FALLS RISK AND DRIVING PERFORMANCE IN OLDER ADULTS

BY

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THESIS

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ABSTRACT

Attention plays an important role in real-world tasks such as driving. Safe driving relies on the ability to allocate attention and perform multiple tasks concurrently. Declines in executive function and dual-task performance have been related to falls in older adults, and recent research suggests that older adults at risk for falls also show impairments on real-world tasks, such as crossing a street (e.g. Nagamatsu et al., 2011). The present study built upon this work by examining the driving performance of older adults at high and low risk for falls. Participants were classified as high or low falls risk based on scores on the Physiological Profile Assessment (Lord et al., 2003) and completed a number of challenging driving assessments in which they responded quickly to unexpected events (e.g. a pedestrian stepping into the road) in a high fidelity driving simulator. High falls risk drivers had slower response times (~2.1 seconds) to unexpected events compared to low falls risk drivers (~1.7 seconds). Furthermore, when asked to perform a concurrent cognitive task while driving, high falls risk drivers sacrificed secondary task performance to a greater extent compared to low falls risk drivers. Low falls risk older adults also outperformed high falls risk older adults on a computer-based measure of dual-task performance and computer-based dual-task performance was correlated with driving response times. Our results suggest attentional differences between high and low falls risk older adults which extend to simulated driving performance with and without secondary task distraction.

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CHAPTER 1

INTRODUCTION

1.1 Attention and Driving

Attention is critical to the successful performance of real-world tasks, such as driving. Driving inherently requires multitasking; drivers must scan for other vehicles and pedestrians, maintain manual control of the vehicle, and plan and navigate a route through the environment, while often performing non-driving activities such as talking on a phone. Declines in cognition and attention are related to driving impairment, particularly for older adults (Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Clay et al., 2005; Hoffman, McDowd, Atchley, & Dubinsky, 2005). This impairment is reflected in increased accident rates for adults over age sixty five (Evans, 2004).

1.2 Aging, Attention, and Gait

In much the same way as driving, attention plays a vital role in balance and walking. The role of attention is highlighted by studies employing dual-task paradigms, where a balancing or walking task is paired with a cognitive task, such as memorizing (see Woollacott & Shumway-Cook, 2002, for a review). Resource models of attention suggest that when two tasks are performed concurrently, dual-task costs (i.e. performance decrements compared to performing the tasks separately) reflect the extent to which tasks compete for shared resources (Pashler, 1998; Wickens, 2002; see Kramer & Madden, 2008, for a review). Indeed, concurrently performing a cognitive task while balancing or walking results in dual-task costs to one or both tasks (particularly for older adults), suggesting the tasks compete for a limited pool of shared attentional resources (Kerr, Condon, & McDonald, 1985; Kemper, Herman, & Lian, 2003; see Woollacott & Shumway-Cook, 2002, for a review).

Dual-task effects typically become exacerbated with age, as cognitive declines leave fewer attentional resources to allocate between competing tasks (Kray & Lindenberger, 2000; Tsang & Shaner, 1998; Kramer et al, 1999). Dual-task studies suggest that balance and gait require more attention for older adults, as evidenced by larger dual-task costs. For example, Lindenberger, Marsiske and Baltes (2000) found increased dual-task costs for older adults compared to younger adults when performing concurrent walking and memorization tasks (also see Li, Lindenberger, Freund, & Baltes, 2001; Huxhold, Li, Schmiedek, & Lindenberger, 2006; Neider et al., 2011; see Woollacott & Shumway-Cook, 2002, for a review).

1.3 Attention and Falls Risk

Declines in the ability to allocate attention are related to balance and gait impairment and result in an increased risk for falls. Approximately 30% of community-dwelling older adults experience one or more falls annually (Tinetti, Speechley, & Ginter, 1988; Blake et al., 1988). Though physical declines undoubtedly play a role, there is strong evidence that the ability to allocate attention when performing dual-tasks is critical to avoiding falls. Beauchet and colleagues (2007), for example, found that dual-task performance (counting speed while walking) was associated with prospective falls over a 12-month period (also see Lundin-Olsson, Nyberg, & Gustafson, 1997; Verghese et al., 2002; Faulkner et al., 2007; but see Bootsma-van der Wiel, et al., 2003). Nagamatsu and colleagues (2011) compared the street crossing performance of older adults at high and low risk for falls under varying levels of distraction (e.g. cell phone conversation) in a high-fidelity simulator. When concurrently performing a challenging secondary task, high falls risk adults were less successful in crossing the street compared to low falls risk adults.

1.3.1 Falls Risk and Executive Function

Impaired dual-task performance for fallers likely results in part from declines in executive function, the ability to strategically allocate attention and plan and execute (or inhibit) responses. Hausdorff and colleagues (2006) found that older adult fallers performed significantly worse on measures of executive function compared to non-fallers (see also Rapport, Hanks, Millis, & Deshpande, 1998; see Yogev-Seligmann, Hausdorf, & Giladi, 2008, for a review). Springer and colleagues (2006) similarly found that older adults who had fallen in the last six months displayed higher dual-task costs compared to non-falling older adults and younger adult controls on a walking task. Importantly, dual-task performance was significantly correlated with measures of executive function. These findings suggest a strong link between falls risk, executive function and dual-task performance.

