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Distracted Driving in Elderly and Middle-Aged Drivers

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Abstract

Automobile driving is a safety-critical real-world example of multitasking. A variety of roadway and in-vehicle distracter tasks create information processing loads that compete for the neural resources needed to drive safely. Drivers with mind and brain aging may be particularly susceptible to distraction due to waning cognitive resources and control over attention. This study examined distracted driving performance in an instrumented vehicle (IV) in 86 elderly (mean = 72.5 years, SD = 5.0 years) and 51 middle-aged drivers (mean = 53.7 years, SD = 9.3 year) under a concurrent auditory-verbal processing load created by the Paced Auditory Serial Addition Task (PASAT). Compared to baseline (no-task) driving performance, distraction was associated with reduced steering control in both groups, with middle-aged drivers showing a greater increase in steering variability. The elderly drove slower and showed decreased speed variability during distraction compared to middle-aged drivers. They also tended to "freeze up", spending significantly more time holding the gas pedal steady, another tactic that may mitigate time pressured integration and control of information, thereby freeing mental resources to maintain situation awareness. While 39% of elderly and 43% of middle-aged drivers committed significantly more driving safety errors during distraction, 28% and 18%, respectively, actually improved, compatible with allocation of attention resources to safety critical tasks under a cognitive load.

Keywords

multitasking; distracted driving; older driver safety; serialization; instrumented vehicle; cognitive decline

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1. Introduction

Multitasking involves competition for limited neural resources by behavioral tasks, such that engagement in one task affects performance of the others. There are also global effects, wherein brain activity for concurrent tasks may be less than the sum of activities for each task performed alone, even when the tasks draw on different brain systems (Just et al., 2008).

Automobile driving is a safety-critical real-world example of multitasking that requires tracking locations of surrounding vehicles, judging when it is safe to pass or merge, and navigating, while also obeying traffic signals and controlling vehicle steering and speed. Added distracter tasks can compete for the neural resources needed to drive safely. Performance may initially improve with heightened arousal (a broad construct representing one s overall stimulation [Hockey, 1984; Hancock and Szalma, 2007; Hanoch and Vitouch, 2004]) before it deteriorates under the added cognitive load (Teigen, 1994), ultimately increasing the risk of single-vehicle crashes (e.g., running off the road) and rear-end collisions (Eby and Kostyniuk, 2003).

Modern vehicles include “traditional” distracters, such as heating/cooling systems, cigarette lighters, and radios, and more modern “infotainment”, such as CD/DVD players and iPod/MP3 players (Strayer and Drews, 2007). Cell phone communication has raised particular concern among public health and policy experts, as even hands-free use may impair driving (Eby and Kostyniuk, 2003; Horberry et al., 2006; Horrey and Wickens, 2006; Shinar et al., 2005; Strayer and Drews, 2004; Strayer and Drews, 2007; Watson and Strayer, 2010). Drivers using cell phones process less visual information in the driving scene (Strayer and Drews, 2004), stop incompletely at stop signs (Strayer and Drews, 2007), and have delayed breaking responses (Watson and Strayer, 2010) and more rear-end collisions (Strayer and Drews, 2007).

Driving, especially under distracted conditions, relies heavily on executive functions, including selective attention and working memory. These abilities decline with age (Shih, 2009), which can reduce driver control over the focus of attention, task switching (Chaparro et al., 2005; Craik and Bialystok, 2006) and vehicle control (Rizzo et al., 2004), increasing the risk of crashes (Trick et al., 2004). Several studies have used verbal or auditory-visual tasks to study these effects (Horberry et al., 2006; Strayer and Drews, 2007; Watson and Strayer, 2010) using driving simulator outcomes or performance on a driving course free of other vehicles (Chaparro et al., 2005).

The overarching goal of the current study was to examine the effects of distracted driving in elderly individuals with mind and brain aging affecting central executive and attentional mechanisms required for multitasking. To do so we compared the performances of elderly and middle aged individuals engaged in real-world driving in an instrumented vehicle (IV) under the effects of a controlled auditory-verbal processing load created by a version of the Paced Auditory Serial Addition Task (Gronwall, 1977; Rizzo et al., 2004). The PASAT presents single digits to the participant in a pre-recorded interval and asks that each new digit be added to the one immediately prior to it (see section 2.2.1). We hypothesized 1) that elderly drivers would perform poorer on the PASAT task itself both off-road and on-road compared to middle-aged participants, and 2) that performing PASAT would reduce driver control over speed and steering and increase at-fault safety errors compared to baseline driving on similar road segments without distraction, particularly in the elderly drivers.

