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Time of Day and Age Differences in the Components of Working Memory

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This Dissertation submitted by Maureen J. Winger in partial fulfillment of the requirements for the Degree of Doctor of Philosophy from the University of North Dakota has been read by the Faculty Advisory Committee under whom the work has been done, and is hereby approved.

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This Dissertation meets the standards for appearance and conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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ABSTRACT

The present study examined the effects of time of day on short-term memory efficiency in older and younger adults. Forty-five young (18-35 years of age) and thirty- six older (over 60 years of age) adults were selected for participation. Subjects were tested individually at 0900 hrs, 1400 hrs or 2000 hrs. Two measures of memory scanning and three measures of memory span were employed. Memory scan measures required subjects to scan working memory for sets of 2, 3, or 4 digits or words. Memory span measures included digit span, word span, and sentence span. The digit and word span measures were the largest list of digits or words the subject could repeat without error. The sentence span measure required the subject to read sentences aloud and remember the last word in each sentence. Sentence span was considered the largest set of "last words" the subject was able to repeat in order.

Results revealed no effect of time of day or age on slopes for word scanning. Analysis of the digit scanning task revealed that slopes decreased across time of day, indicating that subjects scanned working memory faster when tested at 2000 hrs than at either 1400 hrs or 0900 hrs. Results of the memory span analysis revealed no effects on digit span. However, younger adults had larger word spans and sentence spans than older adults. The present results replicate previous work indicating that the rate of memory

scanning for digits improves across time of day (Anderson et al., 1988). No effects were observed when words were used as stimulus materials. The absence of any age differences in memory scanning is inconsistent with previous research (Salthouse & Somberg, 1982) suggesting that a larger number of subjects should be tested to examine this result further. The age differences in memory span observed in the present study are consistent with Light and Anderson (1985) suggesting that working memory processes are less efficient in older adults. The lack of any interaction between age and time of day suggests that circadian variations do not differentially affect younger and older adults.

INTRODUCTION

Aging and Memory With the trend in the United States today of the average American living into his/her seventh decade, the process of human aging has become a popular, and relevant topic for the general public as well as for scientific researchers. There are a host of physical changes (Botwinick, 1978) and cognitive changes (Salthouse, 1982) associated with the aging process. The purpose of the present study is to examine cognitive changes, specifically memory processes in younger and older adults. The time of day at which a subject is tested is another factor that has been determined to modulate memory processing in younger adults (Folkard & Monk, 1980; Tilley & Warren, 1983). Therefore, the second purpose of this study is to examine if time of day effects will modulate the degree of age differences in memory performance observed. A broad range of research addressing the aspects of memory skills which are affected by age and time of day will be reviewed followed by an explanation of the present study.

Typical approaches to the study of memory work from a three stage theory, which includes encoding, storage and retrieval of information (Atkinson & Shiffrin, 1968). Using this approach researchers attempted to determine if age differences in memory processes were due to differences in any specific stage of the memory process or if the deficits were uniformly apparent across all three stages. Early work in the cognitive aging area sought to examine whether age differences in memory performance were primarily localized at the encoding stage or the retrieval stage. One method of examining this issue is to compare age differences in performance on recall tasks with performance on recognition tasks. The assumption is that a recognition task places only minimal retrieval demands on the subject, and a recall task places heavy retrieval demands. The encoding demands are similar for both types of tasks. Therefore, if age differences in memory performance are a function of the cognitive demands placed on the subject (Craik & Simon, 1980) then greater age differences should be observed in the recall task than the recognition task.

Schoenfield and Robertson (1966) examined adult age differences in memory performance by comparing recall performance with recognition performance. The subjects were adults between the ages of 20 and 75. Researchers divided the subjects into five age groups (20-30, 31-40, 41-50, 51-60 and 61-75). Each subject was presented a list of 24 words with each word presented for a four second duration. Each list consisted of eight words of high frequency, eight words of medium frequency and eight words of low frequency. Immediately following presentation of the list, subjects were given either a recall or recognition test on the materials. The recall test involved reporting as many words as the words as the subject could remember, in any order. The recognition test required the subject to choose the target word (previously presented in the word list) from a group of five alternatives. Results of this study indicated no age differences in the recognition task, while a steady decline in performance with age was observed on the recall task. The researchers suggested that differences in performance were due to differences in retrieval rather than encoding since presentation in both cases was identical.

Erber (1974) also examined age differences in memory for word lists by utilizing recall versus recognition tasks. Erber, however, suggested that the absence of performance differences between young and old adults on recognition tasks was due to the relative ease of the recognition task used by Schoenfield and Robertson (1966) rather than fundamental differences in retrieval of material. Erber proposed that the use of only high frequency words would serve to make a recognition task as difficult as a recall task. That is, high frequency words are encountered daily and thus, interference would make the task more difficult. Therefore, she presented subjects with one list of 24 (short list) and one list of 60 (long list) high frequency words. Each word was presented for four seconds. The recall task consisted of naming as many words from each list as possible, in any order. The recognition task required the subject to choose the target word from a list of five alternatives. The results of this study indicated that age differences were present for recognition as well as recall performance on both short and long word lists. However, age differences were smaller for recognition than for recall performance. These results are not consistent with the results of Schoenfield and Robertson (1966); rather, Erber's results indicated that both recall and recognition abilities deteriorate with age.

Recall memory for word lists has often been evaluated in terms of the serial position effect. The serial position effect is a well documented effect which reflects recall performance of subjects on tasks like free recall of word lists. Specifically, subjects consistently recall items at the beginning of the list (the primacy effect) and those at the end of the list (the recency effect) while individuals perform more poorly on recall from the middle portion of the list. High recall of items presented at the beginning of a list, that is the primacy effect, is generally thought to reflect effective rehearsal processing of information in working memory (Brodie & Prytulak, 1975). The assumption is that these items would be transferred from short-term to long-term memory during the encoding process to make room for incoming items. High recall of later items on a list, the recency effect, is thought to result from accurate retrieval from short-term memory as these items would have been most recently entered into memory and therefore are accessible from short-term memory (Brodie & Prytulak, 1975). The serial position effect has been used to evaluate

Salthouse (1980) examined the effects of rehearsal on recall of word lists in young and old adults. Salthouse suggested that if older adults are slower at rehearsal of materials, then increasing the number of syllables per word, which results in slower rehearsal, should mimic the effects of age differences in rehearsal processes. Subjects were presented with five lists of twelve high-frequency words, with each list consisting of one- and three-syllable words. Words were presented for 1.5 seconds with a 2- second interval between each word presentation. The speed of rehearsal was indirectly estimated by asking the subject to rehearse the words once, twice or three times during the two second interval. Results of this study indicated that younger adults recalled more than older adults, but both groups showed a similar pattern of serial position effects. The data also indicated that both age and syllable increases had the effect of decreasing performance across the entire list. In addition, older subjects had slower rehearsal times than younger subjects using the indirect measure of rehearsal time. Based on these results, Salthouse suggested that older subjects perform more poorly on memory tasks due to slower rehearsal speed.

Wright (1982) also investigated rehearsal speed as a possible source of age differences in memory tasks. Wright's analysis was based, in part, on the results of the Salthouse

(1980) study which used 10 lists of 12 high frequency words as the stimulus materials. Results of Wright's analysis revealed that younger subjects were able to recall more words than older subjects and the pattern of the serial position effect did not differentiate between the young and older subjects. Thus, for both age groups, the primacy effect decreased from the first to the last list, while the recency effect increased from the first to the last list. In addition, Wright found that later in the session, items from the end of the list were recalled earlier in the subjects' recall while items from the beginning of the list were stated later in the recall sequence. These results suggested that while the primacy and recency effect are evident for both young and older adults, overall performance on this task decreases with age.

In addition to the examination of age differences in recall of word lists, recent work has also examined adult age differences in prose recall. Research in the area of recall of prose material has suggested that individuals recall the main ideas of a passage and forget the non-essential details (Brown & Smiley, 1977). This result is referred to as the "levels effect." This paradigm assumes that subjects are able to make use of the hierarchical organization of a story to recall the main concepts and use them to build a coherent representation of the passage. If individuals are unable to recall more main ideas than details, this deficit in the use of organizational strategies may, in part, account for impaired memory performance.

Meyer and Rice (1981) examined age differences in recall of prose passages to determine whether the "levels effect" would be found in older adults. Young, middle age, and older age adults were used as subjects. Subjects read a 641 word passage and were subsequently asked to recall the passage, fill in a partially completed outline which referred to main idea in the text, and finally, to answer questions dealing with main ideas or details from the text. Results of this study indicated that all three age groups recalled the high important material in the story better than the low important material. However, young adults remembered more of the main ideas than older adults while the older adults remembered more of the non-essential details than younger adults.

A further investigation in this area was undertaken by Petros, Tabor, Cooney and Chabot (1983). Young and old adults of both high and low education were presented with passages at either a fast or slow rate of presentation. The premise of manipulating rate of presentation was to increase demands on the processing capacity of the subjects. Since prose processing requires rapid encoding while at the same time manipulating incoming information in working memory, speed of encoding is an essential component of effective memory performance (Kintsch & van Dijk, 1978). If older adults are slower at these memory processes (Salthouse, 1980) then increasing the rate of presentation should have the effect of emphasizing age deficits. Subjects listened to two narrative passages at a slow rate of presentation (120 words per minute). Immediately following passage presentation, subjects were asked to recall the story. The results indicated that younger adults recalled more idea units than older adults and all subjects favored the main ideas in their recalls. The second portion of this study varied the rate of presentation (120 words per minute versus 160 words per minute) and passage difficulty (7th-8th grade readability versus 9th-10th grade readability). Results indicated once again, that all subjects favored the main ideas in their recalls. In addition, age differences in performance were larger for difficult passages than for easy passages, but no effects of speed of presentation were revealed. These results were not consistent with Meyer and Rice (1981) who found age differences in sensitivity to hierarchical text structure.

The studies discussed previously regarding age differences in prose recall neglected to control for the verbal ability of the subjects tested. Verbal ability has been suggested as a possible source of individual differences in prose memory in several studies. Efficient comprehension of prose material requires the ability to encode incoming information quickly while at the same time manipulating information already existing in the short-term memory store (Perfetti & Lesgold, 1977). Individual differences in the efficiency of specific components of prose processing result in subsequent performance differences.

Zelinski, Light and Gilewski (1984) investigated this inconsistency in age differences in memory for prose. In a series of experiments, the effects of age on sensitivity to thematic importance were examined. The education level of young and old adult subjects was manipulated along with passage difficulty. Both immediate and delayed recall performance were measured. The results indicated that both young and old adults favored the main ideas in their recalls. Older adults recalled less information than younger adults overall, regardless of educational level; however, there were no age differences in sensivitity to text organization. These results are consistent with Petros, Tabor, Cooney, & Chabot (1983) which found no age differences in the pattern of the "levels effect." However, they were inconsistent with Meyer and Rice (1981) who did observe these differences.

A study by Hartley (1986) also examined age differences in recall of prose material as mediated by text characteristics (narrative or expository passages) and learner characteristics (verbal ability). When recalling from expository discourse, the reader can use prior knowledge on a given topic to "fill in the gaps." Therefore, it was hypothesized that the recall of older adults would benefit from the expository genre and be at a disadvantage with narrative passages. In addition, older adults, slower in lexical access, semantic access, and working memory were also hypothesized to exhibit differential recall based on verbal ability. Low verbal individuals are slower in lexical access and working memory (Hunt, 1975). Hartley hypothesized that age differences may be magnified for low verbal individuals. Young students (18-28 years of age), older students (61-75 years of age), and older adults in the community (63-75 years of age) were presented with two narrative and two expository passages and asked to recall them immediately afterwards. In addition, subjects were tested on six cognitive skills assumed to be components of effective discourse memory such as: vocabulary and abstract reasoning, reading comprehension, word-name retrieval, semantic verification, and reading span. Discourse memory was measured by asking subjects to read two narrative and two expository passages from a computer screen one sentence at a time. Reading times were recorded by the computer and subjects were asked to write their recall of each passage. The Shipley-Hartford Scale (Shipley, 1940) was given to each subject as a measure of vocabulary and abstract reasoning. Reading comprehension was assessed using the first half of form 1B of the Davis Reading test (Davis, 1944). This test consists of several short passages with multiple-choice questions following each passage. Word-name retrieval, a measure of lexical access speed, was examined with a word-naming task in which the subject was required to name a printed word as quickly as possible. Speed of semantic access was examined using a semantic verification task. The stimulus materials were 32 simple statements which contained either property or category relations. An example of a property statement is "a volcano has lava" and an example of a category statement is "an uncle is a relative." The subject's task was to respond as quickly as possible as to whether the proposed statement was true or false. Finally, reading span, which was used as a measure of working memory capacity, was assessed by the reading span measure described by Daneman and Carpenter (1980). In this task, subjects were asked to read sets of sentences at their own rate and after the last sentence was read, the subject was to recall the last word of each sentence in order. The sets differed in that they initially contained two sentences and then increased in length to three, four and five sentences. Reading span was defined as the largest reading span level the subject recalled correctly on two of the three sets presented at each level.