1.4 Falls Risk and Driving

Although it is clear at this point that there are differences in dual-task performance during walking between older adults at high risk for falls compared to those at low risk for falls, it is unknown whether these differences extend to other realistic tasks that are not associated with gait-control, such as driving. To our knowledge, only one study to date has examined falls risk in the context of driving. In an epidemiological study, Margolis and colleagues (2002) examined several physical measures and driving accident history in a sample of 1,416 elderly women.

After adjusting for miles driven, falls in the previous year were the best predictor of motor vehicle accidents over the same period.

1.5 Present Study

The present study explored multitasking performance of older adult drivers at high and low risk for falls. Specifically, we classified drivers according to falls risk based on scores on the Physiological Profile Assessment (PPA; Lord, Menz, & Tiedemann, 2003) and examined driving performance systematically in a high-fidelity driving simulator. Drivers completed a number of challenging drives through environments containing unexpected critical events (e.g. pedestrians stepping into the street, lead vehicle braking). Assessing behavior in a simulator allowed us to measure various aspects of driving performance (e.g. manual vehicular control, responses to unexpected events) and to place drivers in critical situations where accidents might occur. Of primary interest was identifying behavioral differences between high and low falls risk drivers that are likely to result in motor vehicle accidents. To further test multitasking performance, we included a non-driving cognitive distraction task during some of the drives. Previous research has shown that secondary tasks impair driving performance and vice versa (e.g. Strayer, Drews, & Johnston, 2003; Becic et al., 2010); older adults, especially fallers, are also more susceptible to dual-task impairment as tasks become more difficult (Nagamatsu et al., 2011; Neider et al., 2011; Lindenberger et al., 2000). Finally, to determine whether differences in driving performance were related to broader attentional differences, participants completed a battery of cognitive tests.

Given that high falls risk older adults demonstrate decrements in executive function and dual-task performance compared to low falls risk adults, we predicted that low falls risk drivers would outperform high falls risk drivers on our simulated assessments. Executive control is critical to safe driving; drivers must allocate attention and manage varying tasks concurrently. Daigneault, Joly, & Frigon (2002), for example, found a history of accidents was related to poorer executive function in a sample of older male drivers. We further predicted that the difference in driving performance between high and low falls risk drivers would be greatest when the driving task was most demanding (i.e. when drivers had to respond to critical events along with maintaining lane and speed control, etc). These periods should impose the highest multitask demand on drivers, and thus multitasking differences between high and low falls risk drivers should be most pronounced. We similarly predicted that, when performing a secondary task while driving, high falls risk drivers would experience greater dual-task costs on one or both concurrently performed tasks. Finally, given that cognitive differences between high and low falls risk older adults are found primarily on measures of executive function and dual-task performance (Beauchet et al., 2007; Lundin-Olsson et al., 1997; Verghese et al., 2002; Faulkner et al., 2007; Nagamatsu et al., 2011; Rapport et al., 1998; Hausdorff et al., 2006; Springer et al., 2006), we predicted that low falls risk older adults would outperform high falls risk participants on a desk-top computer dual-task paradigm.

CHAPTER 2

METHODOLOGY

2.1 Participants

30 independent-living older adults were recruited from the Urbana-Champaign community and paid $8 per hour for their participation. All participants demonstrated normal or corrected-to-normal visual acuity (20/30 or better using a Snellen chart), normal color vision (Ishihara Color Vision Test) and scored above 28 (of 30) on the Folstein Mini-Mental State Exam. All participants had valid drivers' licenses, drove regularly (as indicated on a driving history questionnaire) and reported taking no medications that impair driving. Mobility and balance were assessed using the Timed Up and Go test (TUG) (Podsiadlo & Richardson , 1991). Two participants were excluded after experiencing simulator sickness during the screening drive. Descriptive data are provided in Table 1.

2.2 Apparatus

A PC with a 19-inch screen was used for neuropsychological testing. All tasks were programmed using E-prime (Psychology Software Tools; Pittsburgh, PA). Viewing distance was approximately 77cm for all tasks, although participants were free to move their heads. The Beckman Institute KQ Hyperion Driving Simulator at the University of Illinois (http://isl.beckman.illinois.edu/Labs/Driving%20Simulator/Driving%20Simulator.html) was used to assess simulated driving. The simulator consists of a General Motors Saturn Automobile surrounded by eight screens, creating a highly immersive driving environment. Traffic environments and experimental scenarios were developed using HyperDrive™ Authoring Suite. Data was recorded at 60 Hz.

2.2.1 Driving Screening.

To reduce attrition due to simulator sickness, participants completed a 5-minute screening drive in the simulator. The screening drive comprised a straight, two-lane city road with several intersections. Participants were instructed to drive normally along the route until prompted to stop. Any participants who experienced simulator sickness were excluded from the remainder of the study.

