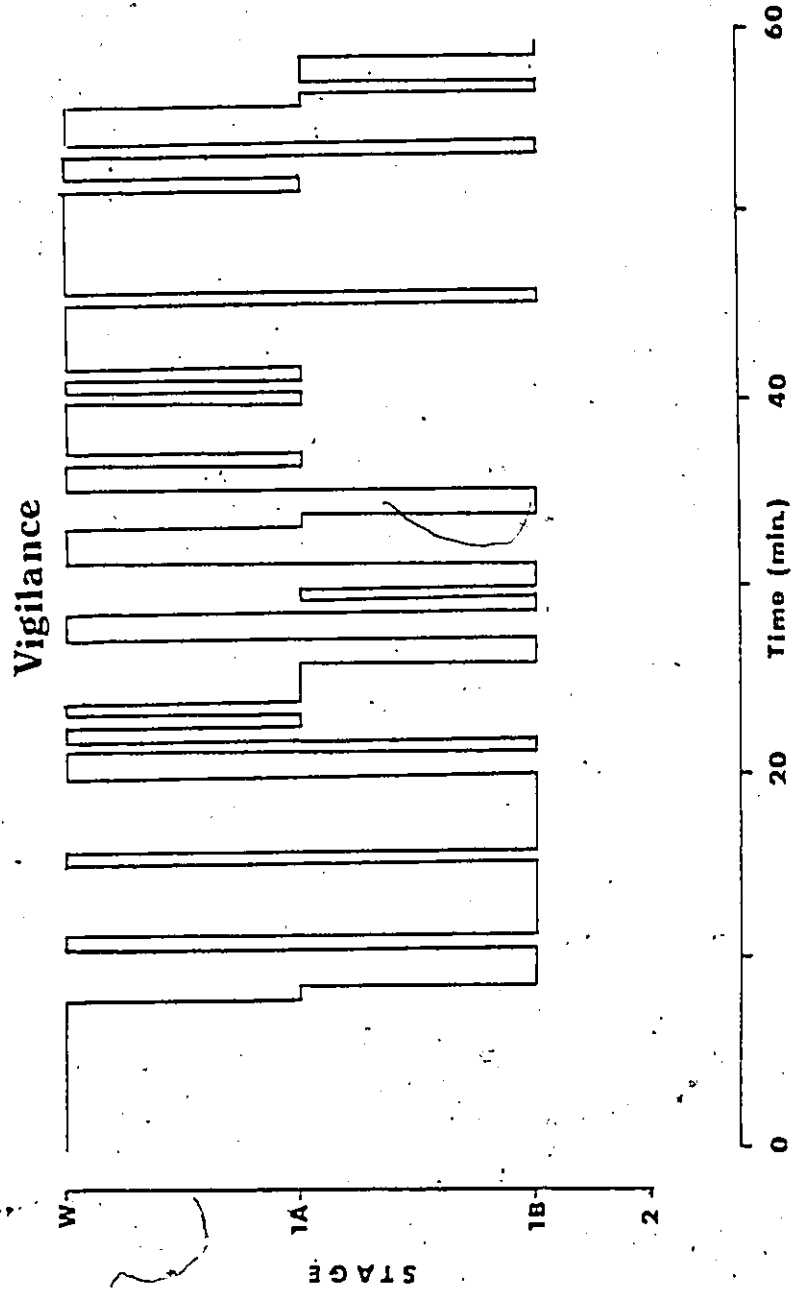


Figure 6. Histogram is based on results of 40 sec epoch scoring of polygraphic record of patient 7 during the auditory vigilance task. The stages and temporal organization of physiological vigilance are depicted. W = wakefulness.

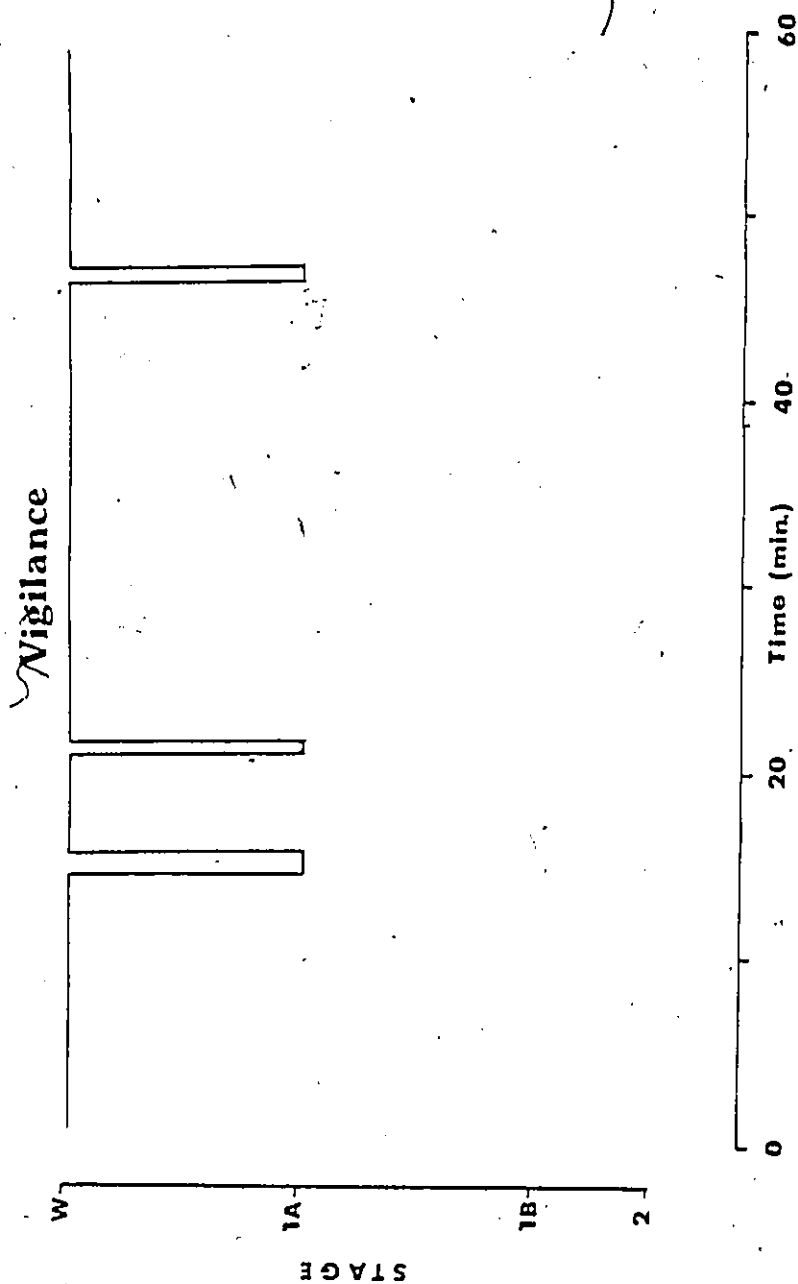


Figure 7. Histogram is based on results of 40 sec epoch scoring of polygraphic record of control subject 3 (control subject with the greatest amount of stage 1A) during the auditory vigilance task. W = wakefulness.

### Vigilance Performance and the Immediately Preceding Physiological State

Performance results analyzed in relation to EEG stage 3 sec prior to each signal are summarized in Table 5 (narcoleptics) and Table 6 (group comparisons for performance during wakefulness). Table 5 shows that for the narcoleptic group, both the hit rate and hit-response rate during wakefulness were significantly greater than those during stage 1A [(38.4 vs 14.5,  $W=4$ ,  $p<.01$ ) (41.2 vs 19.4,  $W=5$ ,  $p<.05$ ) respectively]. The response frequency also decreased significantly from wakefulness to stage 1A (63.8 vs 21.5,  $W=5$ ,  $p<.05$ ). This decline in ability to respond was independent of the decrease in hit-response rate, since hits were measured in proportion to number of responses occurring in each stage. Thus as the level of physiological vigilance declined from wakefulness to stage 1A, ability to respond decreased significantly, but of the existing responses, there was an increase in false positives and a decrease in hits.

Though statistical comparisons were not possible for stages 1B and 2, the findings suggest that performance in stage 1A was better than that in stage 1B, during which only two patients responded (1 hit, 7 false positives), and stage 2, which was characterized by no responses.