2. Material and methods

2.1. Participants

Participants were recruited from the general community as part of ongoing studies on aging and driving. Eighty-six elderly drivers (46 males; 40 females) between 65 and 89 years old (mean = 72.5, SD = 5.0 years) and 51 middle-aged drivers (23 males; 28 females) between 40 and 64 years old (mean = 53.7, SD = 9.3 years) completed the study. All participants were currently licensed drivers without dementia or other medical conditions such as stroke, major psychiatric diseases, vestibular disorders, and alcoholism or other forms of drug addiction. Use of prescription medications was allowed, except for stimulants, antihistamines, narcotics, anxiolytics, anticonvulsants, and neuroleptics. Participants were not excluded because of visual defects unless they had corrected visual acuity worse than 20/50. Informed consent was obtained in accord with institutional guidelines for human participant safety and confidentiality.

2.2. Design and Procedure

Participant age, gender, and years of education were collected from a questionnaire during the visit. Drivers completed a battery of visual, motor, and cognitive tests (Table 1) in addition to assessment of their driving ability. A composite measure, COGSTAT, is a composite score of the Controlled Oral Word Association task, as well as the Auditory-Learning Verbal Test – Recall, WAIS-III Block Design, Complex Figure Test (Copy and Recall), Benton Visual Retention Test, Judgment of Line Orientation, and Trail Making Test – Part B. Each component was standardized to have mean 50 and standard deviation of 10 in a reference group, such that high values represented better abilities. The components were then summed with equal weights. Driving assessment took place during an on-road drive in an instrumented vehicle (IV).

2.2.1. PASAT—PASAT requires participants to add serial pairs of randomized digits so that each digit is added to the preceeding one (Gronwall, 1977). We used a standardized version of the task recorded by a native English speaker who was also a local radio announcer, as in our previous research (e.g., Rizzo et al, 2004). A list of 37 serial numbers is read to the participant at a rate of 2.4s between each number. Incorrect responses and ommissions were totaled to yield the number of errors out of 36. This task was completed during the off-road cognitive testing as well as on-road during the driving assessment. PASAT performance activates brain areas for auditory perception and processing and speech production (Lockwood et al., 2004), placing simultaneous demands on sustained attention, working memory, and processing speed, similar to the demands of engaged conversation (Rizzo et al., 2004; Tombaugh, 2006).

2.2.2. On-road Driving Assessment—Trained research assistants proctored the on-road drive in the IV ARGOS (the Automobile for Research in Ergonomics and Safety) along rural and urban streets around Iowa City. Measurements were collected during both a baseline (off-task) segment and while performing the PASAT on US-218, a rural four-lane Interstate freeway with a speed limit of 65 mph. Participants were informed of the speed limit and instructed to drive as they normally would on the freeway. Both scenarios were performed on road segments with similar traffic density and road profile (straight). The PASAT driving segment length (approximately 1.3 miles) immediately preceded the slightly longer baseline segment (1.5 miles). Video data from the IV drive was reviewed by a certified driving instructor to determine at-fault safety errors. Errors were defined by the Iowa Department of Transportation, as described by Dawson et al. (2009; 2010). For example, crossing the center line, speeding, or stopping in the intersection at a traffic signal

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would all be counted as an ”at-fault” error. In this study, all driving safety errors counted equally.