Results indicated that older subjects recalled less from the passage than younger subjects; however, there was no evidence of differences in recall of narrative versus expository text. In addition, young subjects were found to perform better than older adults on three of the seven cognitive skills assumed to be components of prose processing (word-naming, reading comprehension and abstract reasoning). No age differences were found in semantic verification, reading span, reading comprehension, or vocabulary. Results of this study suggest that age differences in some of the basic cognitive skills related to reading effectiveness may underlie the age differences in memory which have been revealed in some studies. However, age differences in prose memory were still found after each of these components had been statistically removed from the prose recall data. This suggests that age differences in the efficiency of executing the components of prose processing cannot totally account for the age differences observed.

Dixon, Hultsch, Simon and Von Eye (1984) attempted to clarify the discrepancies found in previous studies regarding the age differences in sensitivity to the "levels effect." These researchers suggested that verbal ability may be the factor involved in the observed differences. Previous research suggested that age differences are greater for non-essential details of well structured (narrative) texts (Petros, Tabor, Cooney & Chabot, 1983) while age differences are more pronounced for main ideas in less structured (expository) texts (Meyer & Rice, 1981). In addition, younger adults are able to recall the same number of main ideas of texts regardless of the number of concepts presented in the text (Kintsch, Kozminsky, Streby, McKoon, & Keenan, 1975), while the Dixon et al. (1984) hypothesized that older adults recall more main ideas when the text contains fewer concepts. Therefore, Dixon et al. (1984) utilized well structured texts and varied the number of concepts. This manipulation was expected to increase processing time with increases in the number of concepts and thus, was expected to be detrimental to older subjects' sensitivity to main ideas. Results of this study indicated an overall decline of recall in older subjects. In addition, for low verbal subjects, larger age differences were found for the main ideas of the passages than for non- essential details, while for high verbal subjects, larger age differences were found for non-essential details than main ideas. Regarding the manipulation of the number of concepts, older subjects recalled more of the main ideas when fewer concepts were presented and recalled more of the non-essential details for texts containing many concepts. For young adults however, recall of the main ideas was unaffected by the number of concepts in the text. These results suggest that verbal ability as well as text difficulty mediates the age deficits observed in memory performance.

The literature on aging and memory does not consistently support a clear mechanism that would underlie age deficits in performance. Research using recall of word lists suggests that while younger adults generally recall more than older adults, the pattern of the serial posit'. effect is similar in both age groups. Also, research on prose memory suggests that young adults recall more than older adults but that the pattern of the levels effect is not consistently different as a function of age. Therefore, the pattern of information processing appears similar in both age groups. However, Birren (1974) suggested that the central nervous system deterioration in older adults results in a slower rate of cognitive operations. This cognitive slowing may result in slower decision making and in this way account for the differences in performance among young and older adults.

In a related vein, Salthouse (1980) also suggested a "cognitive slowing" hypothesis to explain the age differences in word list and prose memory. He suggested that older adults process incoming material at a slower rate than younger adults. Since the capacity of working memory is limited, this slower rate of processing results in less available space for processing each item of incoming information. Perfetti and Lesgold (1977) hypothesize that a slower rate of processing creates a "bottleneck" in which short-term memory is unable to keep up with the coding demands placed on it. When an individual falls behind in coding the incoming information in a text, he/she will in turn, revert to a less efficient method of coding which results in the loss of information, and eventually, the individual will fail to comprehend some of the material. In addition to the speed of short-term memory operations, the "cognitive slowing" hypothesis also has implications for long-term memory access. Birren (1974) hypothesized a generalized slowing of mental operations with increasing age. This slowing should be observed in access to long-term memory stores as well as to ongoing short-term memory processing. Several recent studies have been conducted to examine the possibility of a "cognitive slowing" in older adults. These studies have focused on the retrieval of information from long-term memory and the speed of manipulating information in short- term memory.

For example, Bowles and Poon (1981) examined adult age differences in speed of lexical access, or accessing word names from long-term memory. Previous work with young adults has indicated that lexical access time increases with decreases in the frequency of words (Forester & Chambers, 1973). Bowles and Poon (1981) presented subjects with pairs of letter strings that consisted of either two words, two nonwords, or one word and one nonword (N) and asked to decide if both letter strings were real words. Words were of either high (H) or low (L) frequency (Kuchera & Francis, 1967). The stimulus lists consisted of 120 pairs of stimuli, with 20 pairs each of the six possible combinations: H-H, H-L, L-L, H-N, L-N, or N-N. Subjects made their responses by removing their fingers from one of two response keys. If aging results in a slowing of lexical access, then the size of the age differences observed should have increased for low frequent words (Bowles & Poon, 1981).

Slower age related behavior in terms of physical reaction time is well documented in the literature. Bowles and Poon (1981) attempted to account for this physical slowing in order to ascertain an accurate measure of pure lexical access speed. Therefore, subjects were presented with 50 additional trials to establish an estimate of each subjects sensorimotor reaction time. In the pure reaction time trials, subjects moved their fingers off either an upper or lower key depending upon whether the word "upper" or "lower" appeared on the screen. This sensorimotor reaction time was then subtracted out of the response times for lexical decisions. Results indicated that older subjects had slower response times than younger subjects. In addition, the slowest responses were observed for the L- N pairing, followed by the H-N, N-N, L-L, H-L and finally the H-H stimulus pairs. The largest age differences were noted in response times for L-N pairs, followed by H-N and N-N pairs. The remaining stimulus pairs (L-L, H-L, H-H) reflected no significant age differences in response times. More importantly, the interaction of age and word frequency was not significant. Therefore, Bowles and Poon (1981) concluded that age differences in the speed of lexical decisions were due to factors outside of the stage of lexical access.

Cerella and Fozard (1984) also attempted to examine age differences in lexical access by utilizing a pure measure of lexical access. These researchers suggested that there are three stages of word perception: encoding, lexical access, and vocalization. Two tasks were used in this study to examine retrieval time based on this three stage theory. The first task involved naming a target word aloud as it appeared on the screen. This task was assumed to require the use of all three stages of word recognition: encoding, lexical access, and vocalization. In the second task a target word appeared on the screen for 500 msec, and the subject named the word after it disappeared from the screen. The response times from this task were assumed to reflect the simple motor time to complete the task as lexical access was assumed to occur during the time the word appeared on the screen. By subtracting the response times of the second task from the first, Cerella and Fozard (1984) assumed that a pure measure of lexical access was obtained. Results of this study indicated that while there was a significant age related slowing in word-naming response, no age differences in pure lexical access speed were revealed. That is, age differences were no longer observed after the motor response times were subtracted from the original word naming times. One limitation of these findings was that subjects only had 500 msec to access the word name in the task used to measure simple motor response time. However, previous work suggests that word naming takes longer than 500 msec in older adults.

Therefore, the task designed to measure simple motor response time may reflect lexical access time as well for some subjects.

Byrd (1984) examined age differences in the speed of categorical decision making which, like lexical access, is a measure of the speed of long-term memory retrieval. Young and older adults were presented two category access tasks. The first required the subject to respond to a pair of stimuli by deciding whether the second word in the pair was an example of the category named by the first word in the pair (e.g. Fruit: Apple). The second task required the subject to generate an example from the category presented by the first word when provided with the first letter to start out the example word (e.g. Fruit: A). Subjects were presented four blocks of each type of task (12 trials per block for the decision task and 6 trials per block for the example generation task). Subjects were then presented with a mixed trials condition composed of a random combination of both types of tasks. Results of this study indicated that on both types of tasks, older subjects responded more slowly than younger subjects. In addition, both younger and older subjects had longer response latencies in the mixed trials condition than the blocked trials condition, and longer response latencies to the example generation task than the decision task. Of primary interest was a significant interaction between age, type of block (mixed vs. blocked trials), and the type of task (generation vs. decision). Younger subjects produced faster example generation responses in the blocked trial condition than older adults, but example generation times in the mixed block condition did not significantly differ between younger and older adults. Also, response times in the decision task (first task) did not significantly differ in younger and older adults in either the blocked or mixed condition. It appeared that the blocking factor facilitated responses for younger subjects but did not affect response speed for older subjects. The authors suggested that younger subjects appear to be better able to utilize supplemental information (i.e., the blocked condition) to reduce retrieval time from semantic memory.

In part two of this study, younger and older subjects were presented with a category name paired with a category exemplar (Fruit: Apple) and required to decide if the word on the right was a member of the category named on the left. The category names were often repeated with either zero, one, or two category names between the first and second time a specific category was mentioned. These intervening items were comprised of category exemplar pairs in which the exemplar was an incorrect example of the category. An example of a series with one distractor item is: Fruit: Apple, Furniture: Bear, Fruit: Orange. The purpose of the intervening distractor task was to eliminate the "priming effect" observed with the second presentation of the same category. If the subject was "primed", a shorter response latency on the second category response should be observed. That is, in responding to two successive stimuli from the same semantic category one can utilize automatic processing strategies because the information required to make a response is readily available. The author assumed that the distractor task would serve to eliminate this priming effect.

Results indicated that younger subjects had faster reaction times than older adults. Also, for both older and younger subjects, response times on the second presentation were faster when no intervening items were present. There was no difference in response times with one versus two intervening items. Thus, while an overall age decrement was observed in the ability to retrieve information from semantic memory, this decrement was not due to the ability to use automatized information retrieval processes as evidenced by no difference in the priming effect in experiment two. When the task involved simple retrieval of previously learned and stored information, there was no difference between younger and older adults. However, when the task involved manipulation as well as retrieval of stored information (experiment one), age differences were observed. Therefore, Byrd postulated that the age differences in semantic memory retrieval are the result of differences in "effortful" tasks rather than "automatic" tasks (Hasher & Zacks, 1979). That is, no age differences were present in the second experiment which relied on an automatic priming process while age differences did exist with the effortful processing required in experiment one. It appears that younger subjects are better able to make use of the internal activity of effortful processing while older subjects are less able to do so.

Petros, Zehr and Chabot (1983) also examined age differences in the speed of accessing information from long-term memory by examining age differences in word encoding, lexical access, and semantic memory access. Subjects viewed two words simultaneously and were asked to make one of three decisions: whether the words were physically identical (DOG: DOG), had the same name (DOG: dog), or were from the same semantic category (DOG: CAT). Within each decision type, one-half of the examples were highly typical examples of the category and one-half were less typical examples of the category. Previous work with young adults indicated that response times were longest when making semantic category decisions, followed by same name decisions, with the shortest latencies observed for physically identical decisions (Rosch, 1975). Each subject was presented three blocks consisting of 35 trials (20 positive and 15 negative trials) of the same type of decision. Subjects were informed prior to each block which type of decision they were required to make and were asked to press the appropriate key to respond as to whether the trial was a positive or negative example of the decision type. Results indicated that young adults responded faster than older adults. The size of the age difference was greatest for semantic decisions, suggesting that age differences in memory access time increase with more difficult tasks. Furthermore, the authors suggested that slower memory access time may limit the processing resources available in working memory for older adults.