Between group comparisons of performance during wakefulness, shown in Table 6, revealed that narcoleptics obtained a lower hit rate (38.4 vs 59.1,  $U=22$ ,  $p<.05$ ) and a lower hit-response rate (41.2 vs 63.4,  $U=22$ ,  $p<.05$ ) than controls. While the frequency of overall responding during wakefulness did not differ significantly between groups, the frequency of false positive responding did. Narcoleptics made more than twice as many false positive responses relative to time spent in

Table 5

Comparison of Narcoleptic Patients' Vigilance Performance  
(in Mean Percentage  $\pm$  SD) During Wakefulness and Stage 1A

| Performance Measures                 | Stage           |                    |
|--------------------------------------|-----------------|--------------------|
|                                      | 1A              | Wakefulness        |
| Hit Rate                             | 14.5 $\pm$ 18.4 | 38.4 $\pm$ 24.8 ** |
| Hit-Response Rate                    | 19.4 $\pm$ 24.6 | 41.2 $\pm$ 24.6 *  |
| Response Frequency                   | 21.5 $\pm$ 18.7 | 63.8 $\pm$ 35.3 *  |
| False Positive<br>Response Frequency | 18.0 $\pm$ 17.0 | 41.7 $\pm$ 29.2    |

Table 6

Group Comparisons of Vigilance Performance  
(in Mean Percentage  $\pm$  SD) During Wakefulness

| Performance Measures                 | Group           |                   |
|--------------------------------------|-----------------|-------------------|
|                                      | Narcoleptics    | Controls          |
| Hit Rate                             | 38.4 $\pm$ 24.8 | 59.1 $\pm$ 15.3 * |
| Hit-Response Rate                    | 41.2 $\pm$ 24.6 | 63.4 $\pm$ 21.6 * |
| Response Frequency                   | 63.8 $\pm$ 35.3 | 39.0 $\pm$ 14.1   |
| False Positive<br>Response Frequency | 41.7 $\pm$ 29.2 | 16.3 $\pm$ 12.9 * |

Note. SD = standard deviation.

\* $p < .05$ .

\*\* $p < .01$ .

wakefulness than did controls (41.7 vs 16.3,  $U=23$ ,  $p<.05$ ).

Frequent oscillations between wakefulness and the stages of decreasing vigilance, shown by the epoch analysis, lead to the post facto hypothesis that poor performance during wakefulness was related to the inability to sustain wakefulness over time. To investigate this relationship, all signals preceded by 3 sec of wakefulness were divided into those preceded by fragmented (brief) wakefulness (defined as 3 sec wakefulness preceded by 10 or more sec of decreased vigilance), and those preceded by sustained wakefulness (defined as 3 + 10 or more sec wakefulness).

Comparison of narcoleptic performance in these two substages are shown in Table 7 and indicates that the hit rate and hit-response rate during sustained wakefulness were significantly higher than those during fragmented wakefulness [(46.5 vs 17.8,  $W=1$ ,  $p<.01$ ) (38.5 vs 16.3,  $W=2$ ,  $p<.05$ ) respectively]. (In the analysis comparing hit-response rates, only nine patients were compared, since one patient made no false responses during fragmented wakefulness).

Between group comparisons were possible for performance following sustained wakefulness only. Results, shown in Table 8, reveal that the hit and hit-response rates did not differ significantly between the narcoleptic and control subjects [46.5 vs 60.2, n.s.) (50.9 vs 63.6, n.s.) respectively].

In summary, the narcoleptic group's vigilance performance during stages 1B and 2 was characterized by almost complete absence of responding. Their performance during wakefulness was better than that during stage 1A, but worse than the performance of control subjects

Table 7

Comparison of Narcoleptic Patients' Vigilance Performance (in Mean Percentage  $\pm$  SD) During Fragmented and Sustained Wakefulness

| Performance Measures           | Wakefulness Substages |                    |
|--------------------------------|-----------------------|--------------------|
|                                | Fragmented            | Sustained          |
| Hit Rate                       | 17.8 $\pm$ 26.3       | 46.5 $\pm$ 24.4 ** |
| Hit-Response Rate <sup>a</sup> | 16.3 $\pm$ 19.8       | 38.5 $\pm$ 27.6 *  |

Table 8

Group Comparisons of Vigilance Performance  
(in Mean Percentage  $\pm$  SD) During Sustained Wakefulness

| Performance Measures | Group           |                 |
|----------------------|-----------------|-----------------|
|                      | Narcoleptics    | Controls        |
| Hit Rate             | 46.5 $\pm$ 24.4 | 60.2 $\pm$ 15.6 |
| Hit-Response Rate    | 50.9 $\pm$ 28.6 | 63.6 $\pm$ 21.6 |

Note. SD = standard deviation.

<sup>a</sup>Only nine patients were included in this analysis since the tenth patient did not have false positive responses occurring during fragmented wakefulness.

\* $p < .05$ .

\*\* $p < .01$

during wakefulness. The decline in physiological vigilance from wakefulness to stage 1A was accompanied by a decrease in number of responses made. Though the frequency of overall responses in wakefulness did not differ significantly between groups, the narcoleptic group made more than twice as many false positive responses relative to time spent in wakefulness than did controls.

When wakefulness was subdivided into fragmented and sustained, it was found that narcoleptic performance during sustained wakefulness was significantly better, and further did not differ from the performance efficiency of control subjects in the same state. Figure 8 summarizes the hit rate and hit-response rate obtained across all stages including fragmented and sustained wakefulness.

#### Polygraphic Recordings During Brief Tasks (Digit Span and PASAT)

Percentage of time awake differed significantly between groups only for Digit Span ( $U=0$ ,  $p<.005$ ). Pearson correlations of performance with percentage of time in wakefulness were nonsignificant for both tests.

Control subjects were awake throughout both tests. Mean percentage of time in wakefulness for the narcoleptics was: Digit Span  $62 \pm 39$ ; PASAT (trials 1-4);  $76.3 \pm 34.6$ ,  $80.1 \pm 32.2$ ,  $85 \pm 24.2$ ,  $85 \pm 33.7$ . Investigation of inter-subject variation revealed that records of eight of ten narcoleptics were predominated by wakefulness (mean = 86%) with the remaining time being occupied by stage 1A. The two other patients maintained stage 1A throughout Digit Span and spent a larger proportion of PASAT task time in stage 1A than any of the other patients (patient 8,

# Stage

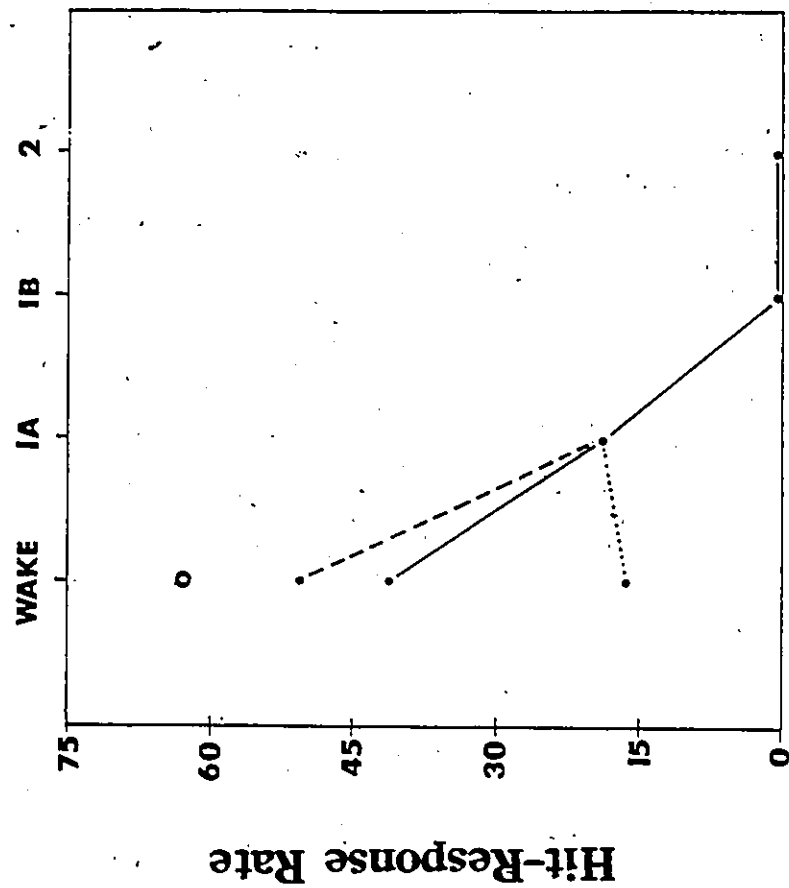
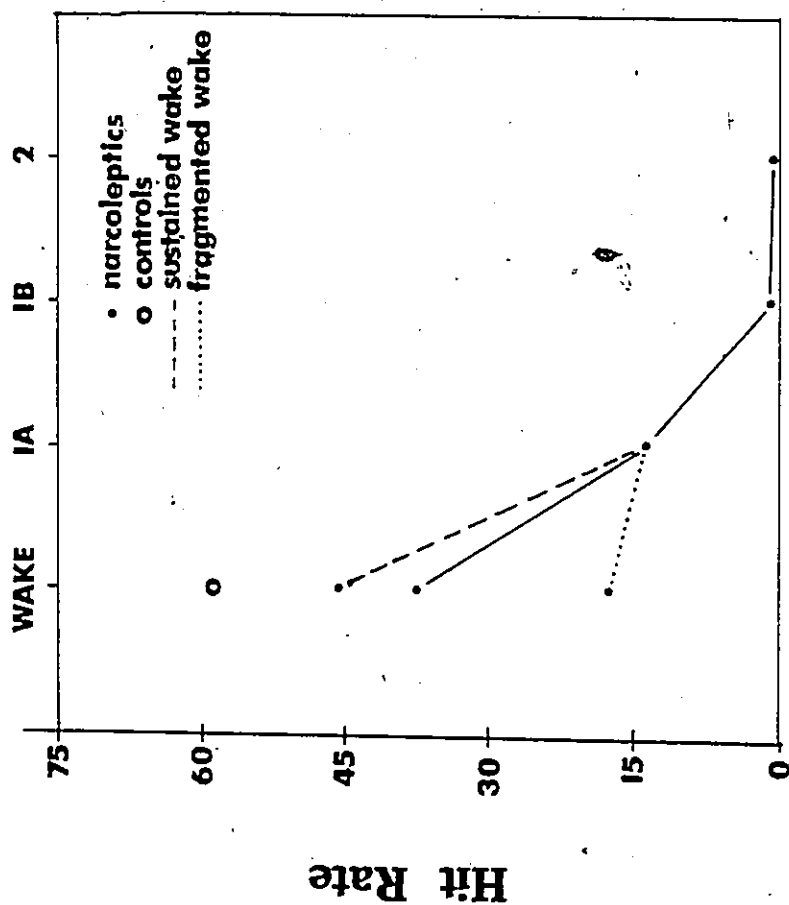


