EFFECT OF EVERYDAY DISTRACTION ON HEALTHY AND COGNITIVELY IMPAIRED ELDERS' MEMORY FOR STORIES

By

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To Tammy, who at a moment’s notice is ready with fake teeth and Coke-bottle glasses, cherry tomatoes, more sass than you can shake a stick at, and a reminder to never waste anything I have, least of all my pretty.

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This study evaluated how older adults' recall of short stories was affected by simultaneously performing a low- or high-speed simulated driving task. Specifically, recall was examined in qualitative terms: did older adults use more paraphrasing than verbatim recall as the driving challenge increased? Did older adults rely more on recall of main ideas, and remember fewer details, with increasing driving challenge? Did cognitive status (healthy versus mildly impaired) interact with distraction's effect on performance?

A sample of 46 healthy older adults (61% women; mean age = 76.39 years, mean education = 15.83 years) and 15 older adults with amnestic mild cognitive impairment (66% women, mean age = 79.4 years, mean education = 16.07 years) were asked to recall brief short stories that were administered under three conditions: no driving, low-speed (30 mph) driving, high-speed (60 mph) driving. Stories were scored in two ways: 1) as the amount of information recalled verbatim (word-for-word) versus recall in paraphrase, and 2) as the amount of main idea information recalled versus amount of detail. Repeated measures analyses of variance were conducted, contrasting the verbatim/paraphrase and main idea/detail dimensions of recall across the three recall challenge conditions and between the two cognitive status groups. Analyses revealed that verbatim recall was higher than paraphrase recall in

every condition, $F(1, 104) = 99.94$, $p<.001$, and that only verbatim recall decreased when a simultaneous driving challenge was added. Verbatim recall did not decrease further between the low- and high-speed conditions. Analyses of main idea/detail recall revealed that recall for main ideas was consistently higher than for details in every condition, $F(1,104) = 380.17$, $p<.001$. Main idea recall did not decrease significantly with the addition of the simultaneous driving challenge, but did decrease when the driving challenge was raised from low to high speed. Recall for details decreased with the addition of the simultaneous driving, but not when driving speed was increased. Cognitive status was not found to significantly interact with the effect of distraction; dual-task performance costs were equivalent between the healthy and impaired groups.

This study demonstrates that when older adults are asked to attend to verbally-presented information while simultaneously driving, their ability to recall details of that information, and their ability to remember it verbatim, declines. As the difficulty of the driving challenge increases, older drivers may additionally recall less of the main points of the information conveyed. This study identifies another potential risk of distracted driving: when potentially important information (e.g., directions, alerts) is presented verbally to older drivers, their ability to retain this information may be substantially degraded.

CHAPTER 1
LITERATURE REVIEW

Overview

This study seeks to examine changes in healthy and impaired older adults' story recall as a result of performing a simultaneous simulated driving task. First an overview of age-related changes in cognition, and the effects of age on various forms of memory, will be explored. The utility of story memory tests for assessing episodic memory will be briefly discussed, followed by the effects of aging on story recall Next, older adults' performance on dual-tasks will be addressed, including tasks requiring verbal recall. Finally, the review of older adult performance in story recall and dual tasks will expand to include the effect of mild memory impairment in these domains.

Cognition, Memory, and Aging

The gradual general decline in cognition associated with advancing age is well-known. The pattern of decline is not uniform (e.g. Singer et al., 2003, Schaie, 1990). Types of cognition related to acquired knowledge, such as fluency and semantic memory, are relatively preserved. Types of cognition related to procedural abilities including reasoning, attention, and perceptual speed are more greatly affected by advancing age. These cognitive changes are subserved by relevant changes in brain structure. Beginning around age 30 and continuing across the adult lifespan, there is a global reduction in brain volume. However, this pattern of change is also not uniform, and is seen most prominently in the prefrontal cortex, followed by the temporal and parietal areas (e.g., Head, 2002). There is also a decline in the integrity of white matter tracts, which is most significant in the prefrontal cortical regions (Mosley et al., 2002, Head et al., 2004).

Aging produces varied effects on the different subtypes of memory. Possibly the most well-known and pronounced effect of aging is on the ability to consciously recall specific events or episodes, referred to as episodic memory (Zacks et al., 2001). Episodic memory appears to be relatively stable until around age 60, when it declines at an accelerated rate with increasing age (Ronnlund et al., 2005). The age-related decline in episodic memory is purported to reflect a weakened encoding capacity. Some argue this is the result of generalized cognitive slowing, which reduces the speed of encoding and affects the total amount of information stored (e.g., Verhaeghen & Salthouse., 1997). Other theories infer encoding is impacted by deficits in specific executive components such as working memory, inhibitory control (e.g. Lovden, 2003), or coordination of cognitive processes (e.g., Fisk & Sharp, 2004). The findings on declines in prefrontal cortical volume and function would support these theories, although it remains unresolved whether age-related changes in episodic memory are the result of reductions in volume or of degraded white matter tracts.

Aging also produces a reliable and significant decrease in working memory capacity, or the ability to simultaneously store and manipulate information. Working memory, like the cognitive components hypothesized to subserve episodic memory, is generally agreed to be a function of the prefrontal cortex. Memory span measures, such as reading span, are commonly used to assess working memory. In reading span tests, persons concurrently read a series of sentences and try to remember the last word of each sentence, and are asked after reading to list each of those words. Older adults consistently demonstrate poorer working memory than younger adults (e.g., Bopp & Verhaeghen, 2005; Reuter-Lorenz & Sylvester, 2005).

While types of memory dependent upon procedural or fluid abilities are sensitive to age-related decline, types of memory that depend on accumulated knowledge are relatively robust to the effects of age. Memory for the contents of a person's cumulative general knowledge– not requiring recollection of specific place, time, or context – is referred to as semantic memory. Verbal memory measures, such as vocabulary tests, are a common way of assessing semantic memory. In a cross-sectional study evaluating several types of memory in age groups across the adult lifespan, Park and colleagues (2002) demonstrated reduced performance with older age in episodic memory, working memory, and short-term memory, but a stable profile for verbal or semantic memory. Stable semantic memory ability with increasing age has also been reliably demonstrated in other studies (e.g., Ronnlund et al., 2005; Allen et al., 2002).

The Utility of Story Memory Measures

Episodic memory can be assessed by recall of text passages such as short stories or newspaper articles (Adams et al., 1990; Verhaeghen et al., 1993). Participants hear and recall aloud a passage in which words and ideas follow a logical sequence, which then provides a context for remembering. The story recall "gold standard" is Wechsler's Logical Memory test (Wechsler, 1997), consisting of two short stories read aloud and immediately recalled aloud, and recalled again after a 25-35 minute delay.

Story recall is an episodic memory measure relevant to real-life demands. It is more ecologically valid to measure memory for a sequence of related events or ideas than, for example, a list of words not united by any cohesive meaning. Daily life often requires memory for short narratives (news events, word-of-mouth stories from friends), but rarely rote memory for word lists. Additionally, story recall allows for the widely accepted notion that real-world recall is rarely word-for-word, but instead usually abstracted, meaning it is often paraphrased and gist- or main idea-based. Story memory measures offer an advantage by assessing these more relevant styles of recall, word lists rely mostly on verbatim recall alone.

Age Differences in Story Recall

The majority of research on story recall in aging has focused on age differences. Older adults consistently remember less story information overall compared to younger groups (Dixon et al., 2004; Johnson, 2003; Verhaeghen et al., 1993; Pratt et al., 1989). Particularly, when older adults are asked to memorize a story verbatim, they perform more poorly than younger adults (Adams et al., 1997). However a recent review suggests that age differences vary depending on whether verbatim- or gist-based memory (memory for main ideas, regardless of whether correct wording is recalled) is required. A meta-analysis by Johnson (2003) found the nature of task instructions and scoring guidelines affects the size of age differences such that age differences were smaller in studies with scoring based on gist criteria rather than verbatim. Therefore scoring guidelines emphasizing word-for-word recall, and recall for details, may be more sensitive to age differences. On the other hand, schemes allowing paraphrasing of information and summarization of main ideas may lead to relatively better memory performance in older adults. Effect sizes of age differences are also much larger for word-list verbal memory measures (Verhaeghen et al., 1993). These tests place greater emphasis on verbatim, text-based recall and do not allow for synonyms, paraphrases, interpretation of meaning, or varying levels of information, such as main ideas and secondary details.

Studies examining the content of information recalled – main ideas versus details – have found that older adults tend to remember fewer details compared to younger peers. But, like younger adults, elders demonstrate better recollection for main ideas than for secondary details. The Victoria Longitudinal Study (Hultsch et al., 1998) that compared to younger age groups, adults aged 74-84 showed poor recall for details at all testing occasions compared to younger adults, but maintained a high level of recall for main ideas six years following baseline testing (Dixon et al., 2004).

A recent study by Chapman and colleagues (2006) investigated older adults' performance on three kinds of gist: memory for global generalized meaning of a passage, memory for main ideas of a passage, and memory for categorical clustering of lists of words. This study found that older adults' memory is poorer for semantic categories and for main ideas than for the global generalized meaning of a passage. The age differences literature supports this finding. Older adults recall less than younger adults when asked to literally retell a story, but outperform their younger peers when asked to interpret the story (Adams et al., 1997). While younger adults excel at text-based story reproduction, older adults are superior at integrating ideas and interpreting story meaning (Adams, 1990). In addition to retelling and summarizing story content, they also often provide more elaborations on the text and inferences from the story than younger adults, including speculation on the psychological and metaphoric meanings of the passage (Adams, 1991). A cross-cultural study replicated these findings in Japanese older adults (Hosokawa, 2006).

Divided Attention in Aging

Regardless of age, performance on a task is known to decline when attention is divided between that and performance of a second, simultaneous task (a dual-task challenge). Studies have shown that this performance decline is also greater with increasing age (Albinet et al., 2006; Holtzer et al., 2004; Chen, 2000).

However, this age difference has not consistently been found (e.g., Anderson et al., 1998; Salthouse et al., 1995). The inconsistency of findings may be in part due to lack of understanding about the underlying reason for differences when they are found. Alternative hypotheses argue that a) older adults' reduced performance is due to reduced ability to perform concurrent tasks, b) older adults' poorer performance is the result of general cognitive slowing, or c) the age difference in dual-tasks is accounted for by different strategies used, with older adults perhaps strategizing more cautiously (Meyer et al., 2001). A recent dual-task study found age differences, maintained after adjusting for individual differences and generalized slowing, which were suggestive of different strategies between the age groups (Rekkas, 2006). Another found that providing strategy instructions reduced age differences (Naveh-Benjamin et al., 2005).

Riby and colleagues (2004) completed a comprehensive review of dual-task aging research conducted between 1981 and 2003. They reported a strong overall effect of age-related dual task impairment (d=.68), but the findings among individual studies varied. Subsequent analyses revealed that one major reason for this was the failure to control for baseline differences. This finding illustrated the value of investigating whether age differences are due to specific dual-task difficulties or to a general decrement in performance. Somberg and Salthouse (1982) purported that age differences in dual task performance would disappear if once baseline differences were controlled for, suggesting dual task age differences were in fact the result of general age-related decline. However, Riby and colleagues found studies that compared relative-to-baseline measures of performance obtained larger effects for age-related dual-task costs than studies that compared absolute measures of performance. These findings suggest that controlling for baseline ability may isolate a true effect of dual-task challenge.

Additionally, this study found that age differences are smaller for verbal tasks and for verbal reaction time responses than for visuospatial tasks. Perhaps because verbal tasks under dual-task conditions have smaller age-related decrements, the role of age in verbal recall during divided attention is somewhat unclear. Several dual-task studies using verbal recall report greater reductions in recall for older adults during dual-task performance (Craik et al., 1998; Park et al., 1989), but others report no age difference (Anderson et al., 1998; Nyberg et al., 1997).

The investigators found that the most critical factor associated with variability of findings for dual-task age differences was the task domain used. Namely, simpler tasks or those requiring relatively automatic processing were associated with smaller age-related performance deficits. On the other hand, dual-task scenarios involving a motor component demonstrated larger age differences in performance, such as walking and memorizing (Lindenberger et al., 2002). A meta-analysis by Verhaeghen and colleagues (2003) expands the relationship between dual-task age difference and task modality by reporting that matched-modality tasks produced reliably larger dual-task costs than paradigms utilizing tasks from two different modalities. Other studies have reported greater age-related dual-task deficits for explicit versus implicit memory (Light, 1991), and for performance of concurrent memory tasks (Salthouse, Rogan, & Prill, 1984), versus performance of concurrent perceptual tasks (Somberg & Salthouse, 1982). Riby and colleagues (2004) also observed larger age-related deficits in dual-task scenarios requiring a substantial amount of effortful, controlled cognitive processing such as working memory, episodic memory, and reasoning tasks.

Elders' Performance in Driving Divided Attention Tasks

The influence of automatic versus effortful tasks on the size of age differences in dual tasks may have implications for the present study, which pairs verbal recall with the everyday task of driving. While driving is a complex task involving the coordination of visual scanning, attention, decision-making, and motor skills, it is also a relatively automatic, daily-practiced behavior for most people. How, then, might older adults perform in a dual-task scenario in which one of the concurrent activities is driving?

The first answer to this question - and the most relevant to this paper - is the finding from Cook (2007), the primary analysis on the same dataset from which this paper is derived. Sarah Cook evaluated older adults' lane navigation performance in a dual-task study of simulated driving and story recall. She found that the addition of a concurrent story recall task had no negative effect on participants' ability to maintain lane position; instead, they actually demonstrated less lane deviation than in the single lane navigation task. One way to resolve these counterintuitive findings is that participants may have prioritized the driving task due to the real-world dangers distracted driving entails, and sacrificed the verbal recall task. This explanation is supported by the finding that verbal recall overall did decline under dual-task conditions, while lane navigation improved. Another piece of the explanation may be that driving is a relatively automatic task, while episodic recall has been regarded as an effortful task. It would then make sense for driving performance to be relatively preserved while recall performance declines. However, the broader findings from similar studies have been varied.

Crook and colleagues (1993) compared different age groups across the adult life span on the simultaneous performance of a verbal recall task and a computer-simulated driving reaction time task. Participants in the older age groups demonstrated greater performance declines on both the verbal and reaction time tasks in the dual-task scenario. After controlling for psychomotor speed, older adults still demonstrated poorer reaction times, suggesting the dual-task effect was due to cognitive rather than psychomotor factors. The greatest age differences were observed between the youngest (18-39 yrs) and the oldest groups (70-85 years).

McPhee and colleagues (2004) found similar results in a concurrent task of visual search for traffic signs and recall of the Wechsler Logical Memory stories. While all age groups suffered dual-task performance costs, older adults demonstrated differentially greater dual-task costs on both tasks. They recalled significantly less of the Logical Memory stories than younger adults in the dual-task condition. They also were slower and less accurate in deciding when a target sign was not present during dual-task conditions, especially in high-clutter scenes on the visual search task.

However the findings on older adults' dual task performance of verbal tasks and simulated driving, like the majority of dual-task literature, is also somewhat inconsistent. A recent study evaluated the effect of verbal production and verbal comprehension on velocity and lane position control during a computer driving simulation (Kubose et al., 2006). This study found that while driving velocity became more variable during verbal production and comprehension compared to driving alone, the concurrent production of speech while driving actually yielded better lane position control, and verbal comprehension had no effect on lane position control. Additionally, verbal production and comprehension performance were not impacted by the added challenge of simultaneously driving.

