

Subsidiary-Task Assessment of Age Differences in Attentional Capacity During Real-World and Simulated Driving

Draft Technical Paper

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Abstract

Advances in ITS in-vehicle technologies promise to impose new information-processing demands upon drivers. Potential information “overload” problems may become especially acute among older drivers -- the fastest growing segment of the driving population. In this investigation, the efficacy of a subsidiary task technique for detecting and quantifying age-differences in the attentional demands of driving-related tasks was evaluated. Young (mean age = 19.6) and old (mean age = 71.3) licensed drivers participated in a simulated driving task while simultaneously performing a series of simple mental arithmetic computations. Response latencies on the mental arithmetic task slowed significantly for the old – but not young – drivers as the primary task of driving was made more difficult. Identical results were obtained when the study was repeated under real-world – rather than simulated – driving conditions. These findings suggest that subsidiary task techniques are sufficiently sensitive tools for detecting and quantifying age-related “shortfalls” in the attentional resources needed to safely and effectively operate a motor vehicle. These techniques may play an important role in assuring that older drivers are not “designed out” of next-generation transportation systems.

Introduction

Development and deployment of Intelligent Transportation Systems (ITS) technology will grow rapidly over the next decade. One consequence of this development will be a fundamental shift in the nature of the driving task itself. The ITS-enabled environment will place new, more sophisticated information processing demands upon drivers. Human factors principles and guidelines will play a crucial role in preventing operator “overload” as ITS developments unfold.

At the same time that ITS technology is emerging, another important trend is affecting the driving population - namely, the ever increasing number of older drivers who rely upon the automobile to meet their basic transportation needs. As we work to develop new transportation systems that accommodate the limited capacity of the driver we must be sure to consider the changing perceptual and information-processing abilities of the older population (Schieber, 1994).

Because driving involves complex interactions between many perceptual and cognitive processes whose level of functioning is subject to a wide range of individual variability, examination of each of these component processes separately often fails to adequately predict performance. However, recent research suggests that the relationship between abilities used in driving and actual driving performance can be better predicted and understood using more general measures of perceptual, attentional and/or cognitive abilities (Owsley, et al., 1991).

Subsidiary task measures of mental workload show promise as a potential means for assessing the total impact of age-related changes in perception and cognition on the performance of demanding tasks such as driving an automobile. Baldwin and Schieber (1995) demonstrated that a subsidiary mental arithmetic task was sensitive to age differences in the attentional demands imposed by a simulated automobile steering task. They found that as steering task difficulty increased, verbal response latency to concurrently processed simple arithmetic problems also increased for older participants in the study. Steering error remained stable across single and dual-task operating conditions indicating that the subsidiary mental arithmetic task did not interfere with steering (primary task) performance. They concluded that their subsidiary task technique should be both safe and effective as a tool for assessing age differences in the attentional demands of real-world as well as simulated driving.

The purpose of the present study was to replicate the laboratory results of Baldwin and Schieber's (1995) pilot study and, more importantly, to investigate whether the subsidiary task technique would be sensitive to age-related differences in the attentional demands imposed by real-world driving tasks.

Method

Participants. Eight young (mean age = 19.6, range = 18-25) and twelve older adults (mean age = 71.3, range = 63-80) participated in the study. The young adults were recruited from undergraduate psychology courses. Older adults were recruited from the active membership roles of community service organizations. All participants were

licensed drivers and agreed to drive their own automobiles during the “field” segment of the study.

Apparatus and Materials: Laboratory Study. The *primary task* of automobile steering was assessed in the laboratory using a modified version of a PC-based driving simulator used at the Transportation Research Institute of the University of Michigan (Green and Olson, 1989). A graphical depiction of a delineated roadway was back projected onto a wide screen using an active-matrix LCD imaging system. The participant’s task was to maintain his or her position in the center of the simulated roadway by operating a steering wheel. Steering accuracy (RMS lateral error) was automatically calculated and logged by the simulation computer. Steering task load was experimentally manipulated by varying the apparent speed and curvature of the simulated roadway. The low task load condition consisted of a relatively slow drive through a simple sinusoidal course while the high task load condition consisted of a relatively fast drive through a geometrically complex course. The *subsidiary task* (mental arithmetic) required the controlled delivery of auditory stimuli and the precise measurement of vocal responses (in order to calculate voice-based reaction times). Toward this end, the participants wore a headset equipped with a speaker positioned over one ear and a sensitive microphone positioned approximately 1 inch in front of their lips. The subsidiary task auditory stimuli consisted of two-digit spoken numbers which were delivered every 3-5 sec via an audio tape player. The participants performed a mental arithmetic calculation upon each two-digit number (subtracting the smaller digit from the larger one) and then verbally reported the result as quickly as possible. The two-digit stimulus as well as the participants’ subsequent response were

recorded on separate channels of a second audio tape system. These separate stimulus-response streams recorded on audio tape were digitized and analyzed off-line to determine both the accuracy and the latency of subsidiary task performance (See Figure 1 for a schematic representation of the laboratory apparatus).