Speed, gas pedal position, and steering wheel position data were captured at approximately 10 Hz during the drive in the IV. These data were used to calculate several electronic vehicle control measures within the baseline and PASAT segments for each driver. Specifically, ”Mean MPH” was the average speed and ”SD MPH” was the standard deviation of speed. Higher speed variability indicates that a driver was not closely controlling vehicle speed. ”Pedal Hold” was the 25th percentile of the duration (seconds) that the driver held the gas pedal in the same position, within a small tolerance (i.e., less than 1% change) (Figure). Smaller pedal hold values indicate more frequent pedal adjustments, which drivers normally make to maintain a constant speed whereas longer pedal hold indicates fewer pedal adjustments and less control over speed. Lateral acceleration captures swerves to the left and right, but because these may average to zero, the standard deviation of the lateral accelerometer (“SD Lateral Acceleration”) was used. Higher lateral acceleration variability tends to result from stronger steering corrections, indicating greater deviation from a central lane position and/or shorter time to line crossing.

Three electronic measures quantified magnitude, rate, and frequency of steering corrections. These were standard deviation of the steering wheel position (“SD Steering”) in degrees, “Steering Dev. ≥6°” and “Steering Dev. ≥10°”, the number of times that the steering wheel crossed respective thresholds of +/− six degrees and +/− 10 degrees from the mean steering wheel position in a driving segment (McGehee et al, 2004). The six-degree threshold captures small corrections whereas the 10-degree threshold captures larger corrections that are generally only observed during lane changes or during attempts to correct undesirable time to line crossing. Note that all three of these steering measures fall under the “time domain” (Diggle, 1990). We also calculated a “frequency domain” metric, the “Steering Frequency.” To do so we partitioned the steering frequency signal into the output of a high-pass filter (comprising high frequency or fast steering corrections above 0.5 Hz) and the output of a low-pass filter (comprising low frequency or slow steering changes below 0.5 Hz). “Steering frequency” was a ratio calculated from dividing the standard error of the high-pass portion by the standard error of the low-pass portion.

2.3. Statistical Analysis

We first analyzed PASAT task performance in the IV and in the lab, comparing age groups using the Wilcoxon rank-sum test and testing for association between IV-based and lab-based performance using Spearman correlation estimates. We then calculated means and standard deviations of nine measures of safety and vehicle control within each segment and age group. These measures have been described above and include mean MPH, SD MPH, Gas Pedal hold, SD lateral acceleration, SD steering, steering frequency, steering deviations greater than 6º and 10º, as well as at-fault safety errors. Between-group comparisons within each segment, again using the Wilcoxon Rank-sum test, were performed. The difference between driving performance meaures during PASAT versus baseline driving indexed the effects of distraction. Within group comparisons used the one-sample t-test to determine if the result differed from zero, while across group comparisons used the Wilcoxon rank sum test. Finally, linear regression assessed non-standardized cognitive predictors of the mean and variance of MPH, steering variance, and the variance of lateral acceleration within the PASAT segment amongst elderly controls. A similar analysis of these same four outcomes as a difference between PASAT and baseline within the elderly group was also performed.

3. Results

3.1. PASAT Performance

Elderly participants performed worse on the PASAT (measured by number of errors) compared to the middle-aged group. This was true both in the lab (p <0.001; elderly mean = 13.34 vs. middle-aged mean = 8.37) and on the road (p <0.001; elderly mean = 16.57 vs. middle-aged mean = 12.07). PASAT performance in the lab was significantly correlated with PASAT performance on the road for both elderly (r = 0.516, p<0.001) and middle-aged (r = 0.555, p<0.001) groups. However, the ratio of on-road PASAT to lab PASAT performance did not differ significantly between the two groups (p = 0.509) indicating that performance on the secondary auditory verbal distracter task was similarly reduced in both groups in the context of real-world driving.

3.2. On-Road Performance

Tables 2 displays between-group comparisons within each drive segment, as well as comparisons of basic demographics. Table 3 presents the comparisons within and between groups of the change in performance from baseline to PASAT. Overall, elderly drivers showed more driving safety errors than middle-aged drivers during the PASAT segment (p = 0.013) with a trend (p = 0.081) for more safety errors during baseline driving. To examine effects of distraction, the error counts for baseline driving were subtracted from driving errors while performing PASAT. Forty-three percent of middle-aged participants and 39% percent of elderly participants made significantly more driving safety errors during PASAT compared to baseline driving, with no between-groups differences (p = 0.437). In addition, 39% of middle aged drivers and 33% of elderly drivers did not differ in safety errors during the PASAT compared to baseline driving segments, while 18% of middle-aged drivers and 28% of elderly drivers actually improved (i.e., made fewer safety errors).

