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Running Head: PROSPECTIVE MEMORY AND THE FRONTAL LOBE

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Abstract

Recent evidence suggests that the frontal lobe plays an intimate role in the meditation of prospective memory (Shallice & Burgess, 1991; Cockburn, 1995). However, there is a paucity of studies linking damage to the frontal lobe to reduced efficacy of prospective memory. The present study attempts to examine three types of participants who differ in frontal lobe functioning and their relative levels of successful prospective memory. The participants consist of younger adults, older adults (55 and over) and individuals with frontal lobe damage determined by a CAT scan or MRI. All three groups will be given a computer-based general knowledge quiz that has two types of prospective memory tasks enmeshed within it: a time based, disembedded task and an event-based, embedded task. The latter necessitates higher attentional processing, requiring both self-initiated retrieval and that the participant break attention from a previous task. The participants will also be given the Stroop test and the WCST which have been implicated as successful predictors of frontal lobe damage. The results indicated that the younger adults performed significantly better than the older adults on both types of prospective memory tasks. However, there was no correlation between the measures of frontal functioning and performance on the prospective memory task. The present study allows comparison of the three separate groups with differing levels of frontal lobe damage, strengthening evidence for a frontal lobe involvement in the mediation of prospective memory. The results are discussed in reference to a possible mechanism for prospective memory related to the executive functioning of the frontal lobes.

The Roles of Age and Frontal Lobe Damage in Prospective Memory

In recent years, a distinction has been drawn in the study of memory that suggests two components: retrospective and prospective memory. Retrospective memory is the recall or recognition of previously stored information. (e.g., remembering what you had for breakfast this morning). Prospective memory is remembering an intention. This type of memory relies on storage of past knowledge or events to be able to recall an action to be performed in the future (Brandimonte, Einstein & McDaniel, 1996). An example of prospective memory would be remembering to take your medicine with breakfast, or remembering to pick up milk at the store on your way home. This type of memory is thought to have origins separate from retrospective memory, specifically related to the executive functioning of the frontal lobe. The present study attempts to provide further support for this conclusion. Prospective memory does rely on the storage and retrieval of a past event, suggesting a retrospective component to the processing. Assuming that there is this interaction, how can one determine if the two are functionally different from each other? If the two memory processing systems are mediated differently, then we would expect the initial coding process to also be dissimilar.

In support of the view that the processes are dissimilar, Kesner and DeSpain (1988) presented evidence that there is a differential memory coding system for different types of memory tasks. The experimenters introduced rats to a 12 arm radial arm maze with 2, 4, 6, 8, or 10 spatial locations open to them. The rats were placed on the maze a second time and were rewarded for entering a novel arm. The results showed that the subject's errors increased as the number of arms increased from 2 to 6, indicating a retrospective coding process. The subjects were recalling which arms had already been visited. However, when the arms were increased from 8 to 10, the number of errors decreased, indicating a switch to a prospective coding process. By increasing the number of arms to remember, the subjects were forced to switch from remembering what arms they had already visited to remembering which arms they had not yet visited.

This same type of coding differential was found with human participants. Participants were shown a grid with 16 squares. 6, 8, 10, 12, or 14 X's were placed within the squares one at a time. The participants were then asked to distinguish two X's:

which one was in the original matrix and which one was novel. When the participants used a retrospective/prospective encoding process, the same pattern of errors were seen. Nallan, Kennedy and Kennedy (1991) provide further evidence that supports the differing coding process in the human participant. These studies suggest that the coding process in human memory also has this coding differential.

To further explore aspects of human memory, several paradigms have been utilized to study the prospective component to memory. Kvavilashvili (1992) critically reviewed some of the existing paradigms within prospective memory itself. Early studies of prospective memory were conducted outside of the experimental laboratory (Meacham & Leaman, 1975; Dobbs and Rule, 1987) creating an environment lacking in experimental control. Alternatively, more recent studies focused on developing tasks designed to be completed within the laboratory (Einstein and McDaniel, 1990). However, these tasks often were not consistent with natural prospective memory tasks in the everyday environment of the participant. Kvavilashvili (1992) concluded that the way to study prospective memory most effectively would be to design a study involving a natural task that would be completed inside the controlled laboratory setting. Although she did not say this directly, Kvavilashvili implies that this would involve some mild deception on the part of the experimenter. To attempt to observe natural behavior, the participant must be unaware of the true focus of the study.