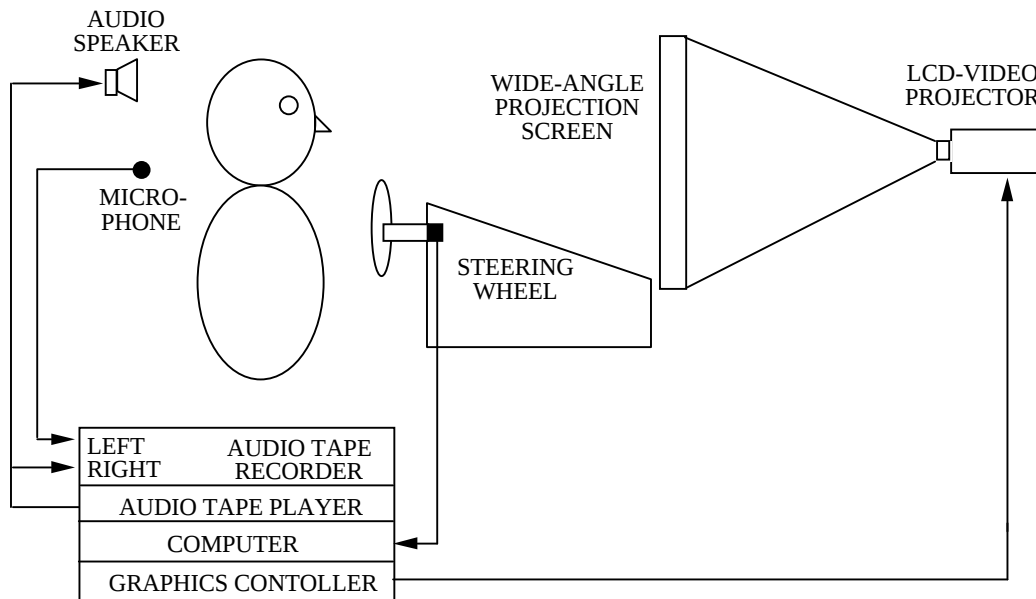


Figure 1. Laboratory apparatus.

Apparatus and Materials: Field Study. In the field segment of the study, participants drove their own automobiles over two predefined courses which presumably differed in their task loading characteristics. The low task load condition consisted of a 20-mile segment of a 4-lane rural divided highway. The high task load condition required the participants to complete several circuits of a course composed of the main streets through the business district of a small town (Vermillion, SD. Population: 10,000). Harms (1986) has previously demonstrated that rural highway versus village driving imposed significantly different workload demands upon professional drivers. Primary task (steering) performance was monitored via a video camera mounted on the right-rear quarter of the participant's vehicle. The camera was positioned so that its field of view

included the roadway's edge line as well as a reference marker fixed to the vehicle. The continuous video tape record from this camera could be digitized off-line and analyzed to quantify moment-by-moment lateral steering deviations (i.e., the angular distance between the fixed reference point on the vehicle and the roadway edge line). The subsidiary mental arithmetic task used in the field study was implemented in the same manner as described above for the laboratory segment of the study (See Figure 2 for a schematic representation of the field study apparatus).

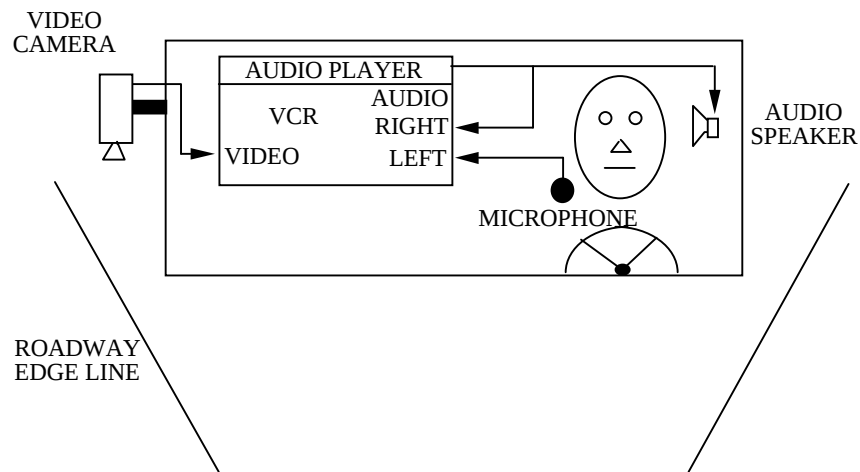


Figure 2. Field study apparatus.

