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Individual differences and the effects of time of day and interference on memory

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Abstract

Using the Wickens, Born, Allen (1963) release from proactive interference paradigm, subjects were tested at both a morning and afternoon period in hopes of observing the effects time of day, age, and interference have on working memory. 42 college students and 21 participants over the age of 65 first completed the Horne-Ostberg (1976) questionnaire for morningness-eveningness. While most younger adults were evening and neutral types, the vast majority of older individuals showed a stronger preference for earlier hours of the day. Recall results indicated that recall performance of older participants decreased from morning to afternoon, while recall performance of younger individuals improved over the same period of time. Thus, the synchronizing of an individual's optimal performance period and testing can be vital in assessing cognitive functions in older and younger individuals.

Individual Differences and the Effects of Time of Day and Interference on Memory.

It has been demonstrated that circadian arousal is correlated with performance on a wide variety of cognitive as well as physical tasks, such that performance peaks at a certain level of circadian arousal, a peak that occurs more or less regularly at a specific point in the day (Yoon, May, & Hasher, 1997). While extensive research addressing general circadian patterns exists, a far smaller literature concerns the extent to which there are individual differences in these patterns and, in turn, differences in performance at different times of day (Folkard, Knauth, Monk, & Rutenfranz, 1976). May, Hasher, and Stoltzfus (1993) found that older adults correctly recognized slightly, but not significantly, more sentences than younger adults when both groups were tested in the morning, a time of day highly preferred by older adults. When tested in the afternoon, a time of day preferred by younger adults, the younger adults correctly recognized significantly more sentences than the older group. In effect, each group performed better when tested at its preferred time of day. Age-related differences in time-of-day preferences may reflect variations in circadian rhythms among younger and older adults, which, in turn, may affect cognitive performance as well as physiological functioning (Anderson, Petros, Beckwith, Mitchell, & Fritz, 1991). May et. al (1993) raised the possibility that the memory abilities of older adults have been greatly underestimated by being tested at non-optimal times.

The Role of Inhibition in Learning and Recall

The processes of learning and recall require both an excitatory attentional mechanism, which aids in the facilitation and activation of goal-oriented, task-appropriate information, and an inhibitory attentional mechanism, which aids in the suppression and deletion of irrelevant and inappropriate off-task information (Navon, 1989). Research suggests that excitatory attentional mechanisms remain intact and fully functional during one's optimal as well as non-optimal times, but one's inhibitory attentional mechanisms are impaired during an individual's off peak, non-optimal period for learning (Yoon, May, & Hasher, 1997). This impairment of inhibitory functioning during a non-optimal period for processing in one's circadian rhythm may be the cause of an individual's tendency to attend to inappropriate, non-goal oriented information that may be present.

Inhibitory mechanisms are critical to the processes of learning and recall. They make information processing more efficient and aid successful retrieval through three basic means (Hasher, Zacks, & May, 1999). First and most importantly, inhibitory mechanisms prevent off-task, irrelevant information from entering working memory, thus limiting access to goal-relevant information. This access allows goal-relevant information to enter the focus of attention with minimal interference from inappropriate irrelevant information. Second, inhibitory mechanisms possess functions that suppress and/or delete information in working memory that may be marginally relevant or that has been deemed inappropriate or unimportant for the current tasks or goals in question. Together the functions of access and deletion serve to rid the working memory of irrelevant information so that information that is left active is relevant to the task, thus facilitating the success of efficient information processing and retrieval. Third, inhibition serves to restrain strong responses from being given before their appropriateness to the task or goal in question has been thoroughly evaluated. The function of restraint basically aids by preventing prepotent candidates for response from seizing control one's actions and thoughts, so that other, less probable candidates can be considered (Hasher et al., 1999).

Hasher et al. (1999) note that there are both direct and indirect consequences of diminished inhibition. Individuals with impaired inhibitory functioning may be more vulnerable to distracting, irrelevant information, whether that distraction is generated from external sources or internal sources. They also note that the inability to delete previously relevant, but currently inappropriate, information may heighten interference between relevant and irrelevant information for poor inhibitors during the off-task time of their circadian rhythm, resulting in difficulties in acquiring new novel information, comprehending questions, and retrieving stored memories.

Inhibition and Interference

Hasher et al. (1999) note that a consequence of diminished inhibition is one's heightened susceptibility to proactive interference. Competition at retrieval is a major mechanism underlying retroactive and proactive interference. Interference paradigms are a classic method used to study real world forgetting

(Hasher et. al., 1999). In an interference paradigm, participants typically learn two or more successive lists of items in which the same set of cues ("A" terms) is associated with successive sets of responses ("B" and "C"). The task for the participants is to retrieve the final set of responses (either "B" or "C" or both), when cued by the items listed in set "A". Interference is demonstrated when subjects who learn both "B" and "C" responses recall less than control subjects who only learn one of the response sets.

Murdock and Carey (1972) also make mention of the fact that forgetting in our working memory is due to two types of clearly identifiable interference, interference from prior items, conveniently described as proactive interference, and interference from subsequent items, generally described as retroactive interference. An obvious example and task that can be used to examine the influence of retroactive and proactive inhibition is the distractor techniques of Peterson and Peterson (1959). In this task, subjects are presented with three stimuli (i.e. words= blue-red-green) for approximately 5 seconds. After presentation of the stimuli, participants are instructed to count backwards by threes for a predetermined amount of time (ordinarily approximately 20 seconds) and immediately following this time interval are required to recall the stimuli previously presented. Proactive interference builds up with each successive trial. As a direct result of this build up of interference, recall becomes increasingly difficult and poor.

Wickens, Born, & Allen (1963) has shown that when the semantic category from which items are selected is changed, much of the proactive interference buildup is released. Therefore, this paradigm can be a useful way to explore the effects of interference and a subject's ability to avoid it.

Hasher et. al., (1999) suggest because inhibitory attentional mechanisms are impaired during off peak times for storage and retrieval, greater amounts of interference should result from each repetition within a category, thus reducing performance. Three mechanisms may produce this result: (1) people with poorer inhibitory control may search more pathways during retrieval, (2) people with poorer inhibitory control over the contents of working memory will not entirely delete from working memory items from the just-recalled set when the next set is presented, creating memory representations for a current set that are cluttered with information from more than one set, and (3) individuals with poorer inhibitory control over the contents of working memory will spontaneously generate more competing responses to a single cue during learning.

Circadian Arousal: Morning vs. Evening Types

Previous research examining the effect of time of day on cognitive performance indicates that the results may not only depend on the time of day one is tested but also the type of person tested. Horne and Ostberg (1976) introduced a questionnaire intended to classify people based on their time of peak arousal. Respondents are classified by the degree to which their periods of peak arousal fit morning or evening patterns. The scores on the questionnaire can range from 16 to 86, with higher scores (scores 59 and above) indicating a person whose period of peak arousal should be relatively early in the day, a degree of morningness, either moderate or extreme, and lower scores (scores 41 and below) indicating a person with a comparatively later period of peak arousal, a degree of eveningness, either moderate or extreme. Psychometric assessments have shown the questionnaire to have good reliability and scores on the test have been shown to correlate with circadian variations in oral temperature, sleep-wake behavior, and periods of perceived alertness and cognitive performance (Buela-Casal, Caballo, & Cueto, 1990).

Petros, Beckwith, and Anderson (1990) in their research on circadian arousal and individual differences found that recall of prose decreased across time of day for morning types, whereas recall increased across time of day for evening types. Furthermore, Anderson et. al. (1991) showed a strong negative correlation between performance on tasks completed in the evening for young adults and their scores on the morningness-eveningness questionnaire. Recent research on individual and group differences in morningness- and eveningness has indicated a significant shift toward morningness as age increases. For example May et. al. (1993) administered the morningness-eveningness questionnaire to over 1,500 college students (age 18 to 23) and over 600 older adults (age 60 to 75) in different regions in the United States. Their results show clear age differences in the pattern of peak arousal times across the day with roughly 40% of younger adults showing eveningness tendencies and less than 3% of older adults showing eveningness tendencies, with the majority (75%) being morning types. These findings suggest that younger and older adults differ markedly in their pattern of circadian arousal over the day and suggest that, for those cognitive functions influenced by circadian arousal, in general performance of many younger adults should improve across the day, while that of most older adults will deteriorate or worsen as the day progresses.

The Present Study

Utilizing the Horne-Ostberg Morningness-Eveningness Questionnaire (1976) and a release from proactive interference paradigm, the purpose of the study in question was to observe the effects time of day and age have on memory and recall. Subjects were tested using the Wickens et. al. (1963) release from proactive interference paradigm. It was predicted that at a subject's non-optimal time, proactive interference would be greater and release from proactive interference would not be as complete as at one's optimal time for memory and recall. It was also hypothesized that younger participants' best performance would occur in the afternoon, in contrast to that of older adults, who were predicted to perform best in morning.

Method

Participants

The participants were 42 young adults (13 males and 29 females, ages 18-29 with a mean of 22.9) and 21 older adults (6 male and 15 female, ages 66-92 with a mean of 75.6). The younger adults were students enrolled in various summer undergraduate psychology courses at Marshall University. Students received extra credit for their participation in the experiment. The older adults were volunteers obtained from the Woodlands Retirement Community, in Huntington, West Virginia, Scope Towers, Grandview Manor and Unity Square Senior Community, both located in Ashland, Kentucky, and volunteers from Beckley, West Virginia. The participants in both age groups were tested in groups that ranged in size from 2 to 30 participants.

Materials

All participants were required to complete the Horne-Ostberg Morningness-Eveningness questionnaire. The Horne-Ostberg (1976) questionnaire consists of 19 items that attempt to determine the time of day that individuals report that they function most effectively. Total possible scores ranged from 16 to 86, with Morningness-Eveningness tendencies determined by the following scales: 16-30 (definitely evening), 31-41 (moderately evening), 42-58 (neutral), 59-69 (moderately morning), and 70-86 (definitely morning).

The stimulus words used for the memory task in question were selected from the tree, fruit, color, instrument, vegetable, animal, spice and bird categories of the Battig & Montague (1969) norms. Each selected category of items in the norms was divided into thirds based on the strength of the association of the items to the category. In other words, the first third of the category consisted of the most frequently produced responses in the norms to that category. The second third were the next most frequently produced items, and the bottom third of the category were the least common responses to the category. Triads were then selected by randomly picking one item from each third of the list and then placing these three items in a random order. Two different lists were formed, each consisting of 16 triads which were divided into four sets of four contiguous triads. Each list contained two control sets and two experimental sets. In the control sets, all four triads were made from items selected from the same category. In the experimental sets, on the other hand, the first three triads in each set were selected from one category, but the fourth triad came from a new category. Lists 1 and 2 differed in whether the experimental sets were Sets 1 and 3 or 2 and 4. The two lists are contained in Appendix A.

Procedure

All participants were tested in the morning (at 8:00A.M, 8:30A.M. or 9:00A.M.), and in the afternoon (at 2:00P.M, 2:30P.M. or 3:00P.M). Upon arrival at the testing location, the participants were given a brief description of the purpose of the study and signed consent forms. Prior to beginning the memory task, they completed the Horne-Ostberg Morningness-Eveningness Questionnaire. Each participant was given as much time as needed to complete the questionnaire. After completion of the questionnaire, each group was given instructions for the memory task and shown a sample triad consisting of names, and stepped through the rest of the procedure described below. The items in each category were presented in triads, via a projector controlled by an IBM laptop computer running a slide show created with Microsoft Power Point. On each trial, the first slide prompted the participants to get ready for the words and appeared for 3 sec. The second slide presented a triad of words for 5 sec. On the third slide, which appeared for 2 sec., subjects were prompted to get ready for a number. The next slide presented a three-digit number for 3 sec. Subjects were instructed to say the number aloud and immediately begin counting backwards (silently) by threes to the rhythm of a clicking sound accompanied by 7 asterisks which appeared on the screen once a second for 7 sec. Therefore, the retention interval from disappearance of the word to the recall cue was 12 sec. At the end of the counting interval, the slides were advanced for a fifth time instructing the subjects to write in a booklet the number reached in the backwards counting task, and then to write the word triad most recently presented. Twenty seconds later, chimes were heard and a sixth slide informed participants that the recall period was over by prompting them to "Stop". Participants would then turn to the next page in their booklet and get ready for the next sequence. Seven sec. after the stop cue, the ready slide appeared for the next triad.

Each individual was given a blank booklet (for the purposes of recall) with designated areas for writing the number last reached in counting and for recording the words of the triad. A separate page was used for each trial. The subjects were instructed to recall the words in their order of presentation, and were encouraged to guess if uncertain. List 1 and 2 were counterbalanced across groups. Half the groups received List 1 in the morning and List 2 in the afternoon and half received the reverse assignment. However, because group sizes were not equal counterbalancing of the list was only approximate across subjects.

Results

Questionnaire on Morningness-Eveningness Preferences

The percentage of older and younger participants who scored in each of the five categories of circadian arousal as defined by the Horne-Ostberg Morningness – Eveningness Questionnaire (1976) is shown on Figure 1. The majority of older adults had high morningness ratings, with a mean score of 63.53 (SD = 9.02). Over 76% of older participants were either categorized as being Moderately Morning or Definitely Morning types. In contrast, younger subjects had a mean rating of 48.86 (SD = 8.88); over 85% of younger participants were categorized as being either Evening or Neutral types. Less than 15% of younger participants were Moderately Morning, and none of the younger subjects was a Definitely Morning type. With regard to older subjects, less than 5% were categorized as being Moderately Evening, and no older subject was a Definitely Evening type.

Insert Figure 1 Here

Memory Performance

Memory performance was scored with a free recall scoring criteria, i.e., participants were given credit for each word correctly recalled from the triad regardless of whether it was recalled in its correct position. These scores were then analyzed with a 2 x 2 x 2 x 4 analysis of variance, with Age (young or old) as a between-subject factor and Test Time (morning or afternoon), Condition (control or experimental), and Trial (1-4) as within-subject factors.

