The Effects of Time of Day of Task Presentation
and Individual Differences in Self-Reported Optimal
Performance Periods on the Memory
of Adolescents Enrolled
In an Early Starting Time High School

By

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Abstract

Time of day as a variable exerts differential effects on long-term and short-term memory. Low arousal states associated with the early morning tend to favor and be associated with immediate memory (Dunne, Roche, & Hartley, 1990). High arousal states of the late afternoon and early evening tend to favor and be associated with superior long-term memory (Anderson, Petros, & Beckwith, 1991).

Individual differences in these arousal patterns are known to exist. Most notable among them is the morningness-eveningness factor operationalized by Horne and Ostberg (1976). Research indicates that many adolescents can be classified as evening individuals (Dunn, 1987). The peak periods of arousal of these adolescents correspond with the hours of the late afternoon and early evening. As a result much of their scholastic day may correspond with low levels of arousal. Colquhoun (1971) maintains that a given change in arousal will have a more marked effect on performance

when the overall level of arousal is lowered due to sleep deprivation. According to recent research many adolescents in schools with early starting times appear to be chronically sleep deprived (Richardson, 1995). This later finding suggests that adolescents enrolled in schools with early starting times may be particularly susceptible to the effects of time of day on memory.

The purpose of this study was to evaluate the effects of time of day on the short- and long-term memory of adolescents enrolled in an early starting time high school. This study also sought to determine the extent to which scores on long- and short-term memory tasks were correlated with the amount of sleep an individual received on the night prior to the testing, as well as with the degree to which an individual classified himself/herself as a morning or evening type person. This study did not find a main effect for time of day on short-term or long-term memory. Performance on memory tasks was not significantly correlated with the number of hours that an individual slept on the night prior to the testing or the degree to which an individual classified himself/herself as a morning- or evening-type person. Students' perceptions of the times during the school day at which they were most tired corresponded to the earliest class periods in the morning as well as the periods following lunch.

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It is hard to believe that I have reached this point, where with the exception of one semester I have spent 25 consecutive years in school. An incredible amount has transpired in that time and I would be terribly negligent not to give thanks where thanks are due. The Babylonian Talmud quotes a sage who attributed his success to his wife, telling his students *'Sheli Veshelachem Shela Hi'* "what is mine and what is yours belongs to her." There have been many such enablers in my life, and while the thanks I give are far from adequate, I hope that at least I can let people know how grateful I am for all of their help.

My first obligation is to give thanks to G-d. In keeping with Jewish tradition, when reaching a milestone such as this, one gives thanks to G-d for having facilitated this attainment, and states *'Shehechyanu Vekiyyemanu Vehiggi'anu Lazzeman Hazeh'* "Blessed are you for giving us life, sustaining us, and bringing us to this point."

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CHAPTER 1

Overview

The purpose of this study was to investigate how the combination of time of day, self-reported individual differences in optimal performance periods, and sleep restriction and/or loss affected short- and long-term memory in adolescents. Time of day as a variable exerts differential effects on short- and long-term memory. The effects of time of day on memory may be moderated by individual differences in optimal performance periods, such that those individuals who are evening types as compared to morning types may be particularly affected when required to learn information early in the morning. Sleep and lack of sleep are two other factors that have been shown to have direct effects on memory. Adolescents, due to their lack of sleep during the academic week and their tendency to be evening types, may be specifically susceptible to time of day effects on memory.

The effects of time of day on memory are thought to be mediated by changes in the basal level of arousal. The basal level of arousal is known to fluctuate throughout the day. These changes in the level of arousal are assumed to affect performance on various tasks as well as learning and memory. Colquhoun (1971) maintains that a given change in arousal will have a more marked effect on performance when the overall level of arousal is relatively low due to sleep deprivation. Recent research indicates that adolescents frequently undergo bouts of acute sleep deprivation, where a single night of sleep is lost, as well as extended periods of chronic sleep restriction, where they obtain insufficient sleep on several consecutive nights (Carskadon, 1990). The natural sleep-wake cycle of many adolescents would be to rise later in the morning than they currently do during the school year. The current time schedules that many high schools adopt make this impossible, and as a result, adolescents are chronically deprived of much needed sleep (Richardson, 1995), and much of the time that they spend in early morning classes may coincide with low basal arousal levels (Lombardi, 1997). The present study examined which types of memory tasks are best suited for lower levels of arousal and which require higher levels of arousal. These results may have implications for schools' scheduling of classes at times that would allow students to garner maximal benefit from them.

Timing of the School Day

The optimal time of day for schooling has long been a subject of research. A large number of studies performed with school-aged children have shown that performance on tests involving short-term memory is superior when these tests are given in the morning hours rather than in the afternoon. Gates (1916) suggests that this inferior afternoon performance on short-term memory tasks is the result of "mental fatigue". On the basis of this finding, in regard to school schedules, he concluded that, "In general the forenoon is the best time for strictly mental work, although the first morning hour is poor, while the afternoon may be taken up with subjects in which motor factors are predominant" (Gates, 1916 p. 149).

Later research casts doubt on Gates' conclusion that mental work should be confined to the morning. This body of research indicates that while performance on tasks involving short-term memory declines from morning to afternoon (Baddely, Hatter, Scott, & Snashall 1970; Dunne, Roche & Hartley, 1990; Folkard, 1975, Folkard & Monk, 1980; Folkard, Monk, Bradbury, & Rosenthall, 1977), performance on tests of long-term or delayed memory is generally superior when the learning initially occurred in the afternoon (Anderson, Petros, & Beckwith, 1991; Breen & Wilding, 1984; Davis, 1987, 1988; Dunne, Roche, & Hartley, 1990; Folkard & Monk 1980; Folkard et. al., 1977; Leirer, Tanke, & Morrow, 1994; Maurry & Queinnec, 1992, 1993; Morton & Kershner, 1985; Oakhill, 1986; Oakhill & Davies, 1989; Petros, Beckwith, & Anderson, 1990).

Changes in levels of performance on various tasks as a function of the time of day have often been attributed to the effects of biological rhythms that are evidenced in changes in body temperature. The basal level of arousal is known to change throughout the day, increasing from a relatively low level in the morning to a peak in the evening, when it again begins to decline in preparation for sleep (Colquhoun, 1971). These changes are assumed to exert differential effects on different types of tasks and learning activities. They are also postulated to affect the strategies that people naturally adopt to learn (Dunne, Roche, & Hartley , 1990; Folkard, 1979; Folkard & Monk, 1979, Maurry & Queinnec, 1992; Monk, 1982). High levels of arousal are assumed to enhance long-term memory, and at the same time impair short-term memory. Concerning complex forms of learning, the assumption is that the level of performance on various tasks increases with increased arousal, but that beyond a certain optimal level of arousal, performance falls (Petros, Beckwith, & Anderson, 1990).

Individual Differences in Optimal Performance Periods

While a large body of literature associates changes in performance with changes in arousal that naturally occur throughout the day, other research suggests that the general effects of time of day are moderated by individual differences in optimal performance periods. This theory, operationalized by Horne and Ostberg (1976), suggests that individuals can be classified as morning or evening types and that their optimal level of performance will occur at a time of day that is specific to them (Petros, Beckwith, & Anderson, 1990). Among junior high school students, one third are thought to be fully awake and ready to learn first thing in the morning, while the majority fully awaken after 10:00 a.m. (Dunn, 1990). In high schools, while as many as 40% of students are early birds, the remaining 60% are late morning-early afternoon preferents, of whom 13% are night owls who do maximally well when learning occurs, or tasks are presented, in the evening (Price, 1980 as cited in Dunn, 1990). In contrast, older adults, or senior citizens, tend to be morning types and experience greater success when learning takes place, and tasks are presented, in the morning (May, Hasher, & Stoltzfus, 1993).

Sleep Deprivation and Memory

Colquhoun (1971) maintains that a given change in arousal will have a more marked affect on performance when the overall level of arousal is relatively low due to sleep deprivation. According to Carskadon (1990) teenagers are likely to undergo frequent bouts of chronic sleep deprivation as well as acute sleep loss during the academic year. Wolfson and Carskadon (1996) report that the amount of sleep that most adolescents receive is generally considered insufficient for their needs. Factors leading to insufficient amount of sleep are suggested to be behavioral as well as biological (Carskadon, 1993). Results of insufficient sleep include impaired long-term and short-term memory (Nesca & Koulak, 1994; Polzella, 1975). Additionally, Rottenberg (1992) states that sleep deprivation can lead to learned helplessness, which negatively affects the learning process. Thus, the lack of sleep may affect adolescent memory in a direct as well as in an indirect way. Lack of sleep can be detrimental to long- and short-term memory, and can also lower arousal levels earlier in the day, making those who suffer from such lack of sleep particularly susceptible to time of day effects on memory.

Learning and Memory

Recently the popular press has reported that the early school starting times that many districts have adopted are detrimental to adolescent learning (Weber, 1998). Learning can be viewed as a process that involves the "acquisition and modification of knowledge, skills, strategies, beliefs, and behaviors" (Schunk, 1991, p.1). Citing Shuell (1986), Schunk defines learning as "an enduring change in behavior, or in the capacity to behave in a given fashion, which results from practice or other forms of experience" (Schunk, 1991, p.2). In explaining the way learning occurs, cognitive theorists stress the importance of the acquisition of knowledge and cognitive structures. Involved in the process of knowledge acquisition is storing information in memory, relating new information to information already stored in memory, and finally, retrieving information from memory when it is needed (Schunk, 1991). Furthermore, information processing theorists equate learning with encoding, i.e., the storage of information in memory in an organized, meaningful fashion (Schunk, 1991).

Types of Memory. Memory itself is thought to have several subdivisions. Based on the information processing theory, information processing begins when a stimulus item from the environment enters the sensory receptor field of one of the senses (i.e., a visual image of the desk appears on the retinal field of the eye). The sensory register receives that information and holds it in sensory form briefly. The information is then transferred to short-term memory, which is roughly equivalent to awareness or what one is conscious of at a given moment. Short-term memory is limited both in terms of capacity and duration. The duration of short-term memory is limited to several seconds (Schunk, 1991). Rehearsal, repeating the information to oneself, allows it to be retained in short-term memory for somewhat longer. While information is in short-term memory, related information already in long-term memory is activated and placed in short-term memory so that the new information can be integrated with it. Once the information is integrated, it can enter long-term memory (Schunk, 1991).

There is debate concerning whether or not information already stored in long-term memory can be forgotten. Views on the duration of information stored in long-term memory range from minutes to the lifetime of an individual (Crooks & Stein, 1988). Information in long-term memory associated with particular events, times, and places is known as episodic memory, while information stored in long-term memory involving concepts and general knowledge is referred to as semantic memory (Schunk, 1991).

Based on the information-processing model, short-and long-term memory are viewed as components of the learning process. The study of the effects of time of day on the individual memory stores therefore provides a theoretical basis for the question of whether the learning process is affected by the time of day at which information is presented.

The Present Research

In this study, the effects of time of day and amount of sleep on the short- and long-term memory of adolescents were evaluated in terms of both arousal and the individual differences theory. The study employed a between groups design in which a series of short-term, delayed, and long-term memory tests were administered at two times of day to two groups of adolescents enrolled in an early starting time high school. Each participant completed the Self-Assessment Questionnaire of Morningness and Eveningness (Horne and Ostberg, 1976), as well as a student questionnaire in which students were asked to indicate the number of hours they slept the previous night.

CHAPTER 2

Level of Arousal and Learning

Research has been done to determine the relationship between physiological arousal during learning, as assessed by changes in galvanic skin response and/or oral temperatures and retention over time. There is evidence that short-term memory is impaired when the information itself triggers a high level of arousal (Kleinsmith & Kaplan, 1963; Levonian, 1972). The question is whether or not the spontaneous fluctuations of basal arousal that occur throughout the day will have the same effects on memory. Colquhoun (1971) has argued that, with the exception of a post lunch dip, the basal arousal level typically rises from a relatively low level early in the day to reach a peak at around 8:00 p.m. This is thought to parallel changes in a person's temperature cycle. Colquhoun maintains that temperature change is not the only variant in arousal, as other physiological measures fluctuate in this manner throughout the day. It is postulated that the general level of sleepiness falls during the waking day to reach its minimum sometime in the evening. At this point it rises again until sleep is achieved. Additionally, a temporary increase in the level of sleepiness occurs at or about lunch-time.

Blake's (1967) study on the effects of diurnal fluctuations in level of arousal on human performance showed that, whereas the level of performance on most tasks improved throughout the day as the level of arousal increased, performance on digit span, a task relying on short-term acoustic memory, tended to decrease (Levonian, 1972). This latter finding suggests an inverse relationship between immediate memory and arousal level when the level of arousal is not manipulated but rather is allowed to fluctuate as a function of time of day. At the same time, it showed that performance on most other tasks, which rely more heavily on long-term memory, improved throughout the day with increased levels of arousal.

Time of Day and Short-Term Memory

A number of studies have shown that performance on tests of short-term memory is better in the morning than in the afternoon. Short-term memory, or working memory, is a person's immediate consciousness. Working memory holds a representation of recent events, and is limited in duration as well as in capacity. Certain tasks rely more heavily on short-term memory than others. The experiments contained in this section are arranged in increasing order of complexity of the types of learning discussed in them. Thus, we progress from digit span, to word lists, to meaningful material presented in prose.

Digit Span. Serial learning tasks such as digit span place a great amount of reliance on short-term memory. Digit span requires the subject to repeat a series of verbally-presented numbers immediately after they have been presented. Using arousal theory, we would expect performance on this task to be best in the morning for subjects whose basal level of arousal is assumed to increase throughout the day. Baddely, Hatter, Scott, and Snashall (1970) attempted to replicate Blake's (1967) finding that digit span performance tends to decrease throughout the day as the level of arousal increases. In this experiment subjects were given an immediate memory test involving the recall of sequences of nine random digits. Subjects were tested twice, once between the hours of 9:00 a.m. and 11:00 a.m. and once between 3:00 p.m. and 5:00 p.m. Half of the subjects were randomly assigned to begin in the morning and the other half began in the afternoon. The results showed a significant effect of time of day. Immediate memory for the series of digits was better in the morning than in the afternoon.

Word Lists. As is the case with digit span, the assumption is that for subjects whose basal level of arousal is assumed to increase throughout the day, the ability to recall a series of words that have been presented either verbally or in written form should be superior immediately after morning presentation, compared to the period following afternoon presentation. Folkard and Monk's (1979) study on time of day and processing strategy in free recall is concerned with the effects of time of day on the free recall of syntactically unstructured word lists, lists of words not connected to one another through the use of punctuation or context. In stage one of this study five groups of adult subjects were recruited via newspaper advertisements. These subjects were shown the same single list of 15 high-frequency words at 5 different times of day (from 8:00 a.m. to 8:00 p.m.) and were told to write down as many of the words as they could recall in any order.

In stage two of this experiment the same subjects were given a 20-minute visual matching task between the end of the list and the beginning of the recall period. Time of day had a significant affect on both recency, recall of the last 6 words of the 15-word list, and pre-recency, recall of the first 9 words shown. Recall was superior in the morning especially for words in the pre-recency positions. This effect disappeared when testing occurred after a 20-minute delay following the initial presentation. The experimenters also wanted to test the possibility that the list learning superiority seen in morning subjects was a result of the fact that, in the morning, subjects place more reliance on maintenance processing, through simple verbal and subvocal repetition or rehearsal of items, and less on elaborate processing (i.e., creating connections to things already known and using other memory devices such as mnemonics) than they do in the afternoon. Thus, the experiment attempted to equate the type of processing that subjects engaged in at 10:00 a.m. with processing used at 4:00 p.m. by enforcing a condition of overt vocalization of the items during presentation. Both control and enforced vocalization conditions showed morning superiority that was largely confined to the pre-recency positions.

Stage three replaced the overt vocalization condition with one of articulator suppression in which verbal rehearsal was prevented by requiring subjects to repeat a series of digits between the presentation of words and their subsequent repetition. Under this condition the morning superiority in free recall disappeared. These findings suggest that in the morning, relative to the afternoon, subjects place a greater reliance on maintenance rehearsal and less on elaborate rehearsal. These findings also suggest that subjects can engage in both maintenance and elaborative processes throughout the day. Therefore, the observed time of day effect was the result of an inclination or propensity and not of a limitation in capacity.