A follow-up to the study by Petros, Zehr, and Chabot (1983) was conducted by Madden (1985) using the same types of tasks. Madden felt that a limitation of the study by Petros et al. (1983) was that the type of task instructions varied across experimental conditions, which may have resulted in comparison and decision processes rather than pure memory retrieval. Therefore, Madden attempted to isolate pure retrieval time by eliminating comparison and decision processes. This was accomplished by presenting word pairs that were physically identical (BUTTON: BUTTON), had the same word in a different typeface (COPY: copy), or were synonyms in a different typeface (TARGET: goal). The decision for all three types of tasks remained constant: that is, "do these words mean approximately the same thing?" This served to eliminate the comparison and decision processes in letter identity and semantic decisions. Subjects were asked to respond to five blocks of 30 trials each. Results of this study indicated that identical word pairs elicited the fastest response time, followed by words in different typeface, and finally synonym words. In addition, younger subjects responded faster to all decision types than older subjects. A significant interaction of age X word pair type was also revealed such that the age differences in response time increased as the amount of the semantic information required to make the decision increased. A closer examination of the data was completed by computing letter information and semantic information retrieval times. Letter information retrieval time was computed by subtracting response times of physically identical words from words in different type face. Semantic retrieval time was obtained by subtracting response times from same word decisions from synonym decisions. Analysis of these data indicated that the proportional increase in response time for older adults was constant across word-pair types. That is, older adults' response times were 37% slower than young adults in physically identical decisions, 38% slower for same word decisions, and 37% slower for synonym decisions. Madden interpreted these results to suggest a generalized age related slowing rather than a slowing related to any specific type of information retrieval process.

Efficiency of long-term memory access is one component affecting prose memory. A second component required in the processing of prose material is short-term memory processing. The efficiency of short-term memory is a source of individual differences in prose processing efficiency

(Daneman & Carpenter, 1980). Several studies have implemented tasks requiring short-term memory skills to determine the effect of aging on short-term memory processes. In particular, Sternberg's (1966) additive factor method has been used to delineate the information processing stages that may be differentially affected by adult aging. In the Sternberg (1966) task, a subject is presented a list of items (usually 1-7) to memorize. After list presentation, a target stimulus appears, and the subject is to decide as quickly as possible whether the target probe was a member of the memory set previously memorized. The variable of interest is the size of the memory set, and measurement is the slope of the line relating reaction time to memory set size. This task requires subjects to search short-term memory to compare the target stimulus with the members of the memory set in order to make the appropriate response. Therefore, increases in memory set size result in an increase in memory search time, hence longer reaction times. Research utilizing this task has shown that reaction time increases approximately linearly with set size. This increase is about 38 msec for each item added to the set. Finally, the zero intercept of the line is about 400 msec for young adults (Sternberg, 1975), however, it has been shown to be higher in older adults (Anders, Fozard & Lillyquist, 1972).

The study by Anders, Fozard and Lillyquist (1972) examined age related differences in short-term memory retrieval using the item recognition task. Sternberg (1969) postulated that short-term memory search is: exhaustive, serial, and executed very quickly. The study by Anders et al. (1972) was designed to examine these three characteristics in young (19-21 years of age), middle-aged (33-43 years of age) and older (58-85 years of age) adults using the Sternberg (1966) item recognition task. Subjects were presented with short lists of digits (1-9) to memorize. Each list contained 1, 3, 5, or 7 digits. Following list presentation, a target stimulus was presented. The subject's task was to respond as quickly as possible as to whether the target stimulus was a member of the memorized list. The test consisted of one block of 24 practice trials and two blocks of 48 experimental trials. Results indicated that response times increased with increasing set sizes, supporting Sternberg's hypothesis that short-term memory search is serial. In addition, response times were not affected by the target probe's position on the list suggesting that the search is exhaustive. Of primary interest was an age related difference in memory search speed such that search speed increased (became longer) with increasing age from young to middle age; however, no differences in memory search speed between middle-aged and older adults were revealed. The authors postulated that the slower response times resulted from the increased time required to search short-term memory and generate the appropriate response.

A study by Anders and Fozard (1973) was conducted to address the shortcomings of the study by Anders et al. (1972). These examiners claimed that the task utilized by Anders et al. (1972) did not exceed the normal capacity of primary memory. This study was based upon the two-stage model of short-term memory proposed by Waugh and Norman (1965), which describes primary and secondary memory. Primary memory is the limited capacity system of short-term memory which holds information only briefly. Secondary memory is the larger, more permanent memory store. Only information that has been successfully stored in secondary memory is available for later recall or for transfer to long-term memory. Anders and Fozard (1973) examined whether the retrieval deficit observed by Anders et al. (1972) operates in secondary as well as primary memory. Young and older adults were asked to make yes-no decisions as to the presence or absence of a stimulus probe from a memorized list of 1, 3, or 5 items which remained fixed over a long series of trials. Testing took place over three consecutive days. Each subject was given secondary memory lists (digits or letters) to memorize each day. Subjects were given these memory lists (digits or letters) well before testing so they were able to memorize them and presumably store them in secondary memory. These lists were followed by primary memory lists which immediately preceded the task. If the secondary lists were digits, primary lists consisted of letters and if the secondary lists were digits, the primary lists were letters. In this way, primary and secondary lists could be differentiated in the recall phase of the study. The task consisted of 124 trials each day. The subject was to decide, after seeing the test item, whether the stimulus probe was a member of the primary or secondary memory list. Subjects were to respond as quickly as possible without sacrificing accuracy. Results indicated that young subjects search through the contents of primary memory at about twice the speed of older subjects. Search speed from secondary memory was slower than that of primary memory, but the size of age differences in search speed was similar for primary and secondary memory tasks. Anders and Fozard (1973) concluded that for older adults, slower search rate of both primary and secondary memory, may in part, account for age differences in memory retrieval speed.

Salthouse and Somberg (1982) also examined age differences in short-term memory using the Sternberg paradigm. In this task, the subject is presented with a short list of items to memorize. He/she is then presented with a target item and asked to respond as quickly as possible whether the target probe was or was not a member of the previous list. Sternberg (1969) postulated that different factors affect different stages of information processing. He proposed that the quality of the stimulus affects the encoding stage; the number of items in a memory set affects memory search time; and the complexity of the response required affects the decision stage. Salthouse and Somberg (1982) suggested that the interaction of age with any of these factors indicates that the particular stage associated with that factor could be assumed to be affected by aging. Younger and older adults were presented one or four randomly selected digits from the set 1-9 for 1.5 seconds as their memory set. A variable memory set procedure was used such that subjects received a new memory set for each trial. A single target digit was then presented for 1.5 seconds immediately following the stimulus set. The subjects were instructed to respond by pressing the appropriate key indicating whether or not the target stimulus was a member of the earlier memory set. Four conditions were created by varying the complexity of the subject's response and the presence or absence of a degradation pattern on the target stimulus. Two keyboards were used. The subjects were to respond on the right keyboard if the target had been presented on the previous list, and to respond on the left keyboard if the target was not a member of the previous list. The response complexity manipulation required the subject to press the "0" key on the appropriate keyboard for a simple response and to press the exact key indicated by the target stimulus on the appropriate keyboard for the complex response. The degradation manipulation consisted of a pattern of random dots on the screen along with the target stimulus while the non-degraded pattern was a target stimulus presented on an otherwise clear screen. The four conditions were simple/ non-degraded, simple/ degraded, complex/ non-degraded, and complex/ degraded. Results of this study indicated that older adults were slower overall than younger adults and this difference increased with each manipulation (set size, degradation and response complexity). These results were interpreted to suggest that an age associated slowing occurs in all three of Sternberg's (1969) proposed stages. Therefore, it was concluded that the age slowing phenomenon was general rather than a slowing of any specific stages of cognitive processes.

Another component of short-term memory along with memory scanning is memory span. Individual differences, including age differences in memory span, have been examined using such tasks as digit span, word span and sentence span (Hartley, 1986; Light & Anderson, 1985; Daneman & Carpenter, 1980). The digit span and word span tasks utilize sets of digits or words in increasing length which are read to the subject. The subject's task is to repeat the items in each list in the order they are given. These tasks are a measure of working memory capacity in that the items from the lists must be stored temporarily for immediate recall. Each increase in list length places greater demands on working memory. Younger adults have been shown to have longer spans for digits and words than older adults (Light & Anderson, 1985). The sentence span task created by Daneman and Carpenter (1980) uses sets of three, four, five and six sentences which must be read aloud by the subject and the last word of each sentence must be reported in the correct order. This task places greater demands on working memory than either digit span or word span because in addition to storing information regarding the last word of each sentence for subsequent recall, the subject must process the sentence itself. Research examining age differences in sentence span performance have produced conflicting results. While one study found no significant age differences in sentence span (Hartley, 1986) another found that young adults perform better on this type of task than older adults (Light & Anderson, 1985).

Previous research suggests that a cognitive slowing with age results in older adults having slower semantic access (Byrd, 1984), and slower speed of short-term memory manipulation (Hartley, 1986; Light & Anderson, 1985). In addition, memory scanning time has been shown to increase with age (Salthouse & Somberg, 1982; Anders & Fozard, 1973). Previous research also suggests that these age differences in memory performance depend on the verbal ability of the subjects tested (Hartley, 1986). Typically, smaller age differences are observed for high verbal individuals than low verbal people.

Time of Day and Memory Another factor affecting memory performance that has received attention recently is the time of day that memory is tested. Circadian variations in arousal have been shown to influence memory performance differentially. For example, speed of long-term memory access has been shown to increase throughout the day (Tilley & Warren, 1983; Millar, Styles & Wastell, 1980), while memory for prose material decreases across time of day (Folkard, Monk, Bradbury & Rosenthal, 1980; Petros, Beckwith & Anderson, 1990). In addition, speed of short-term memory scanning improves throughout the day (Anderson, Petros, Beckwith, Hondel, Witucki & Tinius, 1988). Performance on digit span has been shown to deteriorate later in the day (Blake, 1967); however, a study by Anderson (1988) revealed no effects of time of day on performance on the digit span task.

The purpose of the present study is to examine the effect of time of day and age on memory performance. If individual differences such as verbal ability mediate memory differences for different age groups, then time of day may also modulate the size of the age differences in memory performance.

Several studies have been conducted examining the effects of time of day on memory for word lists and prose material, as well as the speed of long-term memory retrieval and the speed of conducting short-term memory operations. The effects of time of day are often explained as resulting from an increase in physiological arousal (as indexed by body temperature) across time of day (Folkard, 1982; Coloquhoun, 1971). This increase in arousal is reflected in differential memory performance across time of day. Folkard and Monk (1979) examined the influence of time of day on immediate and delayed recall of word lists at five different times of day, ranging from 8 AM to 8 PM. Subjects were presented with a single list of fifteen, high frequency, monosyllabic nouns and were asked to write as many words as they could remember, in any order. The memory test occurred either immediately after the presentation of the word lists or after a 20-minute delay. The results showed no significant effect of time of day on the number of words recalled, but there was a significant effect of time of day on both the recency positions (the last six positions) and the pre-recency positions (the first nine positions). Immediate recall from recency positions was lower at 1100 hrs than at 1400 hrs or 2000 hrs, and recall from the pre-recency positions showed a slight improvement from 0800 hrs to 1100 hrs followed by a significant decrease later in the day. When subjects were required to delay recall by 20 minutes, there was no significant effect of time of day on the total number of words recalled, the number recalled from the recency positions, or the pre-recency positions. However, the general pattern of the delayed recall data for both recency and pre-recency positions "mirrored" the results found in the immediate recall. Recall for words in the pre-recency positions for both immediate and delayed recall decreased throughout the day. Several studies have also examined the influence of time of day on memory for prose passages. For example, Folkard, Monk, Bradbury and Rosenthal (1977) examined the effects of time of day on prose memory in children. Children were presented a story at either 0900 hrs or 1500 hrs. The subjects were asked to listen carefully to the passage, then to complete a multiple-choice test on the story either immediately following the passage presentation, or one week later. Results of this study indicated that children who heard the story in the morning (0900 hrs) obtained higher immediate recall scores than did those who were presented the story in the afternoon (1500 hrs). However, delayed retention was higher if subjects heard the story in the afternoon than in the morning. The results of the immediate memory tests appeared to support the findings of Folkard and Monk (1979) concluding that immediate recall is superior in the morning.