Results revealed a significant main effect for Age, $F(1, 61) = 27.35$, MSe = 156.92, $p < .001$. Overall, younger participants, on average, recalled significantly more than older participants (41.9 vs. 35.3 items correct, respectively). A significant main effect for Test Time was also observed, $F(1,59) = 18.66$, MSe = 37.37, $p < .001$. Recall was slightly better during morning sessions than afternoon sessions (40.56 vs. 38.4 items correct, respectively). These effects, however, must be interpreted in light of the significant Age x Test Time interaction $F(1,61) = 44.16$, MSe = 88.32, $p < .001$. This interaction is displayed in Figure 2. As is apparent in the figure, for older individuals, recall decreased from morning to afternoon. Morning recall performance for older participants yielded a mean of 39.6 words correct out of a possible 48 (SD = 5.08), or 82.4% correct. In contrast, during afternoon sessions, older individuals recalled on average 31 words (SD = 7.33), or 64.6% of the items. The 17.8% decrease in word retrieval by older individuals during afternoon sessions compared to morning performance supports previous results from May et. al. (1993), and Yoon et. al. (1997), which found older individuals had superior cognitive performance in the morning compared to their afternoon cognitive functioning.

Insert Figure 2 Here

Younger individuals recall performance for morning sessions yielded a mean of 41.09 (SD = 5.78), or 85.6% correct. In contrast, as predicted, afternoon performance for younger participants was better, with a mean recall of 43.86 words (SD = 4.24) or 91.3% correct. Although not a large improvement, the 5.7% increase in word retrieval during the afternoon sessions for younger participants gives some support to the hypothesis of evening cognitive optimality for younger individuals.

Follow-up analyses to this interaction indicated that in the morning the recall performance differences between younger and older participants were not significant, $p > .3$. On the other hand, the performance differences between younger and older subjects in the afternoon were significant, $p < .001$. In addition, both the improvement in recall displayed by younger participants from morning to afternoon and the decline in performance displayed by older subjects over the same time period were significant $F(1,41) = 5.5$, $p < .05$, and $F(1,20) = 23.7$, $p < .001$, respectively.

Results of the primary analysis also revealed significant main effects for Condition, $F(1, 61) = 6.66$, MSe = 4.93, $p < .05$; and Trial $F(1, 61) = 20.65$, MSe = 19.97, $p < .001$. However, these effects are best understood with respect to their significant interaction, $F(3,183) = 7.18$, MSe = 6.15, $p < .001$. This interaction is displayed in Figure 3. As is apparent in the figure, correct responses generally decreased across trials in both the experimental and control conditions. However, on the fourth trial, in the control condition where the category of items were the same as on previous trials, performance did not improve, while in the experimental condition, where the category was changed on Trail 4, recall improved dramatically.

Insert Figure 3 Here

Finally, there was a significant Age x Test Time x Condition x Trial interaction, $\underline{F}(6, 177) = 2.25$, MSe = .946, $\underline{p} < .05$. This interaction was the result of some unusual performance by young subjects in the control condition in the afternoon sessions and was not interpretable.

Intrusive Errors

In order to more specifically examine the role of interference in the present experiment, intrusion errors were examined. Intrusion errors were defined as the subject's "recall" of any word that was not a member of the triad being scored. Most of these errors were "recall" of words that had appeared in previous triads in the same category. The intrusion scores were analyzed with the same form of analysis of variance as the recall data described above.

Results revealed a significant main effect for Test Time $F(1,61) = 6.49$, MSe = .644, $\underline{p} < .05$. However, as with the recall results, this effect is really subsumed in the significant Age x Time Test interaction, $F(1,61) = 14.89$, $p < .001$. This interaction is displayed in Figure 4. As is apparent in the figure, for younger participants intrusion errors showed a small but non-significant decline between the morning and afternoon sessions $p > .02$. While for older participants, intrusion errors more than doubled from 5% in the morning to over 11% in their afternoon sessions, $p < .01$.

Insert Figure 4 Here

Discussion

Older and younger participants clearly differed in their Morningness-Eveningness preferences. In the present study, older individuals preferred earlier hours of the day, as opposed to younger participants, who showed strong preferences for later hours in the day. These results indicate a time of day preference shift from early adulthood to later adulthood, and are consistent with other findings that diurnal rhythms vary with age, individuals, and physiological functioning (e.g., Anderson et. al., 1991). Time of day preference may reflect these variations in physiological function (Intons–Peterson et. al., 1998). The high proportion of older individuals who prefer earlier hours of the day is consistent with findings from May et. al., (1993) and Horne et. al., (1976). The low proportion of morning types among younger participants coincides with evidence reported by Anderson et. al. (1991) and May et. al.