Similarly, Folkard (1979), in his study of time of day and level of processing, suggested that the differential effect exerted by time of day on immediate memory in adults is mediated by a shift in the type, or level, of processing that subjects spontaneously use. If free to do so, subjects will place more reliance on maintenance processing in the morning and on elaborative processing in the afternoon. If this is true, then the acoustic similarity effects, where subjects are apt to confuse words with similar sounds, should be greater in the morning. Semantic similarity effects, where subjects tend to confuse words based on their meanings, should be greater in the evening. Subjects were shown 12 control word lists and 12 acoustically similar lists. Half of the subjects were tested at 10:00 a.m., and half were tested at 7:00 p.m. The acoustic similarity effects were greater in the morning. The results were consistent with the suggestion that subjects place more reliance on maintenance processing in the morning than in the evening.

The experiments conducted by Dunne, Roche, and Hartley (1990) were aimed at duplicating Folkard and Monk's (1979) observation of a morning advantage in list learning. Adult undergraduate students were tested twice, two weeks apart- once at 8:00 a.m., and once at 7:00 p.m. They were randomly assigned to the order of these conditions. Subjects were shown 6 word lists of 12 words each and given a recall test 2 minutes after the presentation of each list. After all six lists, subjects received one recognition test, in which they were asked to identify the words that they had seen from an array of words. Memory for the words on these lists was viewed as episodic memory, or memory of discrete items. There were significant effects for time of day. Immediate recall was better for subjects who were tested in the morning, though time of day did not affect performance on the recognition test. The latter finding may suggest that recognition is not influenced by diurnal variation in the same way that recall is, or it may indicate that this measure was not sensitive enough to this task.

With regard to list learning, research indicates that short-term memory is superior following list presentation in the morning than following list presentation in the afternoon. The suggestion has been made that this superiority is the result of the type of processing that is naturally engaged in by subjects tested in the morning. More specifically, subjects tested in the morning place more emphasis on maintenance rehearsal, which leads to superior immediate recall, than subjects tested in the afternoon, who are assumed to engage in more elaborative in-depth forms of processing. This difference in processing strategy is evidenced in the type of mistakes that subjects tested at different times of the day make. While subjects tested in the morning are confused by acoustic similarities between words, during the afternoon, subjects are more apt to be confused by semantic similarities.

Prose. The short-term memory for meaningful prose material presented either in written form or through other media also declines throughout the day for people whose basal level of arousal increases from a relative low early in the morning to a peak in the evening. Folkard and Monk (1980) examined the effects of time of day of presentation of prose material on immediate retention. Adult subjects were presented with six printed magazine articles, one at each of six different times of day. They were told to read as much as they could for comprehension in 3 minutes and then indicate how much of the article they had read. They were then given a 10-question multiple-choice test and their temperatures were taken. Immediate memory proved to be inversely related to that of oral temperature, with the exception of the 2:00 p.m. reading. More specifically, temperature increased throughout the day, from a relative low in the morning to a peak in the evening. Immediate memory decreased from 8:00 a.m. to 11:00 a.m., increased again at 1:00 p.m., but then continued to decrease throughout the afternoon. It is interesting to note that with the exception of the post lunch dip time, accuracy in answering questions tended to decrease throughout the day, while reading speed increased throughout the day.

In a second experiment (Folkard & Monk, 1980), night nurses were used as subjects. Half were shown a film at 10:30 p.m., and half were shown the same film at 4:00 a.m. Immediately after seeing the film, nurses were given a questionnaire on its content and their temperatures were taken. On the basis of their temperature readings, the nurses were divided into two categories. Those nurses whose temperatures increased from 10:30 p.m. to 4:00 a.m. were assumed to exhibit good adjustment to the night schedule. Those nurses whose temperatures showed the opposite pattern were considered to exhibit poor adjustment. Those nurses whose temperatures had adjusted to a nighttime waking schedule showed superior immediate memory when the test was administered at 10:30 p.m. Those nurses who, based on their temperature readings, showed poor adjustment to night schedules scored higher when the test was administered at 4:00 a.m. These results indicate a direct connection between level of arousal and short-term memory.

In Oakhill's (1986) study, adult subjects were read a short story and then were presented with a questionnaire composed of important and unimportant questions. Important questions were integral to the understanding of the story and unimportant questions were not. Half the subjects were presented with the story at 9:00 a.m. and half at 6:00 p.m. In this experiment, immediate recall of important and unimportant information was similar at both times of day. However, in a similar and earlier study done by Folkard, Monk, Bradbury, and Rosenthall (1977), children who were read a story at 9:00 a.m. obtained higher immediate memory scores than did those who were read the same story at 3:00 p.m. This difference between the performances of adults and children might reflect a difference between the stories and questionnaires, or alternatively, a difference between the populations that were tested. Children who are conditioned by school may be more test oriented in the morning and thus attempt to memorize a story instead of understanding it. As such, their memory for detail will be enhanced. In addition, in the case of the children, the immediate memory test was delayed by approximately 15 minutes allowing more time for integration. In the case of the adults, there was no time delay between the end of the story and the presentation of the questionnaire.

A later study by Oakhill and Davies (1989) found that morning subjects benefited from test compatible instructions. In concert with the theory that immediate recall is superior in the morning, recall in this experiment was superior in the morning even for subjects who expected a recognition test. Encoding processes were found to be flexible both in the morning and in the afternoon, showing that the differences in strategies that subjects engage are differences in propensity and not limitations.

The research reviewed in this section shows that short-term memory for prose is best following morning presentation of the material. This morning superiority exists in both children and adults and occurs when the material is presented orally, through the use of film, or in print. There appears to be a difference in the type of material that subjects recall immediately following morning presentations. Subjects were more likely to recall more unimportant information than their counterparts who were initially presented with the material in the afternoon.

In summarizing the research on short-term memory, it seems that early morning and low levels of arousal favor superior immediate memory. Short-term memory is also associated with episodic memory, shown in the ability to recognize and recall events or items clearly distinguishable from one another through specific attributes. When tested in the morning, subjects tend to engage in maintenance rehearsal, which would help explain this trend. Monk and Leng's (1982) article cites evidence to support the explanation that the short-term memory superiority observed on various tasks in the morning is a result of a change in strategy. The use of forms of maintenance processing instead of elaborative processing, rather than an actual change in capacity, may be responsible for the improved morning performance.

Time of Day and Long-Term Memory

Information from short-term memory is transferred to long-term memory for more permanent storage. Information stored in long-term memory may remain for minutes, hours, days, or potentially a lifetime (Crooks & Stein, 1988). Arousal theory predicts that long-term memory should improve throughout the day as the basal level of arousal increases. As in the previous section, the experiments described here will be ordered according to the complexity of the learning tasks involved. This will be followed by a discussion of studies on retrieval regardless of when the initial learning took place, and by applied classroom studies.

Digit span. Digit span, the ability to repeat a series of digits after they have been presented, is a task that relies heavily on short-term memory. In the Baddely (1970) study, the long-term memory test was based on a study by Hebb (1961) in which the ability to recall a repeated series of digits was supposed to represent long-term learning. A single string of nine digits was dispersed and repeated among varied strings of nine digits. The ability to recall the repeated string of digits was considered to be a measure of long-term memory ability. In this study, time of day was not found to have a significant affect on long-term memory. The ability to recall the repeated string did not vary as a function of time of day. The question that arises is whether or not the Hebb method was an accurate measure of long-term memory. For those who believe that long-term memory requires consolidation time, the fact that none was allotted means that this experiment yields no meaningful results with respect to long-term memory.

Word lists. Arousal theory predicts that, unlike short-term memory, long-term memory should improve throughout the day. Dunne (1990) used an 8-minute continuous free retrieval task in which a subject was asked to give as many examples of a nominated category as possible (e.g., names of birds, as a measure of long-term memory). The test was administered once in the morning and once in the evening, two weeks apart. The ability to sustain a search of semantic memory and hence recall from semantic categories was superior in the evening.

Folkard (1979) showed that elaborative processing underlies the greater long-term memory effects after task presentation later in the day. Here the long-term component of the experiment was manipulated by introducing an auditory digit span task between the presentation of the word lists and their subsequent recall. This study demonstrated that there was a substantial semantic similarity effect, where subjects substituted words similar in meanings, after the 7:30 p.m. presentation that did not exist after the 10:30

a.m. presentation.

Prose. According to arousal theory, the ability to retain meaningful material presented in the form of prose on a long-term basis should increase throughout the day as levels of arousal increase. In Folkard and Monk (1980), long-term memory was measured in night nurses, who had seen a filmed educational presentation either at 10:30 p.m. or 4:00 a.m., 28 days after the initial presentation had occurred. Delayed retention was superior for those who had seen the initial presentation at 10:30 p.m. regardless of whether or not their temperatures had adjusted to a night cycle.

In Oakhill (1986), adult subjects were read a story either in the morning or the afternoon and were asked to return a week later to answer questions about the story. Half of the subjects was asked to return at the same time of day as the initial presentation and the other half was asked to return at the other time of day. Subjects who had read the story in the afternoon showed greater differentiation between important and unimportant information (see description of short-term component above). These subjects who received the afternoon presentation had forgotten less of the important and more of the unimportant information than subjects who had heard the story in the morning. Folkard (1977) found similar results in school children. When children received an auditory presentation of a story in the afternoon, they engaged in more selective processing based on meaning and did not attempt to memorize details. Thus, their performance in the afternoon was much like that of the adults.

Oakhill (1986a) explored the hypothesis that superior long-term memory following afternoon presentations may be related to a higher level of integrative processing as subjects are reading texts. In this experiment long-term memory was not examined directly. What was examined was the length of time subjects spent reading texts with referential difficulties compared to the length of time subjects spent reading unambiguous texts. In addition, accuracy and time spent deciphering referential difficulties were measured during question answering, which occurred immediately after the text was presented. Subjects tested in the afternoon spent more time reading ambiguous texts especially when they knew that questions would follow. They spent less time answering questions than did morning subjects. Spending more time on on-line comprehension could help explain the general trend of superior long-term memory following afternoon presentation.

In summary, higher arousal states of the later afternoon tend to favor long-term memory. Semantic processing and elaborative processing seem to be the underlying mechanisms involved in long-term memory. In addition, afternoon initial learning tends to favor the long-term memory of important items but does not do the same for unimportant items.

Retrieval and Time of Day

Retrieval is the only method for testing memory. Retrieval is the process of finding and recovering information stored in both short- and long-term memory (Crooks & Stein, 1988). If retrieval fluctuates as a function of time of day, then what we are testing may not be memory but retrieval. Miller, Styles, and Wastell (1980) contend that, although accurate retrieval does not vary as a function of time of day, retrieval latency (i.e., the amount of time retrieval takes) does. The supposed increase in arousal through the day is associated with improvement in retrieval efficiency such that the difference in the time needed to respond to high and low dominance material (i.e., words commonly used and those not used as frequently) decreased throughout the day. Low arousal might also cause a slowing in decision speed, particularly with low dominance words.

That retrieval per se is not influenced by time of day is also indicated by Folkard (1977) and Oakhill (1986). Conversely, Lemmon administered the Iowa Basic Skills Achievement Tests (Lemmon, 1985, as cited in Dunn, 1990) in reading and math to students whose time preferences, based upon a questionnaire of when in the day they thought that their performance would be best, matched their testing schedules. She reports significantly higher gains compared with each student's 3 years of prior tests when schedules were not matched (Dunn, 1990). Similarly, May, Hasher, and

Stoltzfus (1993) report that the time of day at which a test is administered affects recognition memory. This is particularly true when the test is administered outside a person's optimal period. The authors caution against conducting experiments at only one time of day, especially when this time conflicts with the optimal performance periods of the subjects used. While there are some conflicting results, there is evidence that indicates that retrieval and test performance are affected by time of day.

Applied Classroom Studies

Applied classroom studies of how time of day affects learning and academic achievement are few in number. Learning within the classroom relies on long-term as well as short-term memory, and the assumption is that different subjects and areas rely on each of the two memory stores to different degrees. Davis (1987) postulated that reading instruction involves connecting the printed material to prior knowledge and experience and, hence, relies largely on long-term memory. As a corollary, he assumed that reading achievement should be maximized by providing instruction in the afternoon. He also assumed that instruction in math skills involves considerable use of short-term memory, and therefore, math performance should follow the pattern of performance on other short-term memory tasks. It should peak early in the day.

Davis (1987, 1988) conducted two studies to investigate the effects of time of day on academic achievement. In investigating time of day of instruction on reading and mathematics achievement of eighth graders, he discovered that the afternoon reading group received significantly higher achievement scores than the morning reading group while there was no difference in mathematics achievement between groups. Similarly, afternoon first grade reading instruction relative to morning first grade reading instruction produced higher gains in reading achievement for beginning readers.

Even though evidence has existed for some time that students' ability to retain new information is enhanced in the afternoon, teachers often prefer to teach classes in the morning because behavioral issues complicate afternoon teaching. Jones (1995) in his article, "The Timing of the School Day", eloquently describes this phenomenon, "Lively minds may be more effective in the afternoon, but the strain of guiding such cognitions may contribute to too much wear and tear on an already dispirited and under resourced education service" (p.84).

Recent research using adolescents indicates that sleep and lack of sleep play a role in students' ability to learn and perform in academic settings at different times of day. Dr. Richard Allen, who founded the Sleep Disorders Center at Johns Hopkins University, studied two groups of adolescents with different school starting times. One group began classes at 7:30 a.m., while the second group did not begin classes until 9:30 a.m. Preliminary results from his research indicate that those students who start classes later performed better academically (Richardson, 1995). It is important to note that the enhanced academic performance later in the day may be confounded by the additional sleep received by students who started class later. In another study conducted in the United States, Nicholas Skinner found that marks on college exams were significantly better for the same courses when they were taught in the afternoon or evening than when they were taught in the morning. This was the case even though the afternoon/evening classes were conducted in one 3-hour session, while the morning classes had the assumed advantage of being comprised of three 1-hour sessions (Jones, 1995).

Baker and Colquhoun (1990) have suggested that, when discussing highly complex tasks, variables such as the sex of subjects and time of day interactions decrease in importance. Nonetheless, it appears that time of day can affect academic performance in applied educational settings. More research needs to be done to determine which academic subjects and pupils are most susceptible to these effects.

CHAPTER 3

Individual Differences

The individual difference theory attempts to explain imperfect time of day effects. It predicts that performance on various tasks is affected by the degree to which a person is a morning or evening type. For those who are categorized as evening types, long-term memory should be best when arousal is highest and tasks are presented later in the day in the afternoon or evening. For those classified as morning types, long term-memory should be best when tasks are presented earlier in the day. Conversely, short-term memory seems to be enhanced when levels of arousal are relatively low. Those people who are classified as evening types and experience low levels of basal arousal early in the day should exhibit superior performance on tasks of short term-memory presented in the morning. Those people who classify themselves as morning types and experience higher levels of arousal in the morning should do better on tasks of short-term memory when they are presented later in the day when their levels of arousal are lower. Individual differences in age as well as the amount of caffine a person uses can also differentially affect performance on tasks of long-term and short-term memory.

Differences in Time of Day Preference

Horne and Ostberg (1976) developed a questionnaire to determine the degree of "morningness" or "eveningness" that people exhibit, that is, the degree to which they find themselves more awake and able to engage in complex tasks at a specific time of day. They demonstrated that adults who classified themselves as evening types started their day at lower body temperatures then those who classified themselves as morning types. Furthermore, evening types reached their peak temperatures in the evening approximately one hour later than morning types (Anderson, Petros, & Beckwith, 1991).

A study by Anderson et al. (1991) indicated that adults identified as morning types or those identified as evening types exhibit different patterns of time of day effects on tasks involving the categorization of words. Response times increased throughout the day for morning type individuals and decreased for evening types. Similarly, Carruthers and Young (1979) found that when junior high school math underachievers received instruction that matched their chronobiological time preferences, they became more motivated and better disciplined and showed a trend toward statistically significant increased achievement (Carruthers & Young, 1979; as cited in Dunn, 1990).

Lynch (1981) reported that time preference was a crucial factor in the reversal of chronic truancy among secondary students (Lynch, 1981; as cited in Dunn, 1990). Petros, Beckwith, and Anderson (1990) studied the effect of time of day on prose recall for morning and evening type adults. Results indicated that recall decreased across time of day for adults classified as morning types, and increased slightly but not significantly for evening types.

Horne and Ostberg (1976) validated their questionnaire by taking oral temperature readings. They found significant differences in the patterns of oral temperature fluctuation between those who reported that they were morning types and those who reported that they were evening types. In their study, on the basis of fluctuations in oral temperature readings and self-reported optimal performance periods, they classified 45% of adult participants as either moderate to extreme morning or evening types. The remaining 55% of participants in their study fell into the neither type category. Anderson et al. (1991) administered the Horne and Ostberg scale to a separate sample of 291 undergraduate college students. They found that only 65 individuals classified themselves as evening types while 30 individuals classified themselves as morning types. Consequently, in this study, 32.6% were classified as either moderate to extreme morning or evening types. The remaining 196 participants, 66.4% of their sample, classified themselves as neither type.