A study by Oakhill (1986a) used a procedure similar to Folkard et al. (1977) with college students. Subjects listened to a passage at 0900 hrs or 1800 hrs, and were asked to fill out two memory tests either immediately after the presentation, or after a one-week delay. In the delay condition, one-half of the subjects received their test at the same time of day as the initial presentation, and one-half received their test at the other testing time. Two types of questionnaires were developed to serve as the memory tests. One was considered a cued recall task and the other was considered a recognition task. The cued recall task was an open-ended questionnaire (i.e., subjects were asked to generate a single word or sentence answer to each question) and the recognition task was a forced-choice format (i.e., four alternatives were posed for each question and subjects were asked to choose one). Each memory test contained questions that tapped important information as well as unimportant information from the passage. All subjects received both questionnaires. Results were reported on the open-ended questionnaire data only, although the forced-choice questionnaire produced a similar pattern. Results revealed no effect of time of day on immediate recall. However, in the delayed test, a time of day X importance interaction revealed that subjects who were presented the story at 1800 hrs showed a clearer differentiation of important from less important information than subjects presented with the story at 0900 hrs. Arousal level increases throughout the day (Folkard, 1982) suggesting that the subjects tested at 1800 hrs may have been more aroused than the subjects tested at 0900 hrs. This suggests that higher levels of arousal bias attention toward important information.

Time of day appears to be a manipulation of arousal that affects memory performance across all subjects. However, some researchers have proposed that an individuals' self-perception of their tendency to be a "morning" or an "evening" type of person may differentially mediate these arousal effects on performance. Horne and Ostberg (1976) constructed a questionnaire designed to assess individual's perceptions of their "morningness" or "eveningness." Horne and Ostberg (1976) reported that 45% of adults may be classified as moderate to definite morning types or moderate to definite evening types. The oral temperatures of these individuals were compared across time of day (Horne & Ostberg, 1977) and this revealed that evening types start the waking day at a lower body temperature than morning types. In addition, evening types' temperature rises steadily throughout the day to reach its peak in the mid-evening (2030 hrs). Morning types show a steeper rise in body temperature throughout the day to reach their peak on the average of 68 minutes earlier than evening types.

Horne, Brass and Petit (1980) used the Horne and Ostberg (1976) questionnaire to divide subjects into morning and evening types and then tested them on a simulated production line task. The task consisted of detecting and rejecting faulty playing cards on a conveyor belt. Subjects were tested in 15 sessions during a normal waking day lasting 20 minutes each, at times ranging from 0800 hrs to 2200 hrs. The number of correct and incorrect rejections were tabulated to determine efficiency. Results indicated that performance of morning types declined across time of day, while for evening types, performance improved throughout the day.

A study by Petros, Beckwith and Anderson (1990) also utilized the Horne and Ostberg (1976) questionnaire to determine whether differences in prose memory across time of day are mediated by the type of person tested. This study was also a replication and extension of Oakhill (1986a) in that immediate recall for prose passages was examined. However, rather than the cued recall and recognition used by Oakhill (1986a), Petros et al. (1990) utilized a free recall procedure. Subjects were pre-tested with the Horne and Ostberg (1976) questionnaire. Based upon these scores, thirty-six subjects of each type (morning and evening) were tested at one of three times of day (0900 hrs, 1400 hrs, or 2000 hrs). Subjects listened to four passages: two of which were 5th-6th grade readability and two which were of 7th-8th grade readability (Dale & Chall, 1948). Immediately after the presentation of each passage, subjects were asked to write their recalls in as much detail as possible within eight minutes. Results of this study indicated that subjects favored the main ideas in their recalls over the non-essential details. The difference in recall of high versus low important idea units was most evident for difficult passages suggesting that subjects may bias their attention toward the important concepts in a passage, particularly when the passages are challenging to the subject. In addition, recall at 0900 hrs was superior to recall at 1400 hrs and 2000 hrs for morning type subjects. Although no significant differences were found for recalls of evening type subjects across time of day, there was a general trend toward increased recall for evening types throughout the day. These results supported the conclusions of previous studies, that immediate recall is superior in the morning. However, this study suggested that the effect of time of day on prose recall may critically depend on the type of person (morning type / evening type) tested.

The studies previously discussed examined the effects of time of day on prose processing solely on the basis of subsequent recall of the material. In an attempt to have a concurrent measure of processing while subjects encoded prose, Oakhill (1986b) employed a self-paced reading technique in examining subjects' ability to integrate information in prose at 0900 hrs or 1700 hrs. Sixteen three-sentence passages were read by each subject. The passage difficulty was manipulated by presenting easy passages in which a pronoun unambiguously referred to a specific subject, while in difficult passages, an inference on the part of the subjects was required to determine the pronoun referent. For example, in the sentence "Sam sold the car to Max because he needed the money", the referent "he" most likely refers to Sam. This can be solved syntactically by referring only to this sentence. However, in the sentence "Sam sold a car to Max because he needed it" the referent most likely refers to Max, but this decision is more difficult, because one must draw on inferential knowledge of the buying and selling process to determine "who needed what." Passages with referents which could be solved syntactically were considered easy, while those that required inferential processing were considered difficult.

The results indicated that subjects tested at 1700 hrs appeared to deal with the difficulties in determining the referent while they were reading the text, as indicted by longer reading times for difficult sentences than easy sentences. Subjects tested at 0900 hrs, however, did not adjust their reading time to the difficulty of the text, as indicated by similar reading times at both levels of difficulty. Subjects tested at 0900 hrs delayed the processing of the referent until they were required to answer a question regarding it. That is, subjects tested at 0900 hrs spent more time answering questions about the passage (regardless of difficulty) than subjects tested at 1700 hrs. The two groups did not differ on accuracy of response to questions regarding the passage. The results suggest possible reading strategy differences were used at different times of day.

The original question under consideration was whether or not time of day affects memory and if so, does it enhance or impair performance? This is a question regarding the quantitative effect of arousal on performance postulated by Coloquhoun (1971). Coloquhoun suggested that the efficiency of task performance, that is, the speed and accuracy with which elementary processes are carried out, vary in a systematic manner according to the time of day when the tasks are performed. Many of the studies previously discussed take this approach, examining time of day effects on the efficiency of memory processes. Recent studies, however, have begun to examine whether qualitative changes in the nature of encoding strategies as a function of time of day may underlie the performance differences observed (Folkard, 1979; Oakhill, 1986b). Folkard (1982) described these changes that occur throughout the day in terms of the nature of the style of the information processing strategies used. Folkard (1979) and Oakhill (1986b) suggested that arousal effects may result from a change in processing strategy. For example, Folkard (1979) suggested that subjects, when free to do so, will rely on maintenance processing in the morning (rote memorization or maintaining literal meanings in short-term memory), while in the evening they will use more elaborative processing (elaborate on existing information to form new associations). Oakhill (1986b) also suggested a change in processing strategy throughout the day in that subjects used a rote method in the morning and a semantic approach later in the day. In both cases, the less efficient and less demanding strategy is taken in the morning (when arousal is presumably lowest), while a more demanding approach is taken in the evening (under conditions of higher arousal). Folkard suggested that Coloquhoun's explanation of time of day effects in terms of quantitative differences may in fact be mediated by qualitative changes such as changes in the processing strategy employed.

Recent research has been conducted with Folkard's theory in mind, and thus, the research question has evolved and is now, "How does time of day influence encoding and processing strategies?" For example, Millar, Styles, and Wastell (1980) examined the influence of time of day on retrieval from long-term memory. Subjects tested at 0900 hrs, 1400 hrs, or 1800 hrs were presented 180 trials of a category classification task. Subjects were asked to respond as to whether or not a word was an example of a particular semantic category. Retrieval difficulty was manipulated by using an equal number of words of high, medium, and low dominance in a given semantic category. High dominance words are those that are frequently seen as examples of a given semantic category while low dominance words are members of a semantic category that are less frequently thought of as examples. For example, in the category fruit, apple would be a high-dominance word while plum would be a low-dominance word. Results indicated that overall response time was faster for the group tested in the evening than for those tested in the morning. In addition, retrieval efficiency, that is, a decrease in the difference in latency between high and low dominance classification speed, was greater for the group tested at 1800 hrs than for groups tested at 0900 hrs or 1400 hrs. The authors concluded that the proposed increase in arousal across time of day enhanced the efficiency of retrieval of information from long-term memory.

Tilley and Warren (1983), in a replication and extension of Millar et al. (1980), used eight lists of 48 pairs of category words to examine the effects of time of day on retrieval from semantic memory. The test words were composed of an equal number of high, medium, and low dominance category members. The words were then paired and divided into an equal number of positive and negative category word pairings. Subjects were to respond yes or no as to whether the word pair was categorically related. Subjects were tested at 0900 hrs, 1400 hrs or 2000 hrs. The results of this study indicated that semantic classifications became faster over the day. That is, positive responses were slower at 0900 hrs than at 1400 hrs or 2000 hrs. Positive instances were classified faster than negative instances; however, the time taken to classify high-dominance members relative to low dominance category members was greater for positive examples and smaller for negative examples at 0900 hrs compared with 1400 hrs and 2000 hrs. This is consistent with Miller et al. (1980) suggesting that subjects became more efficient in accessing information from long-term memory later in the day.

The results of the studies mentioned above suggest that retrieval from long-term memory becomes more efficient later in the day. However, an impairment in performance is seen across time of day on tasks that demand short-term memory processes. For example, Blake (1967) tested subjects' performance on eight tasks across five times of day ranging from 0800 hrs to 2100 hrs. This series of tests included the digit span test. Subjects were asked to repeat, in order, a series of single digits recited by the experimenter. The subject's score was the largest sequence he/she repeated without error. Blake found that after initial improvement, performance on the digit span tended to deteriorate throughout the day. However, a study by Anderson (1988), tested subjects on the digit span task at 0900 hrs, 1400 hrs, or 2000 hrs and found no time of day effects on performance on this task. Due to the conflicting results in the previous studies, the present study examined subjects' performance on several different types of memory span measures across time of day.

A study by Baddley, Hatter, Scott and Snashall (1970) also examined immediate recall at two times of day (morning and afternoon) in an attempt to replicate the results of

Blake (1967) along with a measure of long-term memory. Subjects were presented with 24 sequences of nine random digits (which is outside the boundaries of short- term memory), at the rate of one digit per second. The subject's task was to repeat the sequence in order immediately following the presentation. In an attempt to measure long-term retrieval, the subject was also presented a series of nine random digits at the rate of one per second, however, several of the sequences were identical (i.e., sequences 3, 6, 9, 12, 15, 18, 2, and 24). The probability that the subject would recall these repeated sequences correctly should increase gradually, indicating that long-term memory was activated in these cases. Results of this study were consistent with Blake (1967) in that performance in the morning was superior to that in the afternoon for immediate memory. However, there was no significant difference in performance on the long-term memory task across time of day. The authors concluded that the efficiency of immediate memory does vary as a function of time of day. However, they felt that their long-term memory task was not a reliable measure; therefore, results from this portion of the experiment could not be considered conclusive.

Another study examining the effects of time of day on short-term memory processes was conducted by Anderson, Petros, Beckwith, Hondel, Witucki and Tinius (1988). This study employed the Sternberg item-recognition paradigm to investigate the relationship between memory scanning speed and time of day. Since some research suggested that arousal is negatively related to short-term memory performance (Blake, 1967; Baddley et al., 1970), Anderson et al. (1988) hypothesized that memory scanning rate would slow throughout the day. Morning and evening type college students were presented memory sets of 2, 4, or 6 digits (0-9). Immediately after the presentation of the memory set, the subject was presented with a target probe. The task involved deciding whether or not the target probe was a member of the previous memory set and to press the appropriate key on the keyboard. Subjects completed five blocks of 90 trials. Each block contained 30 trials of memory sets of 2, 4, or 6 digits with 15 positive and 15 negative responses. Results indicated that response times decreased as a function of time of day; however, this decrease was less dramatic for the blocks presented later in the testing session. These results are inconsistent with the results of previous studies examining short-term memory performance across time of day. The authors suggested that time of day may differentially affect the separate components of short-term memory such that scanning rate improves across time of day, while the effect of time of day on short-term memory span is conflicting at present.