Figure 8. The hit rate (percentage of signals detected) and hit-response rate (percentage of signals detected out of total number of responses) are illustrated for controls during wakefulness and for narcoleptics across all stages of physiological vigilance, including sustained and fragmented wakefulness. Stage 2 is represented by only four of ten narcoleptics. Abbreviations: wake = wakefulness.

81% 1A; patient 5, 43% 1A). Test scores of these two patients however, were within one standard deviation of the overall test means. Interestingly, both patients had cataplectic attacks immediately following the PASAT. No other cataplectic attacks occurred during the testing session.

## CHAPTER IV

### DISCUSSION

#### Performance Effects

Information from objective performance measures support the first hypothesis, that significant performance decrements exist in narcoleptics in association with monotonous tasks.

A performance profile was revealed that resembles effects traditionally attributed to sleep deprivation. Deficits occurred in the form of lapses and were associated only with the two more monotonous tasks (auditory vigilance and four-choice reaction time) which have previously been shown sensitive to sleep deprivation (Glenville et al., 1979; Wilkinson, 1969). The qualities of monotony and lack of incentive in these tasks are conditions which increase the probability of lapses occurring (Wilkinson, 1965). The lapse hypothesis (Williams et al., 1959) states that performance following sleep deprivation is rendered progressively uneven by lapses or response omissions. These lapses are expressed as missed signals on an experimenter paced task such as vigilance, and as slowed responses or gaps, rather than errors, on self-paced tasks such as the four-choice serial reaction time (Glenville et al., 1979; Williams et al., 1959). In accordance with this hypothesis, the narcoleptic's performance deficit in auditory vigilance was charac-

terized by more than twice as many lapses or undetected signals as controls. This occurred despite the fact that they were at least as willing to respond, as reflected by the similar number of false positive responses (Webb & Agnew, 1974). Likewise, the deficit pattern on four-choice serial reaction time took the form of nearly twice as many gaps (responses  $\geq 1$  sec), while the number of errors did not differ from controls, indicating a tendency to sacrifice speed for accuracy. Reaction times faster than gaps were not affected. Thus, performance was rendered progressively uneven by gaps.

The present deficit patterns substantiate and extend the findings of Billiard (1976) and Guilleminault et al. (1975a) who found that narcoleptics exhibited poorer performance on two self-paced vigilance type tasks (SAT and WAT). Although the significance of the deficit was not stated, the narcoleptic group's performance was characterized by slower responses or gaps. The paradigm of the above investigators, a design which enhanced drowsiness, consisted of repeated assessments throughout the day on these two lengthy and monotonous tasks. This is in contrast to the present study's task variety and single assessments in the morning hours which are considered narcoleptics' most alert time of day (Richardson et al., 1978). Thus the present study demonstrated that a significant performance decrement, approximately twice that of controls, was severe enough to be observed under conditions more closely resembling daily life. Moreover, this decrement was evident in the 10 minute reaction time task, a task briefer than those used by the above investigators.

Furthermore, efficient functioning on Digit Span and PASAT, two brief tasks offering more stimulation, substantiates the critical role of external stimulation in counteracting the effects of drowsiness in narcoleptics. These tasks are characterized by increased response demands, briefer trials, and the incentive value of knowledge of results --characteristics which minimize performance deficits in sleep deprived subjects (Wilkinson, 1969). Therefore the present evidence provides support for the contrasting hypothesis 11, that the narcoleptic performs more efficiently on stimulating tasks.

Narcoleptics' accounts of difficulties in attention (Broughton & Ghanem, 1976; Daniels, 1934; Ganado, 1958; Guilleminault & Dement, 1977) were therefore verified during monotonous work, whereas basic short term attention and concentration abilities required in briefer more stimulating situations were not affected. Likewise, complaints of mental slowing (Ganado, 1958) find support in more tedious tasks measuring response speed. This is evidenced by increased gaps during the four-choice reaction time, which involves preliminary information processing (Tharp, 1978), as well as by the pattern of delayed responding reported by Billiard (1976) and Guilleminault et al. (1975a). Conversely, the stimulating nature of the PASAT counteracted tendencies toward deceleration in information processing.

In general, these findings substantiate reports in the literature that performance impairment and extreme drowsiness in narcoleptic patients occur most frequently during monotonous situations, periods of physical inactivity, and while the patient is alone (e.g., Daniels,

1934; Ganado, 1958). Conversely, the findings suggest that more stimulating interaction with the environment increases arousal and allows the narcoleptic to function efficiently. This suggestion will be qualified, however, since information from subjective and physiological measures suggests a more complicated picture.

#### Subjective Effects

Lack of correspondence between task-related subjective drowsiness and performance efficiency supports hypothesis IV, that the SSS does not reliably predict the narcoleptic group's ability to perform.

The present negative results are in accordance with the findings in studies of long-term partial sleep deprivation (Friedmann et al., 1977; Herscovitch & Broughton, in press a). In contrast, a high negative correlational relationship between SSS ratings and performance ability in acute total sleep deprivation studies (Glenville et al., 1979; Hoddes et al., 1973) suggests that the power of the SSS to predict the level of functioning is dependent on the acuteness of the drowsiness. With more chronically experienced drowsiness associated with long-term partial sleep deprivation and narcolepsy conditions, the factor of habituation to the self-experience of drowsiness may decrease one's sensitivity to changes and degrees of severity of this state. A second factor, the developed ability to adapt to demands despite sleepiness is also more likely to occur in the long-term experience of drowsiness, thus widening the discrepancy between the subjective and objective measures.

Hypothesis III, that the narcoleptic group's self-rated drowsiness would be greater than controls was supported for all tasks. The ability of the SSS to detect increases in general drowsiness, which has been shown in all four of the above sleep deprivation studies, is further extended to narcoleptics. The fact that increased drowsiness was only accompanied by performance decrement on the two more monotonous tasks reflects the principle advanced by Kjellberg (1977) that performance deterioration results from the interaction of the degree of sleepiness with the aspect of monotony in the situation. Hence, the performance effects of drowsiness were minimized by stimulating tasks and maximized by monotonous tasks.

Therefore the statement made in the "Diagnostic Classification for Sleep and Arousal Disorders" (Association for Sleep Disorders Centers, 1979) that excessive drowsiness can be quantitatively measured by subjective rating scales, is only partially validated for narcoleptics. The level of subjectively rated drowsiness as measured by the SSS does differentiate narcoleptics from control subjects during monotonous as well as stimulating work. However, these ratings do not reflect the narcoleptic's ability to function. Therefore the scale should not be used as an indicator of performance efficiency in the research and treatment of narcolepsy. Its use in this manner should probably be restricted for other disorders involving chronic excessive drowsiness as well.

Although subjective drowsiness alone is not an adequate predictor of performance in narcoleptics, its omnipresence during the tasks can

serve as a warning sign for potential behavioral and psychological effects. Indeed, the negative experience of drowsiness while attempting to work is discomforting. It perhaps suggests that one's adaptive ability has been overextended, even though external behavior is affected only when adaptive abilities are pushed to their limits. According to Selye (1956), the process of adapting is itself stressful. Lazarus (1966) and McGrath (1970) added that stress arises when demand exceeds the organism's capacity, and increases gradually as effort and unpleasantness become less tolerable.