In summary, those people who are classified as evening types and experience low levels of basal arousal early in the day should exhibit superior performance on tasks of short term-memory presented in the morning. Those people who classify themselves as morning types and experience higher levels of arousal in the morning should do better on tasks of short-term memory when they are presented later in the day when their levels of arousal are lower.

Age Differences

Age has also been found to be a significant individual difference factor. Senior citizens are more likely to fall into the category of morning types than are adolescents. A study by Leirer, Tanke, and Morrow (1994) on naturalistic prospective memory in senior citizens found that remembering future events, such as taking medication at set times, was better in the morning than in the afternoon. In one of the two studies that they conducted, memory increased again in the evening in comparison to midday when forgetting was at its peak. A study by May and Hasher (1993) compared the performance of young adults to that of senior citizens on recognition and memory tasks in the morning and in the evening. No age differences were found in the morning when older adults were at their peak levels of arousal. However, in the afternoon younger adults performed substantially better than older adults did.

Caffeine Effects

The amount of caffeine that a person imbibes is found to be a factor that interacts with time of day and affects performance. Caffeine markedly improved the performance of subjects early in the morning on tests requiring speed. Caffeine, as it increases basal arousal, should improve task performance at the time of lowest arousal. A history of high caffeine use, however, seems to be related to poorer performance on tasks requiring greater cognitive effort (Mitchell & Redman, 1992).

To summarize, individual differences in peak times of arousal affect performance on memory tasks at different times of day. A high percentage of adolescents may be classified as afternoon-evening type people (Dunne 1990). These adolescents experience their peak periods of arousal later in the day than do others classified as morning type or neither type individuals. In reality many factors influence individuals' levels of arousal and hence their propensity to engage in certain types of cognitive processes. Sleep and sleep deprivation are two such factors.

CHAPTER 4

Sleep and Memory

Sleep is thought to serve many functions, and lack of sleep can lead to severe impairment in a variety of areas. Sleep plays an important role in the consolidation of information (Benson & Feinberg, 1994). The consolidation of information is the process that insures that information learned is retained in long-term memory.

Sleep and Consolidation

A study by Benson and Feinberg (1994) demonstrates the role that sleep plays in the consolidation of information. Two groups of participants were taught a series of nonsense syllables and tested 8 hours latter to see how many of those syllables they retained. One group of subjects was taught the syllables at night, and the other group received morning instruction. After 8 hours, retention, using a free recall measure, was superior for those who learned the material at night, then slept, and were subsequently tested than for those who learned the material in the morning, but did not sleep prior to the retrieval of the information. Twenty-four hours after the presentation of the information, after the morning subjects had slept, their scores improved.

The authors offer three possible explanations for the free recall superiority following evening presentation as opposed to morning presentation. These explanations included: time of day, interference, and sleep. Time of day as a variable is known to affect long-term memory such that evening presentation results in superior long-term memory. The interference explanation postulates that morning presentation is followed by the absorption of more information and a plethora of experiences. Due to retroactive interference, information learned early in the day may be forgotten. Conversely, when material is learned at night and followed by sleep, no such new learning takes place and retroactive interference is not a factor affecting memory. The third possibility is that sleep itself aids in the consolidation of information, and hence later memory. This hypothesis is supported by the fact that free recall scores for morning subjects improved after 24 hours above what they were at 8 hours. Thus, sleep, whether occurring shortly (but not immediately) after learning or after a delay of several hours, may be a factor in promoting the retention of information.

Based on the Nesca and Koulak (1994) study it seems clear that the point at which sleep occurs directly affects the strength of the memory trace. Those subjects whose learning was closely followed by sleep outperformed those for whom sleep was delayed by several hours as well as those who had no sleep at all. It therefore seems likely that the interaction between sleep and circadian rhythms is the factor that promotes consolidation of recently acquired memory traces.

Timing of Sleep

The timing of the onset of sleep following the presentation of materials, and the duration of that sleep are important factors in determining whether or not information will be retained in long-term memory. According to Benson and Feinberg (1975), a study by Goodenough, Sapan, Cohen, Portnoff, and Shapiro (1971), as well as an earlier study by Portnoff, Baekeland, Goodenough, Karacan, and Shapiro (1966), demonstrated that when sleep closely follows the presentation of a stimulus, retention is impaired. Recently, Wyatt, Bootzin, Anthony, and Bazant (1994) found that when subjects are allowed to sleep for 10 minutes or more following the auditory presentation of events, significant portions of the information are lost. More specifically, participants in the study had severe free recall deficits for word pairs presented up to 3 minutes prior to the onset of sleep and could not even recognize information presented 1 minute prior to the onset of sleep. Conversely, when subjects were awakened after 30 seconds of sleep, no equivalent memory deficits were present.

Nesca and Koulak (1994) conducted a similar study in which three groups of subjects learned a list of words and were tested for recognition after 24 hours. One group learned the material at night immediately prior to sleep, one group learned the material in the morning and was tested after a nighttime of sleep, and the third group learned the material at night and was deprived of a nighttime of sleep.

Results indicate that subjects who learned the material at night and went to sleep immediately thereafter performed better on the recognition task than participants who learned the material in the morning. However, the group who was taught at night and then deprived of sleep also outperformed the group who was taught in the morning and then had a regular night sleep prior to the testing. In this study a single night of sleep deprivation did not negatively affect recognition memory. The implications of these findings are significant. If students fall asleep in class, they may not only miss the material presented while they are sleeping but also they may show deficient recall of information presented up to 3 minutes before they fell asleep. In this respect, microsleeps, where students fall asleep for several seconds and then immediately awaken, are not as detrimental to the retention of auditory information as longer periods of sleep.

Not only is the onset of sleep detrimental to the retention of information presented immediately prior to the onset of sleep, but also sleeping immediately prior to learning can adversely affect the retention of material presented subsequent to awakening. A laboratory study by Tilley and Statham (1988) tested two groups of participants on their ability to generate instances of specific categories (e.g., names of birds) and repeated the task again after 20 minutes. One group of participants was tested immediately after awakening from the first hour or so of nocturnal sleep and tested again 20 minutes latter. The other group was tested at the same time of night without any prior sleep. The group awakened from sleep generated significantly fewer instances than their non-sleeping counterparts, during both testings. However, among those awakened from sleep, there was a significant improvement in the ability to generate instances after a 20-minute delay. The fact that retrieval ability improved over the course of the 20 minutes led the authors to suggest that the detrimental effects of prior sleep on semantic material well established in long-term memory may be the result of retrieval difficulties that improve within 20 minutes or so of awakening.

Hence, since most students must arise, get dressed, and somehow get to school before classes actually start, this retrieval factor in and of itself should not hinder learning during early morning classes. The potential detrimental effect that sleep has on subsequent learning becomes a significant issue of concern when students fall asleep in class. When this occurs, the students not only lose out on the material taught immediately before they fell asleep and while they were sleeping but on material taught subsequent to their awakening. Additionally, if a student falls asleep during a testing situation, he or she risks inferior ability to recall information immediately upon awakening and, as a result, inferior performance on the test.

Stages of Sleep

Sleep is not one uniform process, but rather a cyclical group of phases that an individual passes in and out of throughout the course of the night. Of these phases, delta-sleep and rapid eye movement (REM) sleep seem to exert the greatest effects on retention. It is thought that during delta-sleep, information is reorganized based on its importance for subsequent wakefulness. This organizational process is necessary for the consolidation of a variety of emotional and unemotional material. REM sleep interacts with delta-sleep in a way that compensates for the tension engendered by this organizational activity. When delta-sleep deprivation occurs, results include sleepiness, decreased attention, and decreased ability to assimilate new information (Rottenberg, 1992a).

REM sleep seems to have a dual affect on retention. On the one hand it seems to facilitate the positive effect that delta-sleep has on retention, and at the same time, it appears to have its own inhibitory effects. Rottenberg (1992a) reports that success during intense learning of a foreign language correlated with a definite increase in the percentage of REM sleep. Participants who displayed this increase in REM percentage were also free from emotional stress during learning. REM sleep has an important affect on retention. Retention is found to be higher after the second part of the night, when REM sleep predominates, than after the same period of time when the subject is not asleep.

The effects of REM sleep on retention seem to be particularly salient when the information to be remembered touches the subject deeply (i.e., emotionally significant or relevant information), or is highly unusual, such as tasks requiring divergent thinking. At the same time REM sleep has a direct negative effect on retention, which perhaps is the result of interference from dream images on learned material. When awakened immediately following a short period of time in REM sleep, subjects recalled less material that they had learned prior to going to sleep than they recalled after being awakened from the delta-sleep phase that preceded the REM phase. This suggests that REM sleep in and of itself can have an inhibitory effect on retention. However the combined effect of REM sleep and delta-sleep are necessary for consolidation of information (Rottenberg, 1992a).

Dahl and Carskadon (1995) report that among the normal sleep-related changes in adolescents is a decrease in the amount of delta-sleep, which may occur as a result of cortical pruning. Between the ages of 10 and 20 there is a decrement of 40% in the amount of delta-sleep. Additionally, adolescents show reduced REM latency (i.e., a decrease in the amount of time from one REM phase to the next), and also demonstrate an increase in the amount of stage 1 and stage 2 sleep throughout the night.

Sleep Deprivation

Sleep deprivation, whether in the form of acute sleep loss or chronic sleep restriction, can negatively impact short- and long-term memory. Rottenberg (1992) states that when an organism is deprived of REM sleep for long periods of time, learned helplessness may ensue, which negatively impacts on the learning process (Rottenberg, 1992). Additionally, short periods of REM sleep deprivation may produce a form of agitated restlessness, which could cause a learner to actively avoid learning difficult material (Rottenberg, 1992). In either of these two scenarios, the impact of sleep loss on behavior restricts short-and long-term memory by preventing the individual from approaching the task with the necessary degree of perseverance.

Sleep deprivation and short-term memory. Cuttler and Cohen (1979) tested short-term memory for words in a series of subjects who had been sleep deprived for 24 hours. The subjects' ability to recall a series of words immediately after presentation was not worse than the control group who had not been deprived of sleep. In an earlier study Polzella (1975) found that sleep deprivation did indeed impair short-term recognition memory. In this study subjects under one condition were deprived of sleep for 24 hours and were shown a series of matched symbols and then a series of probes. They were asked to indicate whether the probe was one of the matched pairs that they had initially seen. Under the other condition the same subjects were asked to do the same task without being deprived of sleep. Performance under sleep deprivation was significantly worse.

Thus, while sleep deprivation may not impair an individual's ability to repeat a series of words or numbers, it can negatively affect his or her ability to do simple comparisons of visual information held in short-term memory. Results of these experiments are similar to the predictions of arousal theory and experiments on the effects of time of day. After a night of sleep deprivation, ostensibly the basal level of arousal is low, and while this does not necessarily negatively impact short-term memory, it can affect the ability to do any more complicated manipulations of material.

Sleep and Sleepiness in Adolescents

Studies of sleep practices amongst adolescents show three trends: a decrease in total sleep time, a tendency to delay the onset of sleep, and an overall increase in the level of daytime sleepiness (Carskadon, 1990). In light of research on the detrimental effects of sleep deprivation on memory and learning, these three trends may negatively impact school performance, especially when classes are conducted early in the morning.

Decrease in the total amount of sleep. According to Wolfson and Carskadon (1996) the changes in the amount of sleep that adolescents get is paradoxical. While adolescents sleep less than younger children, they generally require more sleep than younger children do. The amount of sleep that most pubertal and post-pubertal adolescents get is generally considered insufficient for their needs. According to Carskadon (1990), older adolescents may actually need more sleep than preadolescents. While 8.5 hours of sleep is generally considered sufficient for adolescents, a recent survey done by Wolfson and Carskadon (1996) in Providence, Rhode Island, found that only 15 percent of adolescents surveyed reported that they slept that much on school nights. Twenty-six percent reported sleeping fewer than 6.5 hours on school nights. Concerning the impact of the decreased amount of sleep on academic performance, Wolfson and Carskadon (1996) found an association between reported higher grades and reported earlier bed times and as a result, longer sleeping times.

The decrease in the total amount of sleep that adolescents receive may be the result of many factors. Increased academic and social involvement may cause adolescents to stay up later, while early school starting times curtail sleep in the morning. Occasionally the demands of scheduled school, work, and social obligations become even greater, and as a result, teenagers undergo acute sleep deprivation (i.e., the loss of a single night's sleep). Even more common among teenagers is chronic sleep restriction where insufficient amounts of sleep are obtained on several consecutive nights. Acute sleep loss causes extreme sleepiness. According to Carskadon, adolescents who miss one night of sleep are pathologically sleepy the next day. As a result they are at risk for unintentional sleep episode, such as falling asleep in class, while driving, or in any low stimulus environment (Carskadon, 1990). Pulling an "all nighter" is also associated with performance decrements and mood alterations. The aforementioned effects are not limited to acute sleep deprivation but can result from chronic sleep restriction as well. Sleepiness is additive over days. Hence, when a teenager stays up late at night and gets up early to go to school the next morning, he or she becomes increasingly more sleepy on subsequent days. If he or she does not recover his or her lost sleep, eventually he or she reaches the pathological level associated with acute sleep deprivation.

When the total amount of sleep time is restricted, Carskadon and Dement (1981) found that the amount of stage 2 and REM sleep are specifically reduced, while other sleep stages are unaffected. This is particularly important considering the affect that REM sleep with its combined impact on delta-sleep is thought to have on the consolidation of information. If adolescents are missing out on this aspect of sleep, their ability to retain information long-term will be impaired.

Delayed onset of sleep. The tendency to go to bed late and sleep in is characteristic of adolescents. The factors that lead to this practice may be both biological and social. According to Carskadon (1993), puberty may be associated with a change in circadian rhythms such that a delay in the time of sleep onset is favored biologically. This biological tendency is compounded by increased amounts of homework, as well as social and job-related obligations, that make it almost impossible to go to bed early (Carskadon, 1993). Early school starting times require that students who have gone to bed late arise early the next morning to attend class. This curtails sleep at a time when adolescents may be biologically inclined to sleep.

An extreme example of delayed onset of sleep is the case of Delayed Sleep Phase Syndrome (DSPS), where people are chronically unable to fall asleep until the wee hours of the morning and do not awaken until the early afternoon. This condition may be caused by a defect in the brain's timing mechanism and needs immediate treatment so that the student can function in the current educational and social environment (Carskadon, 1990). Carskadon reports that teenagers appear to be "more vulnerable" to this sleep disorder (Richardson, 1995).

Daytime sleepiness. Laboratory-based longitudinal studies on sleep and waking behavior in adolescents show a decrease in waking alertness that occurs at mid puberty (Carskadon, 1982). Even with no change in the amount of nighttime sleep, adolescents are sleepier during the daytime than children (Carskadon, 1993). This form of chronic pubescent sleepiness puts adolescents at great risk for the negative effects associated with insufficient sleep (Carskadon, 1990). Thus, when adolescents who have a natural tendency toward daytime sleepiness skip a night of sleep, or receive very few hours of sleep on a given night, they are in danger of falling asleep in a low stimulus environment such as a classroom or a car. Carskadon (1990) reports that the likelihood of students reporting falling asleep in class is significantly greater for students with large amounts of extracurricular or job involvement.

Summary of Research

Time of day as a variable exerts differential effects on short-term and long-term memory. Low arousal states associated with the early morning tend to favor and be associated with immediate memory, episodic memory, acoustic similarities, and maintenance rehearsal. High arousal states of the late afternoon and early evening tend to favor and be associated with superior long-term memory, retrieval efficiency, semantic similarities, and elaborative rehearsal.

There exist individual differences in these patterns. Using the morningness and eveningness factor operationalized by Horne and Ostberg (1976), Petros et al. (1990) demonstrated that the effects of time of day are moderated by the degree to which a person considers himself or herself awake and maximally able to engage in certain tasks at a particular time of day. Those who identified themselves as morning types showed decreased recall for prose across time of day, while those identified as evening types showed slightly, but not significantly, increased recall for prose from morning to afternoon. Dunn (1990) has suggested that the majority of adolescents fall in the afternoon-evening categories. This would make them particularly susceptible to the effects of time of day on long-term memory.