<u>Purpose of the Present Study</u> The purpose of the present study was to examine adult age differences in memory scan-

ning speed across time of day. The study was designed as a replication and extension of the study by Salthouse and Somberg (1982). These researchers found a deterioration in memory scanning performance with age. The authors reported a general age related slowing in mental operations involved in this type of working memory task. Salthouse and Somberg (1982) used digits as the stimulus materials for their study. The present study also used digits as stimulus materials in an attempt to replicate the Salthouse and Somberg (1982) study. In addition, the present study utilized words as stimulus materials for the memory scanning task in an attempt to make the task more complex and therefore place more cognitive demands on the subjects. Scanning for words more directly mimics the process of discourse comprehension in that a portion of discourse processing involves scanning words and accessing word meanings (Kintsch & van Dijk, 1978). Since an age related slowing in cognitive processing results in slower performance when scanning short-term memory for digits, increasing the difficulty of the task by using words should result in larger age related differences.

An additional component of this task is simple button pressing speed. The time required to make a response manually was also included in the present task in addition to the time to scan memory. Simple button pressing speed has been shown to decrease across time of day (Blake, 1967) and adult aging (Nebes, 1978). Therefore, to eliminate the possible confounding of motor response time on memory scanning time, a reaction time control was employed.

A second variable assessed was age related differences in memory span. The present study examined age related differences in digit span, word span, and sentence span. The digit span task consisted of random lists of digits of increasing length. Subjects were to repeat orally the list in the same order it was presented. Two trials of each list length were presented, beginning with a list of two digits. The procedure was discontinued when a subject failed both lists at any given length. The word span task consisted of lists of unrelated words (four to seven letters) of increasing length, beginning with three lists of two words. Subjects were to repeat each list orally in the order presented. The task was discontinued when a subject failed all three trials at a given length. The sentence span task consisted of a series of unrelated sentences (13 to 16 words in length) beginning with a series of two sentences. Three trials at each series length were presented. The subjects' task was to read each sentence orally, and at the end of the series, to recall orally the last word of each sentence in the series. Hartley (1986) found no age differences in sentence span, while Light and Anderson (1985) found that sentence span decreased with age. The present study was designed to examine this discrepancy in the current literature by examining age differences in digit span, word span, and sentence span. Each of these tasks places demands on working memory. Daneman and Carpenter (1980) suggest that individual differences in the efficiency of working memory may be related to a trade-off between the processing (encoding of incoming information) and storage (keeping information available for later recall) functions. If processes are inefficient, this would result in less available capacity for additional information to be maintained in working memory. More demanding span tasks should reflect this inefficiency if it is present. Therefore, if a cognitive slowing with age is present, this should be evidenced in poorer performance on the span tasks in the older adults. In addition, the difference in performance between young and older adults should be more pronounced for the more difficult tasks. Sentence span is assumed to be a more difficult task than either word span or digit span (Daneman & Carpenter, 1980). The correlation of sentence span with reading ability is higher than the correlation of word span or digit span with reading ability; therefore, it is hypothesized to be a more difficult task.

In addition to age related differences in memory performance, the time of day at which a subject is tested has been implicated as a source of performance differences in memory scanning and memory span. Anderson et al. (1988) found a decrease in the rate of scanning for digits across time of day. Blake (1967) reported that performance on the digit span deteriorated throughout the day, while Anderson (1988) found no difference in digit span performance across time of day.

The present study was designed to examine this discrepancy in the current literature by utilizing both memory scanning and several memory span tasks in the same study. Anderson et al. (1988) suggested that the influence of time of day may be more pronounced with tasks that place greater demands on working memory. To examine this possibility, word span and sentence span measures was employed as a more complex task.

A large body of literature exists regarding the effects of aging on memory performance. However, no studies exist examining the possible effect of time of day on age related differences in memory performance. The present study was designed to examine the possibility that age related differences in memory performance may be influenced by the time of day the subject is tested.

Finally, several individual difference variables were assessed that have been found to influence memory performance. Verbal ability has been found to be related to the speed of lexical access (Hunt et al., 1975). Petros, Zehr and Chabot (1983) found age related differences in lexical access speed. Several studies examining age differences in memory performance have examined verbal ability as a possible mediating variable (Zelinski et al., 1984; Hartley, 1986; Petros, Tabor, Cooney & Chabot, 1983). Based on the hypothesis of an age related cognitive slowing, if verbal ability interacts with age, then the performance differences between older and younger adults should be more pronounced for low verbal subjects. The present study assessed verbal ability of subjects by obtaining the subjects' scores on the vocabulary subtest from the Wechsler Adult Intelligence Scale - Revised (Wechsler, 1981).

A second individual difference of interest was subjects' abilities on tasks assessing non-verbal forms of intelligence. Salthouse (1987) found age related differences in both timed and efficiency measures of performance on a block design task. These two measures are correlated with scores on the block design subtest of the WAIS-R. The block design subtest is considered a measure of general non-verbal intelligence (Wechsler, 1981) and therefore, should correlate positively with a variety of tasks that are hypothesized to positively correlate with intelligence. It was expected that performance on the block design task would positively relate to performance on memory scan and memory span tasks.

A third individual difference variable of interest was the subjects' general level of anxiety. Meuller, Kausler, Faherty and Oliveri (1980) tested older adults, highly-anxious younger adults, and low-anxious younger adults on a category judgment task involving typical and atypical category members. Subjects were presented with a category name together with a typical exemplar, an atypical exemplar, or an unrelated exemplar, and asked to respond as to whether the exemplar was a member of the given semantic category. Results indicated that elderly subjects performed more like highly-anxious young adults than low-anxious young adults on atypical words while elderly adults were significantly worse than high anxious and low anxious young adults on typical words. Anxiety has been postulated as a possible source of age related performance differences (Salthouse, 1980). In order to examine this possibility, the subjects' level of state anxiety was measured with the Speilberger State-Trait Anxiety Inventory (Speilberger et al., 1967). An additional factor that was assessed in the present study was the subjects' level of subjective depressive symptoms. The present study employed the Beck Depression Inventory (Beck, 1967) as a measure of subjective depressive symptoms to determine if these symptoms are more often present in either of the age groups tested; and if so, whether they may be a factor in age differences in memory performance.

Finally, an individual's subjective impression of his/her physical health has been hypothesized to be a factor in performance on many tasks. Laidlaw (1988) found a relationship between subjects' scores on the Wahler Physical Symptoms Inventory (Wahler, 1983) and performance on a single word-naming task. Therefore, the present study also employed the Wahler Physical Symptom Inventory to examine the possible influence of subjective physical health on memory scanning and memory span tasks.

This research examined the age related differences in performance on memory scanning and memory span tasks using the measures previously mentioned. In addition, this design allowed for the examination of the contribution of time of day to age related differences as well as providing individual difference measures on variables previously found to be related to memory performance.

METHOD

Subjects

Eighty-one subjects participated in this study. The forty-five young adults were female undergraduate psychology students (age 18-35) who received course credit for participation. The thirty-six older adults (9 males and 27 females) were residents of the local community over the age of 60, who received a five dollar honorarium for their participation. Fifteen young and eleven to thirteen older subjects were randomly assigned to each of three designated testing times: 0900 hrs, 1400 hrs or 2000 hrs.

Materials

Individual difference measures

Each subject completed the vocabulary and block design subtests from the Wechsler Adult Intelligence Scale - Revised (Wechsler, 1981). Subjects also completed three questionnaires: the Wahler Symptoms Inventory (Wahler, 1983); the Speilberger State-Trait Anxiety Inventory (Speilberger et al., 1967); and the Beck Depression Inventory (Beck, 1967).

The Wahler Physical Symptoms Inventory (Wahler, 1983) is a 42-question, self-report questionnaire listing physical problems an individual may experience. Questions are scored on a five point Likert scale. Zero indicates that the respondent almost never experiences the symptom and five symptom nearly every day. The questionnaire includes such physical symptoms as losing weight, heart trouble, dizzy spells, and shakiness.

The Speilberger State-Trait Anxiety Inventory (Speilberger et al., 1967) is a 20-item, self-report questionnaire that persons respond to based upon how they feel at that time. Four alternative responses are available for each item. A response of one indicates "not at all" and a response of four indicates "very much so." The questionnaire includes such items as "I feel calm", "I am worried", and "I am regretful."

The Beck Depression Inventory (Beck, 1967) includes 21 groups of four statements in which the respondent is to mark the one statement in each group which best describes how he/she feels at that moment. Within each of the 21 groups, the initial statement suggests satisfaction with present circumstances, while the remaining three indicate increasing levels of dissatisfaction with life. Higher scores suggest increasing levels of dysphoria.

The vocabulary subtest of the WAIS-R (Wechsler, 1981) is a 35-item word list in which the respondent is to provide a short definition for each word. Words become increasingly more difficult as the list progresses and the test is discontinued when the respondent fails five consecutive items. Responses are scored 0, 1, or 2 based upon the quality of response, with more accurate responses receiving higher scores.

The block design subtest of the WAIS-R (Wechsler, 1981) is a task in which the subjects are provided with either four or nine red and white blocks and are asked to duplicate designs shown to them with the blocks. Five designs are made using four blocks and four designs require nine blocks for successful completion. Bonus points are given for speeded performance. The task is discontinued after the subject fails three consecutive items.

Memory scan measures

Two measures of memory scanning were taken, scanning for digits and words. The digit memory sets consisted of sets of 2, 3, or 4 digits that were comprised of random combinations of the digits 0-9, with no digit repeated in any memory set. The target probe was one of the digits 0-9. The word memory sets consisted of sets of 2, 3, or 4 words, four to seven letters in length with a frequency ranging from 50 to 435 per million (Kuchera & Francis, 1967). The words were initially arranged into a series of 30 memory sets of two words, 30 memory sets of three words, and 30 memory sets of four words. For each memory set size, half of the memory sets were paired with a target word that was a member of the memory set and half were paired with a target word not contained in the memory set. Each target word was of a similar word frequency to those of the memory set. From the initial sequence of 90 memory sets, five additional sequences were created to insure that each word appeared in each memory set size by decision (positive vs. negative) cell equally often.

Memory span measures

Three measures of memory span were employed: digit span, word span, and sentence span. The digit span consisted of random lists of digits of increasing length. Two trials for each list length were presented beginning with a list size of two digits. The procedure was discontinued when a subject failed both trials at any list length. Digit span was measured as the largest list the subject was able to repeat without error (See Appendix A). Word span measures consisted of lists of phonetically unrelated words (four to seven letters) of increasing length. Three trials at each list length were presented. This portion of the span task was discontinued when all three trials at any list length were failed. Word span was recorded as the largest list of words the subject was able to recall without error (See Appendix B). The sentence span test consisted of a series of unrelated sentences, 13 to 16 words in length. Each sentence ended in a different word. Subjects read the sentences aloud at their own pace and the task was to recall the last word in each sentence. Subjects were presented with three trials of increasing length, beginning with three trials of a set of two sentences. The task was discontinued when the subject failed all three trials at any list length. Sentence span was recorded as the largest series of "last words" repeated by the subject without error (See Appendix C).

Procedure

Each subject was tested individually at 0900 hrs, 1400 hrs or 2000 hrs. After providing informed consent and demographic data, subjects completed the Wahler Physical Symptoms Survey, Speilberger State-Trait Anxiety Inventory, and the Beck Depression Inventory followed by the WAIS-R vocabulary and block design subtests.

Memory Scanning

Each subject was then asked to sit in front of an Apple IIe computer and instructions were given. The scan measures for both digits and words consisted of 30 trials of memory set sizes 2, 3, and 4. For each memory set size, 15 positive and 15 negative trials were randomly presented. A varied memory set procedure was used such that subjects viewed a new memory set for each target stimulus. All trials for one memory set size were completed before going on to the next block of 30 trials. The presentation of memory set sizes (2, 3, or 4) was counterbalanced within each type of stimulus (digits or words). Also, the order of presenting digits or words was counterbalanced across subjects.