Hypothesis III, that narcoleptics would report expending greater effort than controls during the stimulating tasks is interpreted within this framework. The hypothesis is supported for PASAT but not for Digit Span. The narcoleptic's reported expenditure of effort beyond that of matched controls during the PASAT suggests a form of adapting to the complex demands of the task while drowsy. Aside from the task's high demands of adding in combination with complex tracking, its externally controlled pace is a stress inducing constraint (Bartely, 1965). A more stimulating task also has inherent qualities of incentive and, in this situation, greater expenditure of effort is more likely to counteract poor performance (Wilkinson, 1961, 1964) which characterized the auditory vigilance and reaction time tasks. In comparison, the demands and degree of stimulation provided by Digit Span seemed optimal for the narcoleptic's drowsy state, since neither performance deficit nor increased effort were encountered. Thus, while the stimulation offered by the brief tasks was successful in counteracting poor performance,

the more subtle effects of subjectively experienced drowsiness during both tasks and the need to exert increased effort during the PASAT persisted.

Various studies relating personality factors to methods of coping with sleep deprivation provide information on the ramifications of stress stemming from attempts to function while drowsy and from adaptation by the increased exertion of effort. The expenditure of compensatory effort is one factor preventing deficits subsequent to sleep deprivation (Malmo & Syrwill, 1960; Strausbaugh & Roessler, 1970; Wilkinson, 1962). Strausbaugh and Roessler (1970) further demonstrated that the ability to mobilize effort subsequent to sleep deprivation demands high ego strength. Murray (1968) stated that suppression of sleep tendency initiates a frustration-aggression mechanism. The irritability and negative affect experienced by narcoleptics (Broughton & Ghanem, 1976) may be an effect of attempting to perform adequately while drowsy. Similarly, Zarcone and Fuchs' (1976) suggestions that narcoleptics need high ego strength, and that psychological disturbances are at least partially the result of increased stress involved in coping with narcoleptic symptoms while attempting to meet daily responsibilities, are supported by the present results.

The work of adaptation itself has post-stress consequences, or a "psychic cost" which leaves fewer resources available for coping with subsequent environmental demands (Glass & Singer, 1969; Selye, 1956). Attacks of cataplexy which occurred in two patients at the termination of the PASAT could represent profound and immediate post-adaptive effects

from previous increased effort in combination with stimulation. More subtle post-adaptive costs may be more prevalent. For example, Glass and Singer (1969) noted lack of perseverance and low tolerance for frustration as post-stress consequences in normals. From the present evidence it is not surprising that these are also common complaints of narcoleptics (Broughton & Ghanem, 1976; Ganado, 1958).

The restorative theories of sleep argue that increased energy is consumed during states of sleep deprivation as well as during increased activity and stress, and is restored by longer and/or deeper sleep (cf. Bonnet, 1980; Hartmann, 1973; Lubin, Hord, Tracy & Johnson, 1976; Oswald, 1970). While stress increases the demand for sleep in normals (Hartmann, 1973), it increases symptomatology in narcoleptics (Mamelak et al., 1979). Certainly the narcoleptic's ability to remobilize energy resources by restorative sleep is diminished; rather, increased sleep need spills into the day, manifested as increased symptomatology.

The post-adaptive effects of energy loss from sleep deprivation have been demonstrated by Lubin et al. (1976) who showed that increased exercise during sleep deprivation, though arousing on the short term, is followed by more profound performance decrement than bedrest. Similarly, Ganado (1958) noted that narcoleptics were sometimes able to perform tasks of high interest for long periods without deleterious effects, but experienced extreme drowsiness and other symptoms for long periods afterwards. This trend is congruent with narcoleptic complaints of being "too tired" after attempting to meet basic requirements of a work day to partake in family and social commitments (Zarcone, 1977).

The above information together with the present results suggest that increased demands on the narcoleptic, even if temporarily stimulating, can lead to a depletion of energy resources. Consequently, these patients would be made more vulnerable not only to poor performance, but also to negative psychological effects and an increase in symptoms.

In summary, it is seen that poor performance in narcoleptics can be counteracted by stimulating tasks. However, even when the situation is stimulating subjective drowsiness is not eliminated. In addition, compensatory effort needed when demands increase may stress the individual and result in the depletion of energy. More stimulating tasks were avoided in studies done by Billiard (1976) and Guillemirault et al. (1975a) in their assessment of narcoleptics and similarly in sleep deprivation research (e.g., Wilkinson et al., 1966) because they are considered insensitive to performance impairment. However, the present findings stress the importance of investigating more stimulating tasks and the interaction of such tasks with subjective states.

This more holistic approach revealed a bidirectional impairment. A bivalent trend was elaborated by Welford (1973) who associated stress with deviations in either direction from the optimal level of activity. In the present study, this general trend explains performance characteristics specific to narcoleptics. In comparison to controls, these patients have much narrower limits for the degree of activity (stimulation and demand) that can be tolerated without deleterious effects. In a task of low stimulation, demands are unlikely to be met. The individual

must grapple with the basic need to stay awake. Conversely, a task of high stimulation increases arousal and allows adequate performance. However, if the task is demanding, it requires compensatory effort to perform with the likely consequence of depleted energy resources or worse, the occurrence of cataplexy. The failure to meet demands as well as the need to expend increased effort must be regarded as having important negative consequences for the narcoleptic.

### Physiological Effects

#### Auditory Vigilance

The lowered cortical arousal in narcoleptics, inferred from the poor performance and subjective reports was confirmed by the results of the epoch analysis of polygraphic records during the auditory vigilance task. The pattern in which lowered physiological vigilance occurs over time is also described by these results. Most notable, however, was the demonstration of the inadequacy of the lapse-microsleep formulation in explaining the performance difficulties of narcoleptic patients. Results of analyses relating performance to the immediately preceding physiological state found that significant deficits occurred at all levels of arousal, with each level having a different degree and pattern of deficit. This is in contrast to the lapse-microsleep formulation which states that poor performance in conditions of decreased vigilance is characterized only by lapses which occur during stages 1B or 2, i.e., levels at which microsleeps occur.

Epoch Analysis During the Auditory Vigilance Task. While it is not

surprising that narcoleptics were not able to maintain full EEG wakefulness throughout the task, it is interesting to note that little stage 2 (2.5% entered briefly by four patients) and no stages 3, 4, REM, or sleep attacks occurred during this very lengthy and monotonous task. This degree of vigilance occurred relatively spontaneously as only two patients were forcefully awakened (three times each). Perhaps the physical factors and demand characteristics of the situation restricted overt sleep. Being seated in a hard chair as opposed to a bed or recliner is not as conducive to sleep and particularly to REM sleep in narcoleptics (Hishikawa et al., 1968). Subjects were asked to keep their eyes open and to try to stay awake, and were told that they would be awakened if they fell asleep for a lengthy period. Although a practice day preceded the test day, the situation was not as sleep promoting as it would probably have been if repeated several times (Oswald, 1962; Wilkinson et al., 1966). However, these characteristics made the situation more similar to daily life and, despite this, the narcoleptics were only fully awake 44% of the time. This is in sharp contrast to the 99% of time controls were able to maintain full wakefulness. The significant difference between these amounts supports hypothesis V, that narcoleptics would spend significantly less time in wakefulness than controls during the auditory vigilance task.

The sequential analysis of epochs revealed a steadily occurring and spontaneous oscillatory pattern between wakefulness and the stages of decreasing vigilance (stages 1A, 1B, and 2). In comparison with both wakefulness and stage 1B, stage 1A was the most transitory. L. Morrell

(1966) also found in normals that stage 1A was more unstable over time than either a waking or theta (stage 1B) pattern, and considered it to be a transition state between wakefulness and light sleep. The present results support this contention.

While some studies in normals have shown a decline in vigilance performance and electroencephalographic indicators with time (e.g., Mackworth, 1970), in the present study, the amount of time spent in each stage remained relatively constant between the first and second half hour, as did performance. The narcoleptics' increased tendency to lowered vigilance most likely resulted in a more immediate decline to some basal level which they were able to maintain in this monotonous performance situation without falling into deeper sleep. While one exceptional patient was able to maintain wakefulness for the first half hour, the other nine were able to maintain it for an average of only 7 epochs or approximately 4½ minutes at task onset. The subgroup of five patients who showed the least amounts of initial wakefulness were also those who had the least amounts of wakefulness overall. A more immediate decline in performance associated with microsleeps was previously reported in narcoleptics (Guilleminault et al., 1975a) and in hypersomniacs (Guilleminault et al., 1975b), further associating decreased physiological vigilance with this trend.

The early appearance and continued occurrence of the narcoleptic's fluctuating physiological state (mean of 36 stage shifts) is contrasted with the lack of any remarkable decline in normal controls (mean of 3.6 shifts in five subjects), accentuating the wide differences between

these groups. Such a fluctuating pattern appears to be characteristic of the transition period between wakefulness and sleep in both narcoleptics and normal individuals. Gradual alternations between wakefulness and light sleep have been previously alluded to in early clinical EEG reports of narcoleptics (Daly & Yoss, 1957; Hishikawa & Kaneko, 1965; Pond, 1952; Roth, 1964). In addition, L. Morrell (1966) indicated that these tend to occur in normals, with time on a lengthy task. Oswald (1962) noted a vacillatory pattern in normals falling off to sleep occurring as a moment to moment interchange between drowsiness and light sleep. Accordingly, Oswald (1962) argued that although vigilante performance over time is presumed to steadily decline, a more uneven pattern of increasingly repeated declines may more accurately characterize the process. This waxing and waning process appears accentuated in narcoleptics, and its early onset and continued occurrence within the same stages during performance implies that they quickly reach a nadir of decline which they are able to maintain without descending into overt sleep, but above which they are unable to rise to sustain full wakefulness.