Procedure. All participants were screened to assure adequate auditory sensitivity for the performance of the subsidiary task. Each participant began by practicing their steering on the driving simulator under single-task conditions. Next, the driving simulator was disabled while the participant was given 40 practice trials on the mental arithmetic task - again, under single-task conditions. Immediately afterwards, the participant was given the opportunity to practice under dual-task conditions: i.e., simultaneous performance of both the primary (steering) and subsidiary (mental arithmetic) tasks. At the completion of this extensive practice protocol, collection of the experimental data began. First, baseline

(single-task) steering data was collected (5 min). Next, baseline (single-task) mental arithmetic data was collected (40 trials). Finally, dual-task performance data was collected during the concurrent performance of the primary and subsidiary tasks (15 min). Steering task load (low versus high) order was counterbalanced throughout the practice and experimental protocols outlined above. At the completion of the laboratory phase of the study, the participant was given a 15 min rest period (during which time the field apparatus was installed upon the participant's vehicle).

The on-the-road (or "field") phase of the study began with the completion of the baseline (single-task) steering task across a segment of the test driving course. The participant was then given the opportunity to practice dual-task performance - namely, performing the mental arithmetic task while driving his/her vehicle over a pre-selected section of roadway. Finally, the dual-task experimental data was collected while the participant drove the selected test course (15 min). This entire sequence was repeated twice: once on a rural 4-lane highway (low task load) and once through the busy business district of a small town (high task load condition). The order of the task load condition was counterbalanced across the experiment.

Results

Mental arithmetic response accuracy and latency were calculated off-line for each participant. Computational errors were rare. A (2) Age by (2) Driving Domain (lab versus field) by (2) Driving Task Load (low versus high) ANOVA was performed upon the latency data for correct responses. Both the main effects of Age and Driving Domain (lab versus field) were statistically significant. More importantly, the anticipated Age by Driving Task Load interaction was significant. No other tests of main effect or interaction were statistically significant.

The significant main effect of Age ($F(1,17) = 7.48, p < .01$) is graphically depicted in Figure 3. The time needed to complete the concurrent mental arithmetic computations (averaged across all experimental conditions) increased from 635 msec for the young participants to 1002 msec for the older participants.

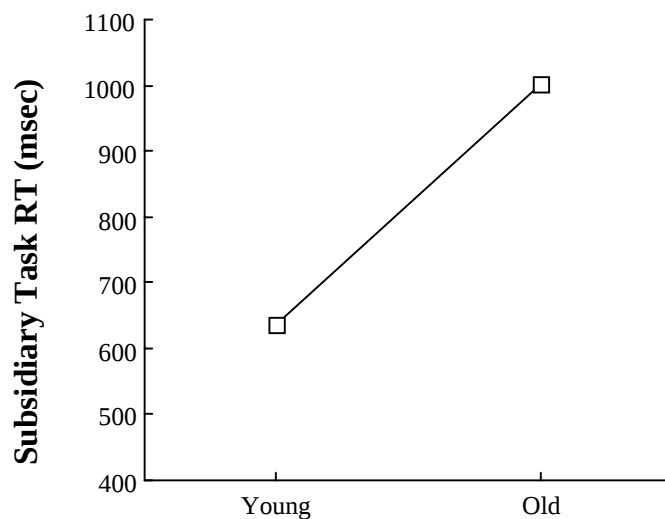


Figure 3. Mental arithmetic latency as a function of age.

The significant main effect of Driving Domain ($F(1,17) = 5.73, p < .02$) is graphically depicted in Figure 4. Subsidiary task performance slowed from an average level of 822 msec in the laboratory simulation of driving to 912 msec during real-world driving in the field segment of the study.