Along with the setting of the experiment, prospective memory has also been classified according to the type of task to be performed. One distinction that has been suggested is "embedded" versus "disembedded" tasks (Cockburn, 1995). Often, the prospective memory task has been separated from the other tasks being presented at the same time. A disembedded task requires the participant to break attention away from the original task and complete the prospective memory requirement. For example, Cockburn (1995) designed a study where the participant was given a stopwatch and was told to stop completing a testing booklet ten minutes after initiation, requiring attention to be redirected from the problems presented in the booklet. An embedded task would be one that is consistent with the task at hand. Cockburn (1995) also designed an embedded task requiring the participant to remember to sign his or her name at the end of the testing booklet. This is consistent with the original task because it does not require the participant to break attention; the task has been completed. The two tasks differ in the amount of attention that is required. The disembedded task requires that the participate concentrate on two tasks at once, necessitating more diligent attention. This is in contrast with the embedded task that does not require this divided attention.

Closely related to the embedded and disembedded classification, the prospective memory tasks can also be either time-based or event-based (Einstein & McDaniel, 1995). The disembedded example is also an example of a time-based retrieval mechanism (Cockburn, 1995). The participant must be internally motivated to check the time that has gone by and determine when to stop the task. The cue to perform the task involves self-initiated retrieval and is higher in attentional processing. An event-based paradigm is mediated by an external cue. The embedded example is also an example of an event-based task (Cockburn, 1995). The completion of the testing booklet serves as an external cue for the participant to sign his or her name. It is important to note that although the disembedded/time-based and the embedded/event-based tasks were one and the same in Cockburn's study, the four may be distinct from one another.

Prospective memory has been studied using a variety of these paradigms, often comparing young adult efficacy to that of older adults when carrying out prospective memory tasks. This has resulted in inconsistent results, with some studies reporting no difference with age as the independent variable (e.g., Dobbs & Rule, 1978; Einstein & McDaniel, 1990), while other experimental paradigms have resulted in the younger participants performing prospective memory tasks significantly better than the older participants (e.g., Maylor, 1990; Brooks & Gardner, 1994; Tombaugh, Grandmaison, & Schmidt, 1995; Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995).

This disparity in results can be elucidated by examining the paradigm in which the task was presented. Often, those studies suggesting differences between the two groups included an experimental task high in self-initiated retrieval, such as a time-based task. Einstein et al (1995) designed a study in which the first experiment involved participants performing an action every ten minutes (time-based task). The second experiment required the participants to perform an action whenever a specific word was presented (event-based task). The experimenters found significant differences in age in the time-based task as opposed to no significant difference between the two in the event based task. This suggests that tasks high in self-initiated retrieval pose a larger problem in prospective memory in the older participants as compared to the younger participants.

The tasks high in self-initiated retrieval require internal motivation and involve the shifting of attention from one task to another. This necessitates higher attentional processing and executive control. Executive control is involved in the higher intellectual functions, such as temporal and spatial ability. Fuster (1989) suggests that the frontal lobe has been implicated in the mediation of those two aspects of behavior. She outlines a prefrontal syndrome through human studies that implies that patients with prefrontal lobe damage have difficulty with a number of tasks requiring the executive function of sustained attention. For example, she lists several common problems: lowering of general awareness, sensory neglect, distractibility, disorder of visual search and gaze control, difficulty in concentration and temporal integration. All of these disorders have been seen in those with damage to the prefrontal region of the cortex.

As individuals age, the frontal lobe and its functioning gradually deteriorate. The prefrontal cortex experiences a 15-20% neuronal loss as individuals age, determined by neuronal counting (Haugh, in Cytowic, 1996). This degeneration of the lobes and the subsequent deterioration in executive behavior would tie the efficacy of prospective memory to the frontal lobe and its involvement in higher attentional processing. It would be expected that with lower frontal lobe functioning, there would be a lower ability to successfully complete prospective memory tasks.

The data supporting the frontal lobe involvement in prospective memory has been limited to only a handful of case studies (Shallice & Burgess, 1991; Cockburn, 1995). Shallice and Burgess (1991) examined three patients with traumatic brain injury to the prefrontal cortices. The participants were required to remember and initiate a certain set of tasks over a fifteen and twenty minute period. The errors that were made were typical of those tasks requiring high attentional processing. The participants would begin a task and would have difficulty stopping that task and going on to another at a specified time period. However, when questioned, the participants remembered the instructions and knew that they should have stopped. This implies that the retrospective component to the memory was unaffected by frontal lobe injury.