2.2.2 Falls Risk Assessment

Participants completed a survey assessing the number of falls within the previous 6 months. Only 3 individuals reported falling in the previous 6 months. Thus, we classified participants as high or low risk for falls based upon their scores on a measure of falls risk, the Physiological Profile Assessment (PPA; Lord et al., 2003). The PPA creates a composite falls risk score based on measures of edge contrast sensitivity, hand reaction time, proprioception, leg muscle strength and sway. The PPA has been shown to reliably predict prospective falls with 75% accuracy (Lord et al. 2003). We set an a priori cutoff score of 0.6 to classify high and low falls risk (i.e. high falls risk ≥ 0.6), based on previous work showing a cutoff score of 0.6 effectively separates individuals based on falls risk (Delbaere et al., 2010).

2.3 Cognitive Battery

2.3.1 Computer Dual-Task

Participants performed two tasks both separately and simultaneously. On each trial, participants responded to a target presented above or below a fixation cross in the center of the display. For one task, participants determined whether a letter was an A or B and pressed corresponding keys with their right hand. In the second task, participants determined whether a number was a 2 or 3 and pressed a corresponding key with their left hand. On single-task trials (50%), only a letter or a number appeared and participants made one response. On dual-task trials (50%), both a letter and a number appeared and participants responded simultaneously. Participants had 3 seconds to respond to the target. Single and dual-task practice trials were followed by an experimental block (80 trials) where single and dual-task trials were randomly intermixed.

2.3.2 Functional Field of View (FFOV)

Participants searched for a white triangle within a circle among square distracters in a briefly (44ms) presented display. Items were arranged in eight radial spokes around a square in the center of the display. Targets were presented with equal probability on each spoke at eccentricities of 10^o, 20^o, and 30^o from fixation. The search display was followed by a 100ms mask display consisting of random black and white lines and shapes. After the mask, a response screen containing lines representing the eight radial spokes appeared. Participants clicked with the mouse on the spoke where the target appeared. Participants completed 24 practice trials followed by 120 experimental trials.

2.3.3 Realistic Change Detection

Participants performed a flicker change detection task (Pringle, Irwin, & Kramer, 2001). Stimuli were 80 pairs of photographs of real driving scenes taken from the driver's perspective. Each pair of images differed in one detail (e.g. a car in one image was removed from the other image). On each trial, participants saw a repeating cycle of 4 images: first image (240 ms), a gray mask screen (80ms), the modified image (240ms), a gray mask screen (80ms). Participants pressed a key when they detected the change and then clicked on the change location with the mouse. Participants had 30 seconds to respond and completed one practice trial followed by 40 test trials.

2.4 Driving Assessment

Drivers completed two separate driving assessments, and completed a single-task and dual-task version of each task. The order of the driving tasks and secondary-task conditions was counterbalanced across participants. In the dual-task condition, participants performed a continuous 1-Back task, where they heard a letter every 3 seconds and indicated whether the letter was the same as, or different from, the previous letter via buttons on the steering wheel. Participants completed a 1-Back-only practice block prior to driving.

2.4.1 Following Task

Drivers followed a lead vehicle along a straight, two-lane highway for approximately 15 minutes. The lead vehicle maintained a speed of 45 mph, and participants were instructed to maintain a constant 5 second headway. To help participants visualize the 5 second headway, they completed a practice drive where feedback indicated whether they maintained the proper distance from the lead vehicle. At 20 random times during the experimental drive, the lead vehicle's brake lights illuminated and its speed decreased. Drivers were instructed to brake as soon they detected lead vehicle slowing. They were warned that if no braking occurred, a collision was possible. As soon as the driver pressed the brake, the lead vehicle accelerated to its original speed.

2.4.2 Hazard Task

Drivers responded to potentially hazardous events as they drove along a straight, two-lane urban road. Ambient traffic and pedestrians were randomly generated such that there was a constant stream of traffic in the opposite lane and the sidewalks were always crowded with pedestrians. Participants were instructed to maintain a speed of 35 mph. Participants encountered a total of 20 randomly-spaced potential hazards in each drive. Hazards comprised pedestrians crossing the roadway from the left or right sidewalk and cars on the right shoulder beginning to pull out and stopping. Participants were instructed to press the brakes as soon as detecting a hazard. To avoid participants becoming hyper-alert during the following (and to avoid simulator sickness), the hazard task was always performed last in each session.

2.5 Procedure

Participants completed three experimental sessions, each lasting between 1 and 1.5 hours. Session 1 consisted of a screening drive in the driving simulator as well as descriptive measures and falls risk assessment. In sessions 2 and 3, participants completed three computer-based cognitive tasks followed by two driving assessments in the simulator.