Age Differences in Recall Under Divided Attention

The qualitative age differences in recall - poorer verbatim memory and superior integration in older adults - appear to be consistent in dual-task scenarios, if not compounded by the additional challenge of divided attention. Arbuckle and colleagues (1985) found that the level of verbatim recall decreased in older adults with the addition of a simultaneous verbal task. Compared to younger adults, they gave fewer verbatim responses and more inferences, elaborations, and overgeneralizations, indicating that in the presence of a second simultaneous task, the quality of older adults' recall again focuses on overall ideas more than on text reproduction.

The Role of Mild Cognitive Impairment

Introduction to Amnestic Mild Cognitive Impairment

The previous sections have focused on changes in verbal recall and dual-task performance in the context of normal, healthy aging. However the course of aging is varied, and can deviate from the typical slow general decline of normal aging to the onset of Alzheimer's Disease (AD) or other cognitive disorders, which become more prevalent with increasing age. Cognitive aging exists on a continuum then, from healthy typical decline to mild impairment to severe dementia (Petersen et al., 1999).

Mild Cognitive Impairment (MCI; Petersen et al., 1999) refers to the area in the middle of the continuum, and has come to represent – with some controversy - a transitional zone between normal age-related cognitive decline and the very early clinical stages of AD (Petersen, 2005). The MCI construct does serve as a clinically relevant predictor of progressing to dementia (Lopez et al., 2003; Daly et al., 2000), and was endorsed as such in 2001 by the American Academy of Neurology (Petersen et al., 2001). However, MCI does not consistently predict progression to AD, and can even be associated with subsequent improvements in cognition. Its presentation is sufficiently heterogeneous as to necessitate clinical subclassifications (e.g. single domain impairment in memory or another domain, multiple domain impairment). These different subclassifications may lead to a wide variety of outcomes, and each is associated with a different set of possible prognoses. The subtypes are primarily distinguished based on presence or absence of memory impairment, and are therefore characterized as amnestic (aMCI) or non-amnestic MCI (Petersen, 2004).

This study focuses on patients of the aMCI subtype, which consists of a mild memory impairment more pronounced than what is normally seen with advancing age (performance $\geq$ 1.5 SD below the norm for a patient's age and education), accompanied by a subjective memory complaint. However cognitive function in other domains such as language and attention is preserved, as are activities of daily living (ADLs; for example, grooming, bathing and feeding), and these patients do not meet the clinical criteria for dementia.

Importantly, aMCI as a categorically-definable phenomenon is a somewhat artificial construct. Much research has focused attention on whether MCI is truly a discrete entity, distinguishable from normal cognitive aging and from dementia. The findings are thus far inconclusive (Davis & Rockwood, 2004). But the difficulty of characterizing MCI as a discrete phenomenon is intuitive. It underscores the notion that if cognitive aging does exist along a continuum, then categorizing cognitive decline into stages is not faithful to its nature. Advocates of establishing guidelines for identifying MCI as a distinct stage understand this issue, but acknowledge that quantifiable performance cutoffs are inevitably necessary for MCI to be used as a clinical entity. The diagnosis and treatment of progressive cognitive decline relies on objective measurement of cognitive abilities, and cutoff points are made as precisely as can be but could never be exact. One method that would be useful in assessing how cutoff points are determined, and which neuropsychological measures are used to classify aMCI, is policy capturing. Policy capturing is a method used by researchers to evaluate how individuals make decisions (Karren & Barringer, 2002). It uses quantitative methods like cluster analysis, discriminant functions, and logistic regression to evaluate the way individuals "weight, combine, and integrate" available information to make a judgment. While this method is frequently used on an organizational or societal level, in job searches and hiring analyses for example, it has relevant implications for investigating the way researchers and clinicians formulate diagnoses of MCI. Policy capturing analyses will be employed later in this document to identify the underlying algorithm that seemed to guide the classifications decisions of our own study's consensus conference judgments.

However, this reality does not negate the pragmatic value of developing and implementing diagnostic criteria to identify MCI. Current clinical criteria have been shown to predict progression to AD, albeit without perfect consistency to date. The additional sophistication of the aMCI criteria has been argued to be a more sensitive predictor of AD pathology, as 10-15% of patients move on to a diagnosis of AD each year, compared to 1-2 of the general population (Petersen et al., 2001). An aMCI diagnosis has also been associated with lower rates of survival (Leep Hunderfund et al., 2005).

Impact of Cognitive Impairment on Story Recall

Research indicates that declines in verbal episodic memory, including for paragraph recall, are among the most commonly reported in older adults with aMCI or in the preclinical stages of Alzheimer's disease (Collie & Maruff, 2000, Kluger et al., 1999). But those with aMCI retain intact activities of daily living, and therefore continue to drive. Because they are still active and independent in daily life but experiencing early memory loss, these individuals may be at greatest risk for forgetting episodic information crucial to their daily functioning, and may be especially vulnerable to forgetting information if they are distracted by other simultaneous, cognitively complex activities such as driving.

The story recall literature indicates that cognitively impaired individuals consistently recall less overall than their healthy peers on stories (Gely-Nargeot et al., 2002; Robinson-Whelen & Storandt, 1992) and on other verbal memory measures (Greenaway et al., 2006; Balota et al, 1999). A study by Johnson and colleagues (2003) compared young adults, healthy older adults, very mildly and mildly demented adults (AD) on measures of both verbatim and gist-based recall for stories. The results of this investigation revealed there was a significant effect of dementia among the older adults, such that very mildly and mildly demented older adults remembered less story information verbatim, and less of the gist of the story, than healthy older adults. The effect of dementia on recall was more severe for verbatim recall than for gist.

Another recent study by Hudon and colleagues (2006) specifically examined recall content – memory for the gist versus the details of a story – and found that adults with MCI and adults with AD recalled less of both the gist and details of a story, compared to healthy adults. Additionally, they reported that even recognition of gist-level information is decreased in individuals affected by greater impairment: they found that adults with AD showed additional deficits in main idea recognition, while this ability was relatively spared in adults with MCI. Similarly, Chapman and colleagues (2006) found that mildly impaired adults performed poorer than healthy older adults on three types of gist memory: semantic categories for word-lists, main ideas of a text passage, and global general meaning of a passage. This is in contrast to healthy older adults, who demonstrate relatively preserved strength in memory for a story's global meaning. It suggests that impaired adults' ability to integrate and interpret stories, which is a strength in healthy older adults, is negatively impacted. Unsurprisingly, in addition to remembering fewer main ideas and details and less overall meaning, impaired adults also show a reduced ability to accurately recognize inferences (Bielak et al., 2007).

Impact of Cognitive Impairment on Dual-Task Performance

Research consistently indicates that compared to healthy older adults, the costs to performance on dual-tasks are significantly larger for those in the early stages of Alzheimer's Disease. However the consistency of dual-task costs, as with normal aging compared to younger adults, is also less clear for persons with MCI. Perry, Watson and Hodges (2000) reported no differentially greater dual-task costs for MCI participants, but consistent impairment for mildly-demented AD participants in dual-task performance and other areas of attention. Conversely, a recent study (Belleville et al., 2007) found that persons with MCI exhibited impaired performance on a divided attention task but preserved performance on other measures of attention, while persons in the early clinical stages of AD exhibited impairments on all measures of attention. Additionally, participants with MCI who demonstrated subsequent declines also showed impaired attentional performance on tests of manipulation abilities compared to MCI participants who did not decline.

As in the normal aging literature, it has been postulated that performance decrements at lower levels of cognitive status are simply the reflection of decreased cognitive capacity and processing speed, and there is no differential effect of divided attention per se. However, Holtzer and colleagues (2004) corrected for age, education, and performance among groups of healthy and cognitively impaired participants and continued to find reliably greater dual-task costs for impaired participants. They also argued, based on the results of a discriminant function analysis, that the dual-task measures were more accurate in discriminating impaired and healthy elders than traditionally-used neuropsychological measures.

Similar to Riby and colleagues' (2004) findings in the normal aging literature, task selection impacts the size of dual-task effects for cognitively impaired persons. Crossley and collaborators (2004) demonstrated that dual-task scenarios requiring little effortful processing may show no impairment-related dual-task costs, but tasks requiring effortful cognitive activity may produce impairment-related costs. The study compared healthy participants and participants with early-stage AD in performance on concurrent unimanual tapping and speaking tasks. When speaking was relatively automatic (speech repetition), there was no discernable difference in dual-task costs between groups. However when effortful speech was required (speech fluency), cognitively impaired participants demonstrated larger dual-task costs than their healthy peers.

Summary

This overview of the research illustrates that in terms of story recall, older adults have a poorer verbatim and detail-based memory compared to younger adults, but are superior at summarizing story themes, interpreting meaning, and elaborating and making inferences upon the story information. The findings on dual-task performance costs in elders are as yet unclear. There have been reports of age differences associated with increased dual-task costs for older adults, but these reports have not been consistent throughout the literature, and several theories have been postulated to address this issue. Finally, the research on cognitive impairment consistently reports that older adults with MCI demonstrate greater general reductions in story recall; however the existing literature provides mixed reports on whether persons with MCI exhibit larger dual-task costs than healthy older adults. The following chapter will discuss the specific aims of this investigation.

CHAPTER 2
STATEMENT OF THE PROBLEM

Episodic memory, or memory for specific events and experiences, is more strongly affected by age-related cognitive decline than semantic memory, or memory for more general, acquired information (Nyberg & Tulving, 1996; Tulving, 1995). Older adults report this change in their everyday lives as more-frequent forgetting of acquaintances' names or details for recent events. Additionally, dividing attention between two simultaneous tasks often reduces cognitive performance. Older adults may be more prone to forgetting episodic information when they are distracted by doing something else simultaneously, such as listening to the radio while driving. Adults whose cognitive decline is greater than normal for age may be especially susceptible to forgetfulness during distraction. If age-related episodic memory loss is compounded by the effect of distraction, then older adults are at a greater risk for forgetting information conveyed to them while driving (such as news bulletins, traffic warnings, or conversations with passengers). Because important verbal information - including verbally-conveyed directions, passenger or cellular phone conversations, or radio news or alerts - is often communicated to older adults while driving, the risk of forgetting has important functional implications for cognitively healthy and impaired adults alike.

The goal of this study was to investigate the effect of simultaneous simulated driving on episodic memory performance, as measured by verbal recall of a brief news story. Driving and story recall tasks were performed under three conditions: alone, under slow-speed dual-task challenge (30 mph driving), and fast-speed dual-task challenge (60-mph driving). Sixty-one community-dwelling older adults with and without memory impairments were asked to participate. Story memory was evaluated in terms of precision, defined as verbatim (word-for-word) versus paraphrase recall, and content, defined as recall for main ideas versus recall of secondary details. There were three main goals of the study.

Dual-Task Effect on Precision

Aim One

To understand the effect of dual-task driving and recall on story memory precision, defined as verbatim and paraphrase. Recall for the number of “idea units” of the Rivermead story paragraphs (Wilson et al, 1985) was compared across single-task, slow-speed dual-task, and fast-speed dual-task conditions in terms of verbatim and paraphrase recall.

Hypothesis One

Story recall will decrease overall with increasing condition difficulty. As a proportion of all possible idea units, verbatim recall will decrease more greatly than paraphrase recall.

Dual-Task Effect on Content

Aim Two

To understand the effect of dual-task driving and recall on story memory content, defined as main ideas and details. Recall for the number of “idea units” of the Rivermead story paragraphs was compared across single-task, slow-speed dual-task, and fast-speed dual-task conditions in terms of recall for main ideas and details.

Hypothesis Two

Overall, story recall will decrease with increasing condition difficulty. Recall for details, as a proportion of the number of detail idea units possible, will decrease at a differentially greater rate than recall for main ideas, quantified as the proportion recalled out of the total main idea idea units possible.

Role of Cognitive Impairment in Dual-Task Effects on Precision and Content

Aim Three

To investigate the role of cognitive ability in story memory performance during dual-task driving and recall. Recall across conditions was compared between healthy and cognitively-impaired older adults in terms of verbatim versus paraphrase and main ideas versus details recalled.

Hypothesis Three

Cognitively impaired adults will show lower levels of story recall than healthy adults in all conditions. Additionally, impaired adults will demonstrate a greater decrease in performance as task condition difficulty increases. Compared to healthy adults, impaired adults will demonstrate a greater decline in verbatim and paraphrase recall with increasing condition difficulty, and a greater decline for recall of details. No group differences are expected for recall of main ideas across increasing condition difficulties.

CHAPTER 3
RESEARCH DESIGN AND METHODS

Overview

Older adults were asked to recall short stories alone and under slow and fast dual-task conditions while performing a simulated lane navigation task. They also completed neuropsychological testing for the purpose of identifying possible memory impairment. A consensus group met to determine cognitive status for all participants. The following sections describe the relationship of the present study to the parent study (Cook, 2007), participants and the selection process, study procedures and the measures used, and the design, procedures and materials of the experimental task.

The Cook Study

This study was conducted as an extension of a study designed and initiated by Sarah Cook (2007). The present study and parent studies shared the same overarching design and data set, and were conducted in tandem. The author and Ms. Cook worked together to accomplish participant recruitment, screening, and consensus classification. The author also completed approximately half of the data collection, administering neuropsychological tests and conducting the experimental protocol. The findings from the Cook study are summarized in the literature review above.

The Cook study used total story recall scores to assess overall changes in recall associated with the dual task challenge. The present study investigated beyond this general overview to explore changes within various dimensions of recall (verbatim or paraphrased recall, recall of main ideas). In order to do this, the author established additional scoring systems to evaluate the precision and content of recall. Division of stories into individual idea units was used to provide a detailed analysis. Two levels of scores (verbatim, paraphrase) were used to quantify recall precision, and each idea unit was coded as a main idea or detail to quantify the content of recall.

Participants

Sixty-one community-dwelling older adults (age 65-91) were recruited from the community. Efforts were aimed at recruiting both healthy older adults, and those with mild memory impairments. Forty-six participants were classified as healthy or normal older adults, and fifteen were classified as impaired, having been identified to have memory impairments. Impaired participants received consensus classification of amnestic mild cognitive impairment (aMCI) or dementia. The consensus classification process is described in the sections below.

Eligibility

Participants with a history of conditions or events that potentially disrupting normal cognitive functioning were excluded. This includes adults with a history of epilepsy, head injury with loss of consciousness, encephalitis, meningitis, Parkinson’s disease, stroke within the last year with residual motor signs, heart attack within the last year, and current cancer treatment or past radiation treatment above the chest. Participants were also excluded who had never had a driver s license or stopped driving more than 2 years ago. Participants with visual or auditory impairments precluding valid testing (e.g. self-report of severe difficulty reading, or self report of severe difficulty hearing in conversation) were also excluded. Participants were asked to identify a friend or relative to who could serve as an informant for the purpose of the Clinical Dementia Rating Scale (CDR).

Recruitment Sources

Participants were recruited from several sources within the community, including existing participant pools at the University of Florida (UF) National Older Driver Research and Training Center (NODRTC) and Institute on Aging. Patients assessed at the UF Psychology

Clinic meeting study criteria were informed of the study by faculty, as well as patients at the UF Memory and Cognitive Disorders Clinic, who were informed by a recruiting research team member or whose information was released by UF's Clinical Alzheimer Program. A town hall meeting was held for recruitment at a local continuing care retirement community, and advertisements were made in local newspapers (*The Gainesville Sun* and *The West End Journal*). In addition, two graduate student researchers studying similar patient groups provided participant contact information for those interested in being contacted about future studies.