In support of this conclusion, Cockburn (1995) also examined a participant with bilateral lobe infarcts. J.B. was determined to have difficulty initiating behavior. Her Wisconsin Card Sort Test score suggested an inflexibility in frontal functioning, implying that she had difficulty deviating from her original behavior.

J.B. was administered a task that required her to monitor her time and stop a task after ten minutes. Although the participant was seen to be repeatedly checking the time, she failed to stop after the allotted ten minutes. After the experimenter stopped the stopwatch, the participant verbalized that she knew she should have stopped. A separate task required J.B. to sign her name after the end of a testing booklet. The participant was able to successfully complete this type of prospective memory task. The first task was an disembedded time-based task that is very high in self-initiated retrieval, while the other task was an embedded event-based task that is much lower in attentional processing. The results further implicate that the frontal lobes are involved in the higher attentional processing that is required of time-based or disembedded prospective memory.

It is also important to note that the participant was able to recall the original instructions of the time-based disembedded task, but was unable to perform the action that was required of her. This suggests that the retrospective component of the memory was intact, but the ability to perform the action in the future or the prospective component was impaired. This underscores the possibility that her executive abilities have been compromised by the damage to the frontal lobes.

Although both studies provide evidence for a frontal lobe involvement in prospective memory, it has only been researched with individual case studies. Past research has also not conducted studies that have combined younger adults, older adults and individuals that have sustained frontal lobe damage. Therefore, no direct comparison could be drawn between the groups. Three groups will be tested: a younger group, an older group and a group with frontal lobe damage. The participants will all be administered a time-based, disembedded task and an event-based, embedded task. In accordance with the current literature, we would expect a decline in the prospective memory functioning for the time-based, disembedded task with increasing age. There should be a much smaller, if any effect on the event-based embedded task. This deficit should be compounded with patients that have sustained frontal lobe damage. We would also expect a correlation between performance on the prospective memory task and one of the cognitive measures of frontal lobe function: the Wisconsin Card Sort Task (measures frontal lobe flexibility) and the Stroop Color Word Task (measures frontal lobe interference). Differing correlations with the two cognitive tasks would suggest a mechanism for efficacy of prospective memory.

Method

Participants.

Three separate groups were tested. 24 undergraduate students who attend Illinois Wesleyan University participated in the study. They ranged in age from 17 to 21 with a mean IQ of 116. Each student was given extra credit for his or her participation. 20 older adults from the Bloomington/Normal community participated. They ranged in age from 57 to 84 with a mean IQ of 114. Each older adult was paid for his or her participation. Two patients with frontal lobe damage were selected and agreed to be tested. The patients were recruited from Carle hospital in Champaign. These patients were selected by a clinical neuropsychologist who pinpointed selective frontal lobe damage by a CAT or MRI scan. The patients were also paid for their participation.

Materials.

All participants were administered the Kaufman Brief Intelligence Test (KBIT) (Kaufman & Kaufman, 1990), the Stroop Color Word Test (Golden, 1978), the Wisconsin Card Sort Task (WCST) (Grant & Berg, 1981) and the information and digit span section of the WAIS-R. (Weschler, 1981).These tasks are intended to measure general intelligence, interference in frontal lobe functioning, flexibility in frontal lobe functioning and general retrospective memory ability.

The participants were given a computer based general knowledge quiz that was developed from questions by Nelson and Narens (1980). It consists of 200 general trivia questions requiring one-word answers. Two types of prospective memory tasks were enmeshed within the general knowledge quiz.

Apparatus.

A Macintosh PowerMac 8500 computer was used to administer the general knowledge quiz to the participants. A Macintosh Powerbook 170 portable computer was used for those participants unable or unwilling to travel to the university.

Design and Procedure.

Each participant was tested individually. All timepieces were removed prior to testing any participants. Participants were either administered the computer task or the KBIT, WCST, Stroop, and Weschler tasks initially. The tasks were presented to the subjects in a partially counterbalanced order.

The participants were all read instructions concerning the computer based general knowledge quiz. The participants were told that the program is not fully operational and that they are required to tell the experimenter every five minutes what question they are on. The participants were told that in order to asses how long the task will take, it will be necessary for the experimenter to know what question they are on.