CHAPTER 3

RESULTS

3.1 Cognitive Battery Results

Three participants (2 high risk, 1 low risk) did not complete the cognitive battery and were not included in the analyses. Data from the cognitive assessments are presented in Table 1. Dual-task cost was calculated by subtracting the single task reaction time from the dual-task reaction time. High falls risk participants had a significantly higher dual-task cost compared to the low falls risk group, $F(1,23) = 6.88$, $p < .05$. Single-task reaction times on the computer dual-task paradigm did not differ between the groups, $F(1,23) = .19$, $p = .67$, indicating that differences were localized to the dual-task condition and not due to general slowing. This is consistent with previous work demonstrating dual-task performance differences between high and low falls risk groups (Lundin-Olsson, Nyberg, & Gustafson, 1997; Verghese et al., 2002; Faulkner et al., 2007; Beauchet et al., 2007; Nagamatsu et al., 2011). There was no difference in accuracy between the high and low falls risk groups on the FFOV task and no interaction with target eccentricity (p's > .70). Though it does appear that there was a trend toward higher FFOV accuracy for the low falls risk group, large inter-individual variability and a low sample size may have masked the effects. Additionally, high and low falls risk participants did not differ on either accuracy or reaction time on the realistic change detection task (all p's > .35). Differences between high and low falls risk participants on the cognitive battery were confined to dual-task cost in the computer dual-task paradigm.

3. 2 Driving Assessment Results

Unless otherwise specified, driving measures were entered into an ANOVA with falls risk group (high vs. low) as a between subjects factor and secondary task condition (single vs. dual) as a within subjects factor.

3.2.1 Response Time

Response time (RT) was defined as the time it took a driver to press the brake pedal following the onset of the lead vehicle brake lights or the triggering of the hazard event. Only events in which the driver successfully responded and avoided an accident were included in the RT analysis. RT's are presented in Figure 1. Low falls risk drivers responded significantly faster to lead vehicle braking compared to high falls risk drivers, $F(1,26) = 11.28$, $p < .01$. Low falls risk drivers also responded faster to the onset of hazard events, $F(1,26) = 9.32$, $p < .01$. In the following task, there was a main effect of task condition, with drivers responding slower in the dual-task condition compared to the single-task condition, $F(1,26) = 5.24$, $p < .05$ In the hazard task, the main effect of task condition was not significant, $F(1,26) = .083$, $p = .78$. Performing the 1-Back task while driving slowed RT's in the following task but not the hazard task. The interaction between falls risk group and secondary task condition was not significant in either the following ($F(1,26) = .04$, $p = .98$) or hazard ($F(1,26) = 1.65$, $p = .21$) task, indicating that the high risk group was not differentially impaired on the driving measures by the secondary task relative to the low risk group.

3.2.2 Continuous driving performance measures.

Average velocity and standard deviation in lane position were recorded over the course of each drive, excluding critical periods (i.e. times when the driver was responding to lead vehicle braking or hazard events). High and low falls risk groups did not differ in average velocity or deviation in lane position and there were no interactions between falls risk group and secondary task condition for any of these measures on either driving task (all *p*'s > .10). On the following task, headway distance was defined as the average distance between the driver's vehicle and the lead vehicle. The main effect of secondary task condition on headway distance was significant, $F(1,26) = 4.078$, $p = .05$ suggesting that drivers in the dual-task condition followed significantly farther from the lead vehicle compared to the single task condition,. The main effect of falls risk group and the interaction between falls risk group and secondary task condition were not significant (*p*'s > .45), indicating the secondary task did not differentially affect headway distance for either group.

3.2.3 Desktop Computer Dual-Task Performance Predicts Driving Performance

To examine whether performance on the computer dual-task paradigm predicted driving performance, we computed the correlation between dual-task cost on the computer paradigm and RT in the driving tasks. Dual-task performance on the computer dual-task paradigm was significantly correlated with RT in both the following ($r = .42$, $p < .05$) and hazard ($r = .45$, $p < .05$) driving tasks (see Figure 2; A & B). Participants with a lower computer dual-task cost (i.e. participants better at dual-tasking) responded faster to lead vehicle braking and peripheral hazard events. Conversely, single task performance on the computer dual-task paradigm was not significantly correlated with RT in either the following or hazard drives (*p*'s > .20; Figure 2; C & D). Computer dual-task performance was not significantly correlated with any continuous measure of driving performance (all *p*'s > .10).

3.2.4 Secondary Task Accuracy

We examined accuracy on the 1-Back task to examine whether drivers sacrificed performance on the secondary task while driving (see Figure 3). Previous research shows secondary task performance may be impaired when paired with a driving task (e.g. Becic et al., 2010). Performance on the last half of the 1-Back practice was used as a measure of single task performance and 1-Back accuracy while driving constituted dual-task performance. 1-Back accuracy was submitted to an ANOVA with task condition (single vs. dual) as a within subjects factor and falls risk as a between subjects factor. 1-Back accuracy was significantly lower in the dual-task condition compared to the single task for both the following ($F(1,26) = 254.5$, $p < .001$) and hazard ($F(1,26) = 173.0$, $p < .001$) drives. This indicates dual-task costs to 1-Back accuracy when concurrently driving. There were no differences, however, between falls risk group and no interactions between falls group and task condition in either driving task (all *p*'s > .15). To determine if a group difference existed when the driving task was most demanding, we divided 1-Back accuracy into critical segments (i.e. during peripheral hazard or lead vehicle braking events) and non-critical segments (i.e. periods between critical events). High falls risk participants performed marginally worse than low falls risk participants during critical periods in both the following ($F(1,26) = 3.27$, $p = .084$) and the hazard drives ($F(1,26) = 3.57$, $p = .071$). There was no difference between groups on 1-Back accuracy in the non-critical segments for either drive (*p*'s > .70) (see Figure 3). This indicates that, when responding to critical events, high falls risk drivers sacrificed performance on the secondary task to a greater extent compared to low falls risk drivers. Though this may have been a compensatory strategy, it did not eliminate group differences in RT to critical driving events.