Elderly drivers drove slower than the middle-aged drivers during both PASAT (p = 0.005) and baseline (p = 0.005). They also made fewer steering deviations of ≥6° compared to the middle-aged drivers during the PASAT (p = 0.005). Both groups slowed down during PASAT (elderly p = 0.013; middle-aged p = 0.019) and showed greater speed variability (i.e., larger standard deviation of speed) during the PASAT compared to baseline (both p <0.001). PASAT affected five of the seven electronic-based measures (all but Mean MPH and SD MPH) differently in the two age groups (Table 3). Elderly drivers showed a greater increase in Gas Pedal Hold (p = 0.027) and Steering Frequency (p < 0.001) from baseline to PASAT, while middle-aged drivers showed more significant increases in lateral acceleration variability (p = 0.049), steering variability (p < 0.001), and number of steering deviations greater than six degrees (p = 0.005) from baseline to PASAT.

3.3. Neuropsychological Predictors

Neuropyschological outcomes were investigated as predictors of the mean and variance of MPH, steering variance, and the variance of lateral acceleration both within PASAT alone and as a difference between PASAT and baseline. Significant outcomes for the difference are reported in Table 4, with several cognitive and visual measures predicting greater change in mean speed (CS, FVA), speed variability (FR), and lateral acceleration variability (CFT-Copy, COGSTAT, and FVA for elderly drivers. Likewise, several cognitive and visual tests significantly predicted vehicle control measures of performance (i.e., speed, steering) during PASAT among elderly drivers (Table 5). Slower drivers had significantly greater vision loss as measured by UFOV and CS, while drivers with greater speed variability had significantly lower performance scores on the Functional Reach (FR) and Get-Up & Go motor tests.

4. Discussion

The introduction of a controlled auditory-verbal processing load in the form of the PASAT produced noticeable effects on driver vehicle control. Distractions (e.g., conducting a conversation with a passenger or on a cell phone) decrease the number of constant minor adjustments drivers normally make to maintain lane position and speed compliance. During periods of distraction drivers are less able to monitor and control lane position and speed compliance thus causing greater drifts in lane position and greater changes in speed. Consequently, when adjustments over vehicle controls are made, they are larger in amplitude, as the driver is forced to make larger steering corrections (e.g., greater than 6°) or depress the accelerator pedal with greater force (Brumby et al., 2009; Horberry et al., 2006; Rizzo et al., 2004).

We observed greater variability in speed and steering among both elderly and middle-aged drivers during PASAT. Middle-aged drivers showed greater increase in lateral acceleration variability from baseline to PASAT than the elderly, consistent with their greater steering variability and speed (greater steering angle at higher speed yields greater lateral acceleration). The increase in steering deviations ≥6° exhibited during PASAT was greater among middle-aged drivers and fits with their greater steering variability. However, they did not show a significant increase in steering deviations ≥10°, a signature of corrective actions to avert lane crossing errors. Elderly drivers, on the other hand, exhibited a greater steering frequency during both baseline and PASAT than middle-aged drivers. Because steering frequency is a ratio between fast steering corrections and gradual steering corrections, a larger ratio would indicate more high rate corrective steering behavior. However, on the whole, these corrections did not make the elderly drivers as safe as the middle aged drivers. As noted above, the elderly drivers showed more driving safety errors than middle-aged drivers during the PASAT segment ($p = 0.013$) with a trend ($p = 0.081$) for more safety errors during baseline driving.

Our findings suggest that elderly drivers exhibited a more time-pressured and vigilant steering strategy during the PASAT (lower magnitude steering corrections at higher rates) compared to a more confident or relaxed strategy in the middle-aged drivers (higher magnitude steering corrections at lower rates). Further details are needed to determine whether these differences reflect greater confidence in driving ability and less susceptibility to PASAT among the middle-aged. For example, had lane position been available in the IV, we could have examined further whether middle-aged drivers allowed greater lateral deviations and exhibited less pressured response to the same lateral deviation or time to line crossing.