This overall pattern appears to be markedly different from the more punctate pattern of microsleeps which as mentioned, occur as brief bursts (1-11 sec) of stage 1, synchronized theta, or stage 2 sleep that intrude suddenly into wakefulness. Of course, the different descriptions are due at least in part to different methods of analysis. Microsleeps are generally analyzed concomitant with performance and therefore the EEG state is measured only in relation to signals. Nevertheless,

differences in the rapidity and brevity of fluctuations may exist as a function of the interaction of sleep pressure with the type of task. For example, the SAT used by Guilleminault et al. (1975a) demanded continual key pressing. Such activity would be a more powerful suppressant of sleep allowing pressure for sleep to build up and at some critical point to "burst" into wakefulness in a more sudden pattern. In contrast, the auditory vigilance task used in the present study demanded only occasional responding (1 signal per 1-2 minutes) thus allowing sleep to be released more continually which may result in more gradual fluctuations. Slower fluctuations would also allow for the appearance of the intermediate stage 1A which tends to be skipped during quick changes in cortical arousal (Simon & Emmions, 1956). In the present study, stage 1A occurred as often as stage 1B. However, this intermediate stage was not considered in the microsleep formulation. Further, synchronized theta, which characterizes microsleeps was seen only rarely in the records of the present study. More gradual fluctuations might be more likely to occur in monotonous situations where continual overt responding is not demanded, such as listening to a lecture, long distance driving, or a scanning task, whereas briefer microsleeps might be favored with more continual albeit monotonous performance demands. It would be of interest to compare polygraphic recordings taken during vigilance tasks which make more continual demands and in which discrete microsleeps are the described characteristic with those of the present study to see whether different patterns in lowered vigilance are expressed.

Vigilance Performance and the Immediately Preceding Physiological State. An accurate indication of the relation of performance to EEG state requires measurement of the EEG state in immediate association with the signal (e.g., Gale, 1977; Groll, 1966; Townsend & Johnson, 1979). Using this type of analysis, the concept of lapses associated with microsleeps has evolved and has traditionally been seen as the major explanation for performance deficits following sleep deprivation (e.g., Williams et al., 1962), and more recently for performance deficits in narcoleptics (Guilleminault et al., 1975a) and hypersomniacs (Guilleminault et al., 1975b).

Similarly, the results of the present analyses of vigilance performance and the immediately preceding physiological state follow the traditional behavior and EEG pattern of the lapse-microsleep formulation. These results support hypothesis V: it is at stages 1B and 2 (the levels characteristic of microsleeps) where lapses or response omissions become a clear characteristic of narcoleptic performance. However, the present study demonstrated that the lapse-microsleep formulation is an insufficient explanation for the performance picture of the present narcoleptic group. In this respect the findings support hypothesis VI, that narcoleptics would also exhibit poorer performance than controls at higher levels of vigilance than those associated with microsleeps, i.e., during wakefulness and stage 1A, and that these deficits would be characterized by an increase in both lapses and false positive responses.

Although narcoleptics' performance during wakefulness was signifi-

cantly improved over that during stage 1A, it was poorer than the performance of controls during wakefulness, consisting of relatively fewer detected signals and more false positive responses. Moreover, narcoleptics made more than twice as many false positive responses than controls for the time they spent in wakefulness.

In comparison with their performance during wakefulness, narcoleptic responses during stage 1A were significantly fewer and characterized by an increased number of false positives, but were not abolished as in stages 1B and 2. Similar performance patterns during this transition state have been reported in normals by L. Morrell (1966) as slower responses and increased response omissions relative to waking performance but better performance than that during EEG theta activity in which responses were absent. Simon and Emmons (1956) found that in normals, decreased recall was associated with this intermediate pattern while no recall was associated with a theta pattern. However, Williams et al. (1962) who introduced the lapse hypothesis, did not consider this intermediate or transitional state, asserting that EEG after sleep loss was of a bimodal quality, vascillating between wakefulness and theta activity. It was during the 4-7 cps theta activity that performance deficits occurred as lapses.

These performance deficits during wakefulness and stage 1A demonstrate the inadequacy of the lapse hypothesis. The findings are most aptly explained by Oswald's (1962) statement that "lapses represent only more extreme ends of a recurrent downward sliding of cerebral vigilance . . . . General disorganization and inappropriateness of response are

also consistent with decline" (p.184).

The occurrence of disturbed visual fixation and sensory problems reported in narcoleptics during drowsiness (Broughton & Ghanem, 1976; Ganado, 1958; Levin, 1943) would certainly contribute to performance deterioration. Though subjects in the present study were not questioned on and did not report such incidents, these occurrences usually develop during stages 1A and 1B (Gastaut & Broughton, 1965) or during deep drowsiness (Foulkes & Vogel, 1965; Rechtschaffen & Foulkes, 1965).

Gastaut and Broughton (1965) found that subjects usually do not perceive themselves to be sleeping during these stages. Similarly, in the present study only three patients, those who had entered stage 2, reported themselves to have fallen asleep during the vigilance task. These results are in support of Johnson's (1973) contention, that only at stage 2 does "true" sleep occur. Similarly when narcoleptics appear to be asleep (to others) they may perceive themselves only to have been drowsy or as having had a lapse of attention (Hishikawa & Kaneko, 1965). This perception may be relevant to the narcoleptic group's increased number of false positive responses during periods of wakefulness. The awareness of a gap in attendance to the task could well result in a need to compensate or "make up" for the lapse. According to Webb and Agnew (1974), false positive responses represent a willingness to respond, hence suggesting that narcoleptics exhibited a higher willingness to respond during existing periods of wakefulness than controls. Alternatively the increased number of false positive responses during wakefulness may have served as a means of stimulation. Welford (1973)

indicated that in a situation of low stimulation, subjects might seek any stimulation available. However, patients who were questioned reported only responding when they perceived a signal. In addition, narcoleptics appeared to be highly motivated and did not report expending less effort than controls. Therefore the possibility that patients were more willing to respond than controls is the more likely explanation. Such an inadequate coping strategy during temporary periods of wakefulness implies some form of compensatory though fruitless effort on this task, a complexity inexplicable by the lapse hypothesis.

The present study demonstrated that poorer performance even during wakefulness in the narcoleptics was associated with a fragmented waking pattern, i.e., the inability to sustain wakefulness. Only when narcoleptics were able to sustain wakefulness for a period of time preceding signals did performance reach the level of control subjects. Thus one can be electroencephalographically and behaviorally awake but directed attention is not optimal if wakefulness is only achieved momentarily. Similar patterns in normals support this finding in narcoleptics. Simon and Emmons (1956) found that awake subjects who have recently been asleep tend to show poorer responses and recall than those who had previously maintained wakefulness. They termed this phenomenon the "inertia effect." Accordingly, L. Morrell (1966) found that a correct response during wakefulness was more likely if the preceding response also occurred during the awake state.

Thus it has been shown that lowered vigilance closely preceding stimuli (fragmented wakefulness), as well as that occurring concomitant with the stimuli, can hinder information processing. In a similar

manner, lowered vigilance occurring just after information input may be involved in the memory problems frequently reported in narcoleptics (Guilleminault & Dement, 1977). Several investigators (Goodenough, Sapan, Cohen, Portnoff & Shapiro, 1971; Guilleminault & Dement, 1977; Portnoff, Baekland, Goodenough, Karacan & Shapiro, 1966) have noted that a permanent memory trace is no longer formed if information is processed just prior to sleep but when the person is still behaviorally awake.. Goodenough et al. (1971) suggested that these deficits may be due to poor information processing as a result of lowered arousal levels just before sleep, rather than to the effect of subsequent sleep itself on memory traces. Accordingly, sleep deprived subjects are less able to perceive and register stimuli and even when registered there is a retention deficit (Elkin & Murray, 1974; McLeod, 1968; Williams, Geisking & Lubin, 1966) which has been attributed to the inability to sustain attention for any length of time (Elkin & Murray, 1974). In the present study, the poorer performance of narcoleptics during fragmented wakefulness may have been due to lowered arousal, even though the stimuli were immediately preceded by electroencephalographically measured wakefulness. Whether or not some form of lowered arousal exists during fragmented wakefulness, it seems reasonable that upon arousal to wakefulness, a period of time longer than that allowed by fragmented wakefulness is needed to re-establish attention and concentration on the task at hand.