CHAPTER 4

DISCUSSION

Previous research demonstrates that older adults suffer disproportionate performance costs when performing two or more tasks concurrently (e.g., Kramer, Larish, & Strayer, 1995; Kray & Lindenburger, 2000; see Kramer & Madden, 2008 for a review). Dual-task costs are observed when a walking task is paired with a cognitive task, and these costs are often greater for older adults (Lundin-Olsson et al., 1997; Verghese et al., 2002; Beauchet et al., 2007; Faulkner et al., 2007; see Woollacott & Shumway-Cook, 2002, for a review). Older adults who have fallen or are at risk for falls show dual-task performance decrements compared to non-fallers on gait and cognitive tasks in both the lab and in simulated real-world tasks (Holtzer et al., 2007; Hausdorff et al., 2006; Delbaere et al., 2010; Anstey, von Sanden, & Luszcz, 2006; Nagamatsu et al., 2011). The goal of the current research was to examine the multitask performance of older adult drivers at high and low risk for falls. Specifically, older adults were classified as high or low risk for falls based on PPA scores (Lord et al., 2003) and completed several challenging drives where they responded to unexpected critical events in a high fidelity driving simulator.

Of greatest importance is the finding that high falls risk drivers responded approximately 400 ms slower to critical events compared to low falls risk drivers. High falls risk drivers responded slower to both central (i.e. lead vehicle braking) events and peripheral hazards. Faster RT’s suggest that drivers at low falls risk might have time to avoid collisions that high falls risk drivers have more difficulty responding to. Previous research by Margolis and colleagues (2002) showed that older adults with a history of falls were more likely to have been involved in accidents. Our results suggest that slower responses times to unexpected events may underlie the increased accident rates.

Our results suggest differences in driving RT were driven by a difference in multitasking performance. On the computer dual-task paradigm, high falls risk participants had significantly higher dual-task costs compared with low falls risk participants. High and low falls risk participants did not differ significantly on single-task reaction times on the computer task, suggesting that differences result from impairments in multitasking ability and not general slowing. Importantly, reaction times in the computer dual-task condition, but not the single-task condition, were correlated with driving response times; participants with lower computer dual-task costs (i.e. better dual-tasking) had faster responses to critical events while driving. Computer single-task reaction times were not correlated with RT in either drive, again suggesting that multitasking differences, and not general slowing, are responsible for differences in driving RT's. Responding to critical events while driving requires the ability to multitask; drivers must scan the environment and plan and execute a response while maintaining control of the vehicle and continuing to monitor other areas of the environment. Drivers who were better able to perform two tasks concurrently on a computer were better able to manage task demands while driving. Previous research demonstrates greater dual-task impairment for high falls risk older adults on a number of dual-task paradigms (Beauchet et al., 2007; Lundin-Olsson et al., 1997; Verghese et al., 2002; Faulkner et al., 2007). Dual-task performance on a computer paradigm also predicts simulated street-crossing performance (Nagamatsu et al., 2011). Our results suggest these dual-task performance differences between high and low falls risk older adults extend to responding to critical events during simulated driving.

Falls are theorized to result from impaired executive functioning, the ability to manage competing task demands and plan and execute responses. For instance, executive function predicts dual-task performance and prospective falls (Springer et al., 2006; Rapport et al., 1998; Hausdorff et al., 2006). Older adults with poorer executive functioning are less able to coordinate multiple concurrent tasks associated with maintaining balance or walking, such as monitoring one's physical movements while attending to the environment. Executive function is also important for safe driving; in order to manage competing task demands, drivers must strategically allocate attention and plan responses to different events. In our hazard driving task, for example, drivers had to continually search areas of the driving scene for potential hazards while monitoring their speed and position in the roadway. When hazards appeared, drivers had to quickly assess the situation and execute a response, while maintaining vehicular control. Decrements in executive function have indeed been linked to accident rates. Daigneault and colleagues (2002) found that poorer performance on a battery of executive function tasks was related to a greater number of retrospective accidents in a sample of older male drivers. We suggest that differences in the ability to manage competing task demands were primarily responsible for group differences in response time in our simulated drives. Further, our research suggests that individuals who are have problems coordinating tasks while maintaining gait also have slower responses when driving. This suggests that decrements in executive function leading to multitasking impairment are general, extending from computer-based tasks to simulated street crossing (Nagamatsu et al., 2011) and simulated driving. Executive function, in addition to physical abilities, appears critical to complex task performance. Further, executive function has also been linked to a number of other real-world tasks and simulations. For instance, executive function performance has been linked to the Instrumental Activities of Daily Living, such as medication adherence (e.g. Cahn-Weiner, Boyle, & Malloy, 2002; Bell-McGinty et al., 2002). This indeed suggests a general executive function mechanism related to performance of real-world tasks and also suggests that high falls-risk older adults might be more likely to have problems with activities of daily living, in addition to driving and crossing the street.