Additionally, during the academic year adolescents tend to undergo frequent bouts of chronic sleep restriction or acute sleep deprivation (Carskadon, 1990). Missing one night of sleep makes adolescents pathologically sleepy the next day. Even without missing one complete night of sleep, chronic restriction of sleep can have the same effects. Colqhoun (1971) maintains that when the overall level of arousal is relatively low due to sleep deprivation, a given change in arousal will have a more marked affect on performance. Thus, adolescents who are chronically sleep deprived may be particularly susceptible to the effects of time of day on memory. Their ability to engage in tasks of long-term memory may be impaired early in the day and enhanced later in the afternoon. As long-term memory is directly related to learning, scheduling classes early in the morning may have a detrimental effect on the academic careers of these teenagers.

Sleep deprivation can have additional negative effects on learning. When students are deprived of sleep they are likely to fall asleep in low stimulus environments such as classrooms (Carskadon, 1993). Falling asleep in class may cause students to miss not only the information taught while they are sleeping, but also the information presented immediately prior to when they fell asleep (Wyatt, Bootzin, Anthony, & Bazant, 1994) and immediately following their awakening (Tilley & Statham, 1988). If school schedules are incompatible with teenagers' chronobiological schedules, they will be more likely to fall asleep at the times when their levels of arousal are the lowest. Scheduling classes at times when adolescents would naturally be sleeping may perpetuate a cycle in which teenagers receive insufficient sleep and as a result do not garner maximal benefit from their classes.

Purpose of the Study

The purpose of this study was to compare the scores of two groups of adolescents, those tested in the morning and those tested in the afternoon, on selected scales of the Wide Range Assessment of Memory and Learning (WRAML; Sheslow and Adams, 1990). Scores on the Self-Assessment Questionnaire of Morningness and Eveningness (Horne & Ostberg, 1976) as well as the number of hours slept the previous night were used as correlates and possible covariates. This enabled an examination of morning and afternoon performance on several tasks of short-term, delayed, and long-term memory. This also allowed investigation of the relationship between self-reported morningness-eveningness preference and morning and afternoon performance on various memory tasks as well as the relationship between hours of sleep and morning and afternoon performance on various memory tasks.

Hypotheses

In light of the research on the effects of time of day on memory, the following hypotheses indicated that on measures of short-term memory participants would show enhanced performance when these measures were administered in the morning as compared with the performance of participants to whom these measures were administered in the afternoon (Baddelly, Hatter, Scott, & Snashall 1970, Folkard & Monk, 1979, Folkard, 1979, Dunne, Roche & Hartley, 1990, Folkard & Monk, 1980, Folkard, Monk, Bradburry and Rosenthall, 1977).

HO1: Scores on the Picture Memory subtest of the WRAML will be significantly higher for participants tested in the morning than for those tested in the afternoon.

HO2: On the Verbal Learning subtest, scores on all four presentations of the word list will be significantly higher for those participants tested in the morning than for those tested in the afternoon.

HO3: On the Immediate Recall section of the Story Memory subtest scores will be significantly higher for those participants tested in the morning than for those participants tested in the afternoon.

HO4: On the Sound Symbol task, scores will be significantly higher for participants tested in the morning than for those tested in the afternoon.

HO5: On the Sentence Memory subtest, scores will be significantly higher for participants tested in the morning than for those tested in the afternoon.

Research on the effects of time of day on long-term memory indicates that the afternoon presentation of materials favors storage in long-term memory (Oakhill, 1986, Dunne, 1990). In the afternoon participants are likely to engage in semantic as well as elaborative and integrative forms of processing which may be the mechanisms that lead to enhanced long-term memory (Folkard, 1979, Oakhill, 1986a). In view of these findings, the following hypotheses were tested:

HO6: On the Delayed Recall section of the Story Memory subtest, scores will be significantly higher for participants who are tested in the afternoon than for those tested in the morning.

HO7: On the Story Memory Recognition subtest, scores of participants tested in the afternoon will be significantly higher than scores of participants tested in the morning.

HO8: During the second testing situation on the Story Memory Recall and Recognition subtests presented immediately upon arrival, scores of participants who initially heard the story in the afternoon will be significantly higher than scores of those who initially heard the story in the morning.

HO9: On the Delayed Recall sections of the Sound Symbol and Verbal Learning tasks, scores of those participants tested in the afternoon will be significantly higher than those tested in the morning.

The effects of time of day on both short- and long-term memory may be mediated by individual differences in chronobiological time preferences. A study by Petros, Beckwith, and Anderson (1990) showed that the ability to recall prose material following morning or afternoon presentation was differentially affected by these individual differences. Recall decreased across time of day for those classified as morning types, while it increased slightly, but not significantly, for those classified as evening types (Petros, Beckwith & Anderson, 1990).

HO10: Morningness-eveningness scores will be significantly positively correlated with scores on long-term memory tasks following morning presentation of materials and scores on short-term memory tasks following afternoon presentation of materials.

HO11: Morningness-eveningness scores will be significantly negatively correlated with scores on long-term memory tasks following afternoon presentation of materials and scores on short-term memory tasks following morning presentation of materials.

Sleep deprivation has been shown to impair short-term recognition memory (Polzella, 1975). Additionally, after a night without sleep or with very little sleep ostensibly the basal level of arousal is low. This depressed level of arousal can affect long-term memory ability as well. Lengthy periods of sleep deprivation may lead to learned helplessness, which negatively affects the learning process

(Rottenberg, 1992).

HO12: Amount of sleep in minutes will be significantly positively correlated with scores on delayed and long-term memory tasks following afternoon presentation of materials and with scores on short-term memory tasks following morning presentation of materials.

CHAPTER 5

Methodology

This section reviews the experimental design employed for the study, as well as the specific instruments utilized. The participants and the school from which the participants were culled are described as is the procedure that was followed. This section also contains a description of the data analysis procedures employed.

Design

This study used a between-groups design with one between subjects factor (time of day of testing). Participants were tested on WRAML tasks of short-term, delayed, and long-term memory. Participants were randomly assigned to one of two testing times (i.e., morning or afternoon). Thus, half of the participants were tested in the morning, while the other half of the participants were tested in the afternoon. Figure 1 gives a representation of the design. A power analysis using SPSS Sample Power (1997) indicated that 28 subjects per group were needed to achieve an effect size of .80 for a one-way analysis of variance. This power analysis served as a basic guide to the sample size needed.

Figure 1.

Schematic Representation of Research Design

WRAML SUBTEST	A.M. TESTING GROUP	P.M. TESTING GROUP
Picture Memory		
Verbal Learning		
Story Memory Recall		
Sound Symbol		
Sentence Memory		
Story Memory Delayed Recall		
Story Memory Recognition		
*Long-Term Memory Story Recall		
*Long-Term Memory Story Recognition		
Sound Symbol Delayed Recall		
Verbal Learning Delayed Recall		

Additionally, participants' morningness-eveningness scores and the number of hours participants' slept the night before testing were used to predict WRAML performance.

* Subtests administered after minimum delay of 1 night.

Instruments

A Self-Assessment Questionnaire to Determine Morningness-Eveningness in Human Circadian Rhythms (Horne and Ostberg, 1976)

This scale, developed by Horne and Ostberg (1976), is a standardized measure that was used in lieu of taking direct physiological measures of arousal. The use of this questionnaire is considered less invasive than taking a physiological measure such as oral temperature at the time of testing. The English version of this scale was normed on a sample of 150 male and female adults in Britain ranging in age from 18-32 years, and was validated by having 48 of these subjects regularly measure their oral temperatures. The method of least squares fitting of polynomials was used, and significant differences in peak times based on oral temperatures were found between morning and evening types. The correlation between physiological peak time and morningness and eveningness is .51 (Horne and Ostberg, 1976).

The questionnaire is composed of 19 items. Items include questions concerning preference times of day for sleeping, engaging in physical activity, and taking tests. Indicating preference for morning times for activities and for early bed times leads to morning type scores, while selecting evening hours to engage in specified activities and preferring to go to bed late at night lead to evening scores. Fourteen questionnaire items have four choices for answers that are keyed to indicate definite morning type, moderate morning type, moderate evening type, and definite evening type. Five items have time scales where a time frame is to be selected. Each choice corresponds to a predetermined number of points depending upon the items. Overall scores of 16-30 correspond to definite evening type, scores of 31-41 correspond to moderate evening type, and scores of 42-58 correspond to neither type. Scores of 59-86 correspond with moderate to definite morning-type categories (Horne & Ostberg, 1976). Unfortunately, these cutoff points were determined using adult British individuals and may not be valid for American teenagers; therefore, a quantitative approach was taken and participants' raw scores on the morningness-eveningness scale were correlated with their scores on tests of short- and long-term memory. The questionnaire is presented in Appendix A.

Selected Subtests of the WRAML, the Wide Range Assessment of Memory and Learning (WRAML; Sheslow and Adams, 1990)

The WRAML is a standardized measure that is useful in assessing short-term and delayed memory abilities amongst children and adolescents. Data in the administration manual indicates that the Coefficient Alpha for the General Memory Index of the WRAML is .96. The range of the person separation indexes for each of the subtests is .79 to .94. The person separation index is a measure of internal consistency which gives an estimate of the amount of error in measurement and indicates the test's capacity to distinguish among people by looking at the total number of items that they answered correctly. The person separation index should be as high as possible with the highest score being 1.0 (Wright and Stone, 1989; as cited in Sheslow and Adams 1990).

Using a sample of 17- and 18-year-olds, the Sheslow and Adams (1990) found a .54 correlation between the WRAML General Memory Index and the Wechsler Memory Scales-Revised. This is given as evidence of acceptable criterion-referenced validity. In correlations with the WRAT-R, the authors found that the General Memory Index of the WRAML is significantly related only to arithmetic achievement in adolescents ($\underline{r}$=.378), but not to other forms of academic achievement. However, when correlating WRAML index scores and WRAT-R subtests the authors found that the WRAML's indexes are significantly related to academic achievement (Sheslow & Adams, 1990).

The WRAML assesses delayed recall and recognition as well as short-term memory. Both types of memory are thought to fluctuate differentially with time of day and level of arousal. The WRAML was therefore selected to assess the effect of time of day on the short-term memory and delayed recall and recognition of adolescents. Due to time constraints, the general administration of the WRAML does not assess long-term memory. By readministering the story memory recall and the story memory recogniton subtests after a minimum delay of one night, this study obtained a long-term memory measure as well. A pattern of interaction between scores on different areas of the WRAML at different times of day may indicate an effect of time of day on the specific area of memory measured. To provide a broader range of scores, and hence the ability to identify smaller differences in performance, raw scores were utilized. Additionally, for this reason, in lieu of difference scores, which are computed by subtracting Delayed Recall raw scores from trial four raw scores and from total raw scores, Delayed Recall raw scores were used as well.

The specific subtests administered and the reasons for their selection were as follows:

Picture Memory. Picture Memory is a measure of short-term visual memory. In this test a participant is shown a complete meaningful scene for 10 seconds. The scene is then removed and the subject is immediately shown a similar picture in which several items have been changed or added. In the administration of the complete WRAML, this subtest is part of the Visual Memory Scale, as it measures short-term visual memory.

Sheslow and Adams (1990) report the item separation statistic for the Picture Memory subtest as 1.00. They report the person separation statistic as .85. According to the authors, high values for the item separation index support the construct validity of the instrument. The person separation statistics are purportedly similar to other measures of internal consistency and as a result estimate the error in measurement.

Coefficient Alpha is used as a measure of internal consistency. For Picture Memory, Coefficient Alpha is reported at .89 for age 13, .83 for age 13.5, and .85 for ages 14-17.

The Picture Memory subtest is composed of four scenes with a total of 47 missing or changed items. The raw score is the number of correctly identified items. While there is no penalty for random guessing, the authors warn that should this occur the validity of the subtest may be compromised. The range of points for the raw score is 0-47.

Concerning relevance to classroom functioning, the basic skills employed in Picture Memory would seem to be those necessary in subjects such as art, biology, chemistry, or geometry where students must hold visual representations of information in their short-term memory in order to perform more complex work on this information or solve problems.

Verbal Learning. The Verbal Learning subtest is adapted from Rey (1958)(Rey, 1958; as cited in Sheslow & Adams, 1990). Using this paradigm the participant is initially read a list of simple words and then immediately asked to recall as many of those words as possible using a free-recall format. After this the participant is re-read the same list of words and asked to recall as many as possible after each reading. This process, a total of 4 presentations of the same list, yields a verbal learning curve over trials. The subtest serves as a measure of short-term memory and evaluates an individual's ability to learn a list of orally-presented, non-related words. A delayed recall trial is provided where the participant is asked to reproduce the list of words after the intervening administration of the Story Memory subtest. The Delayed Recall test serves as a measure of delayed recall.

The item separation statistic for the Verbal Learning subtest is reported at 1.00, while the person separation statistic is reported at .82. Coefficient Alpha as a measure of internal constancy is reported as .82 for age 13, .79 for age 13.5, .82 for age 14, .80 for age 15, and .86 for ages 16-17.

In the Verbal Learning subtest a series of sixteen words are repeated across four trials. One point is given for each word that is correctly repeated during each trial. The total number of words recalled serves as the raw score for this subtest. The range of points for the raw score is 0-64. In the Delayed Recall trial, administered after the Story Memory subtest, the total number of words recalled serves as the raw score. The range of obtainable points in the Delayed Recall trial is 0-16.

The ability to retain verbally presented material is imperative in subjects such as history and science where teachers often quote materials verbally and require students to enter this material into their notebooks. It is especially important in areas such as vocabulary and foreign languages where teachers often dictate lists of words to their students.

Story Memory. In this subtest two short stories are read to a participant, and the participant is asked to retell the stories in as much detail as possible, immediately after the story, as well as after a delay of 20 to 40 minutes. This subtest serves as a measure of short-term memory for verbally-presented, semantically-related information. It is similar to the material referred to as prose in Chapter 2. To determine whether a child's performance is hindered by the nature of the free recall task, a delayed story recognition format in which multiple choice questions are verbally presented is administered as well.

The Story Memory Recall subtest is scored on a participant's ability to recall 51 discrete, specific items contained in the contents of two stories. A free recall paradigm is utilized in which a participant is asked to retell the story, and receives one point for each item recalled. The total number of points constitutes the raw score. The range of points for the raw score is 0-51.

The same procedure is followed for the Delayed Memory Recall subtest. Following the administration of seven subsections, lasting approximately 20 minutes, the participant is asked to once again retell the stories and the raw score is the number of the 51 discrete items mentioned. The range of points for the raw score is 0-51.

The Story Memory Recognition subtest is based on only one of the two stories told. It is comprised of 15 multiple-choice items, with three choices for each item. The items are presented orally and participants respond verbally. Each correct response earns one point. The range of points for the raw score is 0-15.

Sheslow and Adams (1990) report the item separation statistic for Story Memory as 1.00, and the person separation statistic as .87. Coefficient Alpha for Story Memory is .80-.90 for ages 13-13.5, .86 for ages 13.5 & 14, and .88 for ages 15-17.

Remembering verbally-presented, semantically-related information is strongly related to classroom functioning (Sheslow & Adams, 1990). It is a skill that is imperative in areas such as literature and history where students are required to listen to verbal presentations of written accounts, comprehend them, and remember them in significant detail.

Sound Symbol. The Sound Symbol subtest is a test of paired associates in which the participant is required to remember a series of sounds associated with a series of abstract figures. This task involves some of the mechanics of "word calling" or reading. In the sound symbol subtest there are 4 discrete trials in which the individual is provided with immediate corrective feedback on all but the last trial. A delayed recall trial follows the presentation of several other subtests.

The Sound Symbol subtest is comprised of 12 items presented four times across four trials. A participant receives one point for each sound paired with the correct symbol. A sum of the points across all four trials constitutes the raw score. The range of points is 0-48. For the Delayed Recall subtest there is a range of 0-12 points.

The item separation statistic for Sound Symbol is reported at 1.00, and the person separation statistic is reported at .92. Coefficient Alpha for Sound Symbol is reported at .92 for age 13, .90 for age 13.5, and .94 for age 14-17.

In subject areas such as geometry and chemistry students are required to learn names for specific shapes and designs and to associate those names with those designs. Additionally, retaining old material following the presentation of new material is considered an important factor (Sheslow and Adams, 1990). The purpose of the Delayed Recall test is to determine whether or not forgetting has begun to affect the memory trace after 20 or so minutes. When rapid decay occurs it can suggest a serious learning problem.

Sentence Memory. Sentence Memory is an immediate memory task in which the participant is asked to repeat increasingly more complex and lengthy sentences immediately after the examiner recites them. It is similar to the first trial of the Verbal Learning subtest, except that the items are semantically related as they are components of meaningful sentences.