One reason that elderly drivers may have been able to maintain a more vigilant lateral position control may be that they serialized the tasks of speed control, lane position control, and PASAT. Elderly drivers held their gas pedal steady for significantly longer periods of time during PASAT distraction than middle-aged drivers did. It is possible to temporarily ignore the speed maintenance task while distracted to focus on the more safety-critical task of lateral position control. Such serialization of tasks reduces the set of simultaneous tasks from three to two, which mitigates the burden on attentional shifting, a mechanism known to degrade with age (Cosman et al, in press). Given that the reduction in PASAT performance during driving among elderly drivers was similar to that of middle-aged drivers suggests that elderly drivers did not also simplify the PASAT task by adopting a more serial strategy such as skipping every other answer.

These findings fit with recent evidence of passive serialization with time-constrained multitasking in elderly drivers (Boer et al., 2011). Multitasking involves serial switching between information sources. Task performance often involves multiple subtask components (e.g., steering, pedal control, visual search). While subtasks may be performed together in acquired and highly over-learned tasks such as automobile driving, emerging evidence suggests that performance decomposes with cognitive aging. In this vein, elderly drivers show serialization of vehicle control during intersection negotiation (Boer et al., 2011). Rather than the primarily parallel control of pedals and steering wheel observed in younger drivers, they often perform these control subtasks serially. For example, during right turns they perform most of their steering while standing still instead of while accelerating as younger drivers do (Boer et al., 2011). This behavior may reduce the need for rapid time pressured integration and control of information and free mental resources that can be deployed to maintain situation awareness and avoid safety errors, as in the current study in which drivers had to allocate cognitive resources to control their vehicles during an auditory verbal processing load.

Multitasking with cognitive-linguistic tasks, such as we used, can impact gait in older individuals with and without neurological disease (LaPointe, Stierwalk and Maitlad, 2010), suggesting a potential common risk factor for falls and car crashes. One mechanism for managing safety risks posed by multitasking is to reduce the amount of information flow (e.g., by slowing down in a car, as our drivers did during multitasking); another is to control attention so that safety critical task components are assigned higher priority. Drivers control allocation of attention during multitasking to meet specific performance criteria: for example, when performing a non-safety-critical secondary task (such as cell phone dialing), they will usually return attention to steering control to maintain lane position (Janssen and Brumby, 2010). A theory of concurrent multitasking (Salvucci and Taatgen, 2008) posits threads of processing coordinated by a serial procedural resource and executed across other available resources (e.g., perceptual and motor) to help explain dual-choices in complex real-world domains such as driving and driver distraction. EEG data suggest that the lateral prefrontal cortex plays a role in controlling risk-taking behavior, task switching, and multitasking during fast driving (Jäncke, Brunner and Esslen, 2008). Evidence of “serialization of behavior”, as in the gas pedal control data in this study of older drivers, suggests breakdown in these processes caused by neurodegeneration associated with cognitive aging.

Overall, elderly drivers made significantly more at-fault safety errors during multitasking than middle-aged drivers, despite no significant differences between the groups at baseline. This suggests some effect of age on driving performance when a secondary task is introduced. The results are compatible with other reports of age-related decrements in multitasking performance (Craik and Bialystok, 2006; Shih, 2009) and distracted driving (Chaparro et al., 2005; Horberry et al., 2006; Strayer and Drews, 2004). Furthermore, the elderly drivers drove slower than the middle-aged drivers, a behavior that mitigates trade-offs between secondary task performance and driving safety in older drivers (Horberry et al., 2006).

A more challenging on-road drive would likely have produced greater numbers of at-fault safety errors and discriminated more efficiently between the older and middle-aged drivers. However, the magnitude of on-road driving challenges in this study was constrained by the ethical obligation to protect participants and experimenters in the IV. PASAT was administered on a relatively straight freeway segment during the day under good weather and traffic conditions. Driving on the freeway in such favorable circumstances may be a more “automated” process, especially in experienced elderly drivers (Just et al., 2008; Strayer and Drews, 2004). This would allow drivers to perform a complex secondary task such as the PASAT without as much detriment to the primary task of driving safely. The effects of distraction on driving in more dangerous circumstances, such as busy intersections

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or high-traffic scenarios, are more safely studied using the controlled environment of a driving simulator, a trade-off between naturalistic context and experimental control and driver safety.

