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Taxonomy of Older Driver Behaviors and Crash Risk

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16. Abstract

This project's objectives were to identify risky behaviors, driving habits, and exposure patterns that have been shown to increase the likelihood of crash involvement among older drivers; and to classify these crash-contributing factors according to a set of underlying functional deficits specific to, or more prevalent among, the older driver population. Such deficits may result from normal aging, age-related medical conditions, or medication use. A further goal was to identify and critically examine behavioral countermeasures with the potential to mitigate functional loss and/or diminish the occurrence of risky behaviors—and thus ameliorate crashes among older drivers.

The first task was an analysis of older driver injuries and fatalities using national databases (FARS, GES), to identify driving patterns, driving tasks, and contributing factors associated with crashes by older drivers; more details are available in a separate document, Report No. DOT HS 811 093, "Identifying Behaviors and Situations Associated With Increased Crash Risk for Older Drivers." Additional project tasks included a review of the literature describing age-related functional changes, and evaluations of existing behavioral countermeasures to reduce older drivers' crash risk; an expert panel meeting to supplement the information from the database analyses and literature review; and unstructured interviews with older drivers who have had crashes within the previous three years, and an age-matched group who have not had crashes within that period, to determine whether these groups differ in factors such as exposure or use of countermeasures.

The outcomes of these project activities were used to develop and refine a taxonomy table that captures critical relationships between topics and subtopics highlighted in the literature review and crash database analyses. This table identifies critical performance errors that underlie crash types where older drivers are most strongly overrepresented; the functional deficits that are implicated in causing such performance errors; and the countermeasure strategies that presently appear to hold the greatest promise to ameliorate or to accommodate those (age-related) deficits.

The taxonomy table is a resource that provides at-a-glance, state-of-the-knowledge information to assist researchers, health care practitioners, and others concerned about older driver safety to identify particular risk factors, and what can be done to reduce the risk. A hard copy version and an expanded, electronic version of this resource were developed.

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LIST OF ACRONYMS AND ABBREVIATIONS

AMA .... American Medical Association
BTW... Behind the Wheel
CDRS .... Certified Driver Rehabilitation Specialist
CDS.. Crashworthiness Data System
CIR.. Crash Involvement Ratio
DRS.. Driver Rehabilitation Specialist
FARS.. Fatality Analysis Reporting System
GES .... General Estimates System
GIS .... Geographic Information System
GPS .... Global Positioning System
MLE .... Mean Likelihood of Effectiveness
NASS .... National Automotive Sampling System
NHTSA .... National Highway Traffic Safety Administration
OT .... Occupational Therapist
PDI .... Potentially Driver Impairing

EXECUTIVE SUMMARY

This study updates and extends our understanding of how age-related functional deficits can influence driver performance, and in turn crash risk for older drivers. It also examines the potential for behavioral countermeasures targeted to the remediation or accommodation of such deficits to attenuate critical errors in performance, and thus to reduce crash risk. A taxonomy table displaying the demonstrated and inferred links between these variables was developed as the central product of this research.

An analysis of national crash databases (FARS and GES) initially prioritized five crash types where older drivers were most strongly overrepresented in the 5-year period 2002-2006:

(1) The driver turned left at an intersection with stop-sign control, where cross traffic does not stop.

(2) The driver turned left at an intersection with signal control, where the permissive (not protected) green phase was displayed during the driver's approach.

(3) The driver turned right at an intersection controlled by a yield sign, in a channelized right-turn lane, merging with traffic approaching from the left on a principal arterial with operating speeds of 40-45 mph.

(4) The driver merged onto a limited access highway, in a ramp/acceleration lane controlled by a yield sign.

(5) The driver changed lanes on a multilane roadway (4+ lanes).

A review of technical literature provided a detailed summary of the current state of the knowledge regarding age-related functional impairment, driving performance, and safety; medical conditions and medications that can affect driving performance—with a separate chapter addressing dementia and diminished driving skills; plus descriptions and (where available) evaluations of behavioral countermeasures to help older people drive safely longer.

The results of the crash analysis and literature review supported development of the taxonomy table. This resource presents key interrelationships between priority crash types for older drivers and critical driver performance errors implicated as pre-crash events, with additional links to specific sensory/perceptual (primarily visual), cognitive, and physical/psychomotor deficits that can contribute to these errors, *and* to countermeasures advanced as interventions for particular errors or deficits.

An expert panel of researchers and clinicians distinguished in the area of older driver safety and mobility reviewed a preliminary version of the taxonomy table, the crash analysis report, and literature review. The panel gathered for a day-and-a-half meeting and recommended corrections and refinements. The meeting culminated in an exercise to rate the likely effectiveness of all countermeasures discussed by the panel that continued, iteratively, until consensus was reached among the panel members. This input was essential in finalizing the content and format of the taxonomy table, as presented in this report.

Interviews with a sample of 50 older Maryland drivers provided another perspective on the efficacy of behavioral countermeasures. Half of this sample had experienced crashes in the past three years and the other half was crash-free. Participants in each group provided self-reported measures of exposure, of driving situations that present difficulty, and of strategies to avoid or compensate for such difficulties. No clear differences emerged that would suggest more awareness of difficulties associated with functional aging, nor a greater reliance on countermeasures for safe driving, by the crash-free group.

Like the taxonomy table, the conclusions drawn from this work represent a synthesis of the project tasks outlined above. These are presented below.

- All but two of nine critical driver performance errors identified in this study—which in turn manifest age-related functional deficits—could result in any of the major crash types for older drivers. Thus, *effective countermeasures for the remediation of functional deficits have broad potential for crash reduction*; they are not specific to any particular crash type.
- The driver interview data, though reflecting a small sample, reveal that *when older drivers are aware of a functional impairment, they will make an effort to compensate or correct it, but are likely to drive anyway under some circumstances.*
- The older drivers were often unaware of the consequences of functional aging on driving task performance, which suggests *a significant opportunity to improve safety through appropriate educational interventions.*
- *Self-awareness drives the application of any strategy or countermeasure unless it is absolutely passive to the client's will* (e.g., intelligent cruise control). As a corollary, if an individual must remember to employ an intervention or believe that it is needed, a rehabilitation professional should be involved in determining if the intervention is appropriate.
- Attempts to keep impaired drivers on the road longer with devices or strategies that improve competence in very specific areas carry significant risk. Research is needed to define the boundaries of *what can be responsibly prescribed or advocated as a countermeasure for age-related diminished capabilities outside of a formal rehabilitation context, and what interventions should only be administered with the supervision of a driving rehabilitation professional.*
- If cognition is not intact, then vision countermeasures must be supplemented by other strategies that address the cognitive deficit. *Any vision countermeasure requires intact cognition, to realize the desired safety and performance gains.* Similarly, *judgment and self-awareness are critical to the effectiveness of any countermeasure involving legal restrictions on driving*.

Finally, this study has provided important insights about the operating conditions and traffic situations where crashes involving older drivers are most likely. But it is unknown how often older drivers are exposed to the most risky situations, either relative to the exposure of all drivers or to their own exposure at younger ages. The mounting evidence that functional deficits underlie (at-fault) crashes by older drivers similarly requires at least some knowledge of the driving contexts in which performance errors reflecting those deficits are manifested. *An integration of function, exposure, and safety data is needed to describe a true taxonomy of older driver problems, and to permit evaluations of countermeasure effectiveness that are free of the most serious confounds in work performed to date.*

INTRODUCTION AND BACKGROUND

This section describes the rationale behind the project, highlights the objectives, and provides the reader with a brief overview of the technical approach.

BACKGROUND AND UNDERSTANDING OF THE PROBLEM

A substantial body of research has documented declines in older drivers' functional abilities that support driving safely, and has associated these declines with specific errors and with a significantly higher risk of at-fault crash involvement. Countermeasures to mitigate crash risk for older drivers have included improvements in the design and operation of highways; vehicle modifications to improve control, provide warnings of hazards, and enhance occupant protection; and changes in drivers' behavior aimed at reducing exposure to specific risks and/or to equip individuals with strategies and tactics to help them safely negotiate problem situations.

A previous NHTSA report, *Intersection Negotiation Problems of Older Drivers, Volume II: Background Synthesis on Age and Intersection Driving Difficulties* (Staplin, Lococo, McKnight, McKnight, & Odenheimer, 1998) provided a description of specific functional declines associated with increased crash risk. A publication from NHTSA and the AMA, *Physician's Guide to Assessing and Counseling Older Drivers* (Wang, Kosinski, Schwartzberg, & Shanklin, 2003), focused on medical conditions that may impair driving, and identified changes in driving habits that older people could adopt to help keep driving safely as functional abilities decline with advancing age. More recent work sponsored by NHTSA – *Identifying Strategies to Study Drug Usage and Driving Functioning Among Older Drivers* (Lococo & Staplin, 2006) – has improved understanding of the relationship between medication use and driving safety.

The expanding older driver population dictates a need to revisit, update and enhance the base of knowledge manifested in these resources. Continuing investigations into factors that contribute to older driver crashes, coupled with a review of research describing how age-related functional changes can translate into specific driving errors, complement evaluations of the effectiveness of existing behavioral countermeasures while supporting development of innovative strategies to improve older driver safety and mobility in the future.

PROJECT OBJECTIVE

The project's objectives were to identify risky behaviors, driving habits, and exposure patterns that have been shown to increase the likelihood of crash involvement among older drivers, and to classify these crash contributing factors according to a set of underlying functional deficits prevalent among the elderly. Such deficits may result from normal aging, age-related medical conditions, or medication use. A further goal was to identify and critically examine behavioral countermeasures with the potential to mitigate functional loss and/or diminish risky behavior(s), and thus ameliorate crash problems among older drivers.

PROJECT SCOPE

The scope of work in this project is described by the following five major tasks:

- Analyze data on older driver injuries and fatalities from the Fatality Analysis Reporting System (FARS) and National Automotive Sampling System/General Estimates System (NASS/GES) databases to identify driving behaviors and combinations of driver, vehicle, roadway, and environmental characteristics associated with increased crash involvement in older drivers.
- Review the literature to update the information regarding age-related functional changes in *Intersection Negotiation Problems of Older Drivers, Volume II: Background Synthesis on Age and Intersection Driving Difficulties* (Staplin et al., 1998a). The goals of this review were to:
    - Extend the scope of the 1998 report beyond negotiating intersections to include issues identified in the database analyses.
    - Identify evaluations of existing behavioral countermeasures to reduce older drivers' crash risk.
    - Classify risky driving behaviors according to potentially underlying functional declines.
- Create a taxonomy table that captures critical relationships between topics and subtopics highlighted in the literature review and crash analysis, including:
    - Risky driving behaviors/driving errors associated with older driver crash involvement.
    - Operational factors and conditions under which driving errors are most likely to occur.
    - General and specific functional deficits that have been identified as underlying causes of driving errors and crash risk.
    - Behavioral countermeasures that have been developed to address specific functional deficits and/or associated risky behaviors.
    - Countermeasure evaluations, where they exist, and their methodological soundness.
- Conduct an expert panel meeting to supplement the information from the database analyses and literature review, and provide critical review of the taxonomy table.
- Conduct unstructured interviews with two sets of older drivers: those who were involved in a crash within the previous three years, and an age-matched group who were crash free within that period to determine whether these groups differ in factors such as driving exposure or use of countermeasures.

METHODS

This section provides a description of how each of the main tasks in this project was conducted.

DATABASE ANALYSES

The methods and results of the FARS and GES database analyses performed as the initial task in this project are summarized below. More details are available in a stand-alone report, entitled *Identifying Behaviors and Situations Associated With Increased Crash Risk for Older Drivers* (Stutts, Martell, & Staplin, 2009), available on NHTSA's Web site at

Two analytic approaches were undertaken. The first was to carry out separate descriptive analyses of single-vehicle and two-vehicle crashes, looking for situations where older drivers were overrepresented compared to middle-aged drivers. This relied on crosstabulations of FARS and GES data for the 5-year period 2002-2006. A more in-depth, "induced exposure" analysis was undertaken for the two-vehicle crashes. This technique compared the ratios of at-fault to not-at-fault drivers within age groups, producing a crash involvement ratio (CIR) that signifies the degree of over- or under-involvement of each age group with respect to particular risk factors. While feasible only with large data sets, this approach is notable in that it uses each group as its own control, thus taking into account differences in driving exposure across age groups with respect to a particular factor, such as driving at nighttime or on Interstate highways.

Development of Data Files

The examination of factors contributing to older driver crashes used 2002-2006 FARS and GES crash data. Consideration was given to using Crashworthiness Data System (CDS) data; however, the CDS is based on a much smaller number of actual crashes (fewer than 5,000 per year, compared to some 56,000 for the GES). A preliminary analysis of 2006 CDS data revealed only three reported crashes involving an older driver merging in traffic. Although the raw CDS data are weighted to reflect national crash numbers, such small counts can lead to unstable estimates if used in the sort of finely stratified analyses required for the current project.

The FARS and GES data analysis files developed for use in the project were restricted to single- and two-vehicle crashes involving the following vehicle types:

- Passenger cars;
- Sport utility vehicles;
- Light vans;
- Pickup trucks; and
- Other light trucks (GVWR <10,000 lbs).

For a two-vehicle crash to be included in the database, *both vehicles* needed to be one of these body types. This analysis *excluded* crashes involving large trucks, motorcycles, pedestrians and bicyclists, as well as crashes involving more than two vehicles.

A second step in the preparation of the study files was the assignment of fault or responsibility for the crash. Neither the FARS nor the GES data contains a variable indicating driver fault. In a prior crash analysis using FARS and GES crash data, fault status was determined based on contributing factors and/or violations cited by the investigating officer (Reinfurt, Stewart, Stutts, & Rodgman, 2000). In two-vehicle crashes, if one driver was cited for one or more contributing factors or moving violations and the other driver was not cited for any contributing factors or moving violations, the first driver was deemed at-fault. Crashes in which both drivers had contributing factors, or in which neither driver was identified with a contributing factor, were excluded from the analysis. This same approach was followed in the current study for assigning fault to drivers involved in fatal two-vehicle crashes, using the FARS variables *Related Factors – Driver Level (P22)* and *Violations Charged (P21)*. As before, non-performance-related factors or violations – such as "driving with a suspended or revoked license," "obscured vision," and "defective vehicle equipment" – were not considered in determining a driver's fault. Following this approach, <u>88.5%</u> of the two-vehicle crashes involving eligible vehicle types in the FARS data were coded as having one at-fault and one not-at-fault driver.

Applying this approach to the GES data was less successful. While the GES data still include a similar variable (*Critical Event, Precrash 2*) describing contributing pre-crash events, this variable has been revised considerably since Reinfurt et al. (2000) used it. Documentation for data collectors states that culpability should not be considered a factor in determining pre-crash vehicle events. Indeed, when crosstabulating a potential grouping of the *Critical Event, Precrash 2* variable by violation charged, there was substantial disagreement between this variable and the violation charged.

Consequently, fault status in the GES datafile was assigned based purely on the violation variable (*Violation Charged, D02*). The following variable levels were considered indicative of fault: *alcohol, drugs, speeding, reckless driving, failure to yield right-of-way, running a traffic signal or stop sign, violation charged-no details*, and *other violation*. Note that neither "driving with a suspended or revoked license" nor "hit-and-run" were used to assign fault, nor were "unknown if charged" or "not reported." Anecdotal reports suggest that driver violations more often go unreported than contributing factors, and a possible bias in which officers decline to cite a (older) driver for a violation may be acknowledged. Notwithstanding these limitations, the present approach allowed <u>52%</u> of eligible two-vehicle crashes to be coded as one driver at fault and one not-at-fault for use in the induced exposure analyses in GES. However, when generating descriptive two-vehicle crash statistics, the substantial restrictions on determining fault for crashes in the GES datafile led to a decision to include *all* crashes involving eligible vehicle types, without regard to fault status.

There were 109,937 crashes (72,847 single-vehicle plus 37,090 two-vehicle where one driver was identified at fault), used in the FARS data analysis. The raw number of crashes available for the GES analysis was 181,698 (69,689 single- vehicle and 112,009 two-vehicle crashes, without regard to fault status), which translated into 23.5 million weighted crashes. Table 1 shows the distribution of single- and two-vehicle crashes involving eligible study vehicles, and their at-fault status, for both the FARS and GES datafiles.

Table 1. Eligible Single- and Two-Vehicle Crashes for FARS and GES Study Files.

Crash Type and Fault Status	2002-2006 FARS	2002-2006 GES	
		Unweighted	Weighted
Single-vehicle	72,847	69,689	7,860,000
Two-vehicle, only one driver at-fault	37,090	62,090	8,112,000
Two-vehicle, neither driver at fault	1,624	45,062	6,975,000
Two-vehicle, both drivers at fault	3,195	4,857	567,000
Two-vehicle, without regard to fault	41,909	112,009	15,654,000

Data Analysis

As noted, separate analyses were carried out on single-vehicle and two-vehicle crashes, to identify the factors that most strongly characterize older driver crashes. The crosstabulations involving age and other crash descriptors focused on identifying specific vehicle maneuvers and crash types or situations where older drivers were over-represented compared to middle-aged drivers, or where there was a pattern of increased involvement with age. Driver sex was examined as a potential mediating variable, along with other situational variables such as light condition, number of travel lanes, and speed limit. These descriptive analyses identify crash scenarios that comprise the biggest proportion of the older driver crashes. The age groups included in these analyses were: *60-69, 70-79,* and *80+*.

For two-vehicle crashes, an additional set of analyses compared at-fault versus not-at-fault crash involvement ratios across driver age categories, for a particular crash type or crash situation. As previously described, this approach, based on the concept of *induced exposure*, takes into account potentially different exposure levels across different age groups, and is therefore especially useful for pinpointing situations that pose the greatest risks to older drivers. The relative involvement of drivers in at-fault, versus not-at-fault, crashes is expressed as a "crash involvement ratio" (CIR).

The following eight categories of driver age were used in the induced exposure analyses: *<20, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79,* and *80+*. Mid-decade groupings were eschewed, as a relatively small number of drivers in the 85+ category could hinder valid comparisons in some of the less common crash situations (e.g., changing lanes or merging on freeways).

Table 2 shows the typical table layout for the induced exposure analyses, where $D1_a$ is the number of drivers under age 20 who were identified at-fault in the particular two-vehicle crash situation, and $D2_a$ the number of identified not-at-fault drivers under age 20. The at-fault crash involvement ratio (CIR) for drivers under age 20 is then $D1_a$ / $D2_a$. Similar ratios can be calculated for the other age groups, using row and column totals to indicate which groups are over- (or under-) represented in the particular crash situation under study.

Analysis results include full data tables (see template below), which were generated to check for adequate sample sizes. Graphs showing the calculated CIR values illustrate which situations and (combinations of) factors were most problematic for drivers of different ages.

Note that significance testing on the observed differences was *not* performed, as these descriptive analyses were not initiated with any particular set of hypotheses in mind.

Table 2. Sample Induced Exposure Table for a Specified Two-Vehicle Crash Situation.

Driver1 Age (at fault)	Driver2 Age (not-at-fault)								
	<20	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80+**	**Total**
<20									$D1_a$
20-29									$D1_b$
30-39									$D1_c$
40-49									$D1_d$
50-59									$D1_e$
60-69									$D1_f$
70-79									$D1_g$
80+									$D1_h$
Total	$D2_a$	$D2_b$	$D2_c$	$D2_d$	$D2_e$	$D2_f$	$D2_g$	$D2_h$	Total

Summary of Findings

First, across this entire set of analyses there was little evidence of elevated risk for drivers 60 to 69, the "young-old." Most often, the data only began to demonstrate a substantial upturn in crash experience for drivers 70 to79, with over-representation for many crash types then accelerating more sharply for drivers 80 and older. Another notable pattern in these data were crash involvement ratios for older age groups that did *not* bear out conventional wisdom about certain situations being especially risky for these drivers, such as merging, changing lanes, driving on Interstate highways, and driving in bad weather.

The situations that appeared most problematic for older drivers reinforce and extend relationships that are well established in the technical literature. Left turns were highlighted in this regard, as were movements at stop-sign-controlled intersections. Starting at age 70, older drivers in two-vehicle crashes were especially likely to crash at intersections, with the likelihood of an intersection crash strongly associated with increasing age. Over half of all fatal two-vehicle crashes involving drivers 70 and older occurred at intersections. While drivers 70 and older were somewhat overrepresented in two-vehicle crashes at traffic signal locations, they were more strongly overrepresented in two-vehicle crashes at stop sign locations. In an analysis of maneuver (going straight versus turning left) and traffic control at intersections (signalized versus stop-controlled), the most dangerous situation for drivers 70 and older was turning left at a signal-controlled intersection, while the least dangerous was going straight at a signal-controlled intersection. Turning left or going straight at a stop sign posed intermediate and approximately equal levels of risk.

Over a third of fatal two-vehicle crashes involving drivers 80 and older occurred at stop sign locations—twice the percentage as at signal locations. With regard to drivers 80 and older and maneuvers at yield-sign- or stop-sign-controlled intersections, going straight at a yield sign emerged as the most dangerous maneuver. This might occur when merging onto a limited access roadway and having to check behind for traffic.

Although older drivers were under-represented in crashes occurring at non-junction locations and those categorized as intersection-related, the category of “other non-interchange,” appeared most prominently for drivers 80 and older. This category refers to crashes that occurred at same-grade lane channels; for example, when there was a left or right turn lane that was not a through lane (often marked by a traffic island).

Older people were increasingly less likely to be driving the striking vehicle in a two-vehicle crash, and more likely to be driving the struck vehicle. Once a critical event had occurred, older drivers were less likely to brake, steer, or otherwise maneuver their vehicle to avoid the crash. However, in the absence of objective signs such as tire skid marks, this information was typically unreported.

High-speed, two-lane roadways and multi-lane roads with speed limits of 40-45 mph (e.g., suburban arterials) were associated with heightened older driver crash involvement. For fatal crashes, both “young-old” and “old-old” drivers were more likely to make errors at intersections controlled by flashing signals. An error negotiating a yield-sign-controlled intersection was the reason for the crash in 26 of 27 such incidents for drivers 80 and older.

With respect to two-vehicle crashes, failure to yield was the most frequently cited factor among older drivers. Overall, 27% of drivers failed to yield, but this percentage increased to 39% for drivers 60 to 69, 51% for drivers 70 to 79, and 62% for drivers 80 and older. As a group, older drivers were underrepresented in citations for failure to keep in proper lane (e.g., crossing the centerline, going straight in a turn lane), driving too fast, alcohol or drug use, and careless or reckless driving, all of which were important contributors to two-vehicle crashes overall.

With respect to single-vehicle crashes, older drivers were somewhat more likely to be identified as ill or blacking out, drowsy or asleep, using medications or drugs (other than alcohol), and having some other physical impairment (missing limb, hearing loss, etc.). They were less likely to be identified as driving too fast, and somewhat less likely to have overcorrected. Otherwise, their related factor profile did not differ greatly from that of the general driving population.

Situations that were risky for older drivers often included complex visual searches and information from multiple sources that must be processed rapidly under divided attention conditions. These are conditions where context-appropriate driver behavior often depends less upon conformity to formal or informal rules than to judgment or “executive function.” This converges substantially with the cluster of cognitive abilities validated as significant predictors of at-fault crashes by older drivers in previous NHTSA research (see Staplin, Gish, & Wagner, 2003).

Findings Informing Taxonomy Table Development

Based on the findings of the FARS and GES database analyses describing driver, vehicle, roadway, and environmental characteristics of crashes in which older drivers were over-represented, five driving situations were chosen for inclusion in the taxonomy table:

- Left turn at an intersection with stop-sign control for the older driver's approach. Cross traffic does not stop.
- Left turn at an intersection with signal control; permissive phase for older driver's approach.
- Right turn at an intersection controlled by a yield sign in a channelized right-turn lane, merging with traffic approaching from the left on a principal arterial (with speeds of 40-45 mph).
- Merge at a yield sign onto a limited access highway.
- Lane change on a multilane (4+ lanes) roadway.

These five priority crash types were the starting point for an in-depth examination of how crashes may result from age-related functional changes, mediated through specific driver performance errors. Findings from the literature review, described in the next section, enabled a better understanding of these relationships while identifying potential countermeasures for lowering older driver crash risk.

LITERATURE REVIEW

The literature review updated the material from "Age Differences in Functional Capabilities" reported by Staplin et al. (1998a). This review maintains the structure of the earlier report and expands the scope to include potential effects of age-related functional changes on driving situations highlighted through the crash database analyses described above. The present review was also expanded to include the documented or potential effects on driving capability of (1) medical conditions common in older adults and (2) medications commonly used by this population; plus, (3) evaluations of existing behavioral countermeasures that may affect older drivers' safety.

The literature review, included in its entirety as Appendix D, is a 212-page discourse that was prepared to support the expert panel discussion in this project, as well as the development of the taxonomy table. The panelists deemed it sufficiently useful as a reference for researchers and practitioners interested in older driver safety to recommend its inclusion in the final technical report. The literature review contains 7 chapters, as follows:

- Diminished Sensory/Perceptual Capabilities;
- Diminished Cognitive Capabilities;
- Diminished Physical/Psychomotor Response Capabilities;
- Medical Conditions and Driver Safety;
- Medication Use in the Older Driver Population and Effects on Driving;
- Dementia and Diminished Driving Skills; and
- Behavioral Countermeasures to Reduce Crash Risk.

A search for relevant literature published between 1997 and 2008 was conducted in the TRIS, PsychINFO, and AgeLine databases. Keywords were: older drivers, driver age, physical ability, cognitive ability, visual ability, functional ability, attention, vision, strength, flexibility, and range of motion. The searches excluded the keywords alcohol and DUI. This strategy was augmented with a literature search in MedLine in two areas, Alzheimer's Disease/Dementia and Medical Conditions. Dr. David Carr and Dr. Nina Silverstein, respectively, contributed additional references and original writings on these topics. The chapter on medication use was extracted from a recently completed literature review for a curriculum developed for NHTSA by TransAnalytics, to educate pharmacists and pharmacy technicians about medication-impaired driving (Lococo & Tyree, 2008).

The results of the searches for literature addressing the relationships between (deficits in) functional abilities and driving outcomes also described behavioral countermeasures. A supplemental search using terms such as older driver retraining, education, interventions, and self-regulation helped to pinpoint those citations that deserved further review in this regard.

A total of 142 reports were retrieved and reviewed to update the state of the knowledge in the seven areas covered by the literature review (see Appendix D, published separately as DOT HS 811 468C).

TAXONOMY TABLE DEVELOPMENT

The taxonomy table represents the key deliverable in this project. Its development built on the five specific situations/maneuver types emerging from the earlier crash analyses where older drivers are most strongly overrepresented in crashes (see page 10).

With these five crash types as the top level organizing principle for the taxonomy table, the contents of the literature review chapters were examined to identify specific functional deficits that could be implicated as a contributing factor in each crash scenario. Applying the evidence from available research within the framework of driving task analysis (cf. Staplin et al., 1998a), each specific deficit was then associated with one or more driver performance errors that could logically result from the deficit, and in turn lead to a crash. Countermeasures revealed through the present search, which have been suggested or applied to address specific deficits, were then identified.

To summarize and integrate this information, Preliminary Taxonomy Table Detail Pages were developed at the level of general and specific areas of functional deficit for each of the five priority crash types. The specific functional abilities addressed in the Preliminary Taxonomy Table Detail Pages are listed below.

<u>Functional Deficits Relating to Crashes</u>:

- **Sensory/Perceptual (Vision)**
  - Acuity
  - Contrast sensitivity
  - Visual fields
  - Depth and motion perception
  - Dark adaptation and glare recovery

- **Attention/Cognition**
  - Speed of processing
  - Selective attention
  - Divided attention
  - Working memory
  - Executive function (judgment/decision-making)
  - Spatial abilities
  - Knowledge

- **Physical/Psychomotor**
  - Head/neck/trunk range of motion
  - Arm strength/range of motion
  - Leg strength/range of motion

In developing detail pages for each of the five crash types, associated critical driver performance errors and behavioral countermeasures were entered for each included specific functional deficit. An example is presented here pertaining to specific deficits in visual acuity (in the general area of sensory-perceptual capabilities) for Crash Type #1: *Left turn at an intersection with stop-sign control for the older driver's approach. Cross traffic does not stop.* Figure 1 displays the format in which this information was presented in the Preliminary Taxonomy Table Detail Pages.

Finally, a preliminary draft of the taxonomy table was developed. The goal was to capture the key inter-relationships among each of the priority crash types and the critical driver performance errors implicated through task analysis as pre-crash events. Additional links were provided to the specific functional deficits that can contribute to these errors, as well as the countermeasures that have been advanced to address a given performance error or functional deficit. An expert panel (in a subsequent project task) critically evaluated the Preliminary Taxonomy Table. Critical driver performance errors, functional deficits, and behavioral countermeasures were modified based on the panelists' recommendations.

		CRASH TYPE #1: LEFT TURN AT INTERSECTION WITH STOP SIGN CONTROL FOR OLDER DRIVER'S APPROACH (CROSS TRAFFIC DOES NOT STOP).			
General Deficit	**Specific Deficit**	**Associated Driver Performance Errors**	**Behavioral Countermeasure**	**Countermeasure Evaluations?**	**Commentary: Experts & Older Drivers**
Sensory/ Perceptual (Vision)	Acuity	Could contribute to a failure to visually detect a potential threat. Marottoli et al. (1998) acuity poorer than 20/40 independently associated with self-reported crashes, moving violations, being stopped by police in prior 5-year period. McKnight and McKnight (1999): Acuity (score and response time) related to unsafe driving incidents; correlations higher for time to respond to acuity stimuli than acuity errors. Acuity response time rather than acuity score related to driving exam score (Staplin et al., 1998). Acuity slightly worse than 20/30 independently associated with self-reported difficulty driving on interstates, at night, in the rain, on high-traffic roads, during rush hour, alone, and making left turns (McGwin, Chapman, & Owsley, 2000). Poorer dynamic acuity related to crash involvement in prior 2-year period (Shinar, Mayer, & Treat, 1975). Dynamic acuity included in model predictive of closed course driving performance (Wood, 2002). Shinar, McDonald, and Treat (1978): significant relationship between acuity and improper lookout. (Cont'd)	Refractive correction Cataract surgery	No before-after studies on refraction correction (updating prescription for corrective glasses) and driving safety uncovered. McGwin, Scilley, Brown, and Owsley (2003) found improvements in acuity with cataract surgery, and that improvement in visual acuity had a significant, independent association with the change in activities of daily vision scale (that includes daytime and nighttime driving). Wood and Carberry (2006) found that improvement in acuity that accompanied cataract surgery was related to improvement in overall driving score.	

Figure 1. Preliminary Taxonomy Table Detail Pages for Crash Type 1 and Visual Acuity Deficit.

Functional Deficits That Influence Crash Risk	CRASH TYPE #1: LEFT TURN AT INTERSECTION WITH STOP SIGN CONTROL FOR OLDER DRIVER'S APPROACH (CROSS TRAFFIC DOES NOT STOP).				
General Deficit	**Specific Deficit**	**Associated Driver Performance Errors**	**Behavioral Countermeasure**	**Countermeasure Evaluations?**	**Commentary: Experts & Older Drivers**
Sensory/ Perceptual (Vision) (Cont'd)	Acuity (Cont'd)	• McGwin, Chapman, and Owsley (2000): visual impairment worse than 20/30 in the better eye was independently associated with self-reported difficulty making left turns in sample of 384 drivers 55-85. Refractive error most frequent cause of impairment for the subsample with acuity worse than 20/40 but better than 20/60; cataract next most frequent cause (both conditions are correctable). • Decina and Staplin (1993): combined criterion using acuity, CS, and horizontal visual fields significantly related to prior crash involvement in drivers 66+, but no visual measure alone was significantly associated.	Avoid challenging driving situations	• Gallo, Rebok, & Lesikar (1999). Self-reported vision impairment was related to avoidance of challenging driving situations, but not to self-reported citations or crashes in prior 2 years. Authors conclude that vision impaired drivers who self restricted were less likely to crash. Vision impairment categories: no trouble seeing; a little trouble, a lot of trouble (i.e., may not be specific to acuity). • Ball, Owsley, Stalvey, Roenker, Sloane, & Graves (1998): No relationship between avoidance score and crashes in subsequent 3 year period. • De Raedt & Ponjaert-Kristoffersen (2000): poor performers on a road test who were free of (self-reported) at-fault crashes (prior 12 mo) used significantly more strategic compensation tactics (avoidance of challenging situations) than poor-performing drivers with a history of at-fault crashes.	

Figure 1 (Cont'd). Preliminary Taxonomy Table Detail Pages for Crash Type 1 and Visual Acuity Deficit.

Functional Deficits That Influence Crash Risk	CRASH TYPE #1: LEFT TURN AT INTERSECTION WITH STOP SIGN CONTROL FOR OLDER DRIVER'S APPROACH (CROSS TRAFFIC DOES NOT STOP).				
General Deficit	**Specific Deficit**	**Associated Driver Performance Errors**	**Behavioral Countermeasure**	**Countermeasure Evaluations?**	**Commentary: Experts & Older Drivers**
Sensory/ Perceptual (Vision) (Cont'd)	Acuity (Cont'd)		Driver Safety Education (Theory)	• Owsley, McGwin, Phillips, McNeal, and Stalvey (2004) found no difference in crash rate during 2 year follow up period for drivers with 40% or more reduction in UFOV or a visual acuity deficit (20/30 to 20/60) in an educational intervention group ("Knowledge Enhances Your Safety") who reduced their overall exposure and avoided driving at night, in the rain, in rush hour, and made right turns around the block to avoid left turns across traffic. Avoidance and exposure were self-reported, so social desirability may have been operative; or restriction was not frequent enough to be protective. Also, crash type was not restricted to at-fault in the study.	

Figure 1 (Cont'd). Preliminary Taxonomy Table Detail Pages for Crash Type 1 and Visual Acuity Deficit.

EXPERT PANEL

Purpose of the Panel

An expert panel examined and supplemented the information compiled in earlier tasks about functional status, crash risk, and countermeasure strategies to aid older drivers. Panelists included key researchers and clinicians working in this area. The panel sought first to identify topics that were not covered adequately in the literature review, then to reach consensus (or at least broad agreement) about which functional losses best explain the performance errors highlighted in the FARS and GES analyses, as well as the feasibility of addressing them with behavioral countermeasures.

The project team modified the preliminary taxonomy table based on the panel's guidance to produce a resource that captures the state of the knowledge about how crash types may result from age-related functional changes, mediated through specific driver performance errors; while highlighting the most promising countermeasure strategies and priorities for continuing research.

Planning and Logistics

Panelists included physicians, geriatricians, and vision specialists with expertise in aging, functional change, and mobility outcomes; occupational therapists/rehabilitation professionals who routinely seek behavioral countermeasures to assist their clients; and epidemiologists who supplemented the project team's understanding of the statistical and operational significance of crash contributing factors.

The expert panel was convened at the Conference Center at the Maritime Institute, in Linthicum, Maryland. The meeting began at 1 pm and continued through 5 p.m. that day, then resumed at 9 a.m. the next morning and ended at 3 p.m. The meeting was professionally recorded (audio only) and transcribed.

Two weeks prior to the meeting, panelists were provided with the crash analyses and literature review completed earlier, as background for the meeting. One week before the meeting, they were provided with taxonomy table worksheets that provided bullet point summaries of key research findings in each general area (e.g., vision) and specific sub-area (e.g., contrast sensitivity), describing the impact of a deficit in function on driver performance or safety. This information was included as preface to a table addressing "Associated Behavioral Countermeasures."

A central mission in this project was to document the state-of-the-knowledge about the existence of such countermeasures and evaluations (if any) of their effectiveness. A related goal was to generate ideas about potential new interventions to ameliorate crash risk for older drivers, and/or develop sound research designs to evaluate promising but untested approaches.

Prior to their arrival at the meeting, participants were asked to add countermeasures to those listed for each sub-area of driver function in the worksheets. They came to the meeting prepared to discuss what has been tried, what has worked and has not worked, and what deserves either further research or application for clinical practice.

Meeting Proceedings

The discussion of countermeasures and their relationship to different deficits and sub-deficits (taxonomy table worksheets) was scheduled for the last two hours on Day 1. However, that discussion lasted well into Day 2, as the assembled experts continued to discuss links between countermeasures and functional deficits. Since this was the part of the taxonomy table for which the research team was most dependent upon the contributions of these professionals, the discussion was encouraged. Panelists discussed at length a variety of countermeasures that clinicians often use in practice, but that lack evidence-based research. Identifying countermeasures that clinicians commonly use, but which have not been evaluated, is important for setting research agendas to clarify which countermeasures are effective in improving older adults' driving performance and safety.

Reflecting panelists' comments, the phrase "Speed of Movement" was added to the deficits originally listed as "Arm Strength/Range of Motion" and "Leg Strength/Range of Motion" in the Preliminary Taxonomy Table. In addition, panelists recommended: (1) changes to the wording of eight of the countermeasures; (2) eliminating three countermeasures; and (3) adding six countermeasures. The changes to countermeasure descriptions resulting from the expert panel discussion are shown in Table 3.

The three countermeasures that panelists recommended eliminating were: perceptual training in collision detection, peripheral movement detection practice, and passengers as co-pilots. The rationale for these changes is as follows.

Perceptual training in collision detection. This countermeasure was suggested by Andersen and Enriquez (2006), but no evaluations were found in the literature. Panelists stated that this is not a trainable ability because it is dependent on the sensation of "optical flow." This cannot be trained; however, a driver could be educated to recognize the deficit (using executive function) and compensate for it.

Peripheral movement detection practice. Johnson and Leibowitz (1974) conducted a laboratory study with four psychology students experienced in visual psychophysics, and found that practice improved motion detection in the periphery at eccentricities greater than 20 degrees (20 to 80 degrees). However, the overall panel was highly skeptical that this is a trainable ability; it is specifically related to flicker rate.

Passengers as copilots. Hing, Stamatiadis, and Aultman-Hall (2003) found that in multi-vehicle crashes, the presence of 2 or more passengers was the riskiest for drivers 75 and older (RR=1.8), but even 1 passenger increased the risk slightly compared to driving alone (RR = 1.6 versus 1.5). The study included a general population sample (not dementia). Bédard and Myers (2004) found that for drivers 65 to 79, the presence of passengers overall was protective compared to driving alone. As per the FARS analysis in this project, it appears that the presence of passengers is protective for some actions but detrimental for others; for example, passengers increase the risk of unsafe actions related to obeying signs/warnings/right of way, for young-old and old-old drivers.

The consensus of the expert panel was that this was not an appropriate countermeasure. Although several commented that a copilot may be appropriate for someone who is cognitively intact who only needs help with navigation, panelists were concerned about potential application to drivers with progressive diseases and that copilots would be used for other driving tasks, such as telling drivers when to stop or go in response to signs, signals, and traffic conditions.

Table 3. Recommended Changes by Panelists to Countermeasures Listed in the Preliminary Taxonomy Table.

Original Description	Revised Description
Refractive Correction	Refractive Correction (Including wavefront technology[1])
Avoidance of Challenging Driving Situations	Avoidance of Challenging Driving Situations (includes license restriction, driver rehabilitation specialist initiated, or self-restriction)
Bioptic Telescopic Lenses	Central Vision Enhancement Systems (bioptic telescopic lenses, implantable telescopes)
Bioptic Amorphic Lenses	Visual Field Expansion Systems (prisms, bioptic amorphic lenses, video feeds)
Training in Compensatory Head/Eye Movements	Training in Compensatory Head/Eye Movements, Scanning Strategies
Physical Aerobic Activity	Physical Aerobic Activity/Training
Driver Education Theory	Driver Education Theory/Classroom
Flexibility Exercises	Strength and Flexibility Exercises

The six new countermeasures recommended by panelists for inclusion in the taxonomy table were:

- Medical management (including pharmacy review).
- Cognitive rehabilitation (including memory training) for normally aging drivers.
- Compensatory cognitive/memory training for the impaired/mild cognitive impairment (MCI) population.
- Pre-trip planning.
- Education about driving aids: CarFit, features/adaptive equipment, diabetic shoes, etc.
- Driver safety education: interactive/computer-based technology.

The final products of the expert panel discussion were changes in language that qualified six of the eight critical driver performance errors listed in the Preliminary Taxonomy Table. This was done to highlight assumptions (e.g., "assuming no sensory deficit"), exclusions (e.g.,

[1] Wavefront technology diagnoses higher-order vision errors represented by the way the eye refracts or focuses light; such aberrations defocus images even with 20/40 acuity. Wavefront guided lenses can reduce certain higher-order aberrations, which potentially can improve low light image quality during activities such as driving at night.

"not willful or aggressive driving"), or to avoid overlap between categories of performance errors. Also, a ninth critical driver performance error was added, and panelists provided input helpful in mapping deficits to the critical driver performance errors.

The changes to descriptions of the critical driver performance errors are shown in Table 4. The additional critical driver performance error endorsed by the expert panel – "Inappropriate response selection (pedal errors)" – is included in Figure 2, which also reveals how panelists mapped functional deficits to critical driver performance errors.

Finally, review of the meeting transcript by project staff led to a reconsideration of deficits associated with Critical Performance Error 1, "Failure to visually detect potential conflicts, hazards, or traffic control information," and the subsequent qualification of this entry by adding "without regard to cognitive status." This preserves a focus on purely sensory factors and the need to address deficits at the earliest stages of driver information processing—without in any way diminishing the panel's emphasis on attentional and cognitive factors as more potent predictors of crash risk.

Following discussions about the appropriateness of countermeasures for selected impairments and populations, countermeasures were mapped (through panel consensus) to functional deficits[2] as shown in Figure 3. Appendix A provides a description of each of the 21 countermeasures; a summary of research evaluating countermeasure effectiveness (where available); a summary of the panelists' comments about the countermeasure; and the functional deficits addressed by the countermeasure. The appendix includes a metric describing panelists' opinions regarding the likelihood that the countermeasure will be effective in promoting safe driving when it is targeted to a particular deficit. The next report section describes this metric and the exercise used to obtain it.

Follow-Up Exercise: Gauging the Likelihood of Countermeasure Effectiveness

Two weeks following the meeting, panelists were emailed a request to review the countermeasure-by-deficits table (shown in Figure 3) in a two-step exercise. In Step 1, they indicated their agreement or disagreement that each "X" placed in the matrix was appropriate, i.e., that the indicated countermeasure has some potential value as an intervention to promote safe driving practices for the indicated deficit. In Step 2, they provided a subjective evaluation of the countermeasure's level of effectiveness for the indicated deficit using a rating scale. Specific instructions for this exercise are included in Appendix A.

[2] One potential new countermeasure suggested by panelists during the meeting – "backing aids" – is not included in this table, as it does not relate to any of the crash problems shown to be most problematic for older drivers in the FARS and GES analyses. One potentially new critical driver performance error – "Lack of Awareness" [of changes in functional abilities] – also was not included, in the interest of establishing associations between functional deficits *per se* and countermeasures.

Table 4. Changes to Critical Driver Performance Errors Based on Panel Input.

Original Description	Revised Description
CRITICAL DRIVER PERFORMANCE ERROR 2 Gap judgment errors (inability to accurately estimate closing speed and distance)	CRITICAL DRIVER PERFORMANCE ERROR 2 Gap judgment errors (assuming no sensory deficit) (inability to accurately estimate closing speed and distance)
CRITICAL DRIVER PERFORMANCE ERROR 3 Inability to predict the development of future conflicts from current traffic & contextual information	CRITICAL DRIVER PERFORMANCE ERROR 3 Inability to predict the development of future conflicts from current traffic & contextual information (assuming no sensory deficit)
CRITICAL DRIVER PERFORMANCE ERROR 4 Slowed vehicle control response	CRITICAL DRIVER PERFORMANCE ERROR 4 Slowed vehicle control response (assuming appropriate response)
CRITICAL DRIVER PERFORMANCE ERROR 5 Inadequate visual search/improper lookout (attentional failure, includes "looked but didn't see")	CRITICAL DRIVER PERFORMANCE ERROR 5 Inadequate visual search/improper lookout (assuming no sensory deficits) (attentional failure, includes "looked but didn't see")
CRITICAL DRIVER PERFORMANCE ERROR 6 Slowed decision making; traffic situation has changed by the time a maneuver is initiated, resulting in potential conflict	CRITICAL DRIVER PERFORMANCE ERROR 6 Slowed decision making (assuming no sensory deficit); traffic situation has changed by the time a maneuver is initiated, resulting in potential conflict
CRITICAL DRIVER PERFORMANCE ERROR 8 Lack of understanding of safe driving practices (communication, use of and aiming of mirrors, etc).	CRITICAL DRIVER PERFORMANCE ERROR 8 Lack of understanding (leading to failure to apply) safe driving practices (e.g., aiming mirrors, positioning within intersection to increase sight distance). Not willful or aggressive driving.

Eleven of the 12 panelists completed this exercise. In summarizing Step 1, project staff established a criterion for retaining the "X" in any given cell, vis-à-vis the version of the countermeasure-by-deficit matrix provided to the various panel members. To retain the "X" at least 8 of the 11 responding experts were required to show agreement. All entries shown in Figure 2 met this criterion; therefore, none of the "X's" in this matrix was removed.

Similarly, the criterion for adding an "X" in the countermeasure-by-deficit matrix was defined by a simple majority: if 6 or more experts among the 11 responding to this exercise added an "X" in a given cell, it would be retained. No new entries suggested by experts met this criterion. There was one case where 5 panelists added an "X" to the matrix. This was in the cell indicating that cognitive rehabilitation including memory training for the normally aging population was an appropriate countermeasure to address a speed of processing deficit. As per research findings for the ACTIVE trials, memory training did not improve speed of processing performance (Ball et al., 2002). It was also the opinion of a panelist who is an author of the ACTIVE report, and who was *not* among the 5 panelists that entered an 'X" in this cell, that memory training should not be identified as an intervention for a speed of processing deficit.

Deficits	Critical Driver Performance Errors								
	1	2	3	4	5	6	7	8	9
	Failure to visually detect potential conflicts, hazards, or traffic control information (without regard to cognitive status)	Gap judgment errors (assuming no sensory deficit) (inability to accurately estimate closing speed and distance)	Inability to predict the development of future conflicts from current traffic & contextual information (assuming no sensory deficit)	Slowed vehicle control response (assuming appropriate response)	Inadequate visual search/improper lookout (assuming no sensory deficits) Attentional failure (includes "looked but didn't see")	Slowed decision making (assuming no sensory deficit); traffic situation has changed by the time a maneuver is initiated, resulting in potential conflict	Lack of understanding of rules of the road	Lack of understanding (leading to failure to apply) safe driving practices (e.g., aiming mirrors, positioning within intersection to increase sight distance) (not willful or aggressive driving)	Inappropriate response selection (pedal errors)
1. Acuity	X								
2. Contrast Sensitivity	X								
3. Visual Fields	X								
4. Depth & Motion Perception		X	X						
5. Dark Adaptation & Glare Recovery	X								
6. Speed of Processing		X	X	X	X	X			X
7. Selective Attention		X	X	X	X	X			X
8. Divided Attention		X	X	X	X	X			X
9. Working Memory		X	X						
10. Executive Function (Judgment/Decision- Making)		X	X	X	X	X			X
11. Spatial Abiliies		X	X		X	X			
12. Knowledge			X				X	X	
13. Head/Neck/Trunk Range of Motion	X			X					
14. Arm Strength/ Range of Motion/ Speed of Movement				X					
15. Leg Strength/ Range of Motion/ Speed of Movement				X					

Figure 2. Critical Driver Performance Errors by Functional Deficits.

	Functional Deficits														
COUNTERMEASURES	1. Acuity	2. Contrast Sensitivity	3. Visual Fields	4. Depth & Motion Perception	5. Dark Adaptation & Glare Recovery	6. Speed of Processing	7. Selective Attention	8. Divided Attention	9. Working Memory	10. Executive Function (Judgment/ Decision-Making)	11. Spatial Abiliies	12. Knowledge	13. Head/Neck/ Trunk Range of Motion	14. Arm Strength/ Range of Motion/ Speed of Movement	15. Leg Strength/ Range of Motion/ Speed of Movement
A. Refractive Correction (incl. Wavefront technology)	X	X													
B. Cataract Surgery	X	X			X										
C. Avoidance of Challenging Situations (license restriction, or DRS initiated, or self)	X	X	X	X	X	X	X	X							
D. Conformal Vision Enhancement System		X					X								
E. Central Vision Enhancement Systems (Bioptic Telescopic Lenses; Implantable Telescopes)	X	X	X												
F. Visual Field Expansion Systems (Prism, Bioptic Amorphic Lenses, Video Feeds)			X												
G. Training in Compensatory Head/Eye Movements, Scanning Strategies			X										X		
H. Speed of Processing Training						X	X	X							
I. Physical Aerobic Activity/Training						X		X	X	X			X	X	X
J. Strength & Flexibiliy Exercises													X	X	X
K. Visual Perceptual Therapy											X				
L. Driver Safety Education: Theory/classroom only	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. Driver Safety Education: Theory + Behind the Wheel (BTW)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
N. Driver Education: Interactive/Computer-Based Technology	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
O. Education about Driving Aids (Car Fit, Features/Adaptive Equip, Shoes, etc.)			X	X	X							X	X	X	X
P. Collision Warning Systems	X	X				X	X	X					X		
Q. After-Market Non-Planar Driver-Side Mirror													X		
R. Medical Management (incl Pharmacy Review)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. Cognitive Rehab (incl Memory Training) for Normally Aging							X	X	X	X					
T. Compensatory Cognitive/ Memory Training for Impaired/ MCI Population							X	X	X	X					
U. Pre-Trip Planning									X	X		X			

Figure 3. Countermeasures by Functional Deficits.

Mean "Likelihood of Effectiveness" (MLE) ratings were calculated to summarize panelists' judgments of countermeasure effectiveness in Step 2 of this exercise. A "1" to "5" scale was anchored by "extremely unlikely" and "extremely likely" effectiveness ratings, respectively. Mean ratings were grouped into three categories:

- Top third on the rating scale (mean ratings of 3.68 to 5.0).
- Middle third on the rating scale (mean ratings of 2.34 to 3.67).
- Bottom third on the rating scale (mean ratings of 1.0 to 2.33).

MLE ratings in the top third of the range were interpreted to mean that panelists had a relatively high level of confidence that a given countermeasure would be effective as an intervention for a targeted deficit. MLE ratings in the middle third were interpreted to mean that panelists regarded an approach as credible, but that more information/research is needed before they could endorse an intervention for a targeted deficit. MLE scores in the bottom third of the countermeasures rated by the panel signified interventions they considered unlikely to be effective (at least, not in isolation), given the present state of the knowledge in this area.

Figure 4 presents the results of the countermeasure effectiveness rating exercise. It shows the number of panelists indicating agreement for each countermeasure-by-deficit association, and the mean MLE ratings. MLE ratings are color coded in this figure indicating values in the top (green), middle (yellow), and bottom (red) third of the range on the rating scale.

While the majority of the countermeasure-by-deficit associations received MLE ratings in the middle third of the scale indicating a need for more research, the following countermeasure applications (showing the targeted deficits in italics) received the highest ratings:

- Refractive Correction (including Wavefront technology): *Acuity; Contrast Sensitivity.*
- Cataract Surgery: *Acuity, Contrast Sensitivity; Dark Adaptation and Glare Recovery.*
- Training in Compensatory Head/Eye Movements, Scanning Strategies: *Visual Fields; Head/Neck/Trunk Range of Motion.*
- Physical Aerobic Activity/Training: *Arm Strength/Range of Motion/Speed of Movement; Leg Strength/Range of Motion/Speed of Movement.*
- Strength and Flexibility Exercises: *Head/Neck Trunk Range of Motion; Arm Strength/ Range of Motion/Speed of Movement; Leg Strength/Range of Motion/Speed of Movement.*
- All three Driver Education Modes: *Knowledge*.
- After-Market Non-Planar Driver-Side Mirror: *Head/Neck/Trunk Range of Motion.*
- Pre-Trip Planning: *Knowledge.*

At the other end of the range, the following countermeasure applications (showing the targeted deficits in italics) received the lowest ratings:

- Driver Safety Education/Theory Classroom Only: *All deficits with the exception of Knowledge.*
- Driver Safety Education/Theory + BTW: *Acuity.*
- Driver Safety Education/Interactive Computer-Based: *Acuity.*
- Education About Driving Aids: *Depth and Motion Perception; Dark Adaptation/Glare Recovery.*

COUNTERMEASURES	Functional Deficits														
	1. Acuity	2. Contrast Sensitivity	3. Visual Fields	4. Depth & Motion Perception	5. Dark Adaptation & Glare Recovery	6. Speed of Processing	7. Selective Attention	8. Divided Attention	9. Working Memory	10. Executive Function (Judgment/ Decision-Making)	11. Spatial Abiliies	12. Knowledge	13. Head/Neