

DUAL TASK ASSESSMENT OF AGE DIFFERENCES IN MENTAL WORKLOAD WITH IMPLICATIONS FOR DRIVING

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Older drivers constitute the fastest growing segment of the driving population, in terms of both number of drivers and number of miles driven. Accident analyses reveal that older drivers are not able to fully compensate for emerging reductions in perceptual/cognitive capacity. Establishment of a method of assessing older drivers with perceptual/cognitive impairments which place them at risk of accidents is imperative. In this investigation, a subsidiary task of mental arithmetic was demonstrated to be sensitive to age differences in relative mental workload resulting from increased steering task complexity in a simulated driving task. As steering task difficulty increased, verbal response latency to concurrent mental arithmetic problems increased for older, but not younger, participants. Steering error remained stable across single and dual task conditions indicating that the secondary mental arithmetic task did not interfere with steering (primary task) performance. These results provide preliminary support for the use of this assessment technique outside of the laboratory in actual driving situations.

Introduction

The proportion of the population over the age of 65 years is increasing. More of these older persons are relying on driving automobiles to meet their transportation needs. As a result, older persons are driving more miles than they have in the past (Schieber, 1994). Despite the fact that they avoid high-risk situations and employ other behavioral compensations, persons over age 70 years have a higher rate of accidents per mile driven than any other segment of the licensed driving population (Cerrelli, 1989). Perceptual/cognitive errors (e.g., failure to yield the right of way) are the most frequently cited antecedent factor in accidents for older drivers

(Charness and Bosman, 1992). Unfortunately, current methods of assessing driving ability fail to identify drivers with perceptual/cognitive impairments which place them "at risk" of accidents. The current investigation examined the potential sensitivity of a secondary task

technique for revealing age-related reductions in mental workload capacity under simulated driving conditions.

Past research with young drivers has demonstrated that secondary task methods of assessing mental workload have been sensitive to increased driving task load. Brown and Poulton (1961) found that an auditory mental

arithmetic task was sensitive to changes in the mental load of drivers imposed by a high traffic density shopping area as compared to a low traffic density residential area. Harms (1986; 1991) demonstrated that the latency of verbal responses to mental arithmetic calculations performed while driving was sensitive to changes in the complexity of the driving task (driving in villages versus driving on a highway). Both Brown et. al. (1961) and Harms (1986 and 1991) found that their participants were able to perform the secondary task with minimal intrusion on driving performance.

The purpose of this investigation was to examine the efficacy of a dual task assessment of age differences in relative mental workload imposed by a simulated driving task. It was proposed that the dual task paradigm be initially examined in a laboratory setting to ensure that the subsidiary task did not cause significant degradation on driving performance thus jeopardizing participants' safety. For this reason, a major component of the driving task - steering/tracking was examined using a part-task driving simulator. It was hypothesized that as the load of a visually-based steering/tracking task increased, that the latency of verbal responses to the subsidiary mental arithmetic task would increase. Primary task load was operationally defined as the apparent speed and complexity of curvature in the simulated roadway. It was further hypothesized that the "reserve attentional capacity" of many older adults would be diminished; and that as a result, age differences in relative mental workload - as indexed by the latency of response on the subsidiary mental arithmetic task - would be exacerbated as steering task load was experimentally increased.

Method

Participants

The participants in this experiment included 15 persons between the ages of 63 and 83 (mean age of 72.7 years) and 15 undergraduate students between the ages of 18 and 20 (mean age of 19.1 years). All participants were currently active drivers with at least 2 years of recent driving experience. All participants were screened to ensure adequate visual and auditory capabilities.

Materials and Apparatus

Primary Task Apparatus. A Steering (tracking) task based on a modified version of the PC-based driving simulator operated at the Transportation Research Institute of the University of Michigan (Green and Olson, 1989) was presented. The graphics scene was back projected onto a wide screen (80 degrees of visual angle) using an active-matrix LCD projection panel and an overhead projector. The participant's task was to maintain his or her position in the center of the simulated roadway by turning a steering wheel. Steering/tracking load was experimentally manipulated by varying the apparent speed and curvature of the simulated roadway (i.e., simple sinusoid versus difference-of-sinusoids). Root mean squared (RMS) tracking error was used to index primary task (i.e., steering) performance and, to investigate the amount of "intrusion" placed on the primary task by performance of the secondary task (Wickens, 1992). It was predicted that concurrent performance of the secondary task would not significantly intrude upon steering/tracking task performance.

Secondary Task Apparatus. Participants wore headphones and a small microphone was attached at their neckline. The subsidiary mental arithmetic task was similar to the one used by Harms (1986; 1991). Participants heard a two digit number (via headphones) ranging from 21 to 98. For each number the subject was

required to subtract the smaller digit from the larger digit and verbally report the answer. For example, if the subject heard the number 58, he or she should subtract the smaller digit (5) from the larger digit (8) and verbally report the answer (3). The probe numbers occurred in random order with the restrictions that no numbers occurred twice in a row and no numbers were used which resulted in the answer of zero (e.g. 22, 33, 44).

Reaction time (RT) in ms of verbal responses to the mental calculations task, as well as errors, were used to assess performance on the calculation task. Mental workload indices (referred to as delta RT) were operationally defined as the difference between RT scores obtained during dual task performance and baseline RT scores (the average of RT scores obtained in single task mental arithmetic conditions at the beginning and end of the experimental blocks).