Subjects initiated a trial by pressing the space bar on the keyboard. Immediately after the space bar was pressed the memory set disappeared from the screen and an "X" appeared in the center of the screen as a fixation point. The fixation "X" remained on the screen for one second, after which it was replaced by the target probe. The subject responded by pressing the "P" key if the probe was a member of the memory set and pressing the "Q" key if the probe was not a member of the memory set. The "P" and "Q" keys were covered and labeled "Y" and "N." These keys were chosen for use because they are widely separated on the keyboard. Immediately after the subject made his/her response, the target probe disappeared. After a two second interval, a new memory set appeared. A new trial was initiated by the subject by pressing the space bar.

Reaction time control trials were completed both before and after the experimental trials. Reaction time control stimuli consisted of 2-digit memory sets only. Each reaction time control block consisted of 30 trials, 15 positive and 15 negative. The procedure for the reaction time control required the subject to press the space bar to initiate a trial. The fixation "X" appeared for one second followed by the target probe which remained on the screen for three seconds. After the three second interval the target probe disappeared from the screen, and was replaced by an "X." The subject was asked to respond as to whether the target probe was a member of the memory set as quickly as possible after the "X" appeared.

Memory Span

In the memory span portion of the session, the experimenter initiated trials in which subjects were presented a series of digits or words one at a time on a computer screen, and were asked to recall them. The digits (words) were presented in lists of increasing length, at the rate of one digit (word) per second, beginning with three digits (words). Two trials of digits and three trials of words were presented for each list length. Subjects were required to recall orally the digits (words) in the exact order of presentation. The highest level the subject completed without error was used as a measure of digit (word) span.

The sentence span test required the subject to read a series of sentences aloud at his/her own rate. The sentences were presented on a computer screen in lists of increasing length beginning with lists of two sentences. The experimenter initiated the display of each sentence as the subject articulated the last word of the previous sentence. Three trials were presented at each list length. At the end of each list presentation, the subject was asked to repeat the last word of each sentence in the order of presentation. The highest level the subject recalled without error was used as the measure of sentence span.

The order of digit, word, and sentence span tasks were counterbalanced within each age by time of day cell of the design. In addition, the order of span and scanning tasks was counterbalanced between each age by time of day cell of the design.

Design

The design of the experiment for both the memory scanning tasks consisted of two between subjects factors and two within subjects factors. The between subjects factors were age (young, older) and time of day (0900 hrs, 1400 hrs, 2000 hrs) while the within subjects factors were memory set size (2, 3, or 4 digits/words) and response type (positive, negative). The design for the memory span tasks consisted of the between subjects factors of age (young/older) and time of day (0900 hrs, 1400 hrs, and 2000 hrs).

RESULTS

The median response time was computed for each set size by response type cell of the design separately for each subject for both digit and word scan. Response times associated with errors were excluded from these calculations. Also, the proportion of errors was computed separately for each set size decision type cell of the design separately for each subject for both digits and words. These median response times and error rates were then used to compute the slope and intercept of the regression line relating memory set size and response time (Pedhazur, 1983). A separate regression line was computed for digits and words for both response times and error rates, resulting in four different slopes and intercepts for each subject. The computation of these slopes and intercepts was collapsed over response type to allow six data points to go into each slope and intercept. The slope represents the increase in the dependent variable associated with one unit increase in memory set size and is assumed to reflect the rate of memory scanning (Sternberg, 1975). The intercept is assumed to reflect the time needed to respond to the memory probe independent of memory scanning time (Sternberg, 1975).

Digit Scan

A 2(Age) X 3(Time of Day) mixed analysis of variance was conducted on the slopes and intercepts computed from the median response times of the digit scan task. This analysis revealed a main effect of Time of Day on the slope $F(2,75) = 5.34$, $p = .007$. As can be seen in Table 1, subsequent analysis of this main effect indicated that the slope of the line relating set size to median response time was significantly smaller at 2000 nrs (33.5 msec per unit change), than at 1400 hrs and 0900 hrs which did not significantly differ (109.9 msec per unit change and 123.3 msec per unit change, respectively). These slopes indicate that memory scanning rates became faster across time of day. The main effect of Age and the Age X Time of Day interaction were not significant.

A main effect of Age on the intercept was also revealed $F(1,75) = 30.15$, $p < .001$. The intercept for older subjects was significantly higher than the intercept for younger subjects (923 msec vs. 545 msec). No significant main effect of Time of Day or Age X Time of Day interaction was revealed in this analysis (See Table 2).

A 2(Age) X 3(Time of Day) analysis of variance was conducted on the slopes and intercepts of the error rates corresponding to the response times for digit scanning. This analysis revealed no significant main effects or interactions (See Tables 1 and 2).

Word Scan

A 2(Age) X 3(Time of Day) analysis of variance was also conducted on the slopes and intercepts of the word scanning data. No significant effects of Age, Time of Day,

Table 1

Slope of the Line Relating Set Size to Response Time and Set Size to Error Rate for Digit Scanning as a Function of Time of Day

Time of Day	0900 hrs	1400 hrs	2000 hrs
Young	117.8 msec (.018)	103.0 msec (.019)	41.8 msec (.034)
Older	128.7 msec (.025)	116.8 msec (.020)	25.1 msec (.009)
Overall	123.2 msec (.022)	109.9 msec (.019)	33.5 msec (.022)

(error rates are in parentheses)
Note: Tabled values indicate the rate of change in the dependent variable (response time or error rate) for every unit change in the independent variable (set size).

Table 2

Intercept of the Line Relating Set Size to Response Time and Set Size to Error Rate for Digit Scanning as a Function of Time of Day

Time of Day	0900 hrs	1400 hrs	2000 hrs
Young	555.6 msec (.005)	517.1 msec (.015)	565.1 msec (.001)
Older	749.7 msec (.004)	1104.8 msec (.016)	914.5 msec (.043)
Overall	652.7 msec (.005)	810.9 msec (.016)	739.8 msec (.022)

(error rates are in parentheses)

Note: Tabled error rates indicate the estimated error rate for a set size of zero.

or Age X Time of Day interaction were observed on the slope (See Table 3). However, results of this analysis revealed main effects of Age $F(1,73) = 23.7$, $p < .001$ and Time of Day $F(2, 73) = 6.3$, $p = .004$ on the intercept. The intercept was larger for older subjects than for younger subjects (901 msec vs. 593 msec). Also, a subsequent analysis of the Time of Day effect (Table 4) indicated that the intercept was larger at 1400 hrs (895 msec) than at 2000 hrs and at 0900 hrs which did not significantly differ (722 msec and 624 msec, respectively).

A 2(Age) X 3(Time of Day) mixed analysis of variance was conducted on the slopes and intercepts of the error rates corresponding to the median response times for the word scanning task. This analysis revealed no main effects or interactions of these corresponding error rates (See Tables 3 and 4).

Reaction Time Control The median response times were computed for the reaction time control trials for both the pre-experimental trials and post-experimental trials, excluding response times associated with errors. A 2(Age) X 3(Time of Day) X 2(Decision) mixed analysis of variance was conducted on the pre-experimental and post-experimental trials separately followed by an analysis comparing the pre- and post- experimental trials. Analysis of the pre-experimental reaction time control revealed main effects of Age $F(1,75) = 21.469$ $p < .001$ and Time of Day $F(2, 75) = 3.615$ p

Table 3

Slope of the Line Relating Set Size to Response Time and Set Size to Error Rate for Word Scanning as a Function of Time of Day

Time of Day	0900 hrs	1400 hrs	2000 hrs
Young	44.4 msec (.004)	42.3 msec (.000)	46.9 msec (.008)
Older	20.7 msec (.014)	34.6 msec (.017)	36.4 msec (.008)
Overall	32.5 msec (.009)	33.5 msec (.008)	41.6 msec (.008)

(error rates in parentheses)

Note: Tabled values indicate the rate of change in the dependent variable (response time or error rate) for every unit change in the independent variable (set size).

Table 4

Intercept of the Line Relating Set Size to Response Time and Set Size to Error Rate for Word Scanning as a Function of Time of Day

Time of Day	0900 hrs	1400 hrs	2000 hrs
Young	620.5 msec (.042)	667.1 msec (.043)	493.3 msec (.042)
Older	824.5 msec (.033)	1123.9 msec (.080)	755.9 msec (.027)
Overall	722.5 msec (.037)	895.5 msec (.062)	624.6 msec (.034)

(error rates in parentheses)

Note: Tabled error rates indicate the estimated error rate for a set size of zero.

= .032. Young subjects had significantly faster response times than older subjects (406.9 msec vs. 735.4 msec) and response times at 2000 hrs (703.8 msec) were significantly longer than response times at 1400 hrs and 0900 hrs which did not significantly differ (519.8 msec and 488.4 msec respectively). No main effect of Decision Type was revealed. An interaction of Age X Time of Day $F(2,75) = 5.6$ $p = .006$ was also revealed (See Table 5). Subsequent analysis of this interaction indicated that while response times did not significantly differ across time of day for younger subjects, for older subjects, response times were significantly longer at 2000 hrs than at 1400 hrs and 0900 hrs, while latencies at 1400 hrs and 0900 hrs did not significantly differ (See Table 5).

The proportion of errors for every subject was computed as a function of Age, Time of Day and Decision Type for the pre-experimental reaction time control data. These data were subjected to a 2(Age) X 3(Time of Day) X 2(Decision) analysis of variance. This analysis revealed a main effect of age $F(1, 75) = 5.79$, $p = .019$, indicating that older subjects had significantly higher error rates than younger subjects (.126 vs. .035).

A 2(Age) X 3(Time of Day) X 2(Decision) mixed analysis of variance of the post-experimental reaction time control trials revealed only a main effect of Age $F(1, 75) = 4.59$, $p = .019$. As can be seen in Table 6, younger subjects had

Table 5

Median Response Times for Pre-Experimental Reaction Time Control as a Function of Age and Time of Day

	Time of Day		
Age	0900 hrs	1400 hrs	2000 hrs
Young	458.9 msec (.078)	375.4 msec (.024)	386.5 msec (.002)
Older	517.9 msec (.150)	664.2 msec (.085)	1021.0 msec (.142)

(proportion of errors in parentheses)

significantly faster post-experimental reaction time control trials than older subjects (367.8 msec vs. 454.6 msec).

Finally, the proportion of errors for every subject was computed as a function of Age, Time of Day, and Decision Type for the post-experimental reaction time control data. These data were subjected to a 2(Age) X 3(Time of Day) X 2(Decision) mixed analysis of variance. Significant interactions of Time of Day X Decision $F(2, 75) = 3.746$, $p = .029$ and Age X Time of Day X Decision $F(2, 75) = 4.968$, $p = .010$ were observed. Subsequent analysis of the Time of Day X Decision interaction (See Table 7) indicated that error rates did not differ across time of day for "yes" responses. However, for "no" responses, error rates were significantly lower at 0900 hrs than either 1400 hrs or 2000 hrs, while error rates at 1400 hrs and 2000 hrs were not significantly different.

Subsequent analysis of the Age X Time of Day X Decision interaction revealed that for young subjects for both "yes" and "no" responses, error rates were significantly higher at 1400 hrs than at 0900 hrs and 2000 hrs which did not significantly differ. For older subjects the only significant pairwise comparisons were that error rates for "yes" responses were larger at 0900 hrs than at 1400 hrs and for "no" responses, error rates at 2000 hrs were higher than at 0900 hrs (See Table 8).