Study Procedures

Screening

Participants were screened by telephone to exclude those who did not meet the inclusion criteria stated above. Cognitive functioning was briefly assessed using the Modified Telephone Interview for Cognitive Status (TICS-M; Brandt et al., 1988). This measure provides a preliminary estimate of function and possible impairment with cutoff scores for MCI (<34) and dementia (<20).

Administration of Neuropsychological and Experimental Tests

After giving informed consent, participants completed a neuropsychological assessment and experimental task, which was completed during a single visit in one 3-hour block. The visit was broken into 3 parts, each lasting approximately 1 hour (represented in Figure 3.1). First, a primary neuropsychological battery was administered to assess cognitive status and other possible factors contributing to task performance. Second the experimental task, described in the following pages, was administered. Third, questionnaires and secondary neuropsychological measures were administered as part of a larger study. Breaks were provided during the experimental task and offered during neuropsychological testing as needed. Some participants were recruited from another study using some of the same neuropsychological measures: the

Mini Mental Status Examination, the Hopkins Verbal Learning Test, and Useful Field of View. One participant who had completed these measures within the past month consented to have his data shared for the study. Those measures were not re-administered to him for this study. Participants who had completed the other study more than one month ago were re-administered the tests, taking into account the progressive nature of MCI and the importance of making the most accurate possible classification.

Consensus Classification

A consensus conference panel consisting of the investigator, a neuropsychology faculty member, a cognitive psychology member, and a neuropsychology student met at the conclusion of data collection to identify participants with aMCI and early-stage AD. Assignment to a cognitive impairment group was decided based upon cognitive performance and on ability to carry out daily functions as reported on the Clinical Dementia rating scale. Neuropsychological test results were reviewed in percentile format, with special attention given to participants whose test scores ranked at or below the 7th percentile (according to the definition of impairment as 1.5 SD below the mean by Petersen et al., 1999). Each panel member individually identified impaired participants before the list was reviewed and a vote was made for the status of each participant identified by a panel member. If the vote was unanimous, the participant was identified as impaired; if there was disagreement, the participant's performance and daily functions were further discussed until a majority vote (3 out of 4) could be reached. After consensus, the sample sizes of the two impaired groups were found to be much smaller than the healthy sample. Consequently, a dichotomous (normal vs. impaired) conceptualization was used for analyses of the results instead of the original three-group experimental design.

Neuropsychological Measures

Telephone Screening Measure

To establish whether participants met inclusion criteria, they were asked several questions about medical history and demographics. They also received the Modified Telephone Interview for Cognitive Status (TICS-M; Brandt et al., 1988), a short measure designed to assess cognitive ability in situations where in-person evaluation is inconvenient or impractical. It is similar to the Mini-Mental Status Examination, but with a more extensive memory component and can be administered over the telephone.

Neuropsychological Consensus Measures

To ensure that participants met criteria for inclusion in one of the 3 cognitive groups (healthy, mild cognitive impairment, or probable dementia), we administered a battery of measures assessing memory and other areas of cognitive functioning. The battery was chosen based on measures identified by the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) to be useful in assessing for Alzheimer's disease and other dementias associated with aging. The cognitive domains assessed were chosen in order to identify not only memory impairment, a primary feature of dementia, but also to establish breadth and depth of impairment across multiple areas of functioning. These domains were also selected in order to rule out impairment based on primary deficits in areas other than memory, such as attention.

Global cognition. The Mini-Mental Status Exam (MMSE; Folstein et al., 1975) was used to assess global cognition. The MMSE is a brief 30-point measure of orientation, memory, language, attention, and visuospatial processing. These abilities were examined more in-depth with other measures.

Verbal memory. Verbal memory was assessed using the Hopkins Verbal Learning Test (HVLT; Brandt & Benedict., 2001) and the Wechsler Logical Memory subtest (Wechsler, 1997).

The HVLT is a list-memory task in which 12 semantically-related nouns are read aloud and participants are asked to recall them. The list is repeated and recalled for 3 trials, and after a 25-minute delay participants freely recall the list one more time. After the delayed recall, the test includes a recognition task in which participants hear a list of words from the original list, new but semantically related to the original list, or new and not semantically related. Participants are asked to identify whether or not they recognize each word from the original list.

The Wechsler Logical Memory test is a paragraph-memory test in which a short story is read aloud and participants are asked to recall it immediately after hearing it. Then a second story is read twice, participants recalling the story each time after hearing it. Participants are prompted to remember the story for a later time in testing. After a 25-35 minute delay, participants are asked to recall each of the stories once more. Finally in a recognition trial, participants are asked 15 yes-or-no questions about each story.

Language. Language was assessed using the Boston Naming Test (BNT; Kaplan et al., 2001) and the Control Oral Word Association Test (COWAT; Benton & Hamsher, 1989). The BNT measures the ability to name pictured objects; a 15-picture shortened version of the test was established by CERAD for clinical testing and was used for this study. The COWAT is a measure of verbal fluency in which participants are given one minute to generate as many words as they can beginning with a particular letter. Three trials are given, each with a different target letter. A fourth trial requires participants to name as many members of a category (e.g. animals) as they can within one minute.

Processing speed. Processing speed was measured using the Trail Making Tests A and B (Reitan, 1992), in which participants connect circles in a prescribed order as fast as they can. This task requires visual scanning and sequencing, psychomotor speed, concentration, and cognitive flexibility.

Visuospatial construction. Constructional ability was assessed using the Rey-Osterrieth Complex Figure Copy task (Rey, 1941). The participant is shown a complex figure and asked to copy it on a piece of paper. Scoring is based on both how accurately components of the figure are drawn, and on how accurately those components are placed within the figure.

Attention. Attention was assessed with both the Wechsler Digit Span subtest (Wechsler, 1997) for verbal attention and the Ruff 2 & 7 Selective Attention Test (Ruff & Allen, 1996) for selective attention. Digit Span consists of two parts in which participants are first read a string of digits and asked to repeat them, and second are asked to repeat a string of digits in reverse order. The Ruff Selective Attention test requires visual search and cancellation, assessing both sustained and selective attention. It consists of twenty 15-second trials in which the participant is asked to visually search lines of numbers, or lines of numbers and letters (there are 10 trials of each type). Participants are to draw a line through the numbers 2 and 7. Scoring takes into account both correct hits and errors of omission to calculate the tradeoff between speed and accuracy.

Visual attention. Visual attention and processing speed, which decline with age and can increase the difficulty of driving performance, was assessed using the Useful Field of View (UFOV; Ball & Owsley, 1993. This computer-administered task measures sustained, selective, and divided attention. The first subtest of the task requires identification of a centrally-presented target (car or truck). The second subtest requires simultaneous identification of the centrally-presented target and of the location of a peripherally-related target (car). The third subtest is similar to the second but requires the peripheral target to be located amid visual clutter (triangles across the visual display). A fourth subtest required participants to determine whether two centrally presented targets were the same (two cars or two trucks) or different (car and truck), as well as identifying the location of the peripheral target. Each subtest adapts to the participant's performance such that the score is based on the fastest speed at which the participant is able to identify 75% of stimuli accurately.

Working memory. Working memory was assessed using an auditory n-back task including 1-back, 2-back and 3-back tests. For the 1-back task, participants hear a series of letters over a sound file and are asked to indicate with a button press whether each letter they hear is the same or different as the letter before it. Similarly, with the 2- and 3-back tasks, participants are asked to indicate whether the current letter is the same or different as the letter presented 2 letters ago or 3 letters ago, respectively. Scoring incorporated both accuracy and response time.

Mood. Mood was assessed with the Geriatric Depression Scale (GDS; Yesavage, 1983). The GDS consists of 30 yes-or-no, self-report items about symptoms of depression common among older adults. The GDS was included to account for any possible effect of depression on participants' memory and attentional performance.

Daily function. The Clinical Dementia Rating Scale (CDR; Morris, 1993) was collected as a measure of daily functioning for participants whose neuropsychological test results were ambiguous regarding impairment. This measure was administered over the telephone after testing. It included questions for both the participant and his or her designated informant about memory, orientation, judgment and problem solving, home and hobbies, community affairs, and basic self-care. Scores were based on an algorithm of the scores assigned for each of these domains. A CDR score of 0 indicated no impairment, 0.5 indicated mild impairment, and 1.0 indicated moderate impairment.

The tests and specific scores used to measure each area of cognitive ability for the purpose of consensus classification are described in Table 3-1.

Experimental Task

Experimental Procedure

The experimental task was administered after the primary neuropsychological battery and before the secondary measures and questionnaires, and took approximately one hour to complete. Participants first heard and, after a 35-second delay, recalled aloud three Rivermead short stories. Stories were administered and recalled one at a time. All responses were recorded using a digital recorder, and were later transcribed for scoring. After recalling three stories under single-task conditions, participants completed a five-minute lane navigation acclimation task on the driving simulator in order to become comfortable with operating the equipment. They completed two short driving courses at 30 mph, the first consisting of all right-hand turns and the second of all left-hand turns.

Following acclimation, the dual-task part of the experiment was administered in two 13.5-minute segments, with a 4.5 break period in between to prevent fatigue. Within each segment three stories were administered concurrently with simulated lane navigation. Each story was completed under slow or fast driving conditions (either 30 or 60 mph), and alternated such that the three stories in segment one were given in slow-fast-slow conditions respectively, and segment two stories were given as fast-slow-fast. Participants received a period of single-task driving as a buffer between each story administration.

Participants listened to stories through a digital recording played over a speaker beside the desktop. At the end of the story, the program instructed them to remember what they just heard. After 35 seconds, participants were prompted to say aloud what they remembered. To keep recall from overlapping with the beginning of the next driving condition, response time for each story was limited to one minute.

An illustration of the experimental study procedure can be found in Figure 3-1.

Experimental Measures and Materials

Short story measures

Nine stories were administered altogether: three alone without simultaneous simulated driving, three with simultaneous slow driving, and three with simultaneous fast driving. The nine stories were divided into three groups of three, and each story group was randomly administered in the alone segment, during the first dual-task segment, or during the second dual-task segment, so that each participant heard each of the nine stories only once.

Four of the stories were from the Paragraph Recall Task of the Rivermead Behavioral Memory Test (Wilson et al., 1985). The other five stories had been used in a memory training study and were created using an algorithm created to make them to correspond directly to the Rivermead paragraphs in complexity, structure, and number of idea units. The term “idea unit” is used to refer to each individual lexical item within the story. For example, the following sample sentence is divided into “idea units”:

> Ms. Virginia / Boone / a mother of two / won / the mother of the year award / on Sunday / during a community celebration / in Chicago.

The complete text for all stories is included in Appendix A. For brevity, the Rivermead-type paragraphs will be referred to as “Rivermead” stories throughout the rest of this document, acknowledging that not all of them came from the actual Rivermead Behavioral Memory test.

Stories administered alone were read aloud by the testing technician. Stories in the dual-task condition will be presented on the computer as a recorded male voice. After presentation (about 45 seconds) participants were given 35 seconds to mentally rehearse the story before recalling it aloud within a one-minute time limit. Participant responses were digitally recorded and later transcribed.

Short story scoring

Stories were scored for precision based on the accuracy and completeness of recall. Each idea unit was scored as 0 (not recalled), 0.5 (paraphrase or incompletely recalled), or 1 point (verbatim or completely recalled). This scoring method was based on the system already developed for the Rivermead paragraphs, and adapted also for the algorithm-generated stories.

Stories were also scored for recall content, or how much of recall consists of main ideas and how much of it consists of supporting details. Idea units were coded as either main idea or detail information, based on a consensus process. Investigators initially met with language and discourse experts to evaluate what criteria existed for coding main idea and detail phrases. Given that no validated method was found, investigators recruited ten college-educated individuals to code each story. Idea units identified as a main idea by five or more consensus members were considered main ideas for the purposes of the study; all other idea units were considered secondary details.

Precision and content were quantified as the percent of idea units recalled out of the total possible. So in the case of precision, because all idea units could be recalled either verbatim or in paraphrase, verbatim recall was calculated as the number of idea units recalled verbatim out of 21 possible idea units. Likewise, paraphrase recall was calculated as number of idea units recalled in paraphrase out of 21. Main idea recall was calculated as the proportion of main idea idea units recalled out of the number of main ideas possible, which varied for each story. Recall of details was similarly calculated as the number of detail idea units recalled out of the number possible within each story. Figures 3-3 and 3-4 depict the formulas used to derive these proportional recall scores.

Scoring reliability

To ensure reliability, two independent raters scored all story recall responses, and the average of these two rating was used in all analyses. An analysis of inter-rater reliability was conducted by correlating the two score sets. Ratings provided by each of the two raters were positively correlated for each story administered in each condition (ranging from r=0.93 to r=0.97, p<.001). Story recall ratings can therefore be interpreted as reliable.

Driving task

STISIM Drive software was used for creation and administration of the simulated lane navigation task. Scenarios were presented on a Dell Optiplex GX270 desktop computer (rather than a driving simulator due to the high probability of simulator sickness in older adults), with a 19-inch flat screen monitor and Logitech MOMO Force Feedback Steering Wheel. The steering wheel was attached to a desk in front of the computer, and participants were seated at the desk with the monitor approximately 18 inches away.

The task involved simulated driving on a two-lane roadway consisting of right and left turns and varying curve angles. There were no traffic lights or signals, and no other vehicles or pedestrians on the road. The terrain to either side of the road was flat and void of any objects, and there was a fixed view of a mountain range in the landscape up ahead. Figure 3.4 depicts a screen shot typical of the driving scenario. Participants were instructed to drive in the right-hand lane as they would on a normal road, and to do their best to maintain their lane position through the curves and through the changes in driving speed.

Table 3-1. Measures used for consensus classification.