Overall, the recall results of the present study indicated that younger participants recalled more than older individuals. However, the magnitude of these age differences varied tremendously across the day. Older participants showed better recall when tested at their preferred time of day, the morning, as opposed to when tested at one of their non-preferred times (in the afternoon). The decrease in word recall and increase in intrusion rate by older individuals during the afternoon sessions is consistent with findings by Yoon et. al., (1997) and May et. al. (1993) who also found that older individuals displayed superior cognitive performance in the morning compared to their afternoon functioning. Younger adults also exhibited slightly superior recall when tested at their preferred performance period, in the afternoon, than when tested at their off-peak period (in the morning); their improvement in performance from morning to afternoon sessions is also consistent with findings by Yoon et. al. and May et. al. Results when participants were tested in the morning, performance differences between younger and older participants were not significant, but when younger participants were tested in the afternoon, large recall differences were observed. Therefore, the effects of time of day on performance are not as consistent across individuals as was once thought. Instead, the effects of time of day vary as a function of the synchrony between individual optimal performance periods and the time at which testing occurs (May et. al., 1993).

The Peterson-Peterson (1959) task is very sensitive to interference effects. In fact, on the first trial of this task, where interference is minimal, forgetting is generally absent (Kepple & Underwood, 1962). Recall errors on subsequent trials are ascribed to the build up of proactive interference. Therefore, that older subjects performed much worse in the afternoon than in the morning demonstrates that they were less able to filter out or inhibit the effects of proactive interference at their non-preferred time of day. This is further supported by the fact that intrusion errors, generally a direct reflection of interference, more than doubled for these subjects in the afternoon. Therefore, as predicted, these results suggest that the primary influence of age and circadian rhythms on working memory were through an effect on inhibitory mechanisms.

In conclusion, one can infer from the present results that when studying age related mental ability and cognitive performance, it is important to guard against potential biases by controlling for individual and group differences in circadian arousal patterns. Studies that fail to do so may otherwise produce results that reflect an over or under estimation of the relationship between age and other variables of interest (Yoon et. al., 1997). Hopefully, these results will join with the work of others to show that differences in cognitive functioning across a life span, among individuals, and across the day within individuals, can be tied together in a framework that emphasizes the fundamental importance of inhibitory attentional control over the contents of consciousness.

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Figure 1

Percentage of Younger and Older Adults in Each of Five Categories of Circadian Arousal as Determined by the "Morningness-Eveningness Questionnaire."