A second analysis of the reaction time control data

Table 6

Median Response Times for Post-Experimental Reaction Time Control as a Function of Age and Time of Day

	Time of Day		
Age	0900 hrs	1400 hrs	2000 hrs
Young	444.1 msec (.073)	323.9 msec (.140)	335.5 msec (.076)
Older	425.9 msec (.125)	446.5 msec (.115)	491.1 msec (.142)

(proportion of errors in parentheses)

Table 7

Proportion of Errors for Post-Experimental Reaction Time Control as a Function of Time of Day and Decision Type

	Time of Day		
Decision Type	0900 hrs	1400 hrs	2000 hrs
Yes	.113	.120	.106
No	.086	.136	.112

was computed to compare the pre-experimental and post-experimental reaction time trials for each cell of the design. A 2(Age) X 3(Time of Day) X 2(Decision) X 2(Pre/Post experimental trials) mixed analysis of variance was conducted on the median response times. Main effects of Age $F(1, 75) = 20.555$, $p = .001$ and Practice $F(1, 75) = 20.694$, $p = .001$ were revealed. Older subjects had longer response times than younger subjects (594.5 msec vs. 387.4 msec). In addition, response times for the post- experimental trials were significantly faster than response times for the pre-experimental trials (570.6 vs. 411.2).

Significant interactions of Age X Time of Day $F(2,75) = 5.606$, $p = .006$, Age X Practice $F(1, 75) = 11.793$, $p < .001$, and Time of Day X Practice $F(2, 75) = 3.94$, $p = .024$ were also revealed. A subsequent analysis of the Age X Time of Day interaction indicated that response times did not differ across time of day for younger subjects, but response times for older subjects were significantly longer at 2000 hrs than at 0900 hrs and 1400 hrs which did not significantly differ (See Table 9).

Subsequent analysis of the Age X Practice interaction indicated that younger subjects' response times did not differ from pre-test trials to post-test trials. However for older subjects, response times for the pre-experimental trials were significantly longer than response times for the post-experimental trials (See Table 10).

Table 8

Proportion of Errors for Post-Experimental Reaction Time Control as a Function of Age, Time of Day and Decision Type

Time of Day	0900 hrs		1400 hrs		2000 hrs	
Age	Young	Older	Young	Older	Young	Older
Yes	.076	.150	.142	.097	.084	.127
No	.071	.100	.138	.133	.067	.158

Table 9

Mean Response Times of Combined Reaction Time Control as a Function of Age and Time of Day

	Time of Day		
Age	0900 hrs	1400 hrs	2000 hrs
Young	451.5 msec (.076)	349.6 msec (.082)	361.0 msec (.039)
Older	471.9 msec (.137)	555.4 msec (.100)	756.1 msec (.142)

(proportion of errors in parentheses)

Finally, subsequent analysis of the Time of Day X Practice interaction revealed that at 0900 hrs no significant differences were observed from pre-experimental to post-experimental trials. However at 1400 hrs and 2000 hrs, post-experimental response times were significantly faster than pre-experimental response times. Also, while no significant differences in response times across time of day were observed in post-experimental response times, for pre-experimental trials, response times were significantly longer at 2000 hrs than at 1400 hrs and 0900 hrs which did not significantly differ (See Table 11).

The proportion of errors for every subject was computed as a function of Age, Time of Day and Decision Type for the combined pre- and post-experimental reaction time control data. These data were subjected to a 2(Age) X 3(Time of Day) X 2(Decision) X 2(Pre/Post Experimental trials) mixed analysis of variance. Interactions of Age X Time of Day X Decision $F(2, 75) = 4.119$, $p = .021$ and Time of Day X Practice X Decision $F(2, 75) = 5.15$, $p = .009$ were revealed. Subsequent analysis of the Age X Time of Day X Decision interaction revealed that for the "yes" responses, older subjects' error rates at 1400 hrs were significantly smaller than error rates at 0900 hrs and 2000 hrs which did not significantly differ. Older subjects' error rates for "no" responses did not significantly differ across time of day. For younger subjects, error rates for "yes" responses were

Table 10

Mean Response Times of Combined Reaction Time Control as a Function of Age and Pre/Post Experimental Trials

	Type of Subject	
Practice Level	Young Subjects	Older Subjects
Pre-Experimental	406.9 msec (.126)	734.4 msec (.035)
Post-Experimental	367.8 msec (.128)	454.6 msec (.096)

(proportion of errors in parentheses)

Table 11

Mean Response Times of Combined Reaction Time Control as a Function of Time of Day and Pre/Post Experimental Trials

	Time of Day		
Reaction Time Control	0900 hrs	1400 hrs	2000 hrs
Pre-Experimental	488.4 msec	519.8 msec	703.8 msec
Post-Experimental	435.1 msec	385.2 msec	413.3 msec

significantly larger at 0900 hrs than at 1400 hrs and 2000 hrs which did not significantly differ. Regarding error rates for "no" responses, the only significant pairwise comparison was that error rates at 1400 hrs were larger than error rates at 0900 hrs (See Table 12).

Subsequent analysis of the Time of Day X Pre/Post X Decision Type interaction indicated that for "yes" responses, error rates during the pre-experimental reaction time control trials were significantly higher at 0900 hrs than at 1400 hrs and 2000 hrs which did not significantly differ. However error rates for "yes" responses did not significantly differ across time of day during the post-experimental reaction time control trials. Regarding "no" responses during the pre-experimental reaction time control trials, response times at 0900 hrs were significantly longer than response times at 1400 hrs and 2000 hrs which did not significantly differ. Finally, "no" responses during the post-experimental reaction time control trials were significantly faster at 0900 hrs than at 1400 hrs and 2000 hrs which did not significantly differ (See Table 13).

<u>Memory span measures</u>

A 2(Age) X 3(Time of Day) analysis of variance was also conducted on the memory span measures. While no significant time of day or age differences were observed on digit span performance, a significant main effect of Age was revealed for both Word Span $F(1, 75) = 20.5$, $p < .001$ and Sentence

Table 12

Proportion of Errors of Combined Reaction Time Control Trials as a Function of Age, Time of Day and Decision Type

Time of Day	0900 hrs		1400 hrs		2000 hrs	
Age	Young	Older	Young	Older	Young	Older
Decision Type						
Yes	.078	.150	.085	.024	.002	.142
No	.073	.125	.140	.115	.076	.142

Table 13

Proportion of Errors for Combined Reaction Time Control Trials as a Function of Time of Day, Pre/Post Experimental Trials and Decision Type

Time of Day	0900 hrs		1400 hrs		2000 hrs	
Type of Trial	Pre	Post	Pre	Post	Pre	Post
Decision Type						
Yes	.113	.113	.069	.120	.069	.106
No	.114	.086	.040	.136	.076	.112

Span $F(1, 75) = 15.16$, $p < .001$. Young subjects had significantly larger word spans than older subjects (5.57 vs. 4.61), as well as significantly larger sentence spans (3.31 vs. 2.75). No significant main effects or interactions involving Time of Day were observed for any of the span measures (See Table 14).

Individual Differences

A final series of 2(Age) X 3(Time of Day) ANOVAS was conducted on the individual difference measures collected during testing (See Table 15). Analysis of the individual difference measures revealed several main effects involving Age and Time of Day but no Age X Time of Day interactions were revealed. Main effects of Age were observed for Block Design $F(1, 74) = 33.49$, $p < .001$; Physical Symptoms $F(1, 75) = 4.9$, $p = .039$; as well as scores on the Beck Depression Inventory $F(1, 75) = 7.59$, $p = .008$. Older subjects had significantly lower scores than young subjects on the block design task (21.5 vs. 33.5). Older subjects also scored higher on the Wahler Physical Symptoms questionnaire (.853 vs. .621) and the Beck Depression Inventory (6.41 vs. 3.93) than younger subjects.

Finally, main effects of time of day were revealed for Vocabulary Scores, $F(2, 75) = 11.69$, $p < .001$; Physical Symptoms, $F(2, 75) = 5.39$, $p = .007$; and the Beck Depression Inventory, $F(2, 75) = 8.9$, $p < .001$. Subsequent analysis of these main effects indicated that vocabulary scores were

Table 14

Memory Span Measures as a Function of Time of Day and Type of Subject

Time of Day	0900 hrs		1400 hrs		2000 hrs	
Type of Subject	Young	Older	Young	Older	Young	Older
Span Measures						
Digit Span	6.7	6.4	6.9	5.6	6.6	6.7
Word Span	5.5	4.9	5.7	4.2	5.5	4.7
Sentence Span	3.2	3.0	3.4	2.6	3.2	2.6

Table 15

Individual Difference Measures of Subjects as a Function of Time of Day and Type of Subject

Time of Day	0900 hrs		1400 hrs		2000 hrs	
Type of Subject	Young	Older	Young	Older	Young	Older
Demographic Characteristics						
Vocabulary	46.5	46.0	40.1	34.5	38.2	33.7
Block Design	34.9	25.2	32.6	19.4	33.1	20.0
Phys. Symptoms	.541	.492	.719	1.15	.603	.915
Beck Depression	2.1	2.9	5.6	7.7	4.1	8.6
Trait Anxiety	28.8	32.0	34.5	35.9	34.5	33.0

significantly higher for subjects tested at 0900 hrs (46.3) than for those tested at 1400 hrs and 2000 hrs (37.3 and 35.9, respectively) which did not significantly differ. Subsequent analysis of scores on the Wahler Physical Symptoms questionnaire revealed that the only significant pairwise comparison was that scores were significantly higher for subjects tested at 1400 hrs (.935) than for those tested at 0900 hrs (.516). Finally, scores on the Beck Depression Inventory were significantly lower for subjects tested at 0900 hrs (2.49) than for those tested at 1400 hrs (6.66) which in turn were lower than scores for subjects tested at 2000 hrs (6.34). No significant main effects or interactions of age or time of day were observed for scores on the trait anxiety questionnaire.

DISCUSSION

The present study was designed to examine age differences in memory performance across time of day. One major purpose was to determine if the efficiency of short- term memory processes differ depending upon the age of the subject. A second purpose was to examine whether the time of day that subjects are tested differentially affects older and younger adults. Short-term memory scanning was assessed by collecting response times to the Sternberg (1966) item-recognition task using digits and words. Short-term memory span was assessed by collecting digit, word and sentence spans for each subject.

Analysis of the slope of the line relating response time to memory set size indicated that the slopes of younger and older subjects did not significantly differ for either words or digits. These results are inconsistent with previous work (Salthouse & Somberg, 1982; Anders, Fozard & Lillyquist, 1972) which found that older adults have steeper slopes than younger subjects when scanning for digits. One possible explanation for the lack of differences in the present study is that the present measure of verbal ability suggested that the verbal ability of our subjects, both young and older, was somewhat lower than would be expected (Wechsler, 1981). Previous studies have used educational attainment rather than WAIS-R vocabulary scores and therefore are not directly comparable. However, one would expect educational attainment and verbal ability to be positively related. If this is the case, subjects in the present study would have lower levels of verbal ability than those in previous studies. Perhaps age differences in the slopes are only present when the verbal ability of the subject exceeds some minimal level.

Analysis of the slopes indicated that digit scanning became faster across time of day, while no time of day differences emerged for word scanning. In addition, the present study suggests that the time of day effects were similar for both young and older adults. The time of day differences for digit scanning are consistent with previous work (Anderson et al., 1988) which suggested that digit scanning speed improves throughout the waking day. However, there were no time of day differences for word scanning. In addition, the slopes for digit scanning were larger for all subjects at all set sizes than were the slopes for word scanning. One might assume that because words are larger chunks of material that they would require more processing time. However, it appears that scanning for digits is a more difficult task. Perhaps because words are more meaningful units of information, a context is provided which promotes faster memory scanning. Alternatively, since words are larger units of information, there is also more potential for variation in physical appearance. Therefore, rather than searching for a single digit which must be distinguished from other single digits, subjects may discard words as inappropriate after cursory inspection reveals physical characteristics which are not consistent with those of the target word. The absence of time of day differences for the word scanning task may be due to the level of difficulty of the task. Perhaps the subtle effects of time of day are only present for more demanding tasks such as larger memory sets.

Analysis of the intercepts, which is generally assumed to reflect the time needed to respond to a memory probe, revealed that for both digit and word scanning, older subjects had larger intercepts than younger subjects. This is consistent with previous work (Salthouse & Somberg, 1982; Anders, Fozard & Lillyquist, 1973) suggesting that older adults are slower at encoding information into short-term memory.