Participants were also instructed that a clock will appear on the screen when they press the F4 button. The experimenter pressed the key for them initially, so that it is clear where the key is located. Finally, the participants were asked to type their name at the end of the task. The experimenter asked the participants to repeat the instructions, to ensure that they were clear.

The experiment is a 3 X 2 mixed factorial design. The first independent variable is the group type and it is a between subjects variable. Group type consisted of the following: younger adults, older adults and patients with frontal lobe damage. The second independent variable is type of task and it is a within subjects variable. The type of task is the time-based/disembedded task (informing the experimenter of the question) and the event-based/embedded task (typing name). Task accuracy was measured by the experimenter.

Results

Statistical Results of the Older and Younger Adults

This is a quasi-experimental design. The participants could not be randomly distributed between the groups because of the nature of the determination of the groups: age and brain damage. The dependent variables are percent accuracy on the time-based/disembedded task and performance on the event-based/embedded task on the computer program.

Because of the ratio data, the parametric test of the Anova was used to compare the older and younger adults. Determined by a one-way ANOVA, the younger and older adults did not differ on intelligence $F(1, 42) = 1.66$, $p = .21$.

On the time-based/disembedded task, percent accuracy was measured. The response was considered accurate if it was given within a minute on either side of the expected five-minute interval. Determined by a one-way ANOVA, the younger adults (M=96.5, SD=16.1) performed significantly better than the older adults (M=49.9, SD=39.8) on percent accuracy of the disembedded/time-based task $F(1,42) = 25.19$, $p<.0001$. Within the task itself, the older adults performed significantly fewer time checks (M=6.9, SD=3.6) than the younger adults(M=13.2, SD=5.3), $F(1,42) = 20.54$, $p<.0001$. The pattern of how the participants checked the time also varied by age. Please see figure one for a graphical description. The younger adults exhibit a scalloped pattern to time checking, making more time checks as the five minute intervals approach. The older adults have a much more linear cumulative time check pattern.

On the embedded/event-based task, the task was successful if the participant signed his or her name at the end of the computer task. The name task was either successful or non-successful, therefore a the non-parametric test of a Chi Square was used to compare the nominal data. The younger adults (M=.79, SD=.41) also performed significantly better than the older adults (M=.40, SD=.50) on this second type of prospective memory task $X^2(1, N = 43) = 7.05$, $p<.05$.

The younger and older adults were significantly different from each other on both the cognitive frontal measures. The older adults exhibited higher interference on the Stroop test than the younger adults $F(1,42) = 13.69$, $p<.005$. The older adults also had a significantly higher percentage of perseverative responses on the WCST than the younger adults $F(1,42) = 4.47$, $p<.05$. There was no correlation between the interference score of the Stroop and accuracy on either prospective memory task. We also found no correlation between perseveration determined by the WCST and either prospective memory task.

Determined by a one-way ANOVA there was no significant difference in the younger and older adults on either section of the WAIS-R.

<u>Observations of Patient Behavior</u>

<u>Frontal patient #1</u>

This 35 year old male sustained a right frontotemporal injury. His highest level of education prior to the injury was obtaining his GED. He was very involved in the computer task, frequently answering and reading the questions out loud. Although he repeated the instructions perfectly, he did not tell the examiner once what question he was on. In fact, he never checked the time. At the end of the test, he did remember to sign his name. When questioned as to why he did not tell the examiner what question he was on every five minutes, he simply stated that he forgot that that was required of him. It is important to note that he did remember that he was told that in the instructions. His score on the Stroop was average for his age and he performed average on the information section of the WAIS-R. He did score below average on the digit span. He could recall all the numbers that had been read to him, but the sequencing was consistently reversed for the last two numbers as the lists got longer.

<u>Frontal patient #2</u>

This 56 year old female had an anterior communicating artery aneurysm, causing frontal injury. Her highest level of education was a 3 year nursing degree. She was also very involved in the task, again repeating questions out loud repeatedly. She checked the time twice before telling the examiner that "five minutes was up", although she couldn't remember what she was supposed to do at that five minute mark. After being reminded, she checked the time at 11 minutes, 35 seconds and at 16 minutes, 10 seconds. She knew she was late and again could not remember what was required of her. At the end of the task, she did not remember to sign her name. When questioned as to why she did not, she indicated that she remembered that we told her to do so, but forgot through the test. She was measured as having some interference on the Stroop test. She performed slightly above average for both the information and digit span section of the WAIS-R.

Discussion

The results suggest that the hypothesis that there would be a differential between performance of the younger and older adults was supported. The younger adults performed significantly better than the older adults on the time-based/disembedded task. The older adults also performed significantly fewer time checks than the younger adults. As we can see from the pattern of time checks (fig. 1) the younger adults were not only checked more often, but did so particularly around the established five minute mark. Requiring internal motivation and higher attentional processing, the task requires vigilance on the part of the participant. This lack of vigilance in the time checks may have resulted in the lower means of the older adult population. Only one older participant did not check the time at all, suggesting that the problem is not stemming from a few outliers who did not understand or remember the directions.

The younger adults also performed significantly better than the older adults on the event-based/disembedded task, although this effect was not as pronounced as the previous prospective memory task. Counter to our prediction, when the two tasks are compared, both the younger and older adults had more difficulty performing the event-based/disembedded task. This may be due to the singularity of the task. The participant had only one chance to complete the task, while on the time-based/embedded task, the participant had three chances for success. Another problem with having the event-based/embedded task only at the end of the computer quiz asks the participant to remember over a twenty minute interval, while the time-based/disembedded task requires the participant to remember the task in three five minute intervals.

The measure of frontal interference (Stroop) did not correlate with either of the prospective memory tasks, suggesting that the mechanism is not one of interference. However, the measure of perseveration also did not correlate with the either prospective memory task. This does not support the hypothesis that perseveration or interference may be one of the executive functions that impairs prospective memory performance in older adults. The lack of correlation to the WCST may be due to the limited number of participants and the high IQ of the participants tested. There is a positive correlation between IQ and ability to perform the WCST. This may have established a truncated range where the general correlation is lost in the sample of participants who were tested. A more general sample may produce a significant correlation.

The two frontal lobe patients who were tested had difficulty meeting the requirements of the prospective memory tasks. The older adults also had significant difficulty on both cognitive tasks of frontal functioning. This suggests that the problem is still frontal in nature, if not stemming from the mechanisms mentioned.

These results provide further support that the frontal lobe is involved in the mediation of successful prospective memory. The design of the study allows for comparison between the groups and enhances the knowledge about prospective memory in general. Studies have shown that when older adults are allowed external aids, there is no difference in prospective memory between older and younger adults (Einstein & McDaniel, 1990). Baskin and Sohlberg (1996) have also had some success in training brain injured patients helpful prospective memory techniques by encouraging the use of extensive external aids. This study also implies that if the level of attentional processing is reduced, as in the event-based embedded task, the success also increases and the difference is narrowed between older and younger adults.

There is a retrospective component to the processing of prospective memory. The older adults could be failing to perform on the memory tasks for two reasons. Either the participants could not remember what is required of them in the directions (retrospective) or they did not remember to perform the action at the correct time (prospective). There was no significant difference between the scores for the older and younger adults on the WAIS-R information or digit span section, suggesting that both short term and long term retrospective coding is intact for the older adults. That leads to the problem being solely prospective in nature.

One potential problem in the study is the age effect of familiarity with a computer. The older adults most likely do not have the computer skills or are not as comfortable with a computer as the younger adults are. However, the participants were not required to do anything more than what a typewriter is capable of. The large significant difference that was noted between the groups for the time-based/disembedded task suggests that this could not be the sole reason for the disparity.

The WCST and Stroop both failed to correlate with either prospective memory task. However, both frontal lobe patients did experience difficulty performing the task. FL #1 had difficulty with the sequencing of the numbers on the WAIS-R digit span. He often switched the last two numbers in the series. This suggests that his temporal sequencing ability is impaired. Shimamura, Janowsky and Squire (1990) have established that temporal sequencing is especially problematic to those who have sustained frontal lobe damage. Anecdotally, this switching of numbers in the digit span was also seen with some of the older adults to a lesser degree.

Perhaps prospective memory is not a problem with perseveration, but a problem with the ability to sequence time. If a participant does not have a general idea of when five minutes has gone by, he or she will not be able to check the time in a consistent pattern (Again, see fig.1). Further research needs to examine the possibility that this executive function may be impaired.

The older adults seemed to have a difficult time following the directions of the WCST and often tried to match on principles that were very complicated while the younger adults did not seem to have a problem. Currently, there is a modified version of the WCST that may be used in future research. The version was designed for testing older adults and those who have sustained brain damage. The directions seem to be easier to follow for those populations. This version may be more useful in the future.

The present study also defined older adults as all those 55 and older. This may be too wide of a range to see any significant correlations of the prospective memory tasks to the cognitive measures. A more viable alternative in the future would be to group older adults into smaller categories defined by age.

Lastly, the present study only had two participants who had sustained frontal lobe damage. Future studies need to examine a larger sample size to better generalize to the population. We also did not control for brain damage in general. Future studies may also want to include a population of individuals who have sustained damage to another area of the brain in order to control for an effect due to brain damage itself, rather than frontal damage in particular.

The research may have implications in areas such as medication adherence. If the mechanism for why individuals have difficulty remembering to take medication is elucidated, more effective techniques can be taught to patients susceptible to failure to take medication. This also has repercussions for both individuals who have sustained frontal lobe damage and older adults. If successful prospective memory can be accomplished by establishing cues, neuropsychologists and physicians can teach brain damaged patients and older adults techniques for prospective memory involving salient cues.

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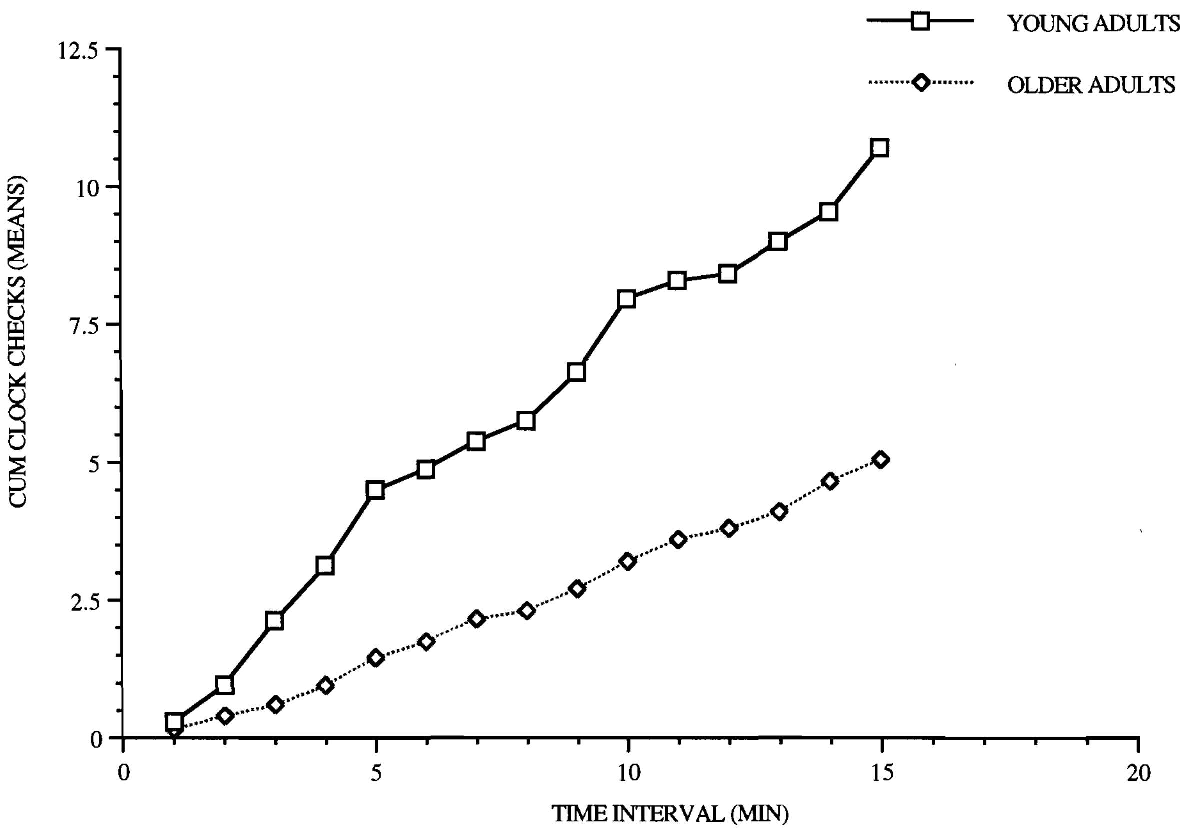
Figure Captions

Figure 1. Mean cumulative time checks for older and younger adults as a function of minutes of time.



YOUNG ADULTS
OLDER ADULTS
CUM CLOCK CHECKS (MEANS)
TIME INTERVAL (MIN)
12.5
10
7.5
5
2.5
0
0
5
10
15
20