Cognitive Domain	Test	Variables of Interest	Published Source
Telephone Screener	Modified Telephone Interview for Cognitive Status	Total Score	Brandt et al., 1988
General Cognitive Screener	Mini-Mental Status Exam	Total score (using serial 7 subtraction)	Folstein, Folstein, & McHugh, 1975
Memory	Hopkins Verbal Learning Test-Revised (HVLT-R)	Total Immediate, Delay, and Recognition	Brandt & Benedict, 2001
	Wechsler Memory Scale-Third Edition Logical Memory	Total Immediate, Delay, and Recognition	Wechsler, 1997
Language	Boston Naming Test 15-item CERAD version (BNT-15)	Total score	Morris et al., 1989
	Control Oral Word Association (COWAT)	Total (F, A, S)	Benton & Hamsher, 1989
	Category Fluency	Total Animals	Goodglass & Kaplan, 1972
Psychomotor Speed	Trail Making Test A and B (Trails A, Trails B)	Time for A, Time for B, Errors for A, Errors for B	Reitan, 1992
Attention	Wechsler Adult Intelligence Test- Third Edition, Digit Span Subtest	Forward Span and Backward Span	Wechsler, 1997
	Ruff 2 & 7 Selective Attention Test	Automatic Detection Accuracy, Controlled Search Accuracy, Speed-Accuracy Difference	Ruff & Allen, 1996
Construction Ability	Rey-Osterrieth Complex Figure	Copy Total	Rey, 1941
Mood	Geriatric Depression Scale (GDS)	Total score	Yesavage & Brink, 1983
Daily Functioning	Clinical Dementia Rating Scale (CDR)	Total score	Morris, 1993

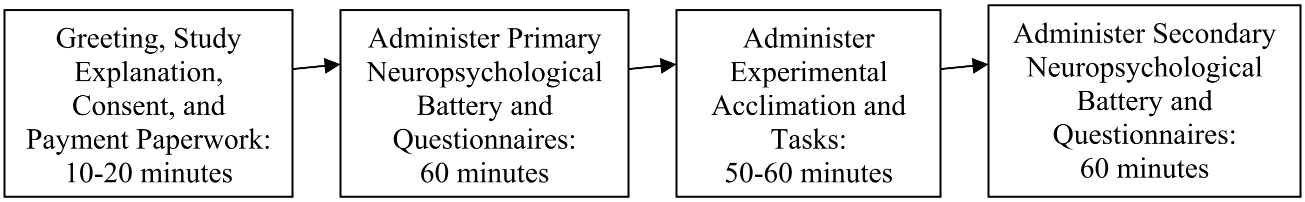
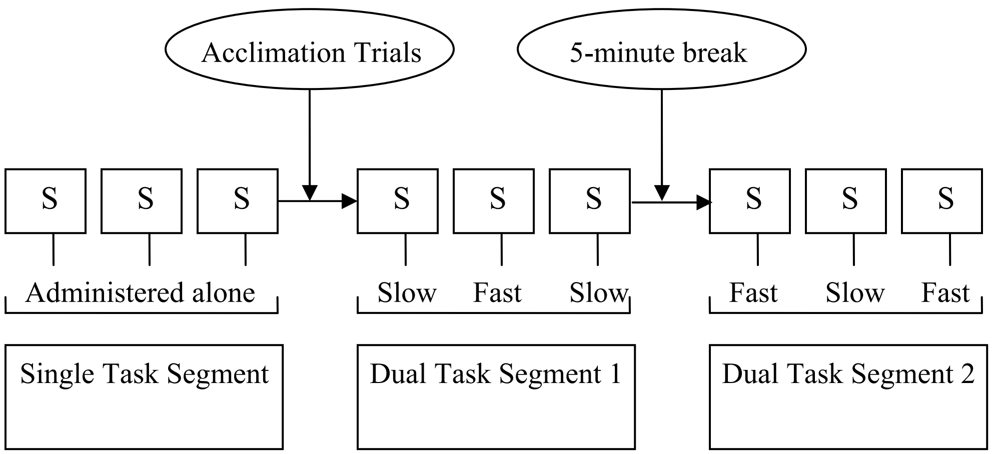


Figure 3-1. Participant visit overview. Participants are introduced to the study for 10-20 minutes. They next complete the primary neuropsychological battery, which takes approximately 60 minutes. They then complete the experimental task, lasting 60 minutes, and finish the remainder of the neuropsychological battery after the experimental task.



Note: S = one story unit; Administered alone = single-task condition; Slow = slow-speed dual-task condition; Fast = fast-speed dual-task condition.

Figure 3-2. Experiment procedures represented by task condition. The experimental task was divided into three segments, each consisting of three story administrations. In the first segment, three stories were recalled without the simultaneous driving task. In the second and third segments, participants completed the story recall and driving tasks simultaneously, alternating between low and high levels of speed for each story.

$$\textit{Verbatim Recall} = \frac{\text{Total propositions recalled verbatim}}{\text{21 (All possible propositions)}}$$

$$\textit{Paraphrased Recall} = \frac{\text{Total propositions recalled in paraphrase}}{\text{21 (All possible propositions)}}$$

Figure 3-3. Calculation of verbatim and paraphrased recall scores

$$\textit{Main Idea Recall} = \frac{\text{Total “main idea” propositions recalled}}{\text{All possible “main idea” propositions (varies with story)}}$$

$$\textit{Detail Recall} = \frac{\text{Total “detail” propositions recalled}}{\text{All possible “detail” propositions (varies with story)}}$$

Figure 3-4. Calculation of main idea and detail recall scores

CHAPTER 4
RESULTS

Overview

This study investigated recall of short stories in older adults aged 65 and older, whose cognitive status ranged from normal to memory impaired. We examined how the addition of a secondary task condition (simulated lane navigation) affected the style of older adults' recall, under two levels of secondary task difficulty (slow speed of 30 mph and high speed, 60 mph). We also investigated whether the effect of distraction by a secondary task would be similar for healthy and impaired participants.

The study addressed three main experimental hypotheses. First, we aimed to confirm that both verbatim and paraphrased recall would decrease as a function of increasing task difficulty, and verbatim recall would decrease more than paraphrased recall. Second, we aimed to confirm that recall for both main ideas and details would decrease with increasing task difficulty, and that this decrease would be greater for recall of details than for main ideas. Third, we sought to determine whether these changes in recall quality (verbatim, paraphrase) and content (main ideas, details) would be disproportionately greater for impaired versus healthy participants.

Preliminary questions were explored regarding the reliability and validity of the story recall measure. We expected scores to be reliable among stories administered in the same condition. To assess the validity of the stories, we investigated whether total recall scores on stories administered in the single-task condition were consistently related to total immediate recall scores obtained on the Wechsler Memory Scale (WMS) Logical Memory paragraphs.

Preliminary analyses also evaluated the effect of the secondary driving task on total recall scores. Setting the specific dimensions of recall (precision and content) aside, adding a simultaneous secondary task was expected to decrease story recall overall. Also, to verify that participants identified as memory-impaired truly differed from those classified as cognitively healthy, preliminary analyses were conducted to identify overall recall differences between the groups on the memory task.

Participant Sickness

Because all assessments for each participant were completed within a single session, there was no participant dropout. There was, however, missing experimental (driving and remembering) data because some participants were unable to complete the experimental task due to sickness associated with the driving simulator task. Although four of the participants completed part of the driving task, eight participants were unable to complete any of the dual-task condition stories, and were excluded from analyses for this reason. Two of these eight were classified as impaired. Because analyses were based on the average percent recalled within each condition, participants who completed at least one story recall in each condition were included in the analyses (with their averages computed from those stories they did manage to recall). Seventeen participants completed at least one story in each condition, but discontinued the experimental task after the end of the first dual-task segment. Reasons for discontinuation included fatigue, complaints of dizziness from driving, or excessive frustration with the task. Table 4-1 contains information on the number of participants with complete, partial, or no data.

Preliminary Analyses

Validity

To evaluate the validity of the Rivermead measures, we tested them against the Logical Memory component of the Wechsler Memory Scale (WMS), a widely-validated measure of immediate verbal short story recall. Every participant in the study recalled three Rivermead stories in the absence of distraction. Every participant also completed both of the WMS Logical Memory short stories without distraction, as part of the neuropsychological battery used for consensus classification. It was expected that if the Rivermeads are a valid measure of short story memory, participants' mean total recall on the Rivermead stories in the distraction-free condition would positively correlate with the Total Immediate Recall score on Logical Memory (Trial One on Stories A and B). Analyses using Pearson bivariate correlations revealed that averaged Rivermead scores correlated significantly with Logical Memory recall scores, r=.672, p<.001. This comparison may be interpreted as supportive evidence of the Rivermead stories' validity relative to the story recall gold standard, with the caveat that the relationship is only moderate. It was not possible to directly compare participants' percentile ranking on the Rivermead-type and Logical Memory stories, since such percentile data did not exist for many of the Rivermead-type stories.

Reliability

If the Rivermead measures are reliable, it is expected that total recall scores of stories administered within the same task condition should positively correlate with one another. We conducted correlational analyses among story scores within each condition, and found that stories were well-correlated within the single-task condition (r=.62-.69, p<.001), the slow dual-task condition (r=.49-.62, p<.001), and the fast dual-task condition (r=.64-.71, p<.001). These findings may be interpreted as evidence that the Rivermead stories are a reliable measure of short story recall.

Dual-Task Effect on Total Recall

Before looking at qualitative characteristics within story recall, we aimed to verify the impact of task difficulty (i.e. addition of a secondary task, at two levels of challenge) on overall memory performance. This question was investigated as part of the primary data analysis conducted by Cook (2007). It was hypothesized that with increasing levels of task difficulty, total recall scores would decline. A repeated-measures analysis of variance (RM-ANOVA) revealed that memory performance did decrease significantly with each greater level of task difficulty ($F(2, 102)=19.36$, $p<.001$). Paired-samples t-tests were then used to compare recall among each of the three difficulty levels (single task, slow dual task, fast dual task). Compared to the single task scenario, memory performance was significantly reduced in the slow dual-task ($p<.001$) and fast dual-task ($p<.001$) conditions. If Bonferroni-corrected, the critical level of alpha would be .017; thus, these comparisons remain significant even after correction. However, there was no significant decline in memory performance between the slow and fast conditions within the dual-task scenario.

Overall Memory Performance between Cognitive Status Groups

To verify that the groups identified as cognitively healthy and cognitively impaired differed on memory performance overall, a one-way ANOVA was conducted comparing total story recall scores between each of the groups across all task conditions (N=41 healthy, 12 impaired). Mauchly's test of sphericity was violated; therefore Greenhouse-Geisser corrections were used. This analysis revealed significant differences between the groups' recall scores in every condition, $F(1,51)=16.38$, $p<.001$, $\eta_p^2=.24$. The means and standard errors of each group's total recall score in each condition are illustrated in Table 4-2. These findings were also part of the primary data analysis conducted by Cook (2007).

Main Analyses

Aim One: Dual-Task Effect on Precision

A repeated measures analyses of variance (RM-ANOVA) was conducted to examine the effect of task condition on recall precision, defined as information recalled verbatim versus information recalled in paraphrase (N=53). The dependent variable for the first analysis was defined as the proportion of idea units recalled out of the 21 possible, averaged across the 3 stories within each condition. We used the 2-level independent variable of recall precision (verbatim, paraphrase), and the 3-level independent variable of condition (single-task, slow dual-task, fast dual-task). This analysis revealed a significant two-way interaction, $F(2,104)=11.32$, $p<.001$, $\eta_p^2=.28$. Verbatim recall was consistently higher than paraphrased, but with increasing task condition difficulty the proportion of idea units recalled verbatim decreased at a differentially greater rate than the proportion recalled in paraphrase. In fact, the proportion of idea units recalled in paraphrase did not change across any level of task difficulty. Post hoc analyses (least squares difference) revealed that while verbatim recall dropped significantly with each higher level of task difficulty ($p=.001-.015$; significant after Bonferroni correction, $\alpha=.017$)., paraphrase recall did not differ among any of the levels of difficulty. These results are illustrated in Figure 4-1.

Aim Two: Dual-Task Effect on Content

A repeated measures analyses of variance (RM-ANOVA) was conducted to examine the effect of task condition on recall content, defined as main idea recall versus recall for details (N=53). This analysis used recall as the dependent variable, this time defined in terms of the average proportion of either main idea or detail idea units recalled out of the number possible within each story. As with the first analysis, this proportion was then averaged across all stories given within the same condition. The 2-level independent variable of recall content - defined as main ideas and details - was used, as well as the 3-level independent variable of task condition as defined above. There was no significant interaction in this analysis. However, there was a significant main effect of content, $F(1,104) = 380.17$, $p<.001$, $\eta_p^2=.88$. with the proportion of recall for main ideas being consistently higher than the proportion of recall for details. There was also a main effect of condition, $F(2,104) = 17.55$, $p<.001$, $\eta_p^2=.25$, with overall decreasing recall with increasing task difficulty.

Post hoc comparisons revealed that recall for main ideas was significantly reduced in the fast dual-task condition compared to the single-task and slow dual-task conditions; however, the increase in difficulty between the single and slow dual-task had no effect on main idea recall. (p=.001-.021; significant after Bonferroni correction, α=.017). Additionally, post hoc analyses showed that detail recall was significantly reduced in the slow and fast dual-task conditions relative to the single-task condition, but did not differ between the two dual-task conditions (p<.001; significant after Bonferroni correction, α=.017). In other words, main idea recall was most reduced at the highest level of difficulty, and detail recall was most reduced when the secondary task was introduced - and was not further reduced by increasing difficulty in the secondary task. The results of this analysis are illustrated in Figure 4-2.

Aim Three: Role of Cognitive Impairment in the Dual-Task Effects

The two dimensions of recall, precision and content, were combined in a 3x2x4 RM-ANOVA to examine the within-subjects effect of task condition (single, slow dual-task, high dual-task), and the added between-subjects effect of cognitive status (healthy, N=41; impaired, N=12), on overall recall style. Precision and content were combined to create 4 levels of the independent variable recall style, defined idea units called verbatim, idea units recalled in paraphrase, main idea idea units recalled, and detail idea units recalled. Recall for each category was calculated as a proportion of the idea units recalled out of all the idea units possible within each story. A significant three-way (task condition, cognitive status, recall style) interaction was obtained ($F(6,306)=2.62$, p=.037, η_p^2=.049). The results of this interaction are illustrated separately for each dimension of recall (verbatim, paraphrase, main ideas, details) in Figures 4-3 through 4-6.

To better understand the interaction, this analysis was further decomposed into two separate 3x2x2 RM-ANOVAs evaluating the effect of impairment on recall precision and content individually. The first RM-ANOVA explored the effect of condition (single-task, slow dual-task, fast dual-task) and cognitive status (healthy, N=41; impaired, N=12) on recall precision (verbatim, paraphrase). There was a significant two-way interaction of precision and condition $F(2,102)=6.43$, $p=.002$, $\eta_p^2=.11$, as seen in the analyses for Hypothesis 1, but the three-way interaction was not significant, indicating recall did not vary by impairment.

Least Squares Difference post hoc comparisons indicated that the cognitive status groups differed significantly on verbatim recall at every level of task difficulty, with impaired adults consistently recalling less information word-for-word than healthy adults (p=.001-.003); these comparisons sustained significance after Bonferroni correction using critical α level of .017. However at the paraphrase level of recall, there was no difference between the two groups at any difficulty level, and in fact there was also no difference for paraphrase recall within either group among any levels of difficulty. There were differences in verbatim recall within each group related to task condition, such that healthy adults demonstrated a decline in recall at every increasing level of difficulty (p=.016-.018, significant after Bonferroni correction, , α=.017). Impaired adults, on the other hand, showed a more gradual decline: while verbatim recall steadily decreased across conditions, a statistically significant difference was obtained only between the single-task and fast dual-task levels of difficulty. The results of this analysis are illustrated separately for healthy and impaired subjects in Figures 4-7 and 4-8.

The second 3x2x2 RM- ANOVA explored the effect of condition (single-task, slow dual-task, fast dual-task) and cognitive status (healthy, N=41; impaired, N=12) on recall content (main ideas, secondary ideas). Mauchly's test of sphericity was violated; therefore Greenhouse-

Geisser corrections were used. The three-way interaction was not significant, but a significant two-way interaction was obtained for content and cognitive status, $F(1,51)=5.38$, $p=.024$, $\eta_p^2=.095$. This suggests again that the effect of task difficulty on recall performance does not vary by cognitive status. Both groups demonstrated higher recall for main ideas than for details, but the difference between main ideas and details recalled was larger for healthy participants than for the impaired. Although it did not contribute significantly to the interaction, there was a main effect of condition, $F(2,102)=9.98$, $p<.001$, $\eta_p^2=.16$, with recall decreasing overall as a function of increasing condition difficulty.