In summary the present evidence indicates that the narcoleptic group's deficit in vigilance performance is not due solely to performance lapses during stages 1B or 2 as is the prevailing notion of the lapse-

microsleep formulation (e.g., Guilleminault et al., 1975a; Williams et al., 1962). Indications that deficits also occur at higher levels of physiological vigilance (Kjellberg, 1977; L. Morrell, 1966; Oswald, 1962; Simon & Emmons, 1956) are confirmed and elucidated in the narcoleptic group of this investigation. Deficits occurred at all levels of vigilance from wakefulness through stage 2, with the degree and nature of the decrement oscillating with the physiological state. As vigilance declined from wakefulness, ability to respond gradually decreased and was characterized by an increase in false positive responses relative to hits. Lapses alone occurred only at the extreme low levels of vigilance.

Moreover, different stages of physiological arousal are not totally independent processes but can have a temporal effect on each other. Poor performance even during wakefulness was shown to be related to the existence of preceding stages of decreased vigilance. Narcoleptics only performed efficiently when wakefulness was sustained over time.

From the present evidence, a graduated model of consciousness can be constructed. Loss of consciousness or "perceived sleep" appears to occur at stage 2 sleep. Although consciousness has apparently not yet been lost at stages 1A and 1B, it is certainly clouded. The stage 1B level of physiological vigilance is associated with "behavioral sleep," i.e., the loss of ability to perceive and/or respond to external stimuli. While behavioral response is still possible during stage 1A it is less likely to occur as often as during wakefulness and is characterized by increased errors, possibly as a result of distorted perceptual ability. In comparison, wakefulness is associated with definite improved

ability to perceive and respond to the external world. However, if wakefulness is continually interrupted by stages of decreased vigilance, it too is associated with decreased perceptual and response efficiency and thus cannot be considered to be a full level of consciousness.

Full consciousness is only achieved if wakefulness can be sustained over time. In a situation such as the auditory vigilance task in which the narcoleptic's vigilance levels continually fluctuate between these stages but rarely enter stage 2, consciousness is almost never lost, but full consciousness and efficient performance can also be considered a rare occurrence.

This model supports previous associations of stages 1A and 1B with and "obscuring of consciousness" (Gastaut & Broughton, 1965) and with the loss of controlled, purposeful thinking (Gibson et al., in press; Zilberg, 1978) and further suggests that momentary wakefulness also has similar characteristics. Moreover, the model explains the occurrence and differentiated nature of inappropriate responses as well as omitted responses while the lapse-microsleep formulation addresses only a monotonic pattern of the latter.

#### Performance and Physiological State During Digit Span and PASAT

The brevity of stimuli-response periods in recordings made during Digit Span and PASAT precluded analysis comparing responses to the immediately preceding physiological state. However, an epoch analysis of the data was conducted to provide preliminary information on the

degree of cortical arousal present.

Narcoleptics did not differ significantly from controls in percentage of time awake during the PASAT while they did spend relatively less time in wakefulness during Digit Span. Thus hypothesis V, that narcoleptics would not spend significantly less time in wakefulness during these tasks was supported for PASAT but not for Digit Span. On both of these tasks, lowered vigilance characterized by stage 1A did not appear to affect performance, as evidenced by lack of group differences in performance and by lack of correlation between percentage of time awake and test scores. Moreover, the two patients who spent the majority of task time in stage 1A performed as well as the other eight who spent only minimal amounts of time in stage 1A. It is interesting to note that cataplexy occurred in these two patients immediately after the PASAT. It is known that excitement or emotional stress, particularly when combined with drowsiness, increases vulnerability to cataplexy. This information and the present findings suggest that when a patient is experiencing more drowsiness or pressure for sleep, stimulating work is not only less successful in preventing decreased vigilance from spilling into wakefulness, but it may act as a catalyst leading to REM pressure release in the form of cataplexy at task termination.

The levels of physiological vigilance during these brief tasks and during the vigilance task further illuminate the bivalent nature of the narcoleptic's impairment. According to stress theorists (Lazarus, 1966; Welford, 1973), an individual's resources, which would include his level

of vigilance, must be matched with environmental demands. Accordingly, the lower basal level of arousal in narcoleptics, further promoted by the monotony of the vigilance task was not adequate to meet performance demands. Conversely, the higher amount of sleep suppression induced by the stimulation and task requirements of the PASAT may have been too great a deviation from the amounts narcoleptics could comfortably tolerate, resulting in the need for compensatory effort and in severe cases, cataplexy. The occurrence of cataplectic attacks following the PASAT rather than Digit Span may have been due to the fact that the latter's decreased complexity and stimulation were more optimally balanced with the narcoleptic's drowsy state, as this task did not demand compensatory effort and allowed more decreased vigilance to occur without affecting performance. Certainly the simpler task requirements and self-paced nature of this task did not require the degree of sustained alertness as would be needed to perform the PASAT. This idea is congruent with statements made by Head (1923) and Oswald (1962), that the greater complexity of a task, the greater the degree of cortical arousal required.

Although responses during the brief tasks were not amenable to individual analysis as were responses during auditory vigilance, it is surmised that narcoleptics were able to perform these more stimulating tasks adequately even during stage 1A, while performance on the vigilance task during this state and during wakefulness was more vulnerable to decrement. Thus the ability of electroencephalographically determined drowsiness to disrupt performance apparently increases when compounded

with monotony. This possibility, recently mentioned by Townsend and Johnson (1979), would provide support for Kjellberg's (1977) contention that performance deficits are the result of the interaction between drowsiness and the monotonous nature of the task.

It can also be inferred that the occurrence of stages 1B and 2 during the vigilance task made subsequent performance during stage 1A more vulnerable to decrement in the same manner as they affected performance during fragmented wakefulness. The sparsity of data precluded this analysis. However, L. Morrell (1966) has reported such a trend in normals. Similarly, the absence of stages 1B and 2 during the brief tasks may have allowed efficient performance during stages 1A and wakefulness.

#### Applications and Recommendations

The problems of the narcoleptic which affect daily performance appear to stem from the manner in which the tendency to decreased vigilance is manipulated in its interplay with the type of daily routine or tasks. Based on the present performance, subjective and physiological findings, one can formulate a hypothetical picture of the narcoleptic's functioning in various routines.

In a situation of low stimulation such as auditory vigilance task, the narcoleptic soon, perhaps even instantaneously, experiences waves of drowsiness. He may perceive himself to be awake but in fact, he only rarely and sporadically achieves a full level of consciousness. As decreased vigilance levels intrude and wane in a vacillatory fashion,

so also will the degree and nature of the performance deficit fluctuate. Abilities to perceive and respond to stimuli are either decreased or lost resulting in abnormally high rates of errors of omission and commission relative to the number of accurate responses. If the task were self-paced the narcoleptic might slow his progress by pausing intermittently but be less likely to make errors of commission.

Upon shifts to the waking state, the patient may attempt to re-establish attention which is inadequate initially but improves if wakefulness can be maintained. During waking periods the perception of having had a previous lapse of attention may prompt increased responses to compensate for lapses. In this situation an increase in errors of commission is likely. Both decreased vigilance and momentary wakefulness during information intake can distort the perception of information. Similarly, decreased vigilance following information input during wakefulness may affect its retention. The few interspersed periods of sustained wakefulness during which adequate attention is possible allow little progress in comparison to a continual waking pattern. This is to be expected particularly in a task of high complexity which would demand higher levels of alertness. Such continually disrupted performance in situations of decreased stimulation does not allow for a continuity of thought processes needed to build concepts or follow a chain of related events such as listening to a lecture, reading a text, or performing some complex mental work alone at a desk.

In contrast, if the task were briefer and continually stimulating, the narcoleptic would be able to perform much more efficiently. Yet

the negative experience of drowsiness would not be eliminated. If the task were also complex the patient would most likely have to expend compensatory effort to meet the performance demands. Such a situation appears to command the mobilization of effort and possibly the suppression of the tendency to sleep or decreased vigilance beyond the amounts he can comfortably tolerate. Under these conditions the narcoleptic might experience irritability or some negative emotional tone, and subsequent to his efforts feel fatigue and increased drowsiness, thus having less initiative and perseverance for continued work. If the patient were experiencing a high degree of drowsiness such a stimulating situation could facilitate cataplexy.

In a routine which is adequately stimulating yet with simpler demands the narcoleptic finds performance much more pleasant. Though he continues to experience drowsiness, he is able to perform adequately without having to mobilize already depleted energy resources or suppress the tendency to decreased vigilance to a high degree.

Thus some light is shed on the question of the best routine for the narcoleptic to follow in order to minimize performance and psychological effects and to some degree, episodic symptoms. The suggestion that stimulation may be advantageous to the work situation must be qualified. High degrees of stimulation and demand can stress the narcoleptic leading to energy depletion with consequent performance and psychological effects, or worse, cataplexy. Conversely, low degrees of stimulation only enhance drowsiness and result in performance deterioration. Thus to avoid the stressful effects



of compensatory energy expenditure on the one hand, and the effects of poor performance or unmet demands on the other, the narcoleptic must seek more moderate levels of stimulation and demand which do not promote extreme variations from his low basal vigilance level.