Procedure

Participants practiced the steering task at one of two medium load complexities selected at random (either slow speed with high curvature or fast speed with low curvature) until their performance reached an asymptotic level. Four levels of the variable tracking load were administered to all participants in randomized order. The low load condition consisted of the moderate tracking speed combined with the simple curvature. The high load condition consisted of the fast speed combined with the complex curvature. Participants were given standardized instructions via audio tape recordings and were instructed at several points throughout the experiment that steering was the most important task and that they were only to volunteer effort to the secondary task when they could do so without disrupting steering performance.

Differences in mental workload indices between the low load condition and the high load condition were assessed to determine the

sensitivity of the proposed assessment technique. It was predicted that there would be a significant main effect for age with the group of older participants demonstrating higher levels of mental effort (increased delta RT) than the young group in each steering load condition. It was predicted that there would be a main effect for task load with both age groups performing worse (increased RT latency) in the high versus the low condition. Last, and most importantly, it was predicted that there would be an age by tracking load interaction. That is, performance decrements between the low load and high load conditions were expected to be greater for older participants as compared to young participants. This dissociation in performance was expected to reflect age differences in mental workload imposed by tracking/steering task complexity.

Results

A 2 (age) by 2 (steering task load) mixed design ANOVA (with age as a between participants variable and steering task load as a within participants variable) was used to examine age differences in the index of relative mental workload. As predicted the main effect for task load was statistically significant ($F(1,28) = 3.96, p < .05$). The main effect for age was not statistically significant, $F(1,28) = 1.71, p < .20$. More importantly, however, the predicted age by task load interaction was statistically significant $F(1,28) = 4.15, p < .05$. The nature of this interaction is apparent in Figure 1. Older participants experienced greater increases in mental workload index between low and high task load conditions than did their younger counterparts. The means for both age groups are similar in the low task load condition ($M = 62.46$ ms and 65.57 ms for young and old groups respectively; $F(1,28) = .01, p = .92$). However, a large difference between the age groups is found in the high task load condition ($M = 61.59$ ms and 140.33 ms for young and old groups respectively; $F(1,28) = 4.28, p < .05$).

Additional post hoc analysis of these data reveal that differences between the two age groups lie primarily with a small proportion of participants in the older age group (4 of 15). These four participants (OLD2 group) yielded mental workload indices greater than one standard deviation above their group mean in the high task load condition. The remaining older participants (old normals or OLD1 group) were characterized by mental workload indices which more closely resembled that of their younger counterparts ($M = 62.6$ ms and 82.15 ms in the high task load condition for young and old normals respectively.)

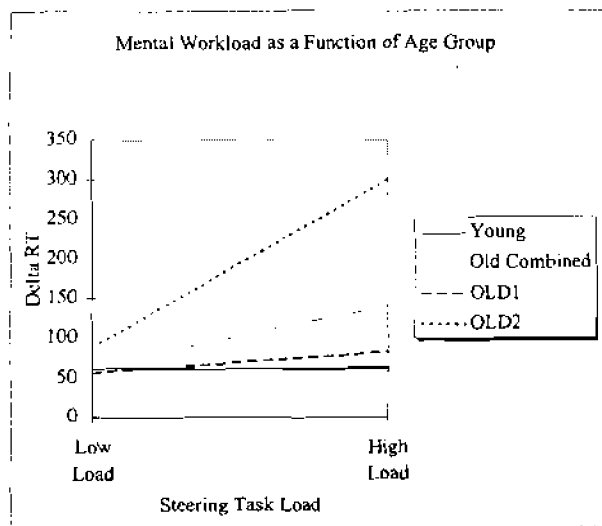


Figure 1. Relative Mental Workload (Delta RT) as a Function of Age Group and Steering Task Load.

Error Analysis

Participants in both the young and the older group made significantly more errors (both errors of omission and errors of commission) in the high task load condition than in the low task load condition, $F(1,29) = 4.36$, $p < .04$. Although the older group had a higher overall mean number of errors as compared to the young group, (low and high conditions combined $M = 1.82$ and 3.95 for young and older groups respectively), this

difference was not statistically significant, $[F(1,29) = 2.25$, $p = .14]$, nor was the interaction between task load and age group, $[F(1,29) = .08$, $p = .78]$. Unlike the mental workload index, the dependent variable number of errors did not differentiate between the old normals (OLD1) and the OLD2 group.

Intrusion

A 2 (age) by 2 (single v dual task condition) ANOVA indicated that the older group had significantly higher RMS steering error, $F(1,30) = 14.52$, $p < .01$, in both single and dual task trials. The single task mean RMS steering error was 84.98 and 113.63 for young and old groups respectively. The mean RMS steering error in dual task trials was 85.6 and 119.61 for young and old groups respectively. However, there was not a degradation in either group upon the introduction of the concomitant secondary mental arithmetic task. The main effect for single versus dual task conditions was not significant, $F(1,30) = 1.27$, $p = .27$. The interaction between condition and age also was not significant $F(1,30) = .83$, $p = .369$.

Discussion

In this investigation, a subsidiary task of mental arithmetic was shown to be sensitive to age differences in relative mental workload resulting from increased steering task complexity. As steering task difficulty increased, delta RT for mental calculations increased for older but not younger participants. This increase in delta RT was dramatically large for a small subgroup of the older participants. Analysis of error rates demonstrated sensitivity to the manipulation of steering task load but failed to differentiate between the age groups. RMS steering error remained stable across single and dual task conditions indicating that the secondary mental arithmetic task did not interfere with steering performance. These results provide preliminary support for the use of this assessment technique outside of the

laboratory in actual driving situations. Current work is underway to explore the use of the proposed technique for assessing age differences in actual on-the-road situations and for assessment of ITS technologies.

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