The Sentence Memory subtest is comprised of 20 increasingly more complex and lengthy sentences. Each sentence repeated without any error earns two points, while repetition of a sentence with one error earns one point. The total range of points obtainable for the raw score is 0-40.

The item separation statistic for Sentence Memory is 1.00. The person separation statistic for Sentence Memory is .94. The Coefficient Alpha reliability estimates for sentence memory are .90 for age 13, .86 for age 14, .88 for age 15, and .89 for ages 16-17.

Sentence Memory resembles classroom learning to the extent that meaningful material is being presented, but differs to the extent that, in classroom learning, depth of comprehension is favored over verbatim recall. In areas such as literature and history students may, however, be required to learn discrete quotes by heart. Additionally, it is not uncommon for a teacher to ask a student who appears to have nodded off ,"what did I just say?", and repeating the last line of what was said relies entirely on this ability.

Several WRAML subtests were omitted from this study for the following reasons:

Design Memory. This is a task in which participants are shown a specific geometric design sequence and asked to reproduce it after a delay of several seconds from memory. It bears little resemblance to classroom activities at the high school level, and visual memory is already tested through the use of the Picture Memory subtest. The grapho-motor skills required to reproduce these designs should also show little variation at this age. For these reasons it was omitted.

Finger Windows. This is a subtest in which a participant demonstrates memory of a rote visual pattern by reproducing that spatial sequence. It is a test of short-term memory using discrete non-meaningful bits of information. It therefore bears little resemblance to classroom learning at the high school level.

Visual Learning. This is a test in which visual designs are presented in particular locations on a board, and the participant is required to remember the specific location of each design. It measures short-term visual memory, much in the way that Picture Memory does, only here the information is non-meaningful. It has four learning trials and therefore takes some time to administer. It was therefore decided that the Picture Memory subtest, which uses meaningful bits of information, would be a more appropriate test to use.

Number-Letter Memory. This is a test of short-term verbal memory of relatively meaningless strings of numbers and letters. As short-term verbal memory is assessed through the Verbal Learning, Sentence Memory, and Story Memory subtests, which all deal with meaningful material that bears more resemblance to classroom learning, this subtest was omitted.

Student Questionnaire

A Student Questionnaire was completed by each participant during the first testing session. The data from this questionnaire provided descriptive statistics concerning students' perceptions of their ability to learn at different times of day.

The questionnaire, a simple pencil-and-paper form, is comprised of 10 short-answer questions, 2 of which are forced choice and require yes or no responses, and 4 of which allow the students to select an answer from an array. Students are asked to select the periods when they feel most tired, alert, etc. from an array labeled according to how the periods are labeled on the attendance sheets that the school used. In this system Period 12, a non academic prayer period, precedes Periods 1 through 11. The remaining 3 questionnaire questions are free-response, short-answer questions. Included in the questionnaire are specific questions about sleep habits, including a question regarding the amount of sleep that each participant received the night prior to the testing. Frequencies were tabulated for each response to provide descriptive information about the sample. The questionnaire is presented in Appendix B.

<u>The Hollingshead Four Factor Index of Social Status</u>

(Hollingshead, 1975)

This is a pencil-and-paper, short-answer, and multiple-choice questionnaire about areas of education, occupation, gender and marital status. The four factors are combined to create an estimate of each participant's nuclear family's status. Six parent questionnaire forms are available. Parents are asked to fill out one of these forms on the basis of their marital status. For the Educational Factor the years of school that a respondent has completed are scored on a 7-point scale. The Occupational Factor is graded on a 9-step scale, which is usually keyed to the three-digit code assigned by the United States Census in 1970. When these codes are insufficient, additional codes are used.

The sex of a respondent is a direct response. Marital status determines whether or not the estimate of social position is a function of the education and occupation of one or both spouses. The estimate of social status is obtained by multiplying the scale weight of an occupation by five and the scale weight of education by three. Computed scores range from a high of 66 to a low of eight. Scores of 8-19 are assigned to unskilled laborers and menial service workers, scores of 20-29 are assigned to machine operators and semiskilled workers; scores of 30-39 are assigned to skilled craftsmen, clerical and sales workers; scores of 40-54 are assigned to medium business, minor professionals, and technical workers; and scores of 55-66 are assigned to major business and professionals. It is assumed that the higher the score of a family or a nuclear unit, the higher the status its members are accorded by society. The Pearson Product Moment Coefficient between the 9-step occupational scale and the NORC Prestige scale is $r = .927$ (Hollingshead, 1975).

The Hollingshead Four Factor Index of Social Status (Hollingshead, 1975) was distributed along with the consent forms. This item was useful in developing descriptive statistics about the sample.

The Scholastic Aptitude Test (SAT)1: Reasoning Test

The SAT 1 Reasoning Test is a standardized measure that assesses developed verbal and mathematical reasoning abilities related to successful performance in college (College Entrance Examination Board and Educational Testing Service [College Board], 1999). The SAT 1 Verbal section is composed of 2 30-minute sections plus 1 15-minute section. There is an emphasis on critical reading. Vocabulary is tested within the context of paragraph reading as well as through analogies and sentence completion questions. In all there are a total of 78 questions to be completed in 75 minutes.

The SAT 1 Math is similarly comprised of 2 30-minute sections plus 1 15-minute section. There is an emphasis on data interpretation and applied math questions. Calculators are permitted but not required. A total of 60 questions are presented and 75 minutes are allotted for their completion. All but ten of these questions are multiple choice. The remaining 10 questions are free response problems in which students must enter their answers into special grids. A seventh section, lasting 30 minutes, is given in either the verbal or mathematical domain and is not counted toward the individual's score. It is used for equating purposes only (College Board, 1999).

The reliability coefficient for the Verbal section of the SAT ranges from .91-.93 with a Standard Error of Measurement (SEM) of 29-31 and a Standard Error of Difference (SED) of 40-44. The reliability coefficient for the Math questions of the SAT 1 is given at .92-.93 with an SEM of 30-31 and an SED of 42-44. The national mean SAT score for college bound seniors in 1998 was 505 on the Verbal section and 512 on the Math section. The national mean SAT score for college bound seniors in 1999 was 505 on the Verbal section and 511 on the Math section. Among college bound seniors enrolled in religiously affiliated high schools in 1999 the mean Verbal score on the SAT 1 was 506 and the mean Math score was 494 (College Board, 1999).

SAT 1 scores are correlated with academic achievement. The correlation between SAT 1 combined verbal and math scores and freshman grade point average (GPA) is .52 (College Board, 1999). The authors of the WRAML note that the WRAML is significantly related to academic achievement (Sheslow and Adams, 1990). SAT 1 combined scores were therefore included in the analysis to control for differences in performance on the WRAML subtests related to differences in academic achievement.

SAT 1 combined scores were culled by the experimenter from participants' academic files after all testing was completed. None of the testers had access to these files or knowledge of these scores.

Participant Selection and Description of School

Participants in the study were solicited from among the seniors enrolled in the two sections of the Advanced Placement Psychology class at the selected private high school (SPHS). Fifty-three seniors were enrolled in the psychology course and, as part of their course work, they had learned about research and the value of research participation. Thus, it was anticipated that they would be likely to volunteer for the study. The experimenter briefly described the study to each section of the class and handed out parental consent forms to students who desired to participate. The parental consent form is presented in Appendix C. In all, 56 volunteers were sought, 28 to be tested in the morning and 28 to be tested in the afternoon.

Because the actual number of volunteers obtained from these psychology classes, 16 students, or 30% of those solicited, was insufficient, the experimenter went to the remainder of the junior and senior classes and described the study. Those students who expressed interest were given parental letters and consent forms as well as the

Hollingshead Four Factor Index of Social Status (Hollingshead, 1975).

The school from which participants were drawn was a senior private high school (SPHS)located on the South Shore of Long Island. The enrollment in SPHS was 490 students, approximately half of whom were male and half of whom were female. The majority of the students were from the upper-middle and upper class socio-economic levels. The school prides itself on its high academic standards, and over 95% of its graduates attended college. During the 1998-1999 academic year, 116 students were enrolled in the senior class and 132 students were enrolled in the junior class. Thirty-two of the volunteers in this study were enrolled in the senior class and represented 28% of that grade while 23 were enrolled in the junior class representing 17% of the junior class. One volunteer was originally supposed to be in the junior class but due to his earlier academic progress was officially classified as part of the sophmore class.

The school day at SPHS began at 8:00 A.M. and continues until 5:10 P.M. on Monday through Thursday. The day consisted of 12 periods, the first of which was a non-academic required period for prayer. That first period was labeled period 12 on attendance records. Periods 1-11 were academic periods, each of which is 40 minutes long with an additional 2-minute break between periods. Most students lunched during period 5 or 6. The schedule differs dramatically on Fridays when the school closes at 1:30 P.M.

It is for this reason that testing was conducted on Monday through Thursday only.

Procedure

Figure 2 gives a representation of the steps employed in the procedure.

Figure 2.

Order of Steps Employed in the Procedure

- Describe study to relevant classes.
- Obtain signed parental consent forms and completed Hollingshead Four Factor Index of Social Status.
- Obtain student assent.
- Randomly assign students to time of day for testing and determine specific date for testing.
- On the day of testing administer: Verbal Learning, Story Memory, Sound Symbol, Picture Memory and Sentence memory, Student Questionnaire, Self- Assessment Questionnaire of Morningness-Eveningness, Delayed Recall of Verbal Learning, Sound Symbol, Story Memory, Story Memory Recognition.
- After minimum delay of one night administer: Story Memory Recall, Story Memory Recognition.

Those students whose parents responded by returning the consent form along with the completed Hollingshead were contacted and asked for their assent. The assent form is presented in Appendix D. Participants were then randomly assigned, using a Ransl randomization software program developed and described by Castellan (1992), to a specific time, and given a date for the initial testing. Half of the participants were assigned to be tested in the morning and the other half in the afternoon.

When students returned for the first testing, they were asked to write their names and birth dates on the WRAML protocol. The subtests of the WRAML were administered in the following order: 1. Verbal Learning 2. Story Memory 3. Sound Symbol 4. Sentence Memory 5. Picture Memory. The Sentence Memory subtest was followed by the administration of the Self Assessment Questionnaire of Morningness and Eveningness (Horne & Ostberg, 1976) as well as the Student Questionnaire to allow for sufficient intervening time before the administration of the Delayed Recall subtests. Similarly, the subtests were presented in this order to allow for sufficient time between the initial subtests and the Delayed Recall. Those subtests with a delayed recall component were therefore administered first. Following the completion of the questionnaires, the Delayed Recall subtests were administered in the following order: 1. Verbal Learning Delayed Recall 2. Story Memory Recall 3. Story Memory Recognition 4. Sound Symbol Delayed Recall. At the completion of the testing students were told that due to the nature of this study, "It is important not to discuss the specific questions with any other students." They were then thanked for their participation, and asked, "what did you think about the testing?" Following their response, they were asked to return the next day at the same time for a brief testing of 5 minutes or less.

As the WRAML does not claim to assess long-term memory, when participants returned for the second testing situation, they were given the Story Memory Recall subtest followed by the Story Memory Recognition subtest immediately upon arrival. This format enabled the measurement of long-term memory based on material taught at a specific time of day. Participants were then thanked for their participation and allowed to ask questions about the specific materials used. They were asked once more not to tell other participants what occurred at this testing, and if asked, to reply, "We were asked more questions."

All participants were tested at school by outside associates of the experimenter. These examiners, both male and female, were either school psychologists, graduate students in school psychology, or teachers. None of the examiners was a current employee of the school where the study was conducted. The examiners were trained in the administration of the WRAML and the questionnaires by the experimenter in a 3-hour training session. During these sessions, the experimenter watched the examiners correctly administer and record responses.

Data Analysis

Student descriptor information was analyzed using a series of _t_-tests for the continuous variables and a chi-square tests for the categorical independent variable (gender). In this study the variable of primary interest was time of day of testing. To determine if there was a main effect of time of day on the dependent variables, the data were analyzed using a series of regression analyses with time of testing as a predictor of WRAML scores. In these analyses time of day was coded as 0 and 1 with 0 representing those individuals tested in the morning and 1 representing those individuals tested in the afternoon.

Other variables of interest included self-reported optimal performance periods and amount of sleep received on the night prior to the test. To test if performance varied as a function of self-reported optimal performance periods and or amount of sleep received on the night prior to the test, morningness-eveningness by time of testing and hours of sleep by time of testing were included in the regression analyses as predictors of WRAML scores.

Prior to conducting the regression analyses, participant descriptor variables were correlated with WRAML scores. In these correlations participant gender was coded 0 and 1, with 1 representing males 0 zero representing females. Additionally, to facilitate statistical comparisons SAT scores were converted to mean deviate form and referred to as _z_-SAT scores. Similarly, scores on the _Hollingshead_

Four Factor Index of Social Status were converted to mean deviate form as were scores on the Self-Assessment Questionnaire of Morningness and Eveningness.

CHAPTER 6

Results

This chapter presents participant descriptive information, correlations of descriptor variables with WRAML scores, and results of tests of the hypotheses. Descriptive statistics for WRAML subtest scores are presented according to time of testing.

Participant Descriptive Information

Participants were 56 high school juniors and seniors. Table 1 presents gender information for participants by time of testing comparison groups. Chi-square analyses indicated that the groups did not differ with respect to gender, $\chi^2(1, N=56) = 3.504$, $p > .05$.

Table 1

Gender of Participants by Comparison Group

Gender	A.M. Test	P.M. Test	Total
Female	11 (39%)	18 (64%)	29 (52%)
Male	17 (61%)	10 (36%)	27 (48%)
Total	28	28	56

Table 2 presents means and standard deviations for the Hollingshead Four Factor Index scores, hours of sleep prior to testing, morningness-eveningness scores, age, and SAT score by time of testing comparison groups. The comparison groups did not differ with respect to mean age of participants, t (51)=-.544, p =.588; SAT 1 scores, t (54)=-1.906, p =.278; score on the Hollingshead Four Factor Index of Socio-Economic Status, t (45)= .667, p =.585; hours of sleep received the night prior to the initial test, t (54)= -.563, p =.576; and self-reported differences in optimal performance periods as assessed by the Self-Assessment Questionnaire of Morningness-Eveningness, t (53)= .079, p =.937.

Table 2

Means and Standard Deviations for Continuous Independent Variables by Comparison Group

Measure/ Group		N	Mean	Standard Deviation
Hollingshead	A.M.	23	59.52	5.01
	P.M.	24	58.40	6.50
Hours Sleep	A.M.	28	6.39	1.36
	P.M.	28	6.61	1.48
Morningness/	A.M.	28	46.30	5.09
Eveningness	P.M.	27	46.17	7.48
Age	A.M.	26	16.96	.77
	P.M.	27	17.07	.73
SAT 1	A.M.	28	1200.00	148.92
	P.M.	28	1245.36	160.45

In the overall population, the mean score on the Hollingshead Four Factor Index of Social Status was 58.95 with a standard deviation of 5.79. This score corresponds to the major business and professional category of socio-economic status. The average number of hours of sleep reported in the overall sample was 6.5 with a standard deviation of 1.42 hours. The number of hours thought to be sufficient for adolescents is 8.5 (Wolfson & Carskadon, 1996).

In the overall sample the mean morningness-eveningness score was 46.24, with a standard deviation of 6.32. This score corresponds to neither morning nor evening type. It is of importance to note that among those tested 76% (42 participants) fell into the neither type category, 4% (2 participants) fell between the neither type category and the evening type category (i.e. scores of 41.5), 16% (9 volunteers) fell into the evening type category, 2 (4%) classified themselves as morning types, and 1 participant did not complete enough of the questionnaire to have the data included.

The mean SAT1 score in the overall sample was 1222.68 with a standard deviation of 155.08. This score exceeds the 1999 national mean by 222 points.

Correlations of Descriptive Variables with WRAML Subscale Scores

Intercorrelations of all variables used in this study are given in Appendix E. The range of Pearson Product Moment correlations between age and each of the dependent variables was $r(52)$ =-.11 to.36. Out of 13 comparisons only 1 reached significance at the $p < .05$ level; this could have been due to pure chance. Point-Biseral correlations between gender and the independent variables ranged from $r_{bp}(55)$=-.36 to .10. Out of the 13 comparisons conducted only 1 reached significance at the $p < .05$ level; this could have been due to chance.