Least Squares Differences post hoc analyses showed that the cognitive status groups differed at every difficulty level for detail recall, with impaired participants recalling fewer details in each condition (p=.001-.046); these comparisons would have sustained significance after Bonferroni correction using a critical α level of .017. Regarding main idea recall, impaired participants recalled less information than healthy participants in the single-task and slow dual-task conditions only; in the fast dual-task condition, the two groups performed equally.

Within-group post hoc comparisons revealed that there was no effect of task difficulty on main idea recall within the impaired group, but the healthy group demonstrated a significant decline in main idea recall during the fast dual-task condition ($p=.001$; this would have held significance under Bonferroni correction, $\alpha=.017$). In terms of details recall, the impaired group showed a steady but slight decline in performance such that only the single-task and fast dual-task conditions reflected significantly different levels of recall. The healthy group demonstrated a significant reduction in detail recall between the single-task and slow dual-task conditions, but performance did not continue to decline between the slow and fast dual-task conditions.

The results of this analysis are illustrated separately for healthy and impaired adults in Figures 4-9 and 4-10.

Follow-Up Analyses

Policy Capturing and Cognitive Status Classification

Policy capturing, a method used to evaluate how individuals make decisions, lends insight for this study in understanding the process employed to classify cognitive status groups. The present study relied substantially on the decision-making of the consensus conference to conduct its analyses. Participants were classified into healthy and impaired cognitive groups based on the collective decision of the neuropsychological consensus panel. The neuropsychological data from all measures was available to the panel, represented as scaled or T scores and percentile ranks. However, decisions about a participant's cognitive status were made in accordance with the most up-to-date criteria for MCI classification. That is, special attention was given to measures of memory, such as the Hopkins Verbal Learning Test (HVLT) and Wechsler's Logical Memory Scales. It was scores of <1.5 SD below the mean score on these measures that were used to make assignments of amnestic MCI.

To verify the consistency of the panel's classification, policy capturing analyses were conducted on the assignment of cognitive status groups. A single discriminant function was extracted to separate the two groups. This function had a canonical correlation of 0.90 with group membership, suggesting that the function was strongly predictive of normal-vs.-MCI classification. Congruently, the function was significantly predictive of group membership (λ=.19, $\chi^2(5)$=83.91, η_p^2=.81, $p < .001$).

Standardized canonical discriminant function coefficients (which assess the unique contribution of each predictor, controlling for others in the model) were used to identify the relative salience of our variables for predicting group membership. The loadings (*L*) [note to

Shannon...put each of these "L"s in italics] were as follows: HVLT Percent Retention percentile, *L* = .68; UFOV Same/Diff, *L*= -.51; HVLT Recognition Index T Score, *L*=.44; HVLT Delayed Recall T Score, *L*= .38; and Digit Span percentile, *L*= .33. Consistent with prediction, three of the variables are HVLT-based (i.e., verbal memory), with a particular emphasis on variables that should be lower in amnestic MCI (i.e., impaired delayed recall and reduced ability to profit from retrieval support via recognition). The other two variables (Useful Field of View and Digit Span) are somewhat less central to the amnestic MCI definition. This may either have reflected the idea that the consensus panel used additional expertise regarding concepts that might aid in classification, or that these other measures were correlated with MCI group membership, reflecting the onset of more global decline processes associated with incipient dementia. In any event, the results suggest that while there were elements of policy capturing (four of the five variables reflected some component of memory), group assignments did not seem to be based on a single one or two variables.

The discriminant function analysis achieved a high degree of sensitivity and specificity in the classification of participants. Overall, 60 out of 61 participants were classified correctly (98.4%). Sensitivity was 100% (15 out of 15 persons with MCI were correctly identified by the function), and specificity was 97.8% (45 out of 46 unimpaired individuals were correctly classified). Leave-one-out cross-validation was further explored to assess generalization of the classification efficiency to the larger population. Here, akin to the jackknifing procedure, classification was examined in *N* resamples from the data set, with each resample leaving out one participant and reexamining the discriminant function classifications for that reduced sample. The results of the leave-one-out cross-validation suggested that, identically to the sample-specific results, 100% of persons with MCI were correctly classified and 97.8% of persons without MCI were correctly classified.

Thus, given high measures of association between the discriminant function and group membership, and high classification accuracy, the results suggest that the obtained discriminant function did an excellent job of capturing the underlying policies that, de facto, governed case classification.

Related to the question of policy capturing is the controversy of using a cutoff point, namely 1.5 SD below the mean or 7th percentile of a distribution, to extract two groups from a continuous distribution. Differentiating two groups out of performances which operate along a continuum is difficult to defend unless the distribution of scores is bimodal. Importantly, one of the memory-based predictors identified using discriminant function analysis, the HVLT Delayed Recall scores, does have a bimodal distribution, as illustrated in Figure 6-1 in Appendix B. Other variables which emerged as important in the discriminant function analysis did not have visibly identifiable bimodal distribution. Participants' scores on the majority of other neuropsychological measures were normally distributed, as reflected in Table B-1 (skewness and kurtosis estimates were generally non-significant, with the exceptions of scores on the TICS and the UFOV Processing Speed and Selective Attention subtests. Performance on these measures typically "ceilings" in healthy adults, causing the distribution of scores to be positively skewed rather than bell-shaped).. This underlies the fact that cognition generally operates along a continuum, and that groups based on neuropsychological performance represent opposite sides of a cutoff point in that continuum, rather than discriminable groups. This issue will be discussed further in the Discussion chapter.

Proportionalized Scoring Relative to Baseline Performance

Reviews of the dual-task literature indicate that discrepancies among findings have historically been due to inconsistencies in controlling for baseline differences. Therefore, we ran an additional set of analyses to address this question in our own dataset. Because the only between-groups comparison was made for Aim 3 (healthy participants versus cognitively impaired), a follow-up analysis was conducted solely for this question. Baseline differences were controlled by dividing each participant's score in each condition (single-task, slow dual task, fast dual task) by his or her score in the single task condition.

Two 3x2x2 (condition by precision by impairment, N=53; condition by content by impairment, N=53) repeated measures analyses of variance were conducted in the same format as the original analyses conducted separately for precision and content in Aim 3; the only difference for these follow-ups was the use of recall scores adjusted for baseline differences as described above instead of absolute recall. The first RM-ANOVA revealed that when using relative-to-baseline scores as the dependent variable, no significant interaction was obtained for condition by precision by impairment. The second RM-ANOVA similarly identified that there was no significant interaction of condition by content by precision using relative-to-baseline scores. Although the results of these analyses were not significant, they are represented as additional data in Figures 6.1-6.4 in the Appendix C.

Table 4-1. Number of participants with complete, partial or no data by cognitive status.

	Normal	Impaired
Complete Data	**38**	**9**
Partial Data	**3**	**3**
No Data	**5**	**3**
Total	**46**	**15**

Table 4-2. Means $\pm$ standard errors of story recall total scores by healthy (N=41) versus impaired participants (N=12).

Cognitive Status Group	Single-Task	Slow Dual-Task	Fast Dual-Task
Healthy	**8.98 $\pm$ .37**	**7.36 $\pm$ .41**	**7.47 $\pm$ .41**
Impaired	**5.63 $\pm$ .67**	**4.81 $\pm$ ..54**	**4.29 $\pm$ .75**

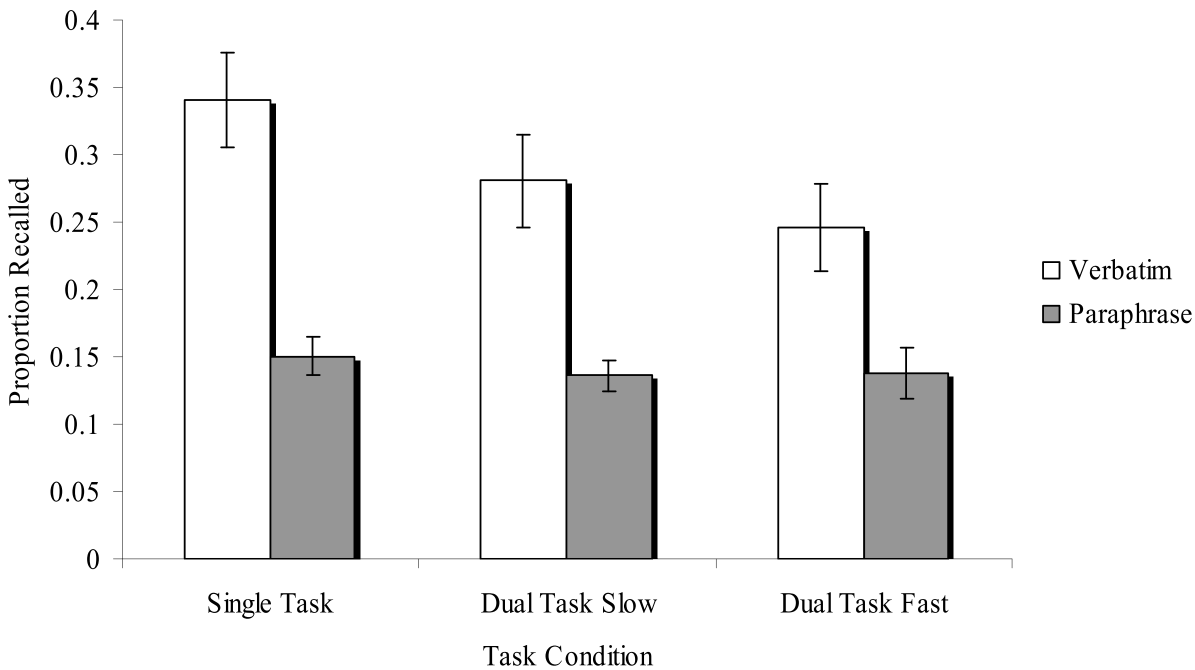


Figure 4-1. Proportion of idea units recalled verbatim or in paraphrase across task conditions (N=53). Verbatim recall is consistently higher than paraphrase in all conditions, and decreases at a significantly greater rate with increasing task condition difficulty. The proportion of information recalled in paraphrase remains relatively stable. Total recall (not shown) would be equal to the sum of verbatim and paraphrase recall, as shown. Error bars represent the 95% confidence interval of the mean.

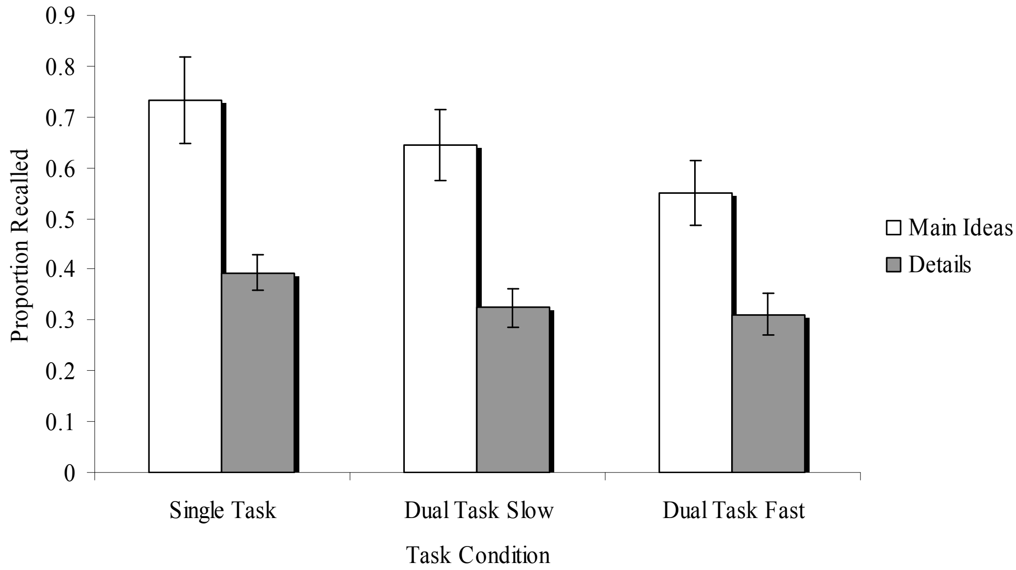


Figure 4-2. Proportion of main idea units recalled and proportion of detail idea units recalled across task conditions (N=53). Recall for main ideas is consistently higher than recall for details, and both types of recall decrease at equal rates with increasing task difficulty. Total recall would be equal to the sum of main ideas and details recalled. Error bars represent the 95% confidence interval of the mean.

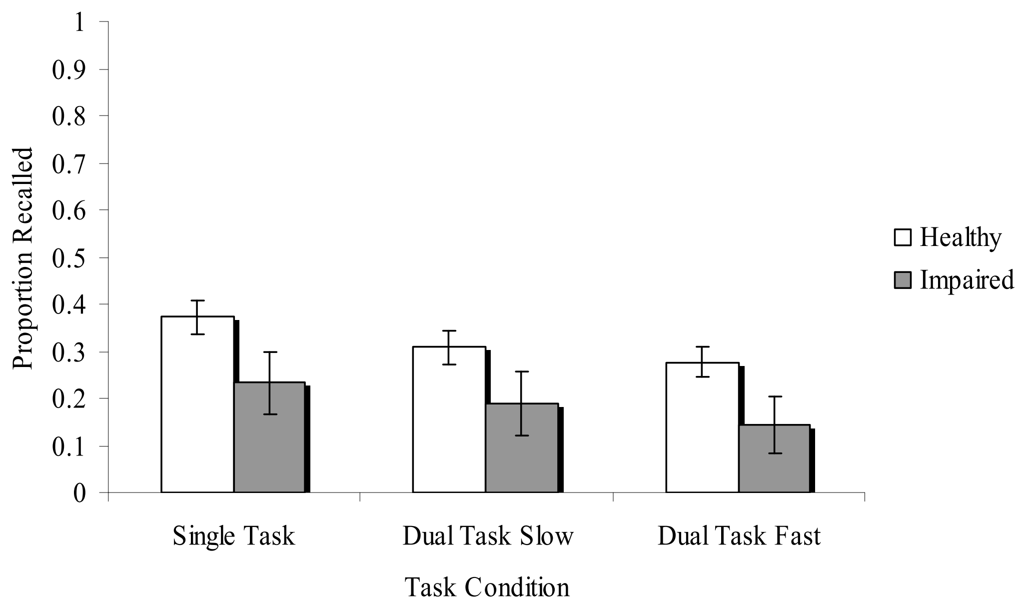


Figure 4-3. Proportion of verbatim recall in healthy (N=41) versus impaired (N=12) participants recall across task conditions. The impaired group demonstrated less verbatim recall than the healthy participants in each condition. There was no interaction between cognitive status and task condition. Error bars represent the 95% confidence interval of the mean.

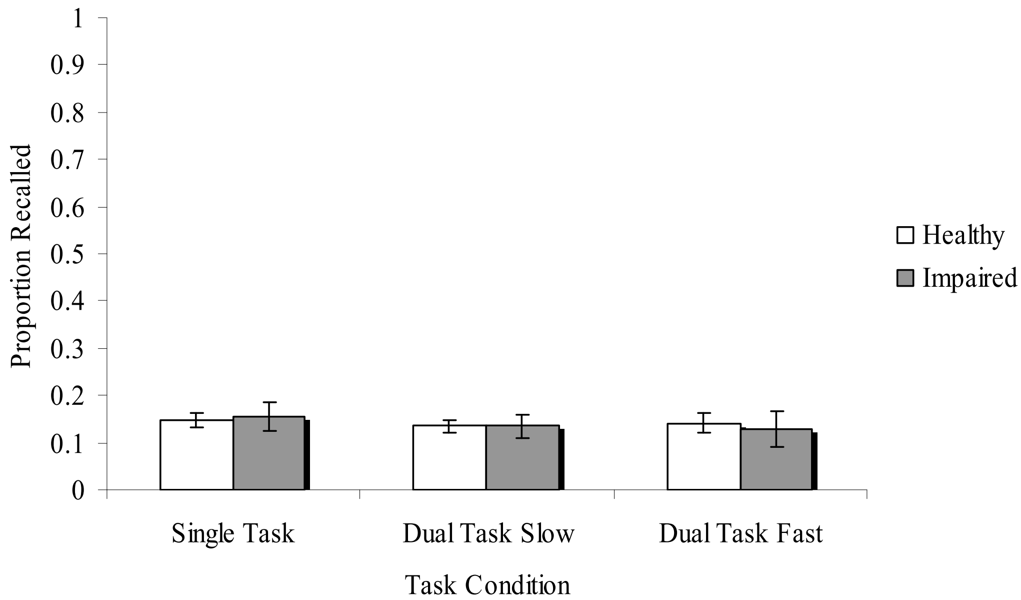


Figure 4-4. Proportion of paraphrased recall in healthy (N=41) versus impaired (N=12) participants across task conditions. Paraphrased recall did not differ between groups, and did not change across conditions. Error bars represent the 95% confidence interval of the mean.

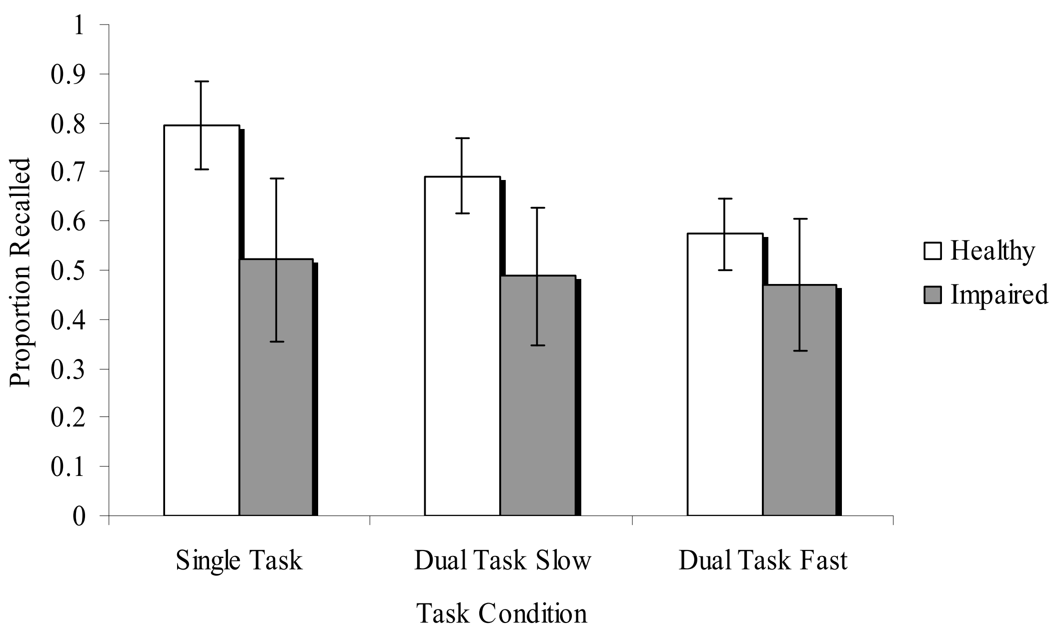


Figure 4-5. Proportion of recall for main ideas in healthy (N=41) versus impaired (N=12) participants ideas across task conditions. Post hoc comparisons revealed the impaired group recalled significantly fewer main ideas than healthy adults. There was no significant cognitive status-task condition interaction. Error bars represent the 95% confidence interval of the mean.

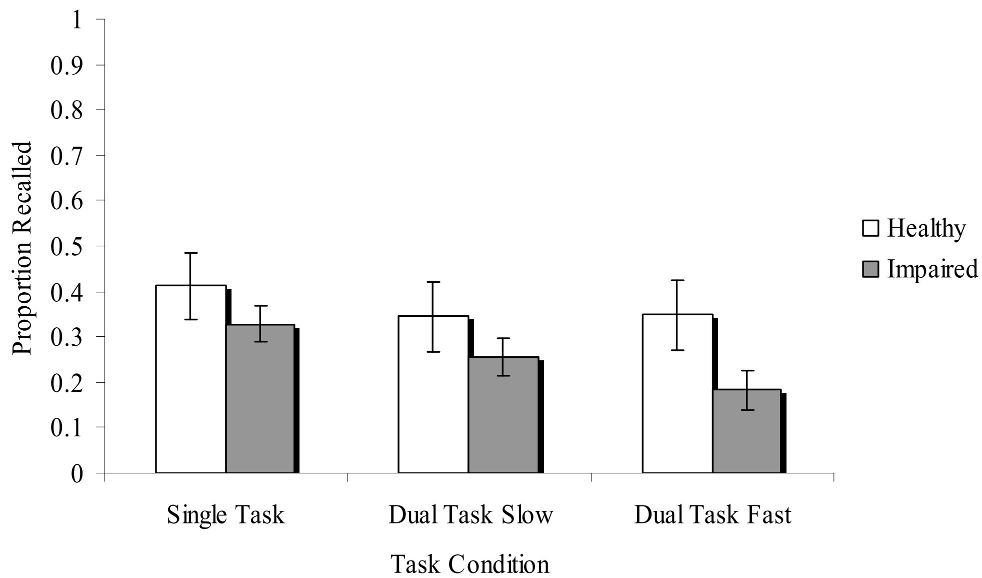


Figure 4-6. Proportion of recall for details in healthy (N=41) versus impaired (N=12) participants across task conditions. No significant interaction was observed between cognitive status and task condition. Error bars represent the 95% confidence interval of the mean.

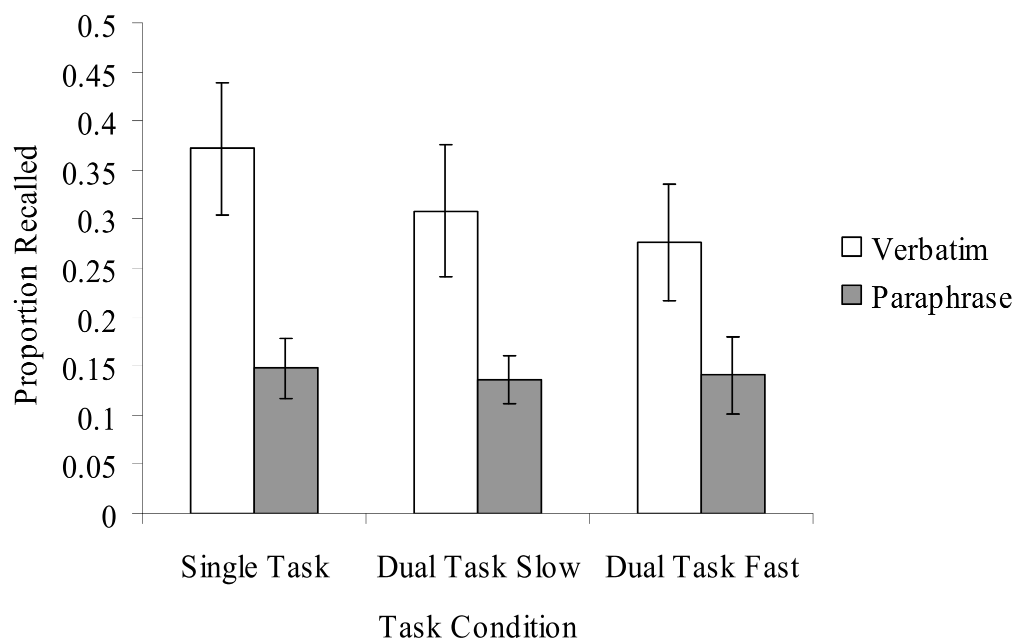


Figure 4-7. Healthy participants' proportions of verbatim and paraphrased recall across task conditions (N=41). Verbatim recall decreased across conditions, while paraphrased recall remained stable. Total recall would be equal to the sum of verbatim and paraphrased recall. Error bars represent the 95% confidence interval of the mean.

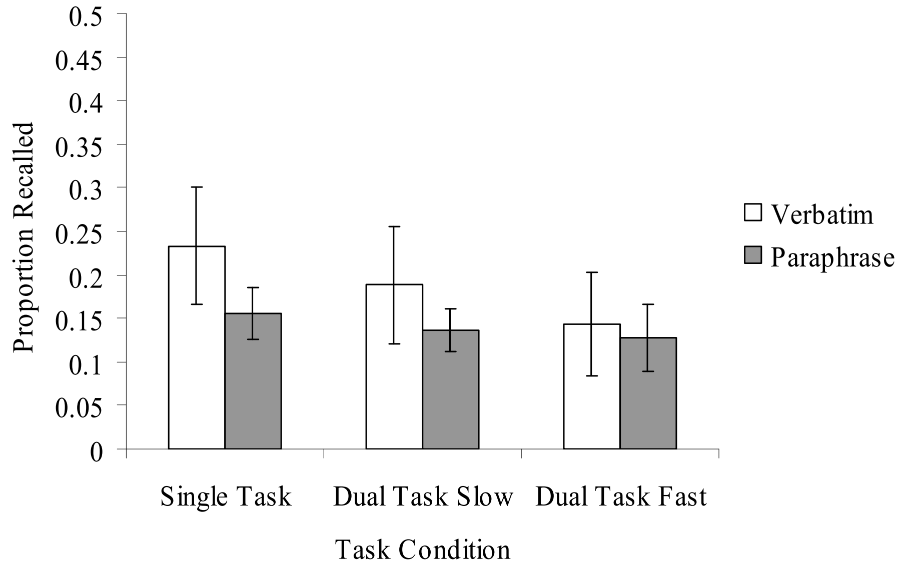


Figure 4-8. Impaired participants' proportions of verbatim and paraphrased recall across task conditions (N=12). Paraphrase recall remained stable, while verbatim recall declined slightly with increasing task difficulty. Total recall would be equal to the sum of verbatim and paraphrased recall. Error bars represent the 95% confidence interval of the difference.

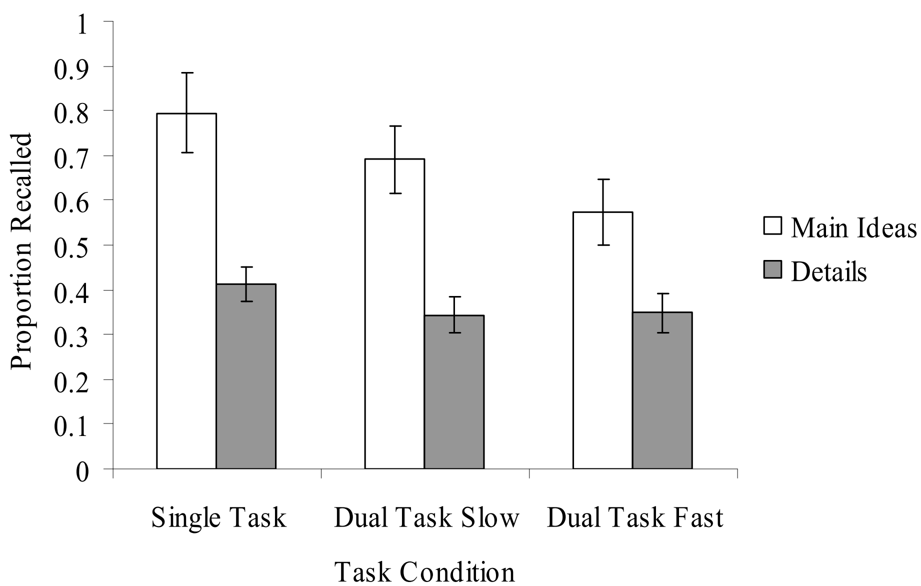


Figure 4-9. Healthy participants' recall for the proportion of main ideas versus details across conditions (N=41). Recall for main ideas declined steadily with increasing task difficulty, while detail recall remained stable. Total recall would be equal to the sum of main ideas and details recalled. Error bars represent the 95% confidence interval of the mean.

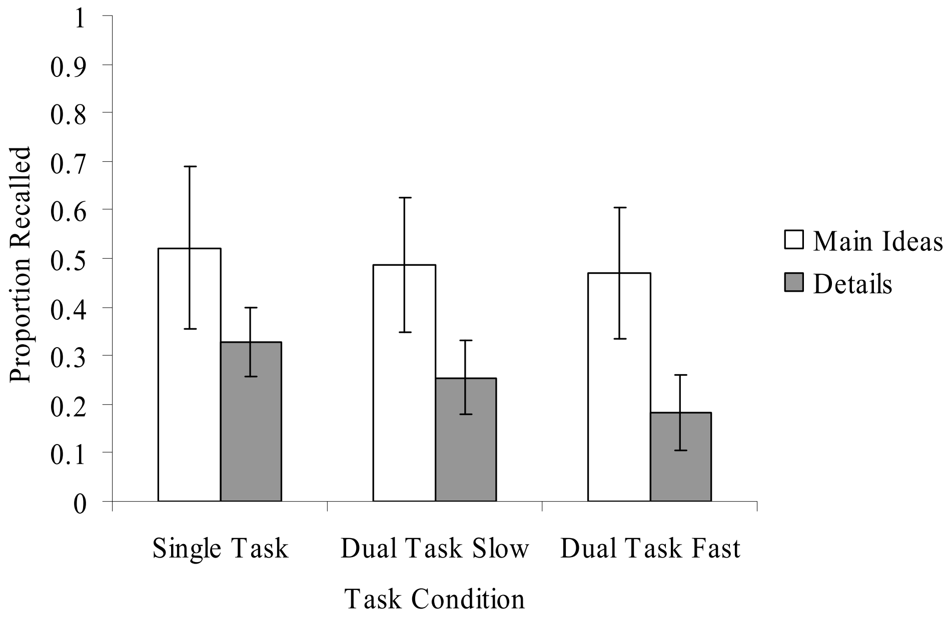


Figure 4-10. Impaired participants' recall for proportion of main ideas versus details across conditions (N=12). Recall for main ideas remained stable, while recall for details declined slightly across conditions. Total recall would be equal to the sum of the main ideas and details recalled. Error bars represent the 95% confidence interval of the mean.

CHAPTER 5
DISCUSSION

Overview

This study examined the effect of a simultaneous secondary task, simulated lane navigation, on two dimensions of story recall in older adults. One dimension was the precision of recall, in terms of the proportion of information remembered either verbatim or in paraphrase. The other dimension was the content of recall, in terms of the proportion of main idea information recalled versus the proportion of detail information. The within-subjects variable of task difficulty was examined under three conditions: story recall alone, story recall in the presence of a slow-speed simultaneous driving task, and story recall in the presence of a fast-speed simultaneous driving task. Cognitive status (specifically, cognitively healthy versus memory impaired) was investigated as a between-subjects variable. The study evaluated the effects of task difficulty and cognitive status, separately and in interaction, on the precision and content dimensions of story recall.