In this study, 39% of elderly drivers and 43% of middle-aged drivers made more at-fault safety errors when driving with an increased auditory-verbal processing load. The remaining drivers either had no change in performance and some actually improved (i.e., made fewer safety errors) compared to baseline. The relationship among measures of performance, workload, and stress in a task such as automobile driving and multitasking is complex (Szalma, 2009), and it is possible that the PASAT produced sufficient arousal for some drivers to improve their driving performance on the road. Arousal theory invokes the inverted-U profile of performance attributed to Yerkes and Dodson (1908) and Hebb (1955), which states that performance improves as arousal increases until reaching a certain threshold, at which point it decreases again (Teigen, 1994). Thus performance declines with under stimulation and increases with workload until it breaks down. According to resource theory, vigilance depends on cognitive resources, which vary with workload, stress, task and target modality, complexity, salience, event rate, and spatiotemporal uncertainty (Baker, 1959); vigilance is restored by rest breaks or novel stimuli (Hull, 1943; Hancock and Szalma, 2007).

Watson and Strayer (2010) found similar performance effects to ours when they tested driving performance in a simulator in participants who concurrently performed an operation span (OSPAN) task. In most cases, driving performance decreased when the OSPAN task was administered. However, in two percent of the study population, performance increased during the OSPAN task. The authors dub such persons “supertaskers,” and suggest that they may have some sort of superior multitasking ability. While we found a tenfold higher percentage of drivers that improved their performance during the PASAT task than Watson and Strayer did in their study of multitasking, it would be difficult to invoke “supertasking” in our middle aged drivers and elderly driver drivers with age related cognitive declines.

We did not find any significant neuropsychological predictors of driving errors among the elderly drivers; the relatively low error count may have contributed. However, various cognitive and visual measures did predict vehicle control measures such as speed and lateral acceleration. Specifically, poorer vehicle control during PASAT in the elderly group was associated with lower scores on tests of visual cognition and memory (CFT-Copy, COGSTAT), reduced motor control (lower scores on FR and Get-Up & Go tests), and poorer vision (FVA, CS). While the breadth of our study increased the chance of Type I errors, these findings appear to support the role of neurocognitive tests in the prediction of driver safety in advancing age (Barrash et al., 2010; Aksan et al., in press; Anderson et al., in press;).

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Highlights

- Examined distracted driving in elderly and middle-aged drivers
- Elderly drivers had decreased speed variability and increased steering frequency
- Elderly drivers “froze up” on vehicle control during distraction
- Elderly drivers made more at-fault safety errors than middle-aged drivers
- Some drivers made fewer safety errors during PASAT compared to no-task driving