Lengthy and continuous tasks should be avoided particularly if the demands and degree of stimulation vary from the optimum. Billiard (1976) has provided evidence that narcoleptic performance improves after naps, and has suggested that frequent naps can provide an alternative to drugs. Breaks or naps can be seen as "re-setting" the level of arousal and allowing some remobilization of energy. Both of these resources wane more quickly in the narcoleptic and are not adequately restored by night sleep. However, Montplaisir et al. (1978) have indicated that the prevention of naps can improve nocturnal sleep in narcoleptics. The effect of daytime sleep prevention on performance ability in narcoleptics is not known and would serve as a valuable area of inquiry.

It is recommended that the narcoleptic become aware of his individual tendencies to decreased vigilance and the manner in which they are affected by different tasks or routines. The ability to predict the interaction of this symptom with daily work and to modulate demands and work schedules can both diminish the unexpected intrusion or leakage of decreased vigilance during performance, and should also result in some preservation of effort, thus decreasing subsequent negative performance and psychological effects. Awareness and predictability of the mechanisms of a disorder as well as the attribution of negative effects to

the syndrome rather than to the person are in themselves stress-reducing (Frank, 1973; Glass & Singer, 1969; Strupp, 1970; Valins & Nisbett, 1971).

Nonetheless, narrowing the range of activity, and taking frequent breaks from work can be very restrictive to the life of the narcoleptic, particularly considering the increase in time pressures, sedentary jobs, educational demands, and complex social stresses in today's society. One would assume that antidepressants and stimulant medications which suppress REM and NREM sleep (e.g., Guilleminault et al., 1974; Parkes, 1976), would diminish the poor performance and stress associated with drowsiness and episodic symptoms. However, as previously mentioned, currently used stimulants are reportedly inadequate in counteracting drowsiness and known to produce side effects (Guilleminault & Dement, 1974). The degree to which these currently used medications alleviate performance deficits has never been assessed objectively. Consequently there is an urgent need for more refined measurement to determine the most efficient use of these medications as well as to investigate more appropriate new drugs. There is some evidence to suggest that narcoleptics exhibit a large degree of individual difference in response to stimulants but little information available on the specific effects of the stimulants (Brooks, 1977; Parkes, 1976). The severity of drowsiness as a side effect of antidepressants (Karacan, Moore & Williams, 1979) should serve as another area of inquiry.

Although a drug's effect on the more episodic sleep attacks and auxiliary symptoms can be accurately obtained by self-report, its effect

on drowsiness and consequent behavior necessitate objective performance measures. As shown by the present evidence, subjective measures of drowsiness would be poor predictors of the ability to function. Similar discrepancies between subjective and objective findings in studies assessing medications which affect vigilance level (e.g., Oswald, Adam, Borrow & Idzikowski, 1979; Visser et al., 1979) further support this contention. As demonstrated by the present investigation, comprehensive assessment involving performance measures which vary in level of demand and stimulation, together with subjective and physiological measures would provide the most thorough information. However, in the interest of practicality, the four-choice reaction time task is particularly recommended. Its demonstrated sensitivity to narcoleptic performance deficits along with its brevity and portability make it a most convenient tool for assessment of drug effectiveness. This task can easily be administered repeatedly to assess drug effects over time and to compare different types and doses of medication on groups or individuals in order to determine the optimal treatment regimen. In addition, this brief task can alleviate for the patient and test administrator the negative and time consuming experience of a lengthy vigilance task. The four-choice reaction time task is amenable to assessment of small changes or degrees of improvement; and, also has the advantage of measuring increased variability and faster decrement with time which are negative effects of stimulants (Talland & Quarton, 1965).

#### Summary

The present study represents the first comprehensive investigation

of the effects of drowsiness on performance in narcoleptics and the relationship of these performance effects to subjective states and physiological vigilance levels. Salient findings are as described below.

In comparison with control subjects, narcoleptics exhibited a significant performance impairment which was associated with the enhancement of decreased vigilance during monotonous tasks. While stimulating tasks counteracted such deficits in narcoleptics, subjective drowsiness was not eliminated. Further, the association of increased effort, increased amounts of wakefulness, and two occurrences of cataplexy with the more complex PASAT rather than with Digit Span suggest that high demands in stimulating situations may stress patients and result in post-stress consequences of subsequent poor performance and an increase in symptoms. This factor may also result in psychological difficulties, possibly explaining the dynamics of such complaints in narcoleptics. This bivalent pattern of impairment is in contrast to the contention that narcoleptics are only affected in situations of monotony. It is recommended that the narcoleptic become aware of his individual limits for the amount of high stimulation and demand, and low stimulation that can be tolerated without deleterious effects. The patient must seek more moderate levels of stimulation and demand as such a situation does not require compensatory effort and allows some decreased vigilance to occur without affecting performance.

An early occurring and continual waxing and waning pattern in which amounts of wakefulness, stages 1A and 1B remained constant across the task (as did performance) characterizes the temporal pattern and level of vigilance in the narcoleptics during the auditory vigilance task.

This fluctuating pattern and level of decreased vigilance is contrasted with the almost complete absence of fluctuations or decreased vigilance in normal controls. The more gradual fluctuations were contrasted with the punctate pattern of microsleeps which are described as sudden brief shifts from wakefulness to stages 1B or 2. These differences were attributed to the different methods of analysis but were also considered to represent different expressions of decreased vigilance which may exist as a function of the type of task performed.

The present study demonstrated the insufficiency of the lapse-microsleep formulation in explaining the performance difficulties of narcoleptics. While performance measures alone indicated a significant increase in lapses, the analysis of performance in relation to the immediately preceding physiological state indicated that these lapses were not only associated with stages 1B or 2 as indicated by the lapse-microsleep formulation. The fact that significant deficits also appeared during wakefulness and stage 1A while the narcoleptics were still able to respond indicates that performance efficiency decreases gradually. Both lapses and false positive responses increasingly replace detected signals before the ability to respond is totally abolished and lapses become the sole characteristic of the performance deficit. Only if wakefulness was sustained did performance reach the level of control subjects indicating that vigilance levels can have a temporal effect on each other, and that full consciousness only occurs if wakefulness can be maintained over time. These patterns have greater face validity and more intricately explain performance deficits in relation to physiological vigilance levels than the lapse-microsleep formulation.

Impaired performance would be expected to improve with stimulant medications. However, the effect of these drugs on performance has not been investigated. The fact that such treatments are reported to be inadequate, together with the demonstrated severity of the performance deficits indicate that such an investigation is urgently needed. The present evidence suggests that subjective measures of drowsiness alone would not be adequate tools to assess treatment effects and that objective performance measures are needed. The present study can provide a model for assessment of the efficiency of medications used to alleviate drowsiness. The four-choice reaction time task in particular is recommended in this pursuit.

D

### Reference Notes

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APPENDIX A

Control Subject Questionnaire

CONTROL SUBJECT QUESTIONNAIRE (CONFIDENTIAL)

112

Name: \_\_\_\_\_ Age: \_\_\_\_\_ Sex: \_\_\_\_\_

Address: \_\_\_\_\_ Tel. No.: \_\_\_\_\_ Date: \_\_\_\_\_

How long do you usually sleep at night during the week? \_\_\_\_\_ on week-  
end nights (Fri. & Sat.)? \_\_\_\_\_

At what times do you usually go to sleep and wake up on week nights? \_\_\_\_\_  
\_\_\_\_\_ on weekend nights? \_\_\_\_\_

How long do you generally take to fall asleep after turning out the light? \_\_\_\_\_  
\_\_\_\_\_

Describe any difficulties you might have in falling or staying asleep? \_\_\_\_\_  
\_\_\_\_\_

Are you a regular sleeper or does your sleep pattern vary substantially from  
night to night? \_\_\_\_\_

Do you \_\_\_\_\_ or have you \_\_\_\_\_ done shift work? If yes, when and for  
how long? \_\_\_\_\_ Did you adapt easily \_\_\_\_\_, or only with great  
difficulty? \_\_\_\_\_

Do you awaken at times with a "thick head" lasting at least 30 minutes? \_\_\_\_\_

If so, does it occur more than once a month? \_\_\_\_\_ more than once a week? \_\_\_\_\_  
\_\_\_\_\_

Do you feel you get enough sleep? \_\_\_\_\_

Do you nap? \_\_\_\_\_ If so, how often and for how long? \_\_\_\_\_

Are you bothered by periods of drowsiness during the day? \_\_\_\_\_ seldom \_\_\_\_\_  
or often \_\_\_\_\_

Would you say these periods affect your ability to work to a substantial degree? \_\_\_\_\_

\_\_\_\_\_ very little \_\_\_\_\_ Generally, do you consider yourself to be an  
alert person? \_\_\_\_\_

Do you take any medication? \_\_\_\_\_ If yes, what kind and in what amount?