Preliminary analyses examined the reliability and validity of the story recall measure. Results revealed that the Rivermead stories are a reliable measure of story recall: paragraphs administered within the same condition correlated positively with one another. Results also indicated that the Rivermead stories are also comparable to a widely-validated test of story recall, the Wechsler Logical Memory Scales: total immediate recall scores on both measures, administered under single-task conditions, were positively correlated.

The remainder of this chapter will address the findings in regard to the study's three specific aims. Next, the theoretical and practical implications of the results will be considered. Finally, we will discuss the study's limitations, as well as possible future directions for this research.

Review of Findings

Aim One: Dual-Task Effect on Precision

The first aim of this study was to evaluate the effect of simultaneous simulated driving on the precision of story memory in terms of verbatim versus paraphrase recall. It was hypothesized that both types of recall would decrease with increasing condition difficulty, but that the decline would be greater for verbatim recall than for paraphrased recall. The analyses revealed that increasing levels of task difficulty were associated with decreasing levels of verbatim recall, but had no significant effect on the proportion of paraphrased recall. But Post-hoc analyses showed that the effect of task difficulty decreased verbatim recall across all conditions, and had no effect on paraphrased recall for any condition. Additionally, participants consistently demonstrated higher levels of verbatim than paraphrased recall.

These results are essentially in support of the hypothesis: the ability to recall information word-for-word is vulnerable to increasing demand on attentional resources, and more so than the ability to paraphrase information. However, it had been hypothesized that paraphrased recall would also decline with task difficulty, albeit at a smaller grade than verbatim recall. The total lack of effect of task difficulty on paraphrased recall suggests this ability is more resistant to increasing cognitive load.

This indication should be interpreted with consideration, though, for the fact that participants relied predominantly on a verbatim style of recall, which was their instructed goal. The proportion of paraphrased recall was low across all conditions, ranging from 15% in the single-task condition to 14% in the two dual-task conditions. This is a small proportion and range compared to verbatim recall, which was 73% in the single-task condition, 65% in slow speed dual-task, and 55% in the fast-speed dual-task condition. It may be that in a population instructed to paraphrase, the proportion and range of paraphrased recall may be more sensitive to changes in attentional demand.

Aim Two: Dual-Task Effect on Content

The second aim of the study was to examine the effect of simultaneous simulated driving on the content of story memory in terms of recall for main ideas versus details. It was hypothesized that while recall would decline overall as condition difficulty escalated, this decline would be stronger for detail recall than for main ideas. Results indicated that recall did generally decrease as the task condition became more difficult; however, the diminishing effect on recall was equivalent for main ideas and details. Post hoc analyses further indicated that detail recall decreased only between the single- and slow dual-task conditions, but decreased across all conditions for main ideas.

One reason for participants' memory for details to be preserved in the face of increasing task difficulty may be primacy and recency effects. These phenomena, well known in the memory literarure, refer to the higher frequency of recall for the first and last items in a list or story. That is, primacy and recency effects may cause participants to be more likely to remember the beginning and end of a story, regardless of whether it is main idea or detail information. In the nine stories used for this study, 83% of the first and last two idea units consisted of detail information. If memory for first and last information is also more resistant to increasing attentional demand, participants were more likely to continue recalling the detail information contained at the beginning and end of each story.

Additionally, recall for main ideas was higher than for details across all conditions. This suggests that although memory for main ideas may be more sensitive to cognitive load than memory for details, participants were nonetheless likely to remember more of the key points and themes of the story than to remember its details.

Aim Three: Role of Cognitive Impairment in Dual-Task Effects

The third aim of the study was to evaluate the interaction of cognitive status (healthy versus memory impaired) with the dual-task effect of simultaneous simulated driving on story recall. It was hypothesized that participants with compromised cognitive status would demonstrate lower levels of recall overall, but in addition, they would show greater costs to memory performance associated with increasing task difficulty. Precision of recall (verbatim, paraphrase) in impaired participants was hypothesized to show differentially greater decrements in both verbatim and paraphrase recall compared to their healthy peers. For recall content (main ideas, details), impaired participants were hypothesized to show a greater decrease in recall for details as condition difficulty increased, but recall for main ideas was expected to remain relatively stable.

Results demonstrated that impaired participants consistently remembered less overall compared to healthy participants, and that higher levels of task difficulty consistently reduced recall for both groups. However, there was no interactive effect between cognitive status and task difficulty; in other words, being memory-impaired did not amplify the cost to memory performance created by increasing levels of challenge. At first glance, it seems counterintuitive for impaired participants to handle increasing demands similarly to their healthy peers; the impact of dividing attention between two tasks would seemingly be more taxing for a person whose cognitive capacity is compromised.

However, the reason for this apparent disparity is likely explained by the match between the type of cognitive task required and the type of impairment studied. In this study, task difficulty was defined as single- versus dual-task, which was further subcategorized in two levels of secondary task speed. Adding a second task requires participants to divide their attention between two simultaneous activities, which increases the burden on attentional resources but not on memory capacity. Participants for the impairment group were selected based specifically on amnestic impairment. Their performance on the memory task supports their classification; they consistently demonstrate poorer memory than their healthy peers. However their impairment is primarily in the memory domain and not necessarily in attention. This is supported by the observation that they perform similarly to healthy participants in terms of coping with greater attentional load. So while we hypothesized a differential effect of divided attention for impaired participants, they in fact perform exactly as we should expect: they demonstrate consistently poorer memory, but in the presence of increasing attentional burden, they demonstrate the same costs to performance as their healthy peers.

Analyses of group differences within precision of recall (verbatim vs. paraphrase) revealed that verbatim recall in both groups was equally reduced, while paraphrase recall was not affected by task difficulty in either group. Recall of main ideas was not significantly affected by task difficulty for either group, but recall for details decreased significantly for each group with increasing task difficulty. This cost to performance was equivalent for both healthy and impaired participants. So again, no interaction was observed between cognitive status and task difficulty. But within the dimension of recall precision, there was also no effect of difficulty on paraphrase recall for either group - only on verbatim recall. Additionally within the dimension of recall content, there was no effect of difficulty on recall for main ideas for either group - only for details. This suggests that while memory impairment does not amplify the effect of task difficulty, task difficulty itself has a negative effect for both groups on the capacity for verbatim recall and for recall of details. Both results are consistent with what would be expected, given that these types of recall are typically more demanding of memory than paraphrase recall and recall for main ideas.

Implications

The findings from Aims 1 and 2 illustrate the impact of divided attention on verbal memory performance for older adults in general. Our results suggest that when older adults are required to listen to and remember verbally-conveyed information while driving, their ability to recall that information may be substantially degraded by the additional challenge of driving. In particular, older adults may experience a reduced ability to remember verbal information precisely, and may recall less of the content, both in terms of main idea- and detail-level information. Older adults may experience these difficulties more strongly if the verbal information is conveyed under especially challenging driving conditions.

Aim 3 demonstrates the impact of divided attention on memory-impaired older adults' story recall, as compared to their healthy peers. Our findings suggest that impaired adults are more vulnerable to forgetting verbally-conveyed information than those who are cognitively healthy. Our findings also indicate that impaired adults experience lowered verbal memory performance when their attention is divided between remembering and driving; however this reduction is comparable to that experienced by healthy older adults. Therefore, although impaired older adults show a reduced capacity for remembering verbal information, they are at no greater risk for forgetting while distracted by driving than are their healthy peers.

Limitations

The study possesses several possible limitations. First, as mentioned in the literature review, smaller age differences are found in dual-task studies employing a relatively automatic task. For many people, driving is a task learned at a young age and practiced almost daily throughout the life span. While at its initial learning it may be an effortful coordination of cognitive processes involving motor coordination, visual attention, and time-sensitive decision-making, it is also an activity that becomes relatively automatic for most people as a result of regular practice.

Second, even if driving is an adequately effortful task, the simulated driving task did not fully emulate the complexity of real-world driving. Participants had no gas or brake pedals and so were unable to adjust their speed as they normally would when navigating sharp curves. Additionally, little visual scanning was required because the landscape was flat and unchanging. Because the only challenge was then to stay within the right lane, the task was far simpler than the complex task of driving in the real world, where numerous cognitive processes occur simultaneously. Such limitations are common to controlled experiments: to evaluate a real-life situation, it must sometimes be simplified in order to be accessible to meaningful analysis.

Third, the method used to classify cognitive status may have played into the absence of a condition-by-impairment interaction. While the memory measure most used to discriminate between groups appeared to be bimodal, the majority of cognitive measures were normally and continuously distributed. Cognition, and cognitive decline in aging, operate along a continuum. The division of participants into groups based on a cutoff is an imprecise conceptualization of cognitive function, and may have led to a loss of interaction effect that would have surfaced if cognition were used as a continuous variable. On the other hand this classification, if somewhat untrue to the nature of cognition, is also necessary for the sake of dissemination for public use. While the point at which cognitive impairment begins is not yet well-defined and certainly not discrete, cognitive impairment itself is nonetheless a real phenomenon with important implications for those who experience it. Classification systems are intrinsic to the application of research findings in clinical diagnostics and treatment; as it is, they are also rarely without flaws. In the case of MCI, it involves the classifying individuals on opposite sides of a dividing line in distributions that do not actually consist of two separate groups. It also reflects, as seen in this study's simplified policy capturing analysis, that while cognition has many dimensions which are represented by many measures, only a handful of measures are typically actually used in the process of classification.

A fourth limitation that could have confounded recall performance is the issue of interference among stories. Participants heard nine short stories within a relatively brief time period, so there is reasonable risk of information from one story becoming mixed up in another. Because the stories were written based on an algorithm, several contained similar items of information such as the story's location, time of day, and character's first and last names. For example, participants sometimes would describe one story's events as having happened "last night", even if this phrase was not part of the story and instead had been heard in a previous story.

Other limitations include the sample population and size. The study sample consisted mostly of highly-educated Caucasian older adults, which is not representative of the broader senior population. The advantage of high education may have led to better performance and possibly different learning strategies in the sample compared to the general population. Additionally, the size of the cognitively impaired group was smaller than was needed for adequate statistical power. The obtained group differences may have demonstrated greater significance had there been a larger group of impaired participants.

Future Directions

One clearly useful next step for the present study would be to match the cognitive demand of the experimental task to the type of cognitive deficit in the population studied. In this study the cognitive demand manipulated was related to attention, but the population studied was memory-impaired. It appears that despite the fact that a recall task was involved in this experiment, a better way to observe differential dual-task effects in an impaired population may be to more systematically manipulate the cognitive burden that is directly related to the population in question. For example, a similar future study may vary the difficulty of the memory task in a dual-task scenario instead of increasing driving difficulty, or may choose to pair a verbal memory with a visual memory test. Such a study should also aim to recruit larger samples of cognitively impaired participants, allowing enough statistical power for group differences to be detected.

Additionally, cognitive status group differences in dual-tasks – or simply age differences in general - may be more readily detected by a scenario employing two tasks within the same modality. As it was mentioned in the literature, same-modality tasks typically yield larger age differences, likely because of greater competition for the same cognitive resources. This study used an auditory story memory task and a visual-motor navigation task, requiring dual-task performance from two different, non-competing modalities. Such experiments have typically been shown to have smaller age differences in dual task performance costs, so perhaps a bigger effect would emerge if tasks using the same modality were performed.

Looking at the driving portion of the experiment, another future direction may be to manipulate the automaticity of this task. As the literature indicated, dual tasks employing relatively automatic cognitive processing such as driving often yield smaller performance costs than those requiring effortful processing. The level of effort required for this task could be increased by incorporating other aspects of the driving experience (e.g., use of brake pedals, varied terrain, participant-controlled speed), or perhaps by increasing the difficulty of the driving scenario. These kinds of changes to the driving component would have the added benefit of increasing the ecological validity of the task. Similar changes could be made to improve the relevance of the verbal task, such as carrying a conversation (or some other experimental task of speech production and comprehension) while driving.

Anecdotally, participants often approached the dual-task challenge by stating they intended to ignore the memory task and focus on driving, since that's what they would do if a news story were on in the car. This occurrence underscores the potential future issue of manipulating attentional allocation, which was not controlled in this study. A more thorough future study might systematically evaluate the effect of attention allocation by emphasizing that participants first prioritize the driving task and sacrifice the story recall, then prioritize the story recall and sacrifice the driving.

Finally, other qualitative aspects of recall could be more deeply explored. Because it was a verbal recall task, responses often contained irrelevant utterances that may be related to lapses in memory or attention. Such utterances include um's, ah's, and verbalizations not directly related to the story, such as comments on the difficulty of the task or unsolicited opinions on the story content. Such information is not typically coded in story recall scores, but is nevertheless useful in understanding the style and quality of responses. This kind of data can be especially informative in comparative studies involving the cognitively impaired.

Conclusion

This study evaluated the precision and content of story recall as affected by memory impairment and by the addition of a simultaneous simulated driving task at both slow and fast speeds. As we hypothesized, overall recall was reduced in the presence of increasing difficulty within the task condition. Verbatim but not paraphrased recall decreased with greater task difficulty, and recall for both main ideas and details decreased at the same rate with increasing task difficulty. Memory impairment was associated with lower overall recall, but impaired individuals demonstrated similar task difficulty-related performance costs when compared to healthy individuals. Major limitations of the study the small sample size of the impaired group, leading to insufficient power to detect potential group differences, potential over-simplification of the secondary task, which reduces ecological validity, and the classification of continuously distributed variables to create cognitive status groups.

This study's findings have valuable implications for the everyday life of older adults. Important information is often conveyed during the everyday activity of driving. This can include driving directions given over a cellular phone, radio traffic alerts, and information conveyed in passenger conversation. When potentially important information is presented verbally to older adults while they are simultaneously driving, their ability to retain this information may be substantially degraded. Specifically, the precision of their recollection, as well as their memory for details of the information, declines. As the difficulty of the driving challenge increases, older drivers may additionally recall less of the main points of the information conveyed. This study also demonstrates that for mildly memory impaired older adults, the risks of forgetting verbal information while driving also apply, but are no greater for persons with mild memory impairment than for those who are cognitively healthy.

APPENDIX A
SHORT STORIES USED IN THE EXPERIMENTAL TASK

Ms. Virginia / Boone / a mother of two / won / the mother of the year award / on Sunday / during a community celebration / in Chicago. / The nominating committee/ of Chicago-Cares / hosted the event / in the flower-decorated / Grace Cathedral. / News reporters / were a large presence / at the event. / A church representative said, / "She is an amazing lady. / She raised those kids / in a rough neighborhood / without a dime of help from anyone."

A Dutch / oil tanker / sank / ten miles / off the Norfolk coast / last night. / The crew / were picked up / by a coast guard patrol boat. / An oil slick / is already forming / and conservationists / are worried / about the effects / on wildlife. / Local enthusiasts / are mounting an operation / to save / any birds / found stranded / on the beaches.

Adam / Aubrey / a Nobel prize winner / was kidnapped / from his home / during a surprising / terrorist attack / in Zurich / yesterday. / The attackers / were all hooded / and were said / to be fleeing / in a private plane. / Swiss representatives / were seeking clues. / A US embassy / representative said, / "We take this very seriously. / He is an international treasure / and we will bring him back home.

Nicolette / Zabrinsky / a Red Cross / volunteer / was infected / with a viral disease / during a blood bank / drive / in Los Angeles / last March. / An accidental slip / while trying to adjust / an intravenous needle / caused the problem. / Disease control experts / were tying to contain / the spread of the virus. / She is highly infectious now, / which is sad. / She was just trying / to help others.