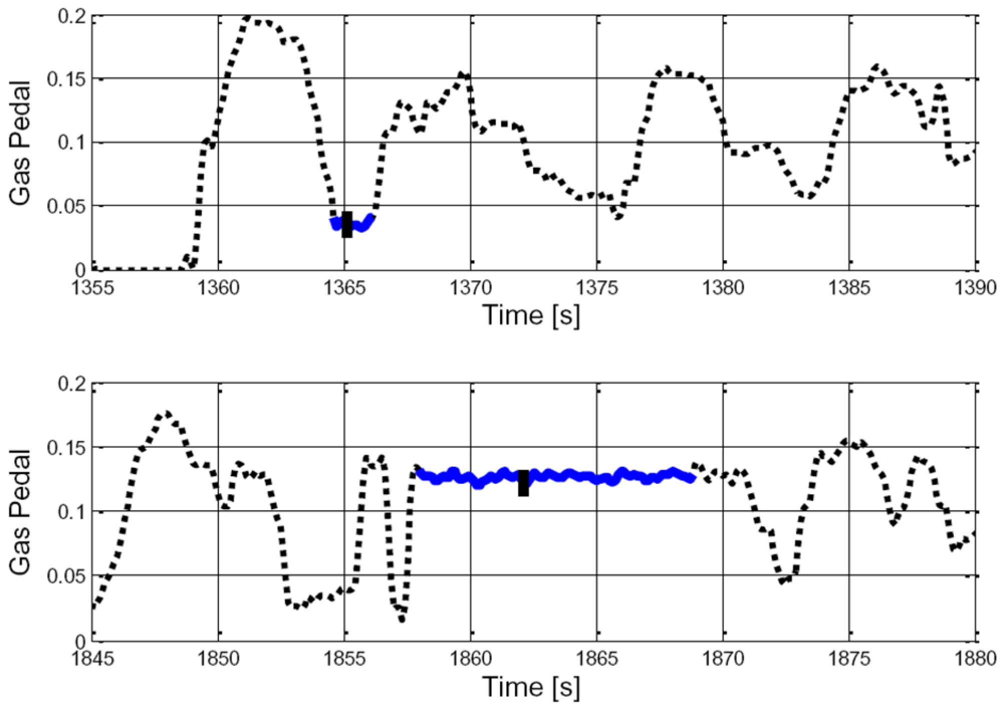

Figure.

A single gas pedal-hold time (PHT) calculation is depicted for two participants. Dashed lines represent actual pedal position. The solid line shows the time interval over which the gas pedal position changed <0.01 compared to pedal position at a specific time (at the vertical time-reference bar). In these examples, PHT is approximately 2s for a middle-aged driver at baseline (top) and 11s for a multitasking elderly driver (bottom). The within-person summary of PHT used in our analyses was the 25th percentile of the PHT values calculated at every specific time, as the vertical reference bar slides across a driver s time series data. Note that the PHT is calculated at every time point. This means that as the time-reference bar slides across the flat regions corresponding to high PHT s, there are many high PHT values that are nearly identical. Hence, using the 25th percentile, rather than a central value such as the 50th percentile or the mean, helps remove the redundancy caused by these repeated values. This choice of the 25th percentile was made *a priori*, rather than being based on empirical sensitivity.

Table 1

Battery of off-road tests completed in addition to the driving assessment.

Measure	Reference
Basic Vision and Visual Perception Measures	
Near Visual Acuity (NVA)	Ferris et al. (1982)
Far Visual Acuity (FVA)	Ferris et al. (1982)
Contrast Sensitivity (CS)	Pelli et al. (1988)
Judgment of Line Orientation (JLO)	Stauss et al. (2006)
Structure From Motion (SFM)	Rizzo et al. (1995); Rizzo et al. (1997)
Useful Field of View (UFOV)	Ball and Owsley (1992)
Motor Function Measures	
Get-up and Go	Podsiadlo and Richardson (1990); Alexander (1994)
Functional Reach (FR)	Duncan et al. (1990)
Grooved Pegboard Test (Pegs)	Heaton et al. (1991)
Visual Cognition and Executive Function Measures	
WAIS-III Block Design (Blocks)	Wechsler (1981)
Complex Figure Test (CFT)-Copy and Recall	Stern et al. (1994)
Benton Visual Retention Test (BVRT)	Sivan (1992)
Auditory-Learning Verbal Test (AVLT)-Recall	Stauss et al. (2006)
Trail Making Test (TMT)-Parts A and B	Reitan and Davison (1974)
Controlled Oral Word Association (COWA)	Benton and Hamsher (1978)
COGSTAT[a]	Dawson et al. (2009), Dawson et al. (2010)

[a]COGSTAT is a composite score of several of the above measures: JLO, Blocks, CFT-Copy and Recall, BVRT, AVLT-Recall, TMT B-A, and COWA.

Table 2

Mean at-fault safety errors, speed, and steering control during baseline and the PASAT, with comparisons between middle-aged and elderly drivers via the Wilcoxon-Rank Sum Test.