Prior to computing the correlations between scores on the Hollingshead Four factor index and the WRAML scores as well as the correlations between SAT scores and the WRAML scores, Hollingshead Four Factor Index scores and SAT scores were converted to z-scores by subtracting the mean score for each of these two variables and dividing by the standard deviation. This was done to facilitate statistical comparisons. The Pearson Product Moment correlations between scores on the Hollingshead Four factor index of Social Status and each of the WRAML dependent variables ranged from r (46)= -.13 to .18. There were no significant relationships between Hollingshead scores and any WRAML scores.

The correlations between z-SAT Scores and each of the WRAML scores are reported in Table 3. Because z-SAT scores correlated significantly with 11 out of the 13 WRAML scores, z-SAT was controlled for in subsequent analyses involving WRAML scores so that scholastic achievement would not confound the results.

Table 3

Pearson Product Moment Correlations Between WRAML Scales and z-SAT Scores

WRAML Subtest	z-SAT Scores
Verbal Learning Trial 1	.42*
Verbal Learning Total	.41*
Story Memory	.45*
Sound Symbol Trial 1	.37*
Sound Symbol Total	.38*
Picture Memory	.39*
Sentence Memory	.38*
Verbal Learning Delayed Recall Trial	.50*
Story Memory Delayed Recall	.41*
Story Memory Delayed Recognition	.09
Sound Symbol Delayed Recall Trial	.36*
Long-Term Memory Story Recall	.42*
Long-Term Memory Story Recognition	.12

*$p < .05$

Time of Testing and WRAML Performance

Table 4 presents the mean scores and standard deviations for the WRAML subtests by time of testing for comparison groups.

Table 4

Means and Standard Deviations for WRAML Subtests Scores By Comparison Group

WRAML SUBTEST	A.M. TESTING GROUP			P.M. TESTING GROUP		
	N	M	SD	N	M	SD
Verbal Learning I	28	7.36	1.66	28	7.96	1.97
Verbal Learning Total	28	40.61	6.52	28	43.04	7.62
Story Memory	28	28.14	7.79	28	29.46	7.77
Sound Symbol I	28	6.54	2.85	28	6.29	2.31
Sound Symbol Total	28	36.18	7.99	28	34.14	8.00
Sentence Memory	28	25.43	3.66	28	26.54	4.15
Picture Memory	28	23.64	6.88	28	25.61	5.92
Verbal Learning Delayed Recall	28	9.82	2.60	27	10.93	2.18
Story Memory Delayed Recall	27	25.19	7.84	28	27.54	8.32
Story Memory Recognition	24	11.54	2.87	21	11.48	2.56
Sound Symbol Delayed Recall	28	10.82	2.65	28	10.43	1.99
Long-Term Memory Story Recall	28	26.25	6.58	24	26.46	7.56
Long-Term Memory Story Recognition	28	24.82	4.46	24	24.83	3.20

Tests of Hypotheses

Hypotheses were tested using 13 regression analyses to predict WRAML scores. Predictor variables were time of testing, morningness-eveningness by time of testing, hours of sleep by time of testing, and *z*-SAT. Results of these analyses are reported in Table 5a-i. Please note that time of testing was coded 0 for those individuals tested in the morning and 1 for those individuals tested in the afternoon. The best predictor of performance on each of the subtests was the *z*-SAT score. Table 5a presents results of the regression analysis predicting Picture Memory scores.

Table 5

Regression Analyses Predicting WRAML Scores from Z-SAT, Time of Testing,Morningness-Eveningness X Time of Testing, and Hours of Sleep X Time of Testing Scores

Table 5a

Picture Memory

Predictor Variables	*B*-weight	Beta	*t*	*p*
Time of Testing	1.722	.134	.38	.705
Morningness-Eveningness X Time of Testing	.003	.011	.04	.971
Hours of Sleep X Time of Testing	-.088	-.057	-.24	.814
Z -SAT	2.354	.364	2.70	<.010

Multiple R = .40, F (4, 50) = 2.34, p = .068

Time of testing was not significantly related to Picture Memory performance. Therefore, Hypotheses 1 was not confirmed. Neither morningness-eveningness scores by time of testing nor hours of sleep by time of testing related significantly to Picture Memory performance. Thus, Hypotheses 10 and 12 were not supported for this dependent variable.

Table 5b presents the results of the regression analysis predicting Verbal Learning Scores.

Table 5b

Verbal Learning Trial I

Predictor Variables	*B*-weight	Beta	*t*	*p*
Time of Testing	2.857	.796	2.46	< .017*
Morningness-Eveningness X Time of Testing	.032	-.459	-1.62	.112
Hours of Sleep X Time of Testing	-1.25	-.288	-1.30	.197
z- SAT	.782	.433	3.48	<.002

*Nonsignificant with Bonferroni correction   Multiple R = .54,

F (4, 50) = 5.12, *p* < .003

Verbal Learning Total

Predictor Variables	*B*-weight	Beta	*t*	*p*
Time of Testing	14.082	.993	3.16	< .004
Morningness-Eveningness X Time of Testing	-.213	-.766	-2.78	< .009
Hours of Sleep X Time of Testing	-.353	-.205	-.96	.342
z-SAT	3.163	.444	3.67	<.002

Multiple R = .57, *F* (4, 50) = 6.09, *p* < .001

Time of testing significantly predicted Verbal Learning; however, as shown in Table 4, the mean score of the afternoon group was higher than the mean score of the morning group. This is the reverse of what was hypothesized; therefore Hypothesis 2 was not confirmed. Morningness-eveningness scores by time of testing were significant predictors of Verbal Learning performance but the relationship obtained was negative as compared to the hypothesized positive relationship. Hypothesis 10 was not supported for this dependent variable. Hours of sleep by time of testing did not predict verbal learning performance; thus, hypothesis 12 was not supported for this dependant variable.

Table 5c presents the regression analysis predicting Story Memory scores.

Table 5c

Story Memory

Predictor Variables	B-weight	Beta	t	p
Time of Testing	1.142	.074	.22	.830
Morningness-Eveningness X Time of Testing	-.036	-.120	-.40	.692
Hours of Sleep X Time of Testing	.133	.071	.30	.763
z-SAT	3.586	.461	3.51	<.002

Multiple R = .45, F (4, 50) = 3.24, $p < .02$

Time of testing was not significantly related to Story Memory performance. Therefore, Hypothesis 3 was not confirmed. Neither morningness-eveningness scores by time of testing nor hours of sleep by time of testing related significantly to Story Memory performance. Thus, Hypotheses 10 and 12 were not supported for this dependent variable.

Table 5d presents the regression analyses predicting Sound Symbol scores.

Table 5d

Sound Symbol Trial 1

Predictor Variables	B-weight	Beta	t	p
Time of Testing	1.495	.292	.85	.400
Morningness-Eveningness X Time of Testing	-.054	-.533	-1.77	.083
Hours of Sleep X Time of Testing	.053	.086	.37	.716
z-SAT	1.098	.426	.323	<.003

Multiple R = .44, F (4, 50) = 3.07, $p < .03$

Sound Symbol Total

Predictor Variables	B-weight	Beta	t	p
Time of Testing	2.087	.131	.38	.705
Morningness-Eveningness X Time of Testing	-.114	-.364	-1.21	.232
Hours of Sleep X Time of Testing	.016	.008	.04	.971
z-SAT	3.43	.427	3.24	<.003

Multiple R = .45, F (4, 50) = 3.13, $p < .03$

Time of testing was not significantly related to performance on the Sound Symbol subtest. Therfore, Hypothesis 4 was not confirmed. Neither morningness-eveningness scores by time of testing, nor hours of sleep by time of testing related significantly to Sound Symbol performance thus, hypotheses 10 and 12 were not supported for this dependent variable.

Table 5e presents the regression analysis predicting Sentence Memory scores.

Table 5e

Sentence Memory

Predictor Variables	B-weight	Beta	t	p
Time of Testing	3.709	.481	1.38	.173
Morningness-Eveningness X Time of Testing	-.066	-.437	-1.43	.159
Hours of Sleep X Time of Testing	-.018	-.020	-.08	.934
z-SAT	1.507	.389	2.91	<.006

Multiple R = .42, F (4, 50) = 2.70, $p < .05$

Time of testing was not significantly related to performance on the Sentence Memory subtest. Therefore, Hypothesis 5 was not confirmed. Neither morningness-eveningness scores by time of testing, nor hours of sleep by time of testing related significantly to Sentence Memory performance. Thus, Hypotheses 10 and 12 were not supported for this dependent variable.

Table 5f presents the regression analyses predicting performance scores on the Delayed Recall section of the Story Memory subtest.

Table 5f

Story Recall Delay

Predictor Variables	B-weight	Beta	t	P
Time of Testing	2.889	.178	.52	.609
Morningness-Eveningness X Time of Testing	-.042	-.132	-.44	.666
Hours of Sleep X Time of Testing	.092	.047	.20	.844
z-SAT	3.381	.418	3.12	<.004

Multiple R = .43, F (4, 49) = 2.82, $p < .04$

Time of testing was not significantly related to performance on the Delayed Recall section of the Story Memory subtest. Therefore, Hypothesis 6 was not confirmed. Neither morningness-eveningness scores by time of testing, nor hours of sleep by time of testing related significantly to Story Memory Delayed Recall performance. Thus, Hypotheses 10, 11, and 12 were not supported for this dependent variable.

Table 5g presents the regression analysis predicting performance scores on the Story Memory Recognition subtest.

Table 5g

Story Memory Recognition

Predictor Variables	B-weight	Beta	t	p
Time of Testing	1.627	.304	.76	.449
Morningness-Eveningness X Time of Testing	-.043	-.419	-1.19	.243
Hours of Sleep X Time of Testing	.033	.050	.19	.852
z- SAT	.326	.127	.79	.435

Multiple R = .21, F (4, 40) = .45, p = .770

Time of testing was not significantly related to performance on the Story Memory Recognition subtest. Therefore, Hypothesis 7 was not confirmed. Neither morningness-eveningness scores by time of testing, nor hours of sleep by time of testing related significantly to Story Memory Recognition. Thus, Hypotheses 10, 11, and 12 were not supported for this dependent variable.

Table 5h presents the regression analyses predicting performance scores on the Long-Term Memory Story Recall and Recognition subtests.

Table 5h

Long Term Memory Story Recall

Predictor Variables	B-weight	Beta	t	p
Time of Testing	6.140	.450	1.30	.199
Morningness-Eveningness X Time of Testing	.120	-.449	-1.40	.167
Hours of Sleep X Time of Testing	-.121	-.073	-.32	.754
z-SAT	3.641	4.95	3.70	<.002

Multiple R = .50, F (4, 46) = 3.85, p < .009

Long Term Memory Story Recognition

Predictor Variables	B-weight	Beta	t	p
Time of Testing	.075	.010	.02	.981
Morningness-Eveningness X Time of Testing	.008	.053	.15	.885
Hours of Sleep X Time of Testing	-.073	-.077	-.29	.774
z-SAT	.480	.120	.78	.437

Multiple R = .14, F (4, 46) = .22, p = .924

Time of testing was not significantly related to performance on the Long-Term Memory Story Memory Recognition or Recall subtests. Therefore, Hypothesis 8 was not confirmed. Neither morningness- eveningness scores by time of testing, nor hours of sleep by time of testing related significantly to Long- Term Memory Story Memory Recognition or Recall subtests. Thus, Hypotheses 10, 11, and 12 were not supported for this dependent variable.

Table 5i presents the regression analysis predicting performance scores on the Delayed Recall section of the Sound Symbol subtest.

Table 5i

Sound Symbol Delay

Predictor Variables	B-weight	Beta	t	p
Time of Testing	1.093	.235	.68	.500
Morningness-Eveningness X Time of Testing	-.041	-.450	-1.48	.145
Hours of Sleep X Time of Testing	.013	.023	.01	.922
z-SAT	.959	.410	3.08	<.004

Multiple R = .43, F (4, 50) = 2.83, $p < .04$

Time of testing was not significantly related to performance on the Delayed Recall Section of the Sound Symbol Task. Therefore, Hypothesis 9 was not confirmed. Neither morningness- eveningness scores by time of testing, nor hours of sleep by time of testing related significantly to performance on the Delayed Recall section of the Sound Symbol task. Thus, Hypotheses 10, 11 and 12 were not supported for this dependent variable.

Student Questionnaire Results

Among the 56 participants, 52% reported eating breakfast regularly and 36% report consuming caffeine in the morning. The average amount of sleep on the night prior to the test was 6.5 hours with a standard deviation of 1.41 hours. Reported average wake up time on the mornings of the tests was 7:02 with a standard deviation of 38 minutes. Reported average time of starting sleep was 11:35 p.m.

The academic day at the SPHS consists of 12 periods. Periods 1 (endorsed by 41% of the sample) and 2 (selected by 34% of participants), were most often selected as times when it when it is hard to learn. These periods are the first two academic periods corresponding roughly to 9:00 - 9:50 and 9:52 - 10:32. Periods 5 (endorsed by 37% of participants) and 6 (selected by 46% of the sample) were most often selected as times when participants feel most alert. Periods 5 and 6 roughly correspond to the time between 12:00 and 1:20 when students in the junior and senior classes have lunch.

In a similar vein, periods 1 (chosen by 41% of the sample) and 2 (selected by 30% of the volunteers), as well as periods 7 (endorsed by 35% of the participants) and 8 (selected by 41% of the sample) were selected most often as times when participants feel tired. Periods 7 and 8 are the periods that immediately follow lunch and roughly correspond to the times between 1:20 and 2:40. (Note that the later percentages total more than 100% because students were allowed to select more than one alternative.) Sixty-two percent of participants reported sleeping in class at some point.

CHAPTER 7

DISCUSSION

This study sought to replicate earlier findings of superior short-term memory in the morning, and enhanced long-term memory in the afternoon using high school juniors and seniors. Results of this study, however, did not replicate earlier findings of morning superiority on tasks of short-term memory, and afternoon superiority on tasks of long-term memory. Hypotheses of differential performance at different times of day were not supported. Following are several potential explanations.

The study proposed to assess the effects of time of day on the short- and long-term memory of adolescents enrolled in an early starting time high school. The National Sleep Foundation recommends that high schools start classes at 9 A.M. or later (Dart, 1998). In concert with this idea, Representative Zoe Lofgren, Democrat of California, introduced a proposal to urge schools to start classes after 9 A.M. with grants of up to 25,000 dollars to cover expenses related to the change ("Lawmakers Seek," 1998). A 1996 survey of Minesota students found a sharp improvement in the scholastic grades of 11^{th} and 12^{th} graders who began school after 8 A.M. (Johnson, 1998). In accordance with the idea that 9 A.M. is an acceptable starting time, the selected school for this study had a starting time of 8:00 A.M., which may indeed be too late to be considered an early starting time.

As each testing session took approximately forty minutes, some tasks were not presented until 8:30 in the morning which may have been too late to coincide with low levels of basal arousal and resulted in enhanced short-term memory. Scores on delayed recall tests and long-term memory tasks based on material taught at the 8:00 a.m. testing time did not differ from those based on the 2:00 p.m. testing time, lending further support to the hypothesis that 8:00 a.m. may indeed not be an early starting time that corresponds to low basal level of arousal.

It is interesting to note, however, that earlier research used similar times for testing and in some cases found significant effects for time of day. In his study, of the effect of time of day of instruction on eighth grade students' English and mathematics achievement, Davis (1987) tested pupils during the first period and last period of their school day. Performance on tests of English achievement was significantly better for those tested in the afternoon. In the Davis study the first period of the day corresponded to the time between 8:10 and 9:10 A.M. and the last period of the day corresponded to 1:00 -2:00 P.M.

In a study of time of day effects on school children's immediate and delayed recall of meaningful material (Folkard et al., 1977), the times selected for the presentation of materials were 9:00 A.M. and 3:00 P.M. Information presented at 9:00 A.M. produced superior immediate recall, but inferior delayed recall when compared with the 3:00 presentation.

Other studies tested participants across several times of day. Examples of studies such as these include, Petros et al. (1990) who tested participants at 9:00 A.M., 2:00 P.M. and 8:00 P.M. and compared their performance across times. Similarly, Mitchel and Redman (1992) tested participants at 4 times of day, 1:00 A.M., 7:00 A.M., 1 P.M. and 7:00 P.M.

Individual differences in self-reported optimal time periods were an issue of primary interest in this study. Recent reports in the popular press have implied, if not explicitly stated, that adolescents have a tendency to be evening types who would generally go to bed later and awaken later than people both older and younger than they are. The Self Assessment Questionnaire of Morningness- Eveningness (Horne & Ostberg, 1976) was used to confirm this notion, as well as to see if patterns of performance on tasks of long-term and short-term memory are related to the degree to which individuals classify themselves as morning or evening types, thereby replicating earlier findings (Petros et al., 1990).

In the present study, among the 56 participants, the mean morningness-eveningness score was 46. While cutoff points and classifications were not used in the analysis due to the fact that this scale was normed using adult British individuals, it is important to note that this mean score corresponds to neither morning nor evening type. Indeed, almost 80% of the sample fell into the neither type category. Does the sample used in this study differ from other teenage Americans, or is it truly representative of current optimal time preferences among American teenagers? If these norms are valid for use with American teenagers and the present population is considered a representative sample in this respect, then based on this study the portion of the teenage population who would be most affected by early school starting times would be approximately 20%, and the remaining 80% would either be unaffected, or in the case of the small number of morning types, actually benefit from an early starting time.

If the cutoff points are indeed valid for use with this population, the large subscription to the neither type category could explain the dearth of results in the present study. If most of the participants in this study were indeed neither type, and thus not susceptible to the pattern of biorhythmic fluctuations that morning types and evening types experience that impacts their performance, the fact that there was no significant difference between groups is not surprising. Future researchers should consider studying groups of participants identified as definite morning types and definite evening types and comparing their results on tests of learning and memory.

The size of the sample selected for this study was based on the minimum number necessary to obtain a large effect size. It is possible that time of day of test administration, morningness-eveningness preference, and number of hours of sleep may indeed affect performance on the specified tasks of short- and long-term memory, but the effects may have been too small to detect with the sample size used. Running the study again using the number of participants necessary to detect smaller effect sizes might lead to significant findings.

Student motivation to succeed academically may have been a factor that influenced the results in this study. The sample population consisted of juniors and seniors from higher socioeconomic backgrounds enrolled in a college preparatory high school. These students were used to taking tests, and may have viewed the WRAML as another test where they were expected to do well, and were therefore motivated to do well. The motivational factor may have overridden the time of day effect as students at both times of day may have been highly motivated to succeed. Additionally, student motivation may have been enhanced by the one-to-one nature of the administration of the WRAML. Each student was paired with a tester and the test was administered in a highly interactive manner. It is unlikely under conditions such as these that any student would have fallen asleep or performed in a manner that did not match his or her level of ability. Using a system more analogous to classroom learning in which students are taught and tested in a group may alter the results and allow a time of day effect, if indeed present, to be visible.

The WRAML was selected because it contained short-term and delayed-memory components that were very similar to those utilized in prior research. Dunne et al. (1990) used a series of word lists, with 12 words per list. A free recall format was used where, upon completion of the lists, participants wrote down as many of the words as they could remember. The Verbal Learning subtest is similar to this task in that participants were asked to recall a series of 16 words but differed in that the method of presentation used by Dunne et al. was exposure of items on a video screen for 2 seconds per word while the WRAML words were read out loud by the examiner.

In the study of time of day effects in school children's immediate and delayed recall of meaningful material (Folkard et al, 1977), the story " A New Horse" by Lo Johanson was read to the children. It was recorded on tape and lasted about 12 minutes. Following the presentation of the story, half of the children were given a written questionnaire with 20 multiple choice questions about the story, the other half of the children were given the same questionnaire one week later. Story Memory Recognition is similar to this process, but the stories used were much shorter, taking approximately two minutes to read aloud. Additionally, the method of individual administration with a human examiner recording the responses to each query represented a noteworthy deviation from the way that the Folkard et al. (1977) study was conducted.

In the study of the effects of time of day and subjects' test expectations on recall and recognition of prose materials (Oakhill & Davies, 1989), participants were presented with a series of sentences that they read to themselves and then were asked to write them down. This is similar to the Sentence Memory subtest of the WRAML but differs to the extent that participants read the sentences to themselves and then wrote them as opposed to hearing them and then repeating them. Additionally, whereas in the WRAML participants repeat each sentence immediately after it is presented, in the Oakhill and Davies study, all sentences were recalled at the same time.

Scores on the SAT-1 Reasoning test were significantly correlated with performance on 11 of the 13 WRAML tests administered. This raises the question of whether differences in performance at different times of day found in earlier studies were the result of differences in aptitude or ability between groups as opposed to being a true time of day effect. A review of the literature indicates that this should not be construed as an accurate critique. Oakhill and Davies (1989) and Oakhill (1988) used a process of random assignment, which should in and of itself control for differences in ability that naturally occur in the population.

The current study which used SAT 1 reasoning scores as a measure of aptitude and random assignment found no significant difference in aptitude, as measured by the SAT 1

Reasoning Test, between groups. Additional studies (i.e, Maury and Queinec, 1993; Michel and Redman, 1992) used repeated measures within subjects' designs where each subject served as his/her own control and was tested at more than one time of day. Folkard (1972) utilized a cyclic latin-square design where an equal number of participants had their first session at each of six testing times. This method was also utilized by Monk and Leng (1982) and Folkard and Monk (1980). Petros et al. (1990) had each participant complete the WAIS-R vocabulary test as a measure of ability. Significant differences in performance were found based on time of day in several of these studies. It is difficult to argue that differences in ability was a confounding variable in any of the cited studies. Results of the current study indicate, however, that it would be wise for future researchers to assess, and if necessary, control for participants' ability.

As the timing of the school day is currently an issue of primary interest in many school districts, future research should take the findings and pitfalls of the current study into account. Schools selected for future research should have starting times earlier than 8:00 a.m. It would be of most interest to do similar studies in schools with the earliest possible starting times.

It would also be useful to conduct future studies in a high school where not all students are as motivated to achieve as the students in the present study. Using a system more analogous to a classroom set up where each student's performance isn't observed directly during the testing might also serve to remove the potentially confounding effects that individual administration of a test might have had on highly motivated students.

The quality of the study might also be improved by administering the measures at several points throughout the day, such as 7 a.m., 7:30 a.m., 8 a.m., 8:30 a.m., 9 a.m., etc., to determine which times of day, if any, are best suited for which types of memory tasks. The specific memory tasks used in future studies should be carefully reviewed to make sure that the range of items is large enough to identify small differences resulting from performance at different times of day. Future research should investigate the actual percentage of students who are evening types, and as a result, might be most affected by early school starting times.

Finally, the Self Assessment Questionnaire of Morningness and Eveningness (Horne & Ostberg, 1976) should be validated for use with American teenagers by taking readings of oral temperature at several points throughout the day. The scale should be normed on a sample of American teenagers.

Even though this study did not find significant differences in performance based on time of day, it is of interest to note that students' perceptions of times at which it is difficult to learn reflected the notion that the early morning hours are not the most ideal time for learning at the high school level. Students selected the first two academic periods as the times at which it was most difficult to learn. Self-reported tired times were also reflective of the notion that the first two academic periods as well as the periods right after lunch are times at which students feel most tired.

While hours of sleep did not correlate with any of the performance measures in this study, the reported mean sleep time of 6.5 hours is less than the 8 hours considered adequate for a population of this age. The average sleep starting time of 11:35 reported by these students may be too late to achieve the 8.5 hours of sleep thought necessary. Starting school later is one solution that would enable longer sleeping times. It is unclear based on this study how amount of sleep affects academic achievement. More studies need to be undertaken using both elemental memory tasks as well as controlled classroom-learning materials to investigate the impact that lack of sleep has on classroom performance and academic achievement.

Appendix A

A Self-Assessment Questionnaire to Determine Morningness -Eveningness in Human Circadian Rhythms.

J. A. Horne and O. Ostberg

Instructions:

1. Please read each question very carefully before answering.
2. Answer ALL questions.
3. Answer questions in numerical order.
4. Each question should be answered independently of others. Do not go back and check your answers.
5. All questions have a selection of answers. For each question place an "X" alongside one answer only. Some questions have a scale instead of a selection of answers. Place an "X" at the appropriate point along the scale.
6. Please answer each question as honestly as possible. Both your answers and the results will be kept, in strict confidence.
7. Please feel free to make any comments in the section provided below each question.

The Questionnaire:

1. Considering only your own "feeling best" rhythm, at what time would you get up if you were entirely free to plan your day?

A.M. 5 6 7 8 9 10 11 12 P.M.

2. Considering only your own "feeling best" rhythm, at what time would you go to bed if you were entirely free to plan your own evening?

P.M. 8 9 10 11 12 1 2 3 A.M.

3. If there is a specific time at which you have to get up in the morning, to what extent are you dependent on being woken up by and alarm clock?

A. Not at all dependent
B. Slightly dependent
C. Fairly dependent
D. Very dependent

4. Assuming adequate environmental conditions how easy do you find getting up in the mornings?

A. Not at all easy
B. Not very easy
C. Fairly easy
D. Very easy

5. How alert do you feel during the first half-hour after having woken in the mornings?

A. Not at all alert.
B. Slightly alert.
C. Fairly alert.
D. Very alert.

6. How is your appetite during the first half-hour after having woken in the mornings?

A. Very poor.
B. Fairly poor.
C. Fairly good.
D. Very good.

7. During the first half-hour after having woken in the morning, how tired do you feel?

A. Very tired.
B. Fairly tired.
C. Fairly refreshed.
D. Very refreshed.

8. When you have no commitments the next day at what time do you go to bed compared to your usual bed time?

A. Seldom or never later.
B. Less than one hour later.
C. 1-2 hours later.
D. More than two hours later.

9. You have decided to engage in some physical excersise. A friend suggests that you do this in hour twice a week and the best time for him is between 7.00 -8.00 AM. Bearing in mind nothing else but your own "feeling best" rhythm how do you think you would perform?

A. Would be on good form.
B. Would be on reasonable form.
C. Would find it difficult.
D. Would find it very difficult.

10. At what time in the evening do you feel tired and as a result in need of sleep?

P.M. 8 9 10 11 12 AM 1 2 3

11. You wish to be at your peak performance for a test which you know is going to be mentally exhausting and lasting for two hours. You are entirely free plan your day. Considering only your "feeling best" rhythm which one of the four testing times would you use?

A. 8.00-10.00 A.M.
B. 11.00 A.M.-1.00 P.M.
C. 3.00-5.00 P.M.
D. 7.00-9.00 P.M.

12. If you went to bed at 11.00 P.M. at what level of tiredness would you be?

A. Not at all tired.
B. A little tired.
C. Fairly tired.
D. Very tired.

13. For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which one of the following events are you most likely to experience?

A. Will wake up at usual time and will not fall asleep.
B. Will wake up at usual time and will doze thereafter.
C. Will wake up at usual time but will fall asleep again.
D. Will not wake up until later than usual.

14. One night you have to remain awake between 4.00-6.00 A.M. in order to carry out a night watch. You have no commitments the next day. Which one of the following alternatives will suit you best?

A. Would not go to bed until watch was over.
B. Would take a nap before and sleep after.
C. Would take a good sleep before and a nap after.
D. Would take all sleep before watch.

15. You have to do two hours of hard physical work. You are entirely free to plan your day and considering only your own "feeling best" rhythm which one of the following times would you choose?

A. 8.00-10.00 A.M.
B. 11.00 A.M.-1.00 P.M.
C. 3.00-5.00 P.M.
D. 7.00-9.00 P.M.

16. You have decided to engage in hard physical excersise. A friend suggests that you do this in hour twice a week and the best time for him is between 10.00 -11.00 P.M. Bearing in mind nothing else but your own "feeling best" rhythm how do you think you would perform?

A. Would be on good form.
B. Would be on reasonable form.
C. Would find it difficult.
D. Would find it very difficult.

17. Suppose you can choose your own work hours. Assume that you worked a five hour day (including breaks) and that your job was interesting and paid by results. Which five consecutive hours would you select?

12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
Midnight Noon Midnight

18. At what time of day do you reach your "feeling best" peak?

12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
Midnight Noon Midnight

19. One hears about " morning" and "evening" types of people. Which one of these types do you consider yourself to be?

A. Definitely a "morning" type.
B. Rather more a "morning" type than an "evening" type.
C. Rather more an "evening" type than a "morning" type.
D. Definitely an "evening" type.

Appendix B

STUDENT QUESTIONNAIRE

We are currently conducting a study about adolescent learning at different times of day. We are interested in finding out when you feel that you are most awake and alert, and able to do your best in school. We are therefore asking you to complete the following questionnaire. Your perceptions of how you learn at different times of day are most important. We thank you for participating in this study. **All answers on this form will be kept strictly confidential. Please do not write your name anywhere on this form.** Once again thank you for your cooperation.

1) Age-____ (Male / Female)
Time you start school ________

2) How many hours did you sleep last night? ____

3) At approximately what time did you fall asleep? _____
At approximately what time did you wake up? ________

4) Below you will find a list of numbers corresponding to the periods of your school day. Circle those numbers that represent the periods during which you are most **tired.**
12—1–2–3–4–5–6–7–8–9—10—11

5) Below you will find a list of numbers corresponding to the periods of your school day. Circle the numbers that represent the periods during which you feel most **awake.**
12—1–2–3–4–5–6–7–8–9—10—11

6) Do you ever fall asleep in class? (Yes / No) If you answered yes, during which period(s) are you most likely to fall asleep?________ What subjects are being taught then?_____________

7) Below you will find a list of numbers corresponding to the periods of your school day. Circle the numbers that represent the periods during which you find it **easiest to learn and remember** what is taught (try to base your answer on how you feel, not on whether a subject is easy or hard for you).
12—1–2–3–4–5–6–7–8–9—10—11

8) Below you will find a list of numbers corresponding to the periods of your school day. Circle the numbers that represent the periods during which you find it **hardest to learn and remember** what has been taught. (Try to base your answers on how you feel, not on whether or not a subject is easy or hard for you).
12—1–2–3–4–5–6–7–8–9—10—11

9)Do you regularly eat breakfast? (Yes / No)
Do you regularly drink coffee or some other beverage with caffeine before your first period class? (Yes / No)

Appendix C

Parental Consent Form

THE
GRADUATE SCHOOL
AND
UNIVERSITY CENTER
THE CITY UNIVERSITY OF NEW YORK

PH.D. PROGRAM IN EDUCATIONAL PSYCHOLOGY
33 WEST 42 STREET, NEW YORK, NY 10036-8099
212 642-2251

Approved: 2/22/99
Expires: 2/21/00

Dear HAFTR Parents,

I am writing to you to ask for your help in a study that I am conducting. My Name is Ditza Berger and I am an employee of the HAFTR High School guidance department. I am also a doctoral student in the Educational Psychology department at the Graduate School and University Center of the City University of New York. The study is being privately conducted as part my graduate work, but the administration at HAFTR has been kind enough to allow me to conduct the study here. No other member of the HAFTR high school Guidance Department is involved in this study.

The study that is being conducted is a study of how times of day as a variable affect memory in adolescents enrolled in early starting time high schools. This study is of theoretical as well as of practical interest, since recently the popular press has begun questioning the how early starting time that some schools have adopted affects learning. While HAFTR Students do not begin classes until 9:00 A.M., students are required to be in school at 8:00 A.M. for prayers.

The study deals with how time of day affects memory in adolescents who start school early. Although this study will not help your child, results may be used to aid others in future by determining optimal times for school learning. Students participating in this study will be asked to complete two questionnaires on their sleeping habits and will be given selected subtests of the Wide Range Assessment of Memory and Learning (WRAML). The WRAML is a standardized measure that assesses both short term and delayed memory. Each participant will be tested twice, once at 8:00 A.M. and once at 2:10 P.M., with approximately two months in between each testing. Each testing session will last between 35-40 minutes, so that only one class will be missed. Parents of students who participate will be asked to fill out the "Hollingshead Four Factor Index of Social Status" that accompanies this letter. This information is being requested to provide descriptive information about the sample.
Results of all tests will be kept strictly confidential and will not be released to or shared with the school. All tests will be administered by outside associates of Mrs. Berger who will conduct the testing in school. These associates are advanced Graduate students in the area of School Pscyhology who will be trained and supervised by Mrs. Berger. These associates will have no access to any school records.

Testing will be scheduled at specified times on days that are most convenient of your child. Your child will not be penalized for missing a class. He or she will be provided with all classwork and help necessary to make up the missing class. This study should not pose any risk to your child.