Baltes and Lindenberger (1997) propose a 'common cause hypothesis' to explain the relation between sensory and cognitive function in older adults. This hypothesis states that differences in sensory and cognitive tasks are the outcome of a third common factor. The present data suggest that differences in a general multitasking ability (or perhaps executive function) are related to performance on a physiological battery (PPA) as well as a computer dual-task paradigm and driving simulator assessments. This mechanism appears to be related to complex task performance; we did not find a relationship between computer-single task performance and driving or group differences on the continuous measures of driving performance.

Somewhat alternatively, the present results may be related to task complexity; complex tasks may be more demanding for older adults with impaired executive functioning. Responding to critical events represented the highest demand conditions in the present study. This is supported by the computer dual-task results; computer-dual task performance was correlated with RT to critical events but not with any continuous performance measure. This suggests critical responses relied more on multitasking ability than did continuous driving behaviors. Multitasking demands likely needed to be sufficiently high to elucidate differences between high and low falls risk participants. Previous research suggests that dual-task components (i.e., the individual tasks, or the combination of tasks) must be challenging to create competition for attentional resources that result in dual-task costs (e.g. Lindenberger et al.,2000; Neider et al., 2011). For example, the simulated street crossing performance of high falls risk older adults only differed from low falls risk controls when the secondary task was most cognitively engaging (i.e. a cell phone conversation; Nagamatsu et al., 2011). Group differences in the present study were thus found when the driving task imposed the highest multitasking demand on drivers. Low falls risk drivers were better than high falls risk drivers in managing the additional demands of responding to an unexpected event, evidenced by faster responses.

Adding a secondary (1-Back) task had a mixed impact on driving performance. The secondary task slowed responses to lead vehicle braking events in the following drive. RT's in the hazard task however, were unaffected by the 1-Back task. This difference potentially reflects the nature of the driving tasks. In the following task, drivers need only focus on the lead vehicle to monitor for brake lights. The hazard task is more complex; drivers must identify hazards and then decide on and execute the proper response. Previous work has demonstrated that secondary task distractions have differing impacts on driver performance depending on the nature of the driving task (e.g. see Horrey & Simons, 2007). Differences in the complexity of our driving tasks likely led to differential impact of the secondary task. Consistent with previous research (Strayer & Drews, 2004; Strayer, Drews, & Johnston, 2003), there was a moderately significant increase in headway distance in the dual-task version of the following drive. This likely indicates a compensatory strategy whereby drivers increased distance from the lead vehicle to account for slowed responses. However although drivers increased headway distance, they still responded slower to lead vehicle braking in the dual-task condition.

In the dual-task condition (driving + 1-Back), dual-task performance costs were observed in 1-Back accuracy. Previous research suggests dual-task performance while driving impairs secondary task performance (e.g. Becic et al., 2010). The decline in 1-Back performance may indicate a compensatory strategy. Older adults compensate for dual-task demands when walking and conversing by prioritizing performance on the most safety-critical task (i.e. maintaining walking performance; e.g. Li et al., 2001). In the case of the present study, accuracy costs on the 1-Back task may indicate a strategy whereby drivers prioritized driving performance over secondary task performance. During responses to critical events, 1-Back accuracy was lower for high falls risk drivers compared to low falls risk drivers. This suggests high falls risk drivers had fewer resources to allocate between the two tasks, and therefore had to compensate performance on the 1-Back task to a greater extent.

One remaining question is what accounts for the difference in driving response time. One possibility is that, because of attentional differences, high and low falls risk drivers utilize different scanning strategies. High falls risk drivers might scan the driving environment less effectively due to impairments in the ability to allocate attention. Alternatively high falls risk drivers may recognize hazards in a similar time but have delays in response execution (i.e. braking or steering away). Further research utilizing eye tracking techniques is needed to elucidate this question. The hazard driving task and other complex driving tasks requiring drivers to search different areas of the environment for potential conflicts may be particularly useful in examining scanning differences between high and low falls risk drivers, as drivers must attend to multiple areas as opposed to just the lead vehicle ahead. However, scanning differences could also exist in the less complex vehicle following paradigm; for example, drivers might differ in the amount of time they need to look at the speedometer to maintain a consist speed, which could divert attention away from the lead vehicle. Research should also examine whether the difference between high and low falls risk drivers exists only when responding to hazard events. Older drivers for example, are overly represented in accidents at left-turn intersections because they fail to scan the environment effectively (Romoser & Fisher, 2009). Future research should explore the implications of attentional differences in other driving scenarios. Research should also compare falls risk and dual-task performance with the Useful Field of View (UFOV) and other established predictors of older driver performance. Performance on the dual-task condition of the UFOV (i.e. central discrimination task and peripheral localization task) has been shown to predict accidents in older adults (e.g. Clay et al., 2005). It would be interesting to determine the relation with the UFOV and to compare the predictive validity of falls risk and the UFOV in predicting driver impairment and the extent to which falls risk predicts the UFOV. Given our findings of a general multitasking mechanism related to falls and simulated driving performance, it seems likely that there would be at least some overlap between these measures.