	Middle-Aged Drivers Mean (SD)	Elderly Drivers Mean (SD)	*p*-values
At-fault Safety Errors			
Baseline	0.30 (0.61)	0.65 (1.09)	0.082
PASAT 218	0.76 (1.05)	1.19 (1.17)	0.021
Mean MPH			
Baseline	61.65 (7.52)	60.00 (5.34)	0.005
PASAT 218	61.00 (6.86)	59.09 (5.27)	0.005
SD MPH			
Baseline	1.62 (1.16)	1.94 (0.91)	0.006
PASAT 218	2.09 (1.72)	2.33 (1.32)	0.012
Gas Pedal Hold			
Baseline	2.19 (1.56)	3.12 (7.76)	0.882
PASAT 218	2.19 (1.32)	4.09 (8.31)	0.164
SD Lateral Acceleration			
Baseline	0.04 (0.004)	0.04 (0.006)	0.586
PASAT 218	0.04 (0.005)	0.04 (0.006)	0.550
SD Steering (degrees)			
Baseline	1.95 (0.47)	2.21 (2.98)	0.583
PASAT 218	2.93 (0.50)	2.64 (1.85)	<0.001
Steering Frequency			
Baseline	0.48 (0.11)	0.53 (0.13)	0.029
PASAT 218	0.39 (0.09)	0.53 (0.16)	<0.001
# Steering Dev. ≥6°			
Baseline	3.86 (4.97)	3.24 (4.81)	0.552
PASAT 218	12.98 (7.89)	8.84 (8.58)	0.001
# Steering Dev. ≥10°			
Baseline	0.00 (0.00)	0.13 (0.61)	0.124
PASAT 218	0.43 (1.08)	0.65 (3.38)	0.322
Demographics			
Education	15.63 (2.31)	15.70 (2.72)	0.6658
Miles/Week	162.86 (157.64)	151.33 (191.01)	0.3471
Gender	23 Males	46 Males	0.3833

Table 3

Mean Individual Differences between the PASAT and baseline segments in at-fault safety errors, speed, and steering control, both within elderly and middle-aged drivers and between-groups. Between group tests were performed using the Wilcoxon-Rank Sum Test, while p-values of variable means were found using the One-sample T-Test.

	Segment Performance Differences (PASAT – Baseline)		
	Middle-Aged Drivers Mean (SD)	**Elderly Drivers Mean (SD)**	**Between Groups *p*-values**
At-fault Safety Errors	0.47 (1.16) [b]	0.54 (1.24) [c]	0.437
Mean MPH	−0.65 (1.91) [a]	−0.91 (3.27) [a]	0.617
SD MPH	0.47 (1.05) [b]	0.38 (1.36) [a]	0.672
Gas Pedal Hold	−0.004 (1.44)	0.965 (3.84) [a]	0.027
SD Lateral Acceleration	0.004 (0.003) [c]	0.003 (0.004) [c]	0.049
SD Steering (degrees)	0.98 (0.51) [c]	0.42 (1.29) [b]	<0.001
Steering Frequency	−0.087 (0.11) [c]	0.004 (0.12)	<0.001
# Steering Dev. ≥6°	9.12 (6.61) [c]	5.60 (9.04) [c]	0.005
# Steering Dev. ≥10°	0.43 (1.08) [b]	0.52 (3.11)	0.195

[a] $p < 0.05$,

[b] $p < 0.01$,

[c] $p < 0.001$.

Table 4

Linear regression analysis of cognitive, motor, and visual predictors of the mean difference in speed, speed variability, and lateral acceleration variability between the baseline and PASAT segments for elderly drivers.

	Estimate	95% CI	p-value
Mean MPH			
Contrast Sensitivity (CS)	4.651	(−0.031, 9.334)	0.052
FVA (LogMAR)	−6.973	(−13.063, −0.883)	0.025
SD MPH			
Functional Reach (FR)	−0.118	(−0.232, −0.004)	0.043
SD Lateral Acceleration			
CFT-Copy[a]	0.0003	(0.0000, 0.0005)	0.018
COGSTAT	0.00002	(0.00000, 0.00003)	0.042
FVA[b] (LogMAR)	−0.008	(−0.015, −0.002)	0.011

[a]CFT-Copy = Complex Figure Test-Copy

[b]FVA = far visual acuity.

Table 5

Linear regression analysis of motor and visual predictors of mean MPH and speed variability (standard deviation) within the PASAT segment for elderly drivers.

	Estimate	95% CI	p-value
Mean MPH			
UFOV[a] – total loss	−0.007	(−0.013, −0.001)	0.015
Contrast Sensitivity (CS)	11.423	(4.120, 18.726)	0.003
SD MPH			
Functional Reach (FR)	−0.150	(−0.260, −0.041)	0.008
Get-Up & Go	0.096	(−0.015, 0.208)	0.090

[a]UFOV = Useful Field of View.