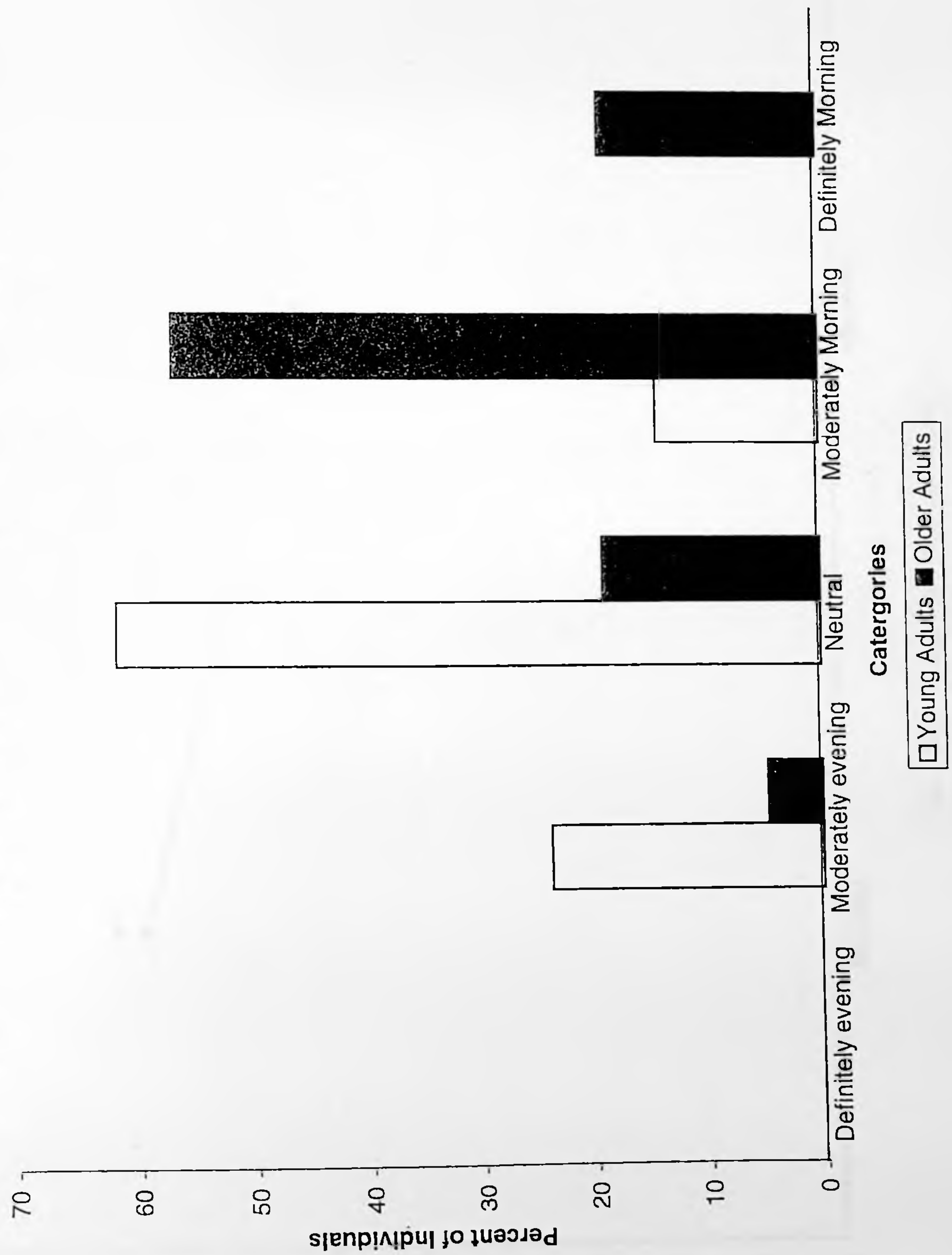


Figure 2

Mean Morning and Afternoon Percent Recall for Older and Younger Adults

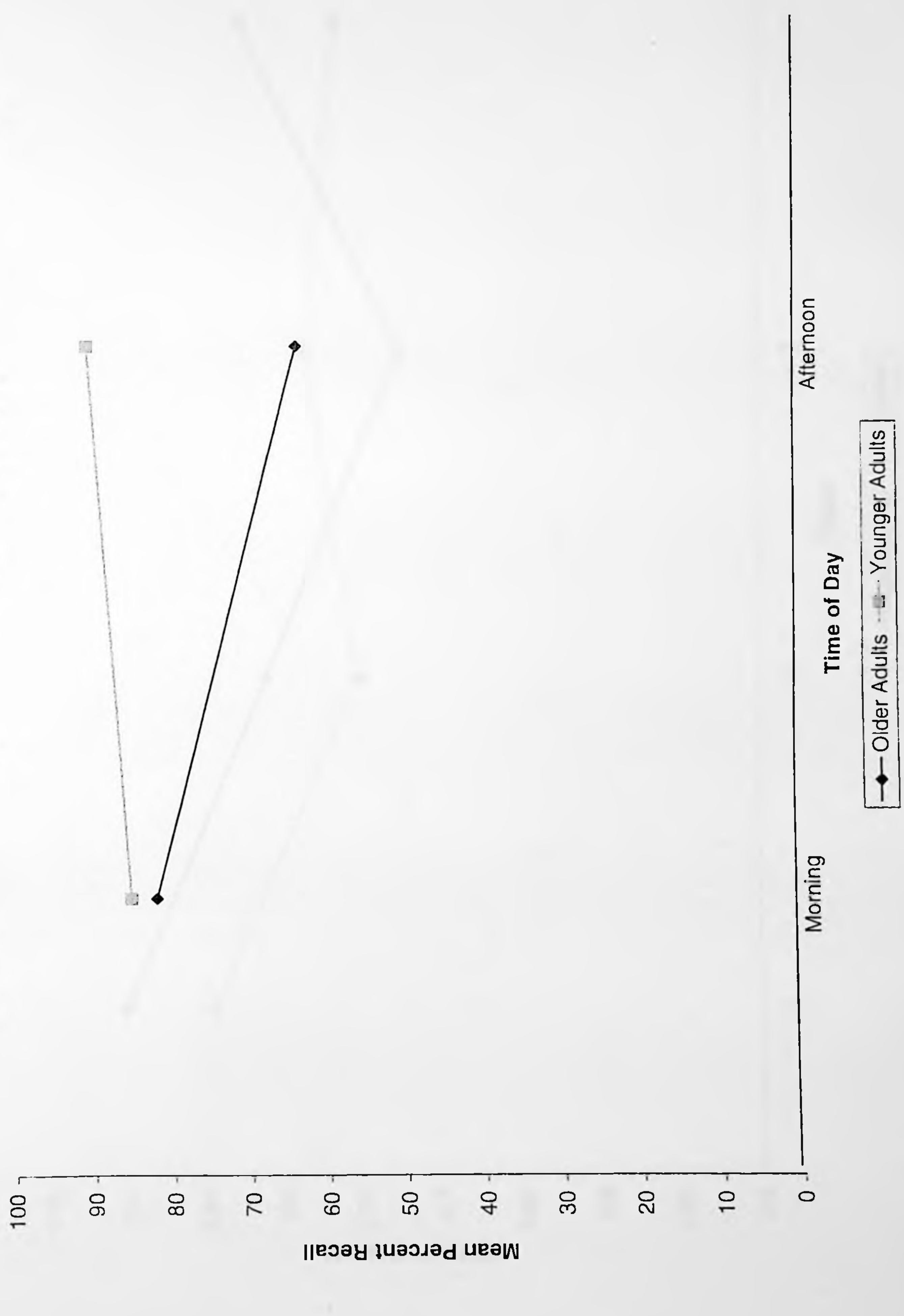


Figure 3
Control and Experimental Conditions Percentage Correct

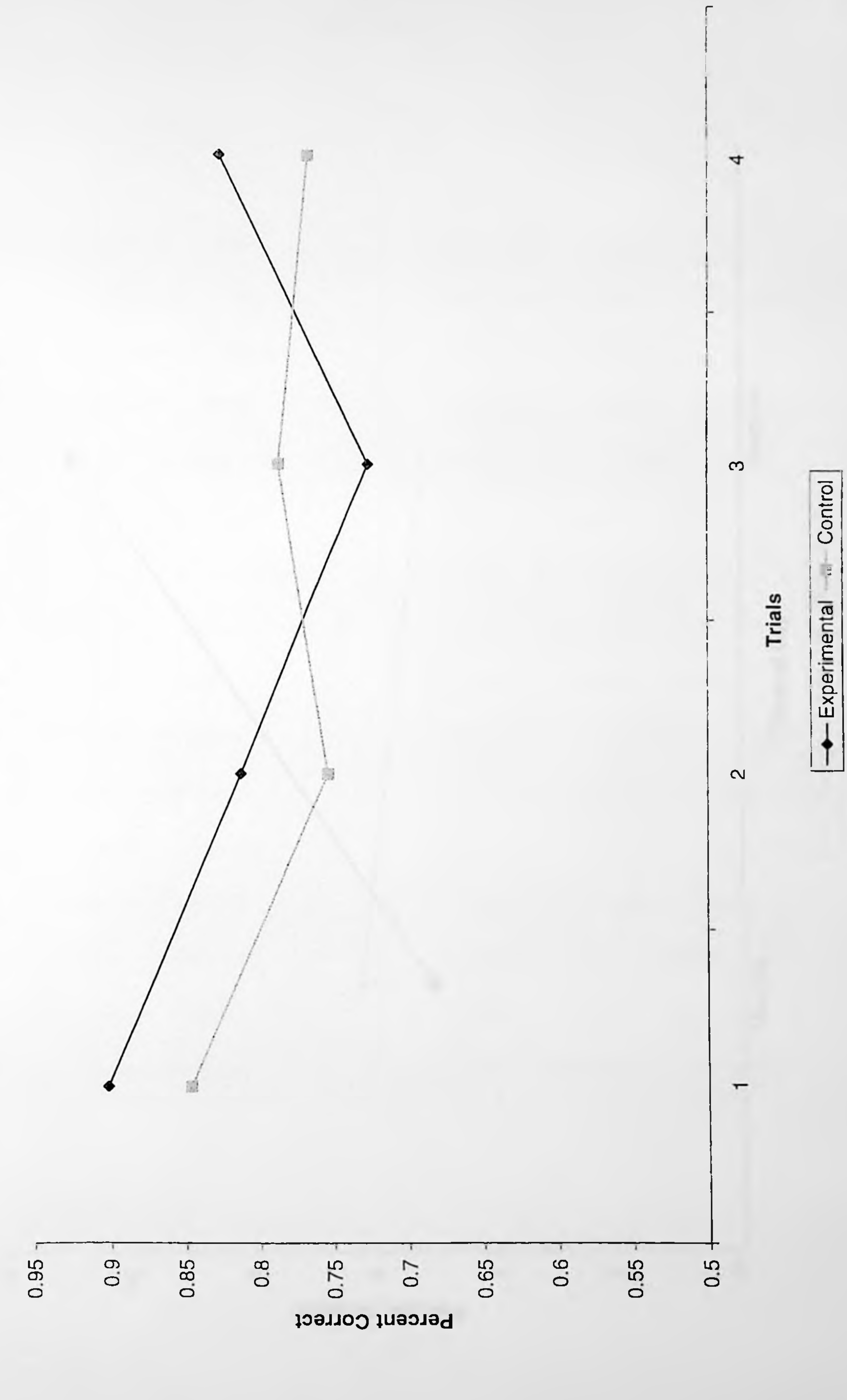
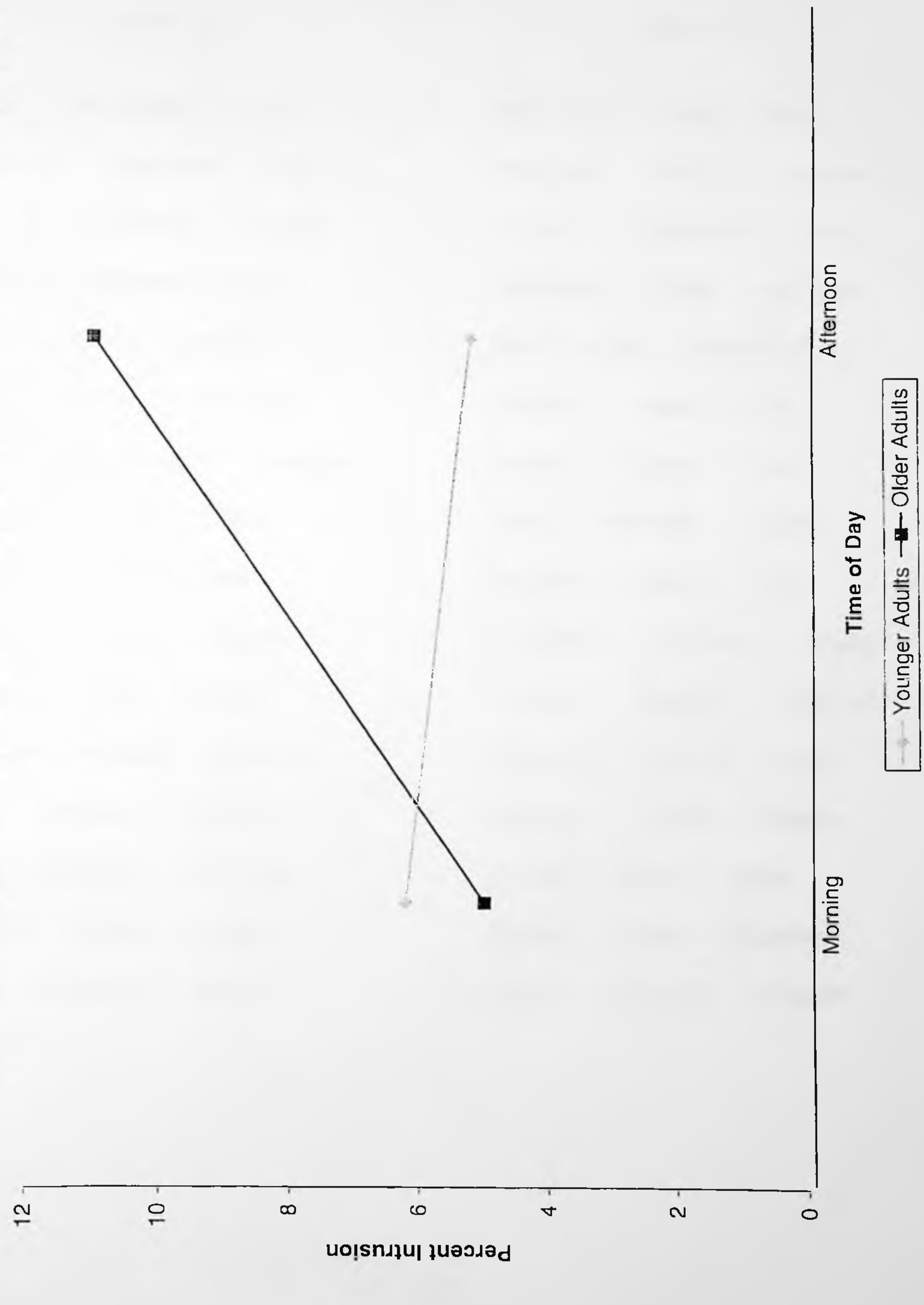


Figure 4

Morning and Afternoon Mean Percentage of Intrusions for Younger and Older Adults



Appendix A

List 1	List 2
Cedar - Mulberry - Oak	Broccoli - Pea - Kali
Hickory - Cypress - Maple	Parsley - Beets - Carrots
Spruce - Popular - Beech	Celery - Peppers - Corn
Holly - Dogwood - Fir	Redwood - Pine - Willow
Apple - Lime - Berry	Goat - Cat - Buffalo
Mango - Pear - Coconut	Donkey - Lamb - Cow
Prune - Blueberry - Grape	Camel - Llama - Pig
Rabbit - Skunk - Dog	Deer - Beaver - Tiger
Violet - Gold - Red	Nutmeg - Sage - Salt
Brown - Purple - Aqua	Oregano - Chives - Sugar
Silver - Pink - Blue	Ginger - Pepper - Almond
Indigo - Black - Green	Maroon - Yellow - Gray
Harp - Piano - Fiddle	Parrot - Crane - Eagle
Tuba - Violin - Guitar	Stork - Duck - Hawk
Banjo - Viola - Organ	Raven - Dove - Pigeon
Crow - Falcon - Robin	Lark - Vulture - Finch