Further, it would be interesting to examine whether interventions could moderate differences in driving performance between high and low falls risk older adults. For example, research has found that training interventions can lower older adults' falls risk (i.e. lower PPA scores; Lord et al., 2003). It would be interesting to examine the extent to which reductions in falls risk were associated with improvements on multitasking paradigms, both computer tasks and real-world simulations. It would also be interesting to examine whether driver training programs could improve "at-risk" drivers' performance by teaching compensatory strategies. Romoser and Fisher (2009), for example, found that individualized training improved the scanning of critical areas at intersections for older drivers. It would be interesting to determine whether drivers who were poorer at multitasking benefited more from instruction on these strategies or whether this training generalizes to other driving environments.

Some limitations should be noted in the current study. Due to population limitations, we were only able to assess individuals based on falls risk (i.e. PPA score; Lord et al., 2003) and not a history of falls. The current study also used a driving simulator instead of assessing performance in a real vehicle. While the simulator does allow assessment of performance in dangerous situations which could not be assessed in an on-road vehicle, there is some inherent mismatch between real-world and simulated driving.

Our results demonstrate that older drivers at high risk for falls respond significantly slower to critical events compared to low falls risk drivers. Falls risk also predicts performance on a computer-based dual-task paradigm and performance on this paradigm predicts driving response times and secondary task (1-Back) accuracy. These results suggest that high falls risk is related to a general decrement in multitasking ability which translates to performance on both laboratory and, importantly, real-world tasks. These differences in multitasking ability are likely related to previous findings of executive function differences between fallers and non-fallers. Falls risk assessment may an accurate tool in predicting driving performance and accident risk for older adults and has the potential to be utilized as a screening measure for safe driving performance.

TABLES AND FIGURES

Table 1.

Demographic and Cognitive Measures

Measure		High Falls Risk (N=14)	Low Falls Risk (N=14)
Age (years)		75.8 (3.3)	74.4 (5.5)
Physiological Profile Assessment Score**		1.67 (.64)	0.33 (.26)
Timed Up-and-Go (seconds)**		13.94 (2.6)	10.18 (2.2)
Activities Balance Confidence Score (of 16)*		14.17 (1.4)	15.43 (.42)
Miles Driven Per Week		55.36 (9.9)	61.42 (7.0)
Years Licensed		58.86 (5.3)	57.86 (3.2)
Accidents in Last 12 Months		3	2
Functional Field of View (FFOV)	% Correct	44.29 (19.9)	47.13 (18.7)
Change Detection	RT	7.40 (1.13)	7.70 (1.28)
	% Correct	53.7 (10.3)	55.39 (8.4)
Dual-Task Cost (Dual RT-Single RT)	RT*	572.7 (207.2)	354.8 (207.8)

Note. Data are expressed as mean (SD).
*p<.05. **p<.001.

Figure 1. Mean response time for the high and low falls risk driver groups in single (drive only) and dual (drive + 1-Back) task conditions in the hazard response and car following paradigms. Error bars represent one standard error of the mean.

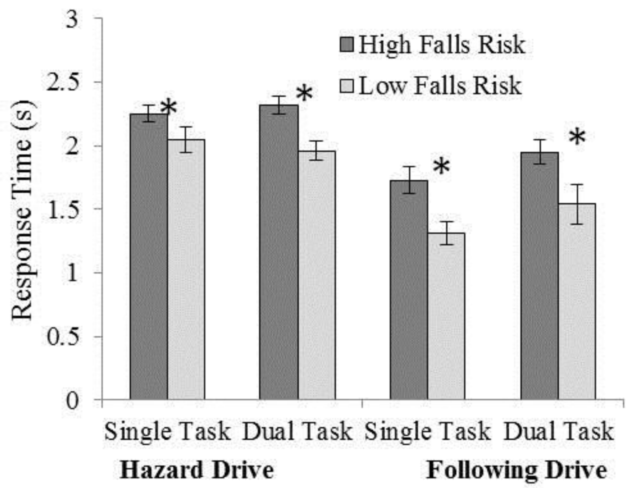


Figure 2. Response time in seconds in the hazard (A & C) and following (B & D) driving tasks plotted against single-task and dual-task reaction time on the computer dual-task paradigm. *p<.05.