Although interesting main effects of time of day and age were found in the memory scanning task, no interactions of age and time of day were observed. This suggests that circadian influences on performance are similar for both young and older adults. However, previous research suggests that time of day differences in memory performance depend upon the type of person (morning type/evening type) tested (Petros et al., 1990). The present study did not examine the "morningness/eveningness" of the subjects and therefore, any interaction may have been masked. Morningness/eveningness is basically a measure of the time of day an individual chooses to engage in certain activities as well as when to go to bed or wake up in the morning. The older subjects in the study ranged from indiviuals who worked full-time to others who had been retired for several years. Thus, while some participants were free to sleep in and engage in activities at any time during the day, others were restricted in their options due to the demands of their occupations. The younger subjects consisted entirely of college students who all presumably had to attend classes daily which would restrict their freedom to sleep in or to choose when to engage in activities. Therefore, there was likely much more variability in the morningness/eveningness of the older subjects than there was in the younger subjects. Possibly, if the morningness/eveningness of the subjects was determined and equally represented across testing times for both older and younger subjects, a clearer pattern of time of day differences would have emerged.

Analysis of the pre-experimental reaction time control (RTC), revealed that young subjects had faster response times than older subjects, and response times became slower across time of day. These results are consistent with previous research which suggests that reaction times are slower for older adults than for younger adults (Botwinick, 1978) but inconsistent with Blake (1967) who showed that reaction time improves across the time of day.

An Age X Time of Day interaction revealed that response times did not differ across time of day for the younger subjects, while response times become slower across the time of day for the older adults. It appears that the time of day effect on reaction time in this case can be accounted for in large part by the older subjects reaction times at 2000 hrs. Previous research has demonstrated that the effect of time of day on performance critically depends on the type of person (morning type/evening type) tested (Petros, et al., 1990). This again suggests that the type of person should be distinguished. Possibly, many of the older subjects tested at 2000 hrs were morning types and therefore not performing at their optimal level.

The longer response times at 2000 hrs for older subjects that was revealed in the analysis of the pre-experimental RTC remained when the two RTC tasks were combined. Again this effect suggests the need to distinguish and control for the type of person differences. In addition, reaction times were faster for post- experimental RTC than they were for pre-experimental RTC at 1400 hrs and 2000 hrs for both older and younger subjects. This suggests that the pre-experimental RTC was utilized as a "warm up" task and the post-experimental RTC is perhaps a more pure measure of simple button pressing speed.

The intercept data indicates that older subjects had slower reaction times than younger subjects on both digit and word scanning tasks. The slower RTC (simple button pressing speed) may in part account for the larger intercepts of older subjects. However, the RTC differences do not account in full for the age differences in intercepts for digit and word scanning. A comparison of the intercept for digit and word scanning with the RTC intercepts suggests that even after simple button pressing speed is considered, response times for older subjects were longer than response times for younger subjects. In addition, the time of day differences in the intercepts for the word scanning task cannot be explained as a result of differences in simple button pressing speed. Again, a comparison of the intercept for the word scanning task with the RTC intercept suggests that word scanning speed became faster across time of day. Unfortunately, while subtracting the reaction time control data from the response time data would have allowed for a more definative statement regarding the age and time of day differences suggested, a strict comparison was not completed due to the inadequacy of the reaction time control task. Given the interactions revealed by the analysis of the reaction time control data, it appears that this was not a measure of simple button pressing speed, rather, some sort of cognitive component may also have been involved. Future research should attempt to clearly isolate simple reaction time.

In addition to examining age and time of day differ ences in memory scanning speed, the present study attempted to examine the possible effects of age and time of day on memory span tasks. Results of the present study revealed that young subjects had larger word and sentence spans than older subjects. These results are consistent with previous work (Light & Anderson, 1985). These tasks require both storage and manipulation of information in working memory. Poorer performance of older subjects suggests that they are less efficient at these tasks than younger subjects. The absence of age differences in memory scanning, yet the presence of age differences in memory span, suggests that both the storage and processing functions in working memory exceed capacity limitations in older adults. Possibly, with additional memory load as in a text processing situation, age differences would become more apparent.

No time of day effects were observed on any measure of memory span. The absence of time of day effects is consistent with previous work by Anderson (1988) who found no time of day effects on a digit span task. However, it is inconsistent with Blake (1967) who found performance on a digit span task deteriorated throughout the day. Future research needs to examine examine the possible influence of time of day on memory span tasks.

Several of the individual difference measures in the present study emerged as significant differences among groups. Visuo-spatial organization skills were superior in younger adults. Older adults acknowledged a greater number of physical symptoms and more signs of dysphoria than younger adults. In addition, subjects tested at 0900 hrs had higher vocabulary scores than those tested later in the day. Subjects tested earlier in the day also acknowledged fewer physical symptoms and fewer signs of dysphoria than those tested later in the day. These significant effects across time of day are difficult to explain. Perhaps random assignment failed to evenly distribute subjects on these variables. It is also possible that the differences represent true effects of time of day on these variables. Future research should investigate these possibilities. Nevertheless, several multiple regressions were conducted to control statistically for the possible impact of these confounding variables on the overall results. These multiple regressions revealed that the same results emerged after the effects of these variables was statistically removed.

Previous research suggests that older adults are less efficient at memory access than younger adults (Salthouse & Somberg, 1982; Anders, Fozard & Lillyquist, 1972). Another body of literature suggests that short-term memory scanning improves across time of day (Anderson et al., 1988). The present study examined whether age differences in memory performance were different depending upon the time of day subjects were tested. The present results provide no support for age differences in memory performance across time of day. Rather, the data suggest similar time of day effects in both young and older adults. However, previous research on the effects of time of day on memory suggest that type of person is a critical factor. Future research examining the relationship of age and circadian variations in performance should distinguish the type of person (morning type/evening type) tested. Perhaps a more detailed life style measure should be employed with older subjects given the various life styles represented in that portion of the population. If reliable differences are present in younger adults with similar life styles (college students), then more robust differences may be present in the older adult population. Finally, since the hypothesis underlying time of day differences in memory performance is based upon circadian variations in physiological arousal, then future research should employ physiological measures of arousal such as body temperature, blood pressure, heart rate, or electrodermal activity, to examine better the physiological changes in arousal and their influence on memory performance across time of day.

APPENDICES

Appendix A

Digit Span Task

Number of digits	Trial 1	Trial 2
3	5-8-2	6-9-4
4	6-4-3-9	7-2-8-6
5	4-2-7-3-1	7-5-8-3-6
6	6-1-9-4-7-3	3-9-2-4-8-7
7	5-9-1-7-4-2-8	4-1-7-9-3-8-6
8	5-8-1-9-2-6-4-7	3-8-2-9-5-1-7-4
9	2-7-5-8-6-2-5-8-4	7-1-3-9-4-2-5-6-8

Appendix B

Word Span Task

2	mouth - bridge farm - space jazz - team
3	heart - club - job staff - rain - book plane - act - child
4	hair - sun - ground - mile vote - wire - smoke - milk voice - post - art - list
5	nail - stage - film - store - gun king - law - race - friend - car plant - road - blood - play - ball
6	hall - sea - floor - wall - face - cloth air - board - song - pool - key - dance church - week - light - spring - science - game
7	girl - door - cent - son - bed - eye - gold oil - land - class - dog - fire - price - queen food - stock - hill - range - month - clay - field

Appendix C

Sentence Span Task

Sentence Span Task

<u>Practice Set I</u>

Driving down a country road we smelled an undeniable skunky odor.

After the heavy electrical storm last night Jane was relieved to see daylight.

<u>Practice Set II</u>

Alex and his brothers are having a great time flying kites on the sunny hillside.

After his baseball broke a neighbor's window Robbie received a stern lecture.

<u>Practice Set III</u>

Even though he enjoyed many riches Tom Canty felt like a captive.

His mother is a tall lady with red hair who shops at all the expensive stores in town.

<u>Span Level 2 Set I</u>

One of the favorite pack animals of the 1800's was the hardy mule.

The morning started bright and cheery with the singing of the lark.

<u>Span Level 2 Set II</u>

One of my favorite smells is the smell of baked bread fresh out of the oven.

Ruth's favorite toy is 'walking and talking Anna' her birthday doll.

<u>Span Level 2 Set III</u>

Perched on the sunny window sill was a beautiful pure white dove.

Acres of golden wheat waved in the wind on the open prairie.

Span Level 3 Set I

One of the pleasures of root beer floats is eating the thick foam.

John's favorite chore around the house is trimming and mowing the lawn.

Jeffrey was so frightened by the dog that he turned white as a ghost.

Span Level 3 Set II

The woman slipped on the ice and spilled her groceries on the pavement.

Throughout her performance the entertainer made the audience laugh and cry.

The Fourth of July picnic included barbecued chicken baked beans and potato salad.

Span Level 3 Set III

One of the most amazing sights is the sturdy dam built by the beaver.

Part of the obstacle course was to run inside a large barrel.

One of Pam's life ambitions is to become a famous song writer and singer.

Span Level 4 Set I

Scamp is a fine dog but at the dinner table he is a little beggar.

The tiny nest was situated on the oak tree's longest and highest limb.

Billy lost control as he raced down the street and fell and scraped his chin.

Summer is the time of year to pick blackberries to make jam and jelly.

Span Level 4 Set II

Captain Cook tried to force Wendy and her brothers to walk the plank.

Ants flies bees wasps and beetles are all insects.

The Williams family was careful to store food for the winter down in the cellar.

Mrs. Edwards spends two hours fixing her hair and she uses a lot of hair spray.

Span Level 4 Set III

The hunter anxiously waited for the buffalo to run so he could try his new weapon.

Supposedly angels fly around in long white gowns singing and playing the harp.

The air was crisp and cool with a gentle salt smell in the sea breeze.

'Give to the Salvation Army' was written in big blue letters on the white banner.

Span Level 5 Set I

The sound of birds and insects filled the air in the muggy swamp.

Marie's favorite dinner is baked eggplant and spaghetti with red clam sauce.

Harold loves to participate in sports especially tennis fishing and golf.

The dining room table looked perfect except for a missing fork.

In the Old West Butch Cassidy and the Sundance Kid were two famous robbers.

Span Level 5 Set II

A carpenter uses many tools such as nails saw and a hammer.

The taxi turned up Michigan Avenue where they had a clear view of the lake.

Mother went to check the baby who was crying in his cradle.

Punctuality accuracy and helpfulness are qualities of a good banker.

Everyone raised their champagne glasses to the bride and groom for the toast.

Span Level 5 Set III

Sharon felt like a Tide commercial because her son's clothes were always full of dirt.

At the corner of Jackson and Willow lay a hit and run victim.

Peter was trying to fix his car when he discovered he lacked a tool.

The summer storm was fiercely tossing the ship and bending the ship's mast.

At midnight Cinderella's dress turned to rags and she lost her glass slipper.

Span Level 6 Set I

On the day of the test many students forget to bring a soft lead pencil.

Deep in the rain forest little spotted lizards slept on the green moss.

Halloween is a special time full of costumes jack-o-lanterns and candy.

The sun is high in the blue sky and all the flowers are in bloom.

'Bonnie Lass' is the registered name of the Johnson family's new yacht.

Mark walked with a limp because his foot was sore from a thorn.

Span Level 6 Set II

Pocahantas busily sews beads and feathers on Running Deer's soft leather vest.

A popular inhabitant of the local pond is the little green frog.

In order to make herself a new dress Wendy went to buy some fabric.

In January February and March you can watch the migration of the gray whale.

Mother and father were aglow with pride and excitement over their new infant.

Baby Cindy fought with her brother Andy over a new red rattle.

Span Level 6 Set III

The criminals were gloating after the chase when they counted all the stolen cash.

Shirts pants and dresses are sometimes called 'threads' and sometimes called 'garments'.

Daisies violets butterflies and honey bees occupy the wide green meadow.

One reason trial procedures are slow is because they must choose an impartial jury.

Dale nervously coasted into the gas station with an empty gas tank.

The antelope was fast and swift but it still was caught by the hunter's arrow.

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