\_\_\_\_\_

Do you drink alcohol? \_\_\_\_\_ If yes, how often, how much, and when? \_\_\_\_\_

\_\_\_\_\_

Do you take nonmedical drugs? (i.e. marijuana) \_\_\_\_\_ If yes, how often, how much, and when \_\_\_\_\_

\_\_\_\_\_

Approximately how much coffee or tea do you drink per day? \_\_\_\_\_

Would you agree to abstain from alcohol and nonmedical drugs on those days we request during the course of the study? \_\_\_\_\_

Have you recently sought treatment for any physical health problems? \_\_\_\_\_

If yes, which ones? \_\_\_\_\_ Do you consider yourself in good physical health? \_\_\_\_\_

\_\_\_\_\_

Have you been treated for any psychological problems? \_\_\_\_\_ If yes, which one (s)? \_\_\_\_\_

\_\_\_\_\_

What are your normal working hours? \_\_\_\_\_ If necessary, can they be rescheduled so that you would be able to spend 2 consecutive morning sessions to participate in the investigations involved (approximately 2 hours per session)?

\_\_\_\_\_

Would you be available at all, for testing on weekends? \_\_\_\_\_

Will you be in town and available for the study for \_\_\_\_\_?

Is there anything else that may be important for us to know about you? \_\_\_\_\_

\_\_\_\_\_

If I will be a subject in this investigation, I agree to complete it once started and comply with all instructions as have been outlined for me.

\_\_\_\_\_  
(signature)

APPENDIX B

Post Assessment Questionnaire

Name: \_\_\_\_\_ (try to answer the questions carefully)

Effort Scale

|                          |             |                   |                                            |                                                |                      |            |
|--------------------------|-------------|-------------------|--------------------------------------------|------------------------------------------------|----------------------|------------|
| 1                        | 2           | 3                 | 4                                          | 5                                              | 6                    | 7          |
| extremely<br>frustrating | frustrating | very<br>demanding | requiring<br>a fair<br>degree of<br>effort | not very<br>demanding<br>but not<br>effortless | fairly<br>effortless | effortless |

Circle one: (use scale ↑)

performing the four-choice test was:

|   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|

performing the adding test was:

|   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|

performing the repeating numbers task was:

|   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|

performing the vigilance task was:

|   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

How would you rate your drowsiness level this morning (before testing) to other mornings of the past week? (circle one:)

|                    |                        |                   |                         |   |   |                     |
|--------------------|------------------------|-------------------|-------------------------|---|---|---------------------|
| 1                  | 2                      | 3                 | 4                       | 5 | 6 | 7                   |
| much more<br>alert | a little<br>more alert | about the<br>same | a little<br>more drowsy |   |   | much more<br>drowsy |

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Do you have any hearing problems? \_\_\_\_\_. If so, can you usually hear people speaking in a normal tone of voice? \_\_\_\_\_. If you have a hearing problem, do you think it affected your performance on the tests?

Did you fall asleep during the vigilance test? \_\_\_\_\_

Did you have any coffee or tea this morning? \_\_\_\_\_ at what time? \_\_\_\_\_ how much? \_\_\_\_\_  
 " " yesterday morning? \_\_\_\_\_ " \_\_\_\_\_ "

APPENDIX C

PASAT

Name \_\_\_\_\_ Age \_\_\_\_\_ Date \_\_\_\_\_ Test \_\_\_\_\_

2

|        |  |  |  |  |        |  |  |  |  |        |  |  |  |  |
|--------|--|--|--|--|--------|--|--|--|--|--------|--|--|--|--|
| 7 (9)  |  |  |  |  | 9 (11) |  |  |  |  | 2 (8)  |  |  |  |  |
| 3 (10) |  |  |  |  | 7 (16) |  |  |  |  | 7 (9)  |  |  |  |  |
| 4 (7)  |  |  |  |  | 6 (13) |  |  |  |  | 5 (12) |  |  |  |  |
| 8 (12) |  |  |  |  | 5 (11) |  |  |  |  | 9 (14) |  |  |  |  |
| 1 (9)  |  |  |  |  | 8 (13) |  |  |  |  | 2 (11) |  |  |  |  |
| 5 (6)  |  |  |  |  | 1 (9)  |  |  |  |  | 3 (5)  |  |  |  |  |
| 6 (11) |  |  |  |  | 4 (5)  |  |  |  |  | 9 (12) |  |  |  |  |
| 9 (15) |  |  |  |  | 1 (5)  |  |  |  |  | 7 (16) |  |  |  |  |
| 1 (10) |  |  |  |  | 2 (3)  |  |  |  |  | 4 (11) |  |  |  |  |
| 3 (4)  |  |  |  |  | 6 (8)  |  |  |  |  | 5 (9)  |  |  |  |  |
| 6 (9)  |  |  |  |  | 3 (9)  |  |  |  |  | 7 (12) |  |  |  |  |
| 4 (10) |  |  |  |  | 7 (10) |  |  |  |  | 6 (13) |  |  |  |  |
| 3 (7)  |  |  |  |  | 5 (12) |  |  |  |  | 8 (14) |  |  |  |  |
| 2 (5)  |  |  |  |  | 8 (13) |  |  |  |  | 1 (9)  |  |  |  |  |
| 7 (9)  |  |  |  |  | 3 (11) |  |  |  |  | 3 (4)  |  |  |  |  |
| 8 (15) |  |  |  |  | 9 (12) |  |  |  |  | 1 (4)  |  |  |  |  |
| 5 (13) |  |  |  |  | 1 (10) |  |  |  |  | 9 (10) |  |  |  |  |
| 9 (14) |  |  |  |  | 4 (5)  |  |  |  |  | 2 (11) |  |  |  |  |
| 4 (13) |  |  |  |  | 8 (12) |  |  |  |  | 5 (7)  |  |  |  |  |
| 2 (6)  |  |  |  |  | 6 (14) |  |  |  |  | 6 (11) |  |  |  |  |

|                | <u>Total</u> | <u>Percent</u> |
|----------------|--------------|----------------|
| 2.4 sec pacing | _____        | _____          |
| 2.0 sec pacing | _____        | _____          |
| 1.6 sec pacing | _____        | _____          |
| 1.2 sec pacing | _____        | _____          |

APPENDIX D

Digit Span

Tape # \_\_\_\_\_

Day \_\_\_\_\_

Subject: \_\_\_\_\_

Forward:

6 4 3 9

7 2 8 6

4 2 7 3 1

7 5 8 3 6

6 1 9 4 7 3

3 9 2 4 8 7

5 9 1 7 4 2 8

4 1 7 9 3 8 6

5 8 1 9 2 6 4 7

3 8 2 9 5 1 7 4

2 7 5 8 6 2 5 8 4

7 1 3 9 4 2 5 6 8

DF Total: \_\_\_\_\_

Comments:

Backward ( counter # \_\_\_\_\_ )

6 2 9

4 1 5

3 2 7 9

4 9 6 8

1 5 2 8 6

6 1 8 4 3

5 3 9 4 1 8

7 2 4 8 5 6

8 1 2 9 3 6 5

4 7 3 9 1 2 8

9 4 3 7 6 2 5 8

7 2 8 1 9 6 5 3

DB Total: \_\_\_\_\_

APPENDIX E

Stanford Sleepiness Scale



APPENDIX F

Task Instructions



### Vigilance Task Instructions:

You will be hearing tones through these earphones and you are to press this button each time you hear a tone that is slightly shorter than the rest. First you will hear an instruction tape that will familiarize you with the test. During this test try to keep your eyes open and try not to fall asleep. In case you do happen to fall asleep, you'll be awakened by a buzzer, sounding like a doorbell. (Start instruction tape).

### Vigilance Practice and Test Tapes:

Next is the actual vigilance test. Remember to keep your eyes open and try not to fall asleep. Do your best. The tape will start in about 15 seconds.

### Four-choice reaction time:

In this test you must press the button corresponding to the light as quickly as you can without error. First you will have a two minute practice trial. Start when I say "begin". I will tell you when to stop. (Practice trial is followed by the ten minute test.) Now we'll do the actual test which is 10 minutes long. Try to do your best. Start when I say "begin".

### PASAT:

In this test you will hear a list of single numbers read one after the other. I want you to add the numbers in pairs. Add each number to the one just before it, not to your answer. First we'll try a sample on paper. (Subject responds to five digits on paper). Now I'm going to say them and let you respond at your own speed. (Subject responds to brief oral sample of six numbers). The first trial will be just like this only alot longer, ten times as long. Keep your eyes

closed during the test and only say the answers. Ready? (Unpaced practice trial is administered). Now we'll try four tape recorded paced trials. Don't worry if you miss some or make a mistake, just do your best. I want to see how many you can get in a row without stopping, and if you do stop, how fast you can start again. Ready? (Before each paced trial the subject was told the next trial would be slightly faster).

(On the test day, only the unpaced practice trial and four paced trials were given).

#### Digit Span:

You will hear some numbers on the tape and I want you to repeat them after. For example if you hear "7 - 2 - 9" you say (subject response). If you hear "3 - 5 - 8 - 2" you say (subject response). Try to do your best. (Digits Forward is administered). Now you will hear some more numbers but this time you are to repeat them backwards. For example if you hear "5 - 3" you say (subject response). If you hear "9 - 4 - 6" you say (subject response). (Digits Backwards is administered).