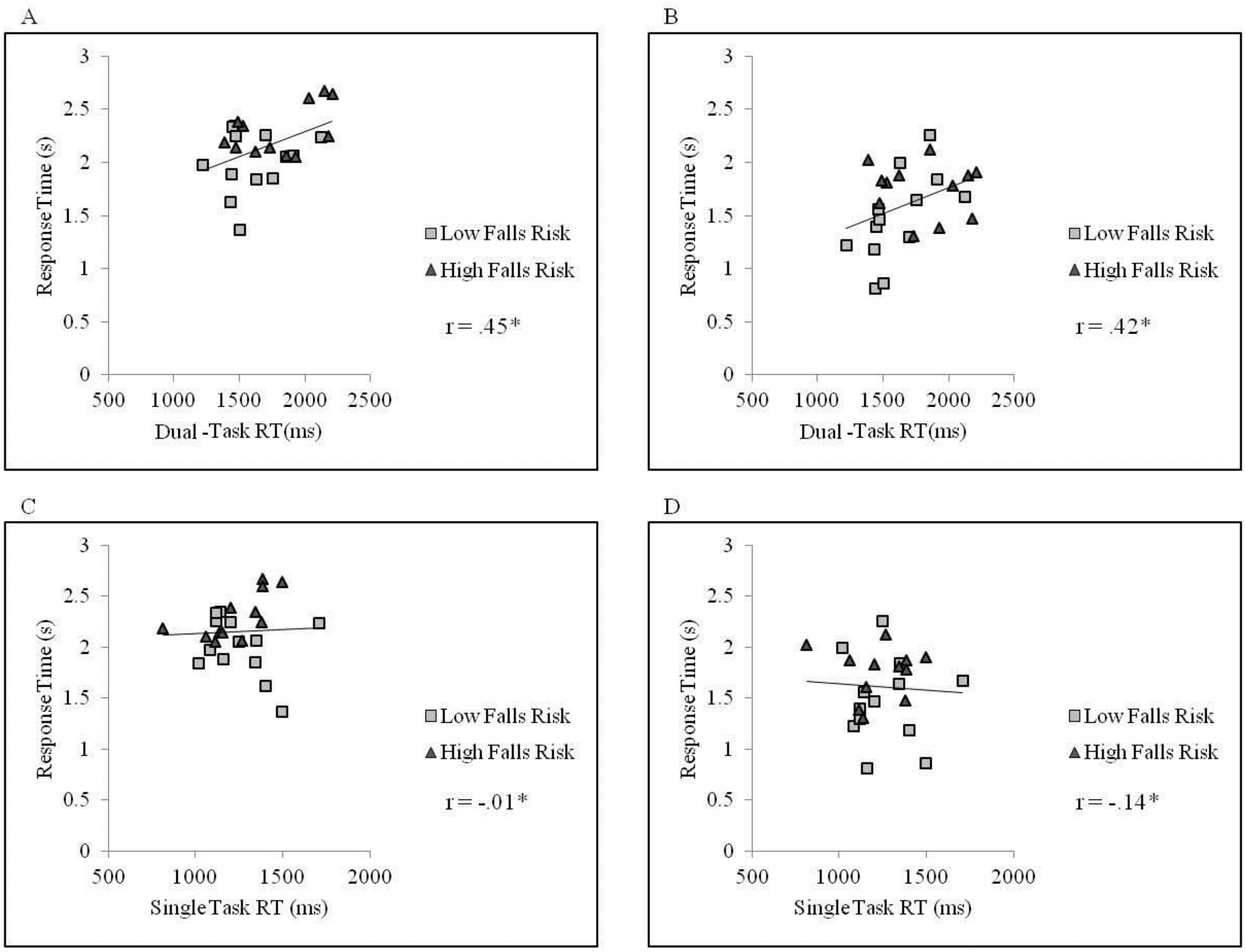
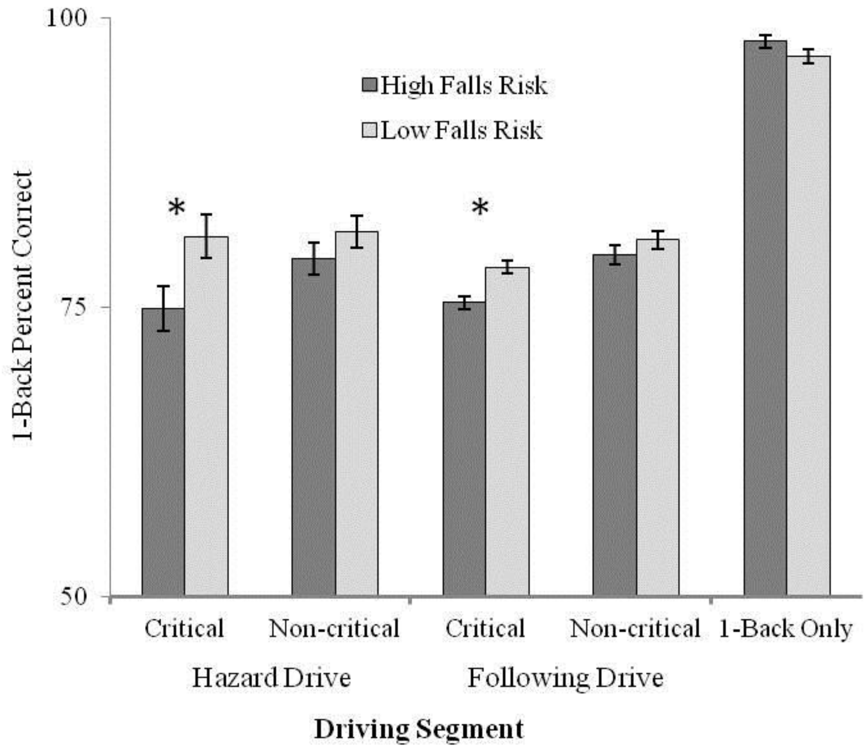


Figure 3. Accuracy on the 1-Back task in critical and non-critical segments of the hazard and following drives and in the single-task (1-Back only) condition. Error bars represent one standard error of the mean.



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