Participation in the study is purely voluntary. You may withdraw your child from the study at any time without penalty. Your child's participation or non-participation will not affect his/ her status at HAFTR in any way. If you agree to have your child participate please complete the appended consent form and questionnaire and return them to the school. If you have any questions regarding the study pleasure feel free to call me at HAFTR at 569-3807. You may also contact my dissertation advisor, Dr. Georgiana Tryon, at the CUNY Graduate Center at (212) 642-2270. If you have any questions regarding your rights as a participant in this study please call Ms. Hillary Fisher at CUNY Graduate Center Sponsored Research at (212) 642-2059.
Sincerely,

Ditza D. Berger

I hereby give my child ____________________________, permission to participate in Mrs. Berger's study on "the effects of time of day on memory in adolescents"

____________________________.
Parent/ Guardian Signature

Appendix D

Student Assent Form

THE
GRADUATE SCHOOL
AND
UNIVERSITY CENTER
THE CITY UNIVERSITY OF NEW YORK

PH.D. PROGRAM IN EDUCATIONAL PSYCHOLOGY
33 WEST 42 STREET, NEW YORK, NY 10036-8099
212 642-2261

Approved: 2/22/99
Expires : 2/21/00

Dear HAFTR Student,

In addition to parental informed consent, participants who are minors are asked for their written assent or agreement to participate in research. Bellow you will find a brief description of the research and what you will be asked to do. Your participation in this study is voluntary and you can withdraw at any time. Participation in a study is usually seen as an excellent opportunity. I can tell you that students who participated in this study previously reported that they really enjoyed it.

The study that is being conducted is a study of how time of day as a variable affects memory in adolescents enrolled in early starting time high schools. Students participating in this study will be asked to complete two questionnaires on their sleeping habits and will be given selected subtests of the Wide Range Assessment of Memory and Learning (WRAML). The WRAML is a standardized measure that assesses both short term and delayed memory. Each participant will be tested twice, once at 8:00 A.M. and once at 2:10 P.M., with approximately two months in between each testing. Each testing session will last between 35-40 minutes, so that only one class will be missed. Participants will be excused form that class. For the early morning testing students will be excused from davening. They will either daven at home prior to coming to school or in the twenty or so minutes that remain before classes start, at the discretion of the individual student. Results of all tests will be kept strictly confidential and will not be released to the school. The testing will be conducted in school by associates from outside of the school. These associates are advanced graduate students in the area of School Psychology who will be trained and supervised by Mrs. Berger. These associates will have no access to any student records. After the testing I will gladly discuss any issues related to the testing and the overall results as they become available.

Testing will be scheduled at specified times on days that are most convenient to you. You will not be penalized for missing a class. You will be provided with all classwork and help necessary to make up the missed class. This study should not pose any risk to you.

The study is being conducted privately as part of a doctoral dissertation by me, Mrs. Berger. I am an employee of the HAFTR High School guidance department, and a doctoral student in the Ph.D. Program in Educational Psychology at the City University of New York Graduate School and University Center of the City University of New York. The study is being conducted as part of Mrs. Berger's graduate work. No other member of the Guidance Department is involved in the study.

Participation in the study is purely voluntary. You may withdraw from the study at any time without penalty. Your participation or non-participation will not affect your at HAFTR in any way. If you agree to participate please complete the appended consent form and questionnaire and return them to the school. If you have any questions regarding the study pleasure feel free to call me at HAFTR at 569-3807. You may also contact my dissertation advisor, Dr. Georgiana Tryon, at the CUNY Graduate Center at (212) 642-2270. If you have any questions regarding your rights as a participant in this study please call Ms. Hillary Fisher at CUNY Graduate Center Sponsored Research at (212) 642-2059.

Sincerely,

Ditza D. Berger

I ____, hereby agree to participate in
Print Name

Mrs. Berger's study on "the effects of time of day on memory in adolescents"

____________________________.
Signature

Appendix E

Intercorrelations of all Variables

		MORNEVEC	CHOLLING	VLI	VLTOTL	STORMEM
TIMETEST	Pearson Correlation	-.011	-.093	167	.172	086
	Sig. (2-tailed)	937	.511	218	.205	528
	N	55	47	56	56	56
AGE	Pearson Correlation	-.143	-.170	361**	161	038
	Sig (2-tailed)	311	269	008	.250	786
	N	52	44	53	53	53
GENDER	Pearson Correlation	-.023	-.099	-.154	-.284*	-.255
	Sig. (2-tailed)	.870	.507	.256	.034	.058
	N	55	47	56	56	56
HRSSLEEP	Pearson Correlation	.133	-.085	-.221	-.196	-.063
	Sig. (2-tailed)	.332	.572	.102	.149	.646
	N	55	47	56	56	56
ZSAT	Pearson Correlation	.188	-.115	417**	.413**	.446**
	Sig. (2-tailed)	.169	.442	.001	.002	.001
	N	55	47	56	56	56
MORNEVEC	Pearson Correlation	1.000	.000	-.089	-.163	.043
	Sig. (2-tailed)	.	.998	.517	.236	.756
	N	55	47	55	55	55
CHOLLING	Pearson Correlation	.000	1.000	.119	.004	.144
	Sig. (2-tailed)	.998	.	427	.980	.336
	N	47	47	47	47	47
VLI	Pearson Correlation	-.089	119	1 000	.732**	434**
	Sig. (2-tailed)	.517	427		.000	001
	N	55	47	56	56	56
VLTOTL	Pearson Correlation	-.163	004	732**	1.000	458**
	Sig. (2-tailed)	236	.980	000		000
	N	55	47	56	56	56
STORMEM	Pearson Correlation	043	144	434**	458**	1 000
	Sig. (2-tailed)	756	336	001	000	
	N	55	47	56	56	56
SS1	Pearson Correlation	-.161	056	389**	.394**	562**
	Sig. (2-tailed)	.240	711	.003	.003	000
	N	55	47	56	56	56
SSTOTAL	Pearson Correlation	-.071	079	346**	428**	581**
	Sig (2-tailed)	605	598	009	001	000
	N	55	47	56	56	56
SENTMEM	Pearson Correlation	-.139	-.125	179	098	137
	Sig. (2-tailed)	311	402	186	471	315
	N	55	47	56	56	56
PICTMEM	Pearson Correlation	063	155	301*	230	344**
	Sig. (2-tailed)	650	297	024	089	009
	N	55	47	56	56	56
VERLDEL	Pearson Correlation	.037	-.026	601**	799**	478**
	Sig. (2-tailed)	790	.865	.000	.000	000
	N	54	46	55	55	55
SSDELAY	Pearson Correlation	-.127	181	.080	.231	376**
	Sig. (2-tailed)	355	223	556	087	004
	N	55	47	56	56	56
STORDEL	Pearson Correlation	036	.091	404**	459**	928**
	Sig. (2-tailed)	.795	.549	.002	.000	.000
	N	54	46	55	55	55
STORRECO	Pearson Correlation	-.181	-.107	010	049	612**
	Sig. (2-tailed)	.233	528	.946	752	000
	N	45	37	45	45	45
LTMRECAL	Pearson Correlation	-.048	172	481**	507**	867**
	Sig. (2-tailed)	.740	264	000	000	000
	N	51	44	52	52	52
LTMRECOG	Pearson Correlation	029	.181	298*	.300*	622**
	Sig. (2-tailed)	838	.241	032	.030	000
	N	51	44	52	52	52

		MORNEVEC	CHOLLING	VLI	VLTOTL	STORMEM
TIMETEST	Pearson Correlation	-.011	-.098	167	172	086
	Sig. (2-tailed)	937	.511	218	205	528
	N	55	47	56	56	56
AGE	Pearson Correlation	-.143	-.170	361**	161	038
	Sig. (2-tailed)	311	269	008	.250	786
	N	52	44	53	53	53
GENDER	Pearson Correlation	-.023	-.099	-.154	-.284*	-.255
	Sig. (2-tailed)	.870	.507	256	.034	058
	N	55	47	56	56	56
HRSSLEEP	Pearson Correlation	.133	-.085	-.221	-.196	-.063
	Sig. (2-tailed)	332	.572	102	.148	646
	N	55	47	56	56	56
ZSAT	Pearson Correlation	.188	-.115	417**	.413**	446**
	Sig. (2-tailed)	.169	.442	.001	.002	.001
	N	55	47	56	56	56
MORNEVEC	Pearson Correlation	1.000	000	-.089	-.163	.043
	Sig. (2-tailed)		998	517	.236	.756
	N	55	47	55	55	55
CHOLLING	Pearson Correlation	000	1.000	119	.004	144
	Sig. (2-tailed)	998		427	.980	336
	N	47	47	47	47	47
VLI	Pearson Correlation	-.089	119	1.000	732**	434**
	Sig. (2-tailed)	517	427		000	001
	N	55	47	56	56	56
VLTOTL	Pearson Correlation	-.163	004	732**	1.000	458**
	Sig. (2-tailed)	236	380	000		000
	N	55	47	56	56	56
STORMEM	Pearson Correlation	043	144	434**	458**	1.000
	Sig. (2-tailed)	756	336	001	000	
	N	55	47	56	56	56
SST	Pearson Correlation	-.161	056	389**	394**	562**
	Sig. (2-tailed)	240	711	003	003	000
	N	55	47	56	56	56
SSTOTAL	Pearson Correlation	-.071	079	346**	429**	581**
	Sig. (2-tailed)	605	598	009	001	000
	N	55	47	56	56	56
SENTMEM	Pearson Correlation	-.139	-.125	179	098	137
	Sig. (2-tailed)	311	402	186	471	315
	N	55	47	56	56	56
PICTMEM	Pearson Correlation	063	155	301*	230	344**
	Sig. (2-tailed)	650	297	024	089	009
	N	55	47	56	56	56
VERLDEL	Pearson Correlation	037	-.026	601**	799**	478**
	Sig. (2-tailed)	790	865	000	000	000
	N	54	46	55	55	55
SSDELAY	Pearson Correlation	-.127	181	080	231	376**
	Sig. (2-tailed)	355	223	556	087	004
	N	55	47	56	56	56
STORDEL	Pearson Correlation	036	091	404**	459**	328**
	Sig. (2-tailed)	795	549	002	000	000
	N	54	46	55	55	55
STORRECO	Pearson Correlation	-.181	-.107	010	049	612**
	Sig. (2-tailed)	233	528	946	752	000
	N	45	37	45	45	45
LTMRECAL	Pearson Correlation	-.048	[illegible]	481**	507**	[illegible]
	Sig. (2-tailed)	740	264	000	000	000
	N	51	44	52	52	52
LTMRECOG	Pearson Correlation	029	181	298*	300*	622**
	Sig. (2-tailed)	838	241	032	030	000
	N	51	44	52	52	52

		SS1	SSTOTAL	SENTMEM	PICTMEM	VERLDEL	SSDELAY
TIMETEST	Pearson Correlation	-049	-129	143	154	228	-085
	Sig. (2-tailed)	720	345	294	257	094	533
	N	56	56	56	56	55	56
AGE	Pearson Correlation	142	071	-110	-020	102	-104
	Sig. (2-tailed)	311	611	434	889	470	457
	N	53	53	53	53	52	53
GENDER	Pearson Correlation	-254	-272*	097	-078	-172	-106
	Sig. (2-tailed)	059	042	479	569	209	436
	N	56	56	56	56	55	56
HRSSLEEP	Pearson Correlation	-082	-098	-105	-120	-.151	-107
	Sig. (2-tailed)	546	474	441	379	270	431
	N	56	56	56	56	55	56
ZSAT	Pearson Correlation	372**	.377**	383**	389**	499**	363**
	Sig. (2-tailed)	005	004	004	003	000	006
	N	56	56	56	56	55	56
MORNEVEC	Pearson Correlation	-161	-071	-139	063	037	-127
	Sig. (2-tailed)	240	605	311	650	790	355
	N	55	55	55	55	54	55
CHOLLING	Pearson Correlation	056	079	-125	155	-026	181
	Sig. (2-tailed)	711	598	402	297	865	223
	N	47	47	47	47	46	47
VLI	Pearson Correlation	389**	346**	179	301*	501**	080
	Sig. (2-tailed)	003	009	186	024	000	556
	N	56	56	56	56	55	56
VLTOTL	Pearson Correlation	394**	428**	098	230	799**	231
	Sig. (2-tailed)	003	001	471	089	000	087
	N	56	56	56	56	55	56
STORMEM	Pearson Correlation	582**	581**	137	344**	478**	376**
	Sig. (2-tailed)	000	000	315	009	000	004
	N	56	56	56	56	55	56
SS1	Pearson Correlation	1 000	373**	288*	412**	472**	514**
	Sig. (2-tailed)		000	031	002	000	000
	N	56	56	56	56	55	56
SSTOTAL	Pearson Correlation	373**	1 000	254	442**	498**	593**
	Sig. (2-tailed)	000		059	001	000	000
	N	56	56	56	56	55	56
SENTMEM	Pearson Correlation	288*	254	1 000	227	172	394**
	Sig. (2-tailed)	031	059		092	209	003
	N	56	56	56	56	55	56
PICTMEM	Pearson Correlation	412**	442**	227	1 000	471**	247
	Sig. (2-tailed)	002	001	092		000	066
	N	56	56	56	56	55	56
VERLDEL	Pearson Correlation	472**	498**	172	471**	1 000	339*
	Sig. (2-tailed)	000	000	209	000		011
	N	55	55	55	55	55	55
SSDELAY	Pearson Correlation	514**	593**	394**	247	339*	1 000
	Sig. (2-tailed)	000	000	003	066	011	
	N	56	56	56	56	55	56
STORDEL	Pearson Correlation	539**	540**	096	237	424**	343*
	Sig. (2-tailed)	000	000	487	082	001	010
	N	55	55	55	55	54	55
STORRECO	Pearson Correlation	227	298*	064	119	039	140
	Sig. (2-tailed)	134	047	674	435	800	358
	N	45	45	45	45	44	45
LTMRECAL	Pearson Correlation	434**	462**	085	345*	506**	[illegible]
	Sig. (2-tailed)	001	001	548	012	000	053
	N	52	52	52	52	51	52
LTMRECOG	Pearson Correlation	247	347*	155	194	263	156
	Sig. (2-tailed)	078	012	272	169	063	268
	N	52	52	52	52	51	52

		STORDEL	STORRECO	LTMRECAL	LTMRECOG
TIMETEST	Pearson Correlation	148	-012	015	002
	Sig. (2-tailed)	286	936	916	991
	N	55	45	52	52
AGE	Pearson Correlation	-010	029	093	-038
	Sig. (2-tailed)	944	853	525	794
	N	52	44	49	49
GENDER	Pearson Correlation	-363**	004	-195	-214
	Sig. (2-tailed)	006	979	166	127
	N	55	45	52	52
HRSSLEEP	Pearson Correlation	-060	-010	-133	-091
	Sig. (2-tailed)	664	950	346	520
	N	55	45	52	52
ZSAT	Pearson Correlation	412**	094	419**	121
	Sig. (2-tailed)	002	540	002	392
	N	55	45	52	52
MORNEVEC	Pearson Correlation	036	-181	-048	029
	Sig. (2-tailed)	796	233	740	838
	N	54	45	51	51
CHOLLING	Pearson Correlation	091	-107	172	181
	Sig. (2-tailed)	549	528	264	241
	N	46	37	44	44
VCI	Pearson Correlation	404**	010	481**	298*
	Sig. (2-tailed)	002	946	000	032
	N	55	45	52	52
VLTOTL	Pearson Correlation	459**	049	507**	300*
	Sig. (2-tailed)	000	752	000	030
	N	55	45	52	52
STORMEM	Pearson Correlation	928**	512**	367**	522**
	Sig. (2-tailed)	000	000	000	000
	N	55	45	52	52
SS1	Pearson Correlation	539**	227	434**	247
	Sig. (2-tailed)	000	134	001	078
	N	55	45	52	52
SSTOTAL	Pearson Correlation	540**	293*	462**	347*
	Sig. (2-tailed)	000	047	001	012
	N	55	45	52	52
SENTMEM	Pearson Correlation	096	084	085	155
	Sig. (2-tailed)	487	574	548	272
	N	55	45	52	52
PICTMEM	Pearson Correlation	237	119	345*	194
	Sig. (2-tailed)	082	435	012	169
	N	55	45	52	52
VERBDEL	Pearson Correlation	424**	039	506**	263
	Sig. (2-tailed)	001	800	000	063
	N	54	44	51	51
SSDELAY	Pearson Correlation	343*	140	270	155
	Sig. (2-tailed)	010	358	053	268
	N	55	45	52	52
STORDEL	Pearson Correlation	1 000	589**	346**	538**
	Sig. (2-tailed)		000	000	000
	N	55	44	51	51
STORRECO	Pearson Correlation	589**	1 000	597**	589**
	Sig. (2-tailed)	000		000	000
	N	44	45	41	41
LTMRECAL	Pearson Correlation	346**	597**	1 000	584**
	Sig. (2-tailed)	000	000		000
	N	51	41	52	52
LTMRECOG	Pearson Correlation	588**	589**	584**	1 000
	Sig. (2-tailed)	000	000	000	
	N	51	41	52	52

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

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