Firemen / and volunteers / worked all day / yesterday / putting out / a bush fire / six miles / south / of San Diego / in southern California. / Fire engines / were unable to reach the area / so firefighting equipment / was brought in by helicopter. / Livestock / was evacuated / from the neighboring / Johnson's Farm / as it was engulfed / in clouds / of dense white smoke.

Mr. Brian / Kelly / a Pinkerton employee / was shot dead / on Monday / during a bank robbery / in Atlantic City. / The four robbers / all wore masks / and one carried / a sawed-off / shotgun. / Police detectives / were sifting through / eyewitness accounts / last night. / A police spokesman said, / "He was a very brave man. / He went for / the armed robber / and put up a hell of a fight."

Two hundred men / at a shipyard / in New Jersey / went on strike / this morning. / The men walked out / over a dispute / concerning fifty / lay-offs. / The shop steward, / Mr. Thomas / told reporters, / "It is outrageous! / The company has full-order books / for the next two years." / A management spokesperson said, / "We are hoping to begin / fresh negotiations / at main office / tomorrow."

Joellen / Reese, / a kindergarten pupil, / shocked spectators / with a performance / of Beethoven's Fifth Symphony / last night. / She was inspired / by a piano / at Garden Place Mall./ Mall-goers / were astounded / by the beautiful music. / Said one mother, / "I was amazed / that a little girl like that / could play / so well. / The piano / just seemed / to take her over."

Mr. Luther / Nathanson, / a Chrysler employee, / was injured / on the job / at a plant / in Toledo. / The assembly line / stopped suddenly / causing a large / car bumper / to hit his chest. / Plant safety officers / were trying to understand / the problem / last night. / A company spokesperson said, / "He's been a great worker. / We're looking forward to / a speedy recovery / and return to the job."

APPENDIX B
DISTRIBUTIONS OF NEUROPSYCHOLOGICAL DATA

Table B-1. Skewness and kurtosis (N=61) of neuropsychological data distributions by measure. Illustrates that scores on most measures are fairly normally distributed, without intrinsic evidence of bimodality.

	Skewness	*Skewness SE*	*Kurtosis*	*Kurtosis SE*
TICS Score	-2.57	0.31	13.54	0.61
MMSE Total	-1.33	0.31	1.68	0.60
HVLT Trial 1-3 %tile	-0.37	0.31	-1.32	0.60
HVLT Delayed Recall T Score	-0.89	0.31	-0.38	0.60
HVLT Percent Retention Percentile	-0.63	0.31	-1.05	0.60
HVLT Recognition Index Percentile	0.10	0.31	-1.20	0.60
WMS LM Trial 1 Total Scaled Score	-0.17	0.31	-0.18	0.60
WMS LM Stories 1 Total Scaled Score	-0.77	0.31	0.33	0.60
WMS LM Story B Learning Scaled Score	0.30	0.31	-0.53	0.60
WMS LM Stories 2 Total Scaled Score	-1.17	0.31	2.08	0.60
WMS LM Percent Retention Scaled Score	-1.35	0.31	2.27	0.60
COWA Fluency FAS Total Scaled Score	0.08	0.31	-0.43	0.60
Category Animals Total Percentile	-0.67	0.31	-0.86	0.60
BNT Total Score Percentile	-0.91	0.31	-0.37	0.60
Rey-Osterrieth Copy Percentile	-0.04	0.31	-1.50	0.60
Trails A Time Scaled Score	0.28	0.31	-0.30	0.60
Trails B Time Scaled Score	-0.49	0.31	-0.29	0.60
Digit Span Scaled Score	0.54	0.31	-0.47	0.60
Ruff Automatic Speed T Score	-0.14	0.31	-0.46	0.60
Ruff Continuous Speed T Score	0.12	0.31	-0.47	0.60
Ruff Total Speed T Score	-0.22	0.31	-0.13	0.60
Ruff Total Accuracy T Score	-1.64	0.31	3.49	0.60
UFOV Processing Speed	3.83	0.32	13.94	0.62
UFOV Divided Attention	2.01	0.32	3.97	0.62
UFOV Selective Attention	0.45	0.32	-0.61	0.62
UFOV Same/Different	-0.52	0.32	-0.37	0.62
GDS Total	1.72	0.31	2.55	0.60

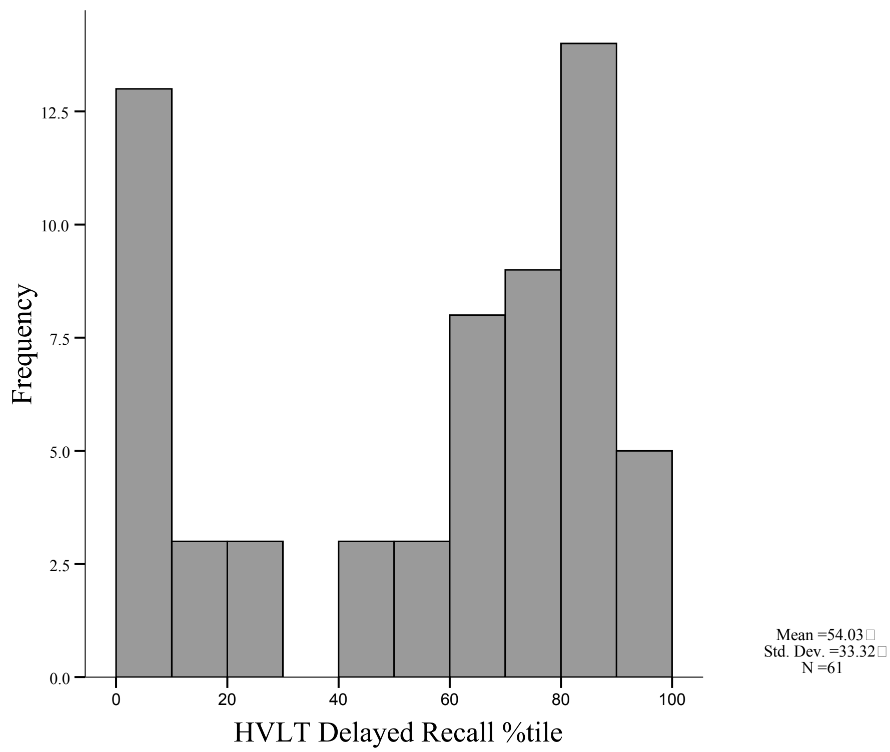


Figure B-1. Histogram representing the frequency distribution of percentile scores for Delayed Recall on the Hopkins Verbal Learning Test, the primary predictor of cognitive status group as detected by discriminant function analysis.

APPENDIX C
FOLLOW-UP ANALYSES USING SCORES RELATIVE TO BASELINE PERFORMANCE

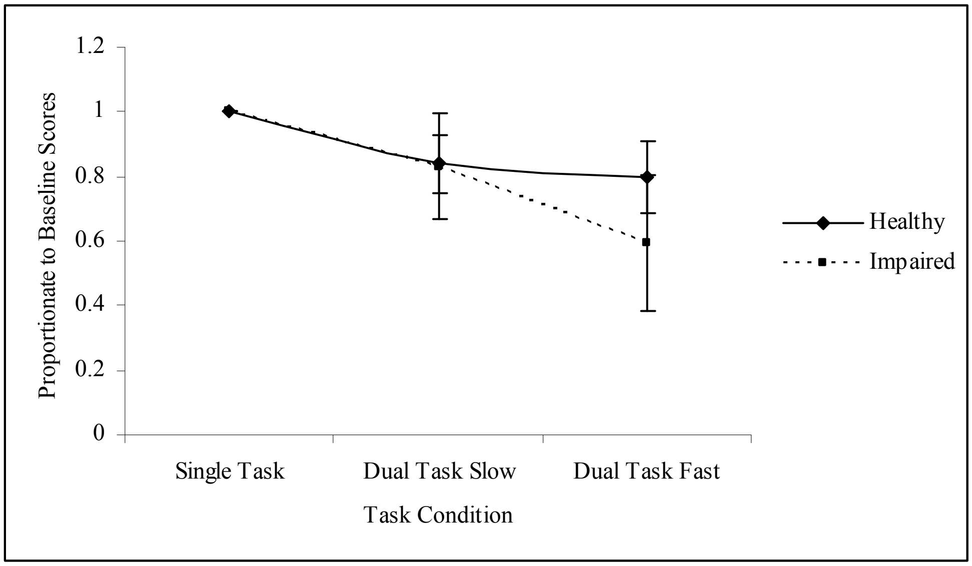


Figure C-2. Comparison of idea units recalled verbatim by healthy (N=41) versus impaired participants (N=12) across task conditions. Scores are represented as relative to baseline; this was accomplished by dividing each participant's score over their score at baseline. Error bars represent the 95% confidence interval of the mean.

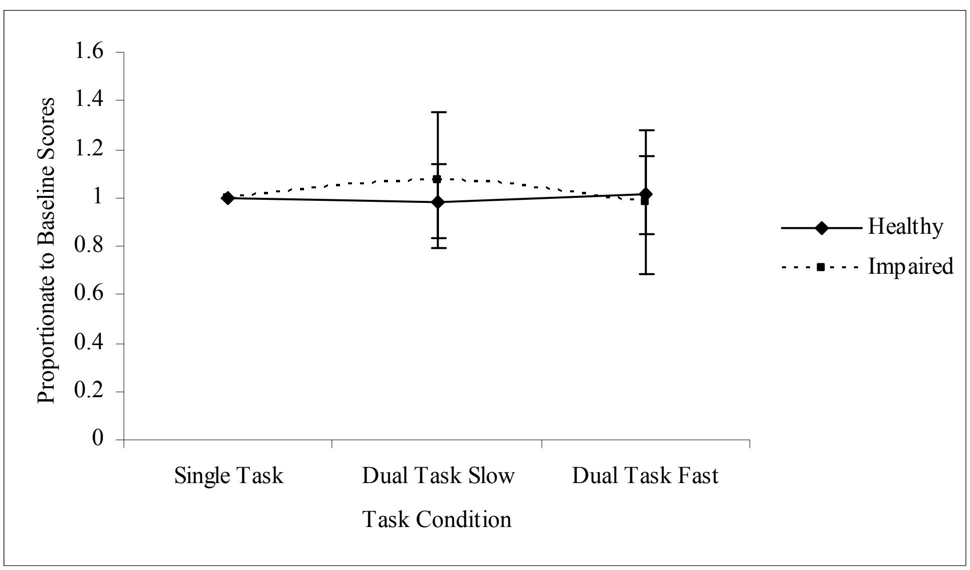


Figure C-3. Comparison of idea units recalled in paraphrase by healthy (N=41) versus impaired participants (N=12) across task conditions. Scores are represented as relative to baseline; this was accomplished by dividing each participant's score over their score at baseline. Error bars represent the 95% confidence interval of the mean.

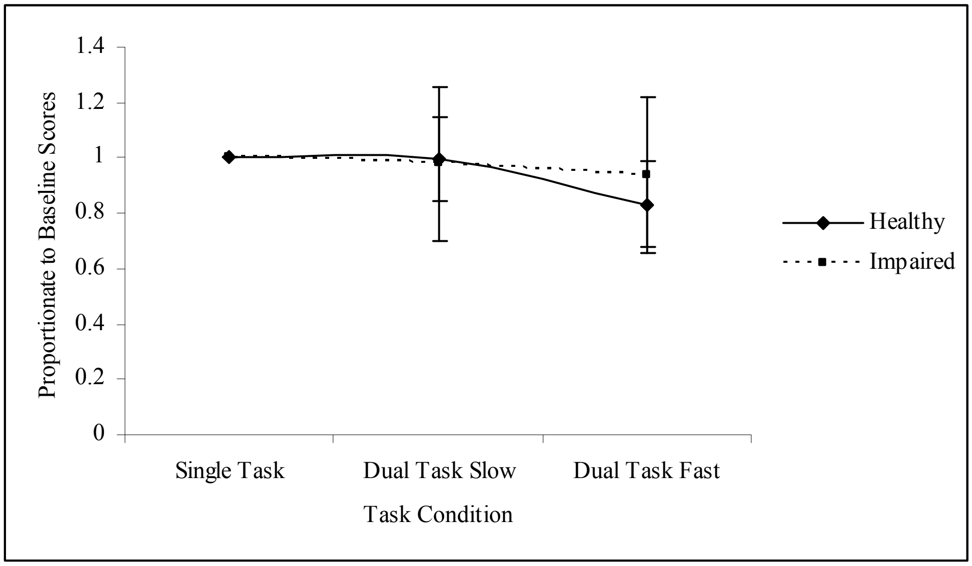


Figure C-4. Comparison of main idea units recalled verbatim by healthy (N=41) versus impaired participants (N=12) across task conditions. Scores are represented as relative to baseline; this was accomplished by dividing each participant's score over their score at baseline. Error bars represent the 95% confidence interval of the mean.

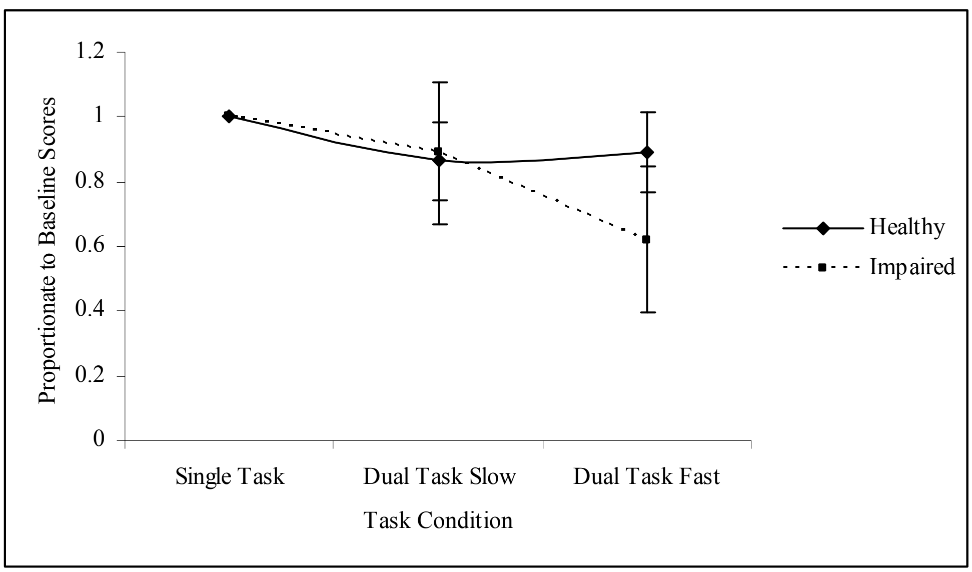


Figure C-5. Comparison of detail idea units recalled verbatim by healthy (N=41) versus impaired participants (N=12) across task conditions. Scores are represented as relative to baseline; this was accomplished by dividing each participant's score over their score at baseline. Error bars represent the 95% confidence interval of the mean.

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BIOGRAPHICAL SKETCH

Shannon Sisco graduated with honors from Calvin College with a bachelor's degree in psychology and a minor concentration in biology. She then spent two years working at a research associate in the Department of Psychiatry and in the Center for Stroke Research in the Department of Neurology, both at the University of Illinois-Chicago. Ms. Sisco was accepted into the doctoral program in Clinical and Health Psychology at the University of Florida in 2006. She is currently there working toward her doctorate in clinical and health psychology, with a specialization in clinical neuropsychology. She is concurrently working toward her certificate in Public Health, also at the University of Florida.