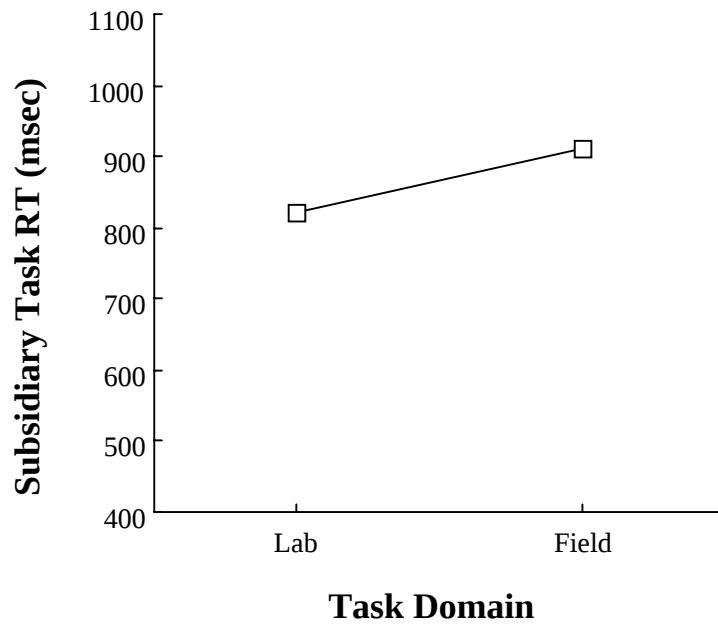


Figure 4. Mental arithmetic latency as a function of driving task domain.

The nature of the significant Age by Driving Task Load interaction ($F(1,17) = 12.52, p < .002$) is graphically depicted in Figure 5. As can be seen in this graph, performance on the subsidiary task slowed significantly for the older participants ($F(1,17) = 12.4, p < .002$) when driving task load was increased from low to high (968 versus 1035 msec, respectively). However, an increase in driving task load exerted no statistically significant effects upon subsidiary task performance for the younger participants in the study.

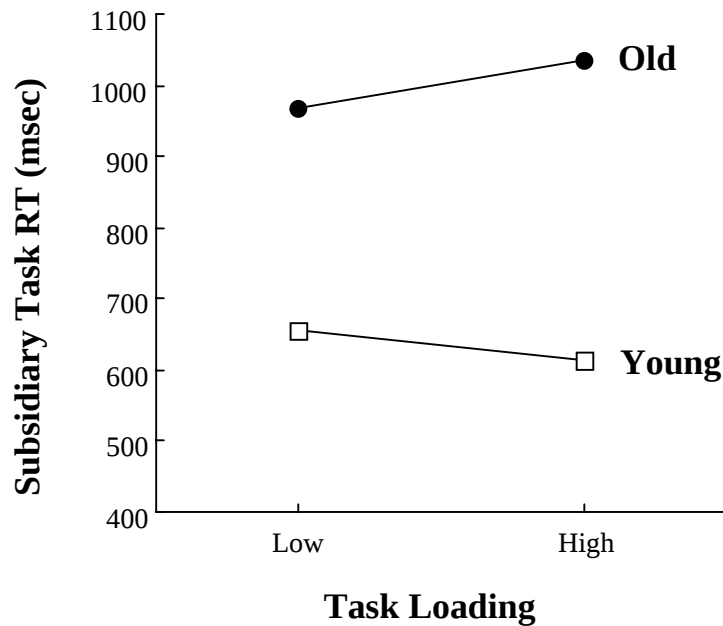


Figure 5. Mental arithmetic latency as a function of age and driving task loading.

Note to the Reviewer: The results reported here represent our initial look at the data. We focused on the subsidiary task (mental arithmetic) data since it was the most important relative to the examination of potential age differences in the attentional demands of simulated versus real-world driving. Primary task (steering) data was readily available from the laboratory segment of the study. However, we have not yet completed our analysis of the video records used to quantify steering behavior during the field segment of the study. This work involves frame-by-frame video analysis and will not be completed until sometime in April 1998. When these analyses are complete, we will be able to address the question of whether simultaneous performance of the subsidiary task interfered with the primary task of steering the automobile.

Discussion

Several notable outcomes have resulted from the conduct of this investigation. First, the laboratory segment of the study replicated and extended the results of a previous pilot study. It now is increasingly apparent that subsidiary tasks (such as the mental arithmetic task used in this study) can play an important role in detecting and quantifying the magnitude of age-related differences in the relative attentional demands of driving-related tasks. When the attentional load imposed by the simulated driving task was increased, performance on the subsidiary task slowed down significantly among the older participants. Yet, no such “attentional cost” was noted in the data of the young participants. This result suggests that: 1) older adults, on average, have fewer attentional resources to dedicate to the overall driving task, and 2) subsidiary task techniques may be sensitive enough to detect potential information processing overload conditions in the older driver that could accompany advanced ITS deployments. Second, and perhaps more important, the field study segment of this investigation found that the results obtained in the laboratory simulator could be generalized to the real-world driving situation.

Unfortunately, we have not yet had the time to analyze the primary task data from the field study. This data will allow us to ascertain whether or not performance of the subsidiary task interferes with, or “intrudes” upon, the primary task of steering the automobile. If this paper is accepted for presentation at HFES '98 we will be sure to include the results of these analyses in our final presentation.

Thanks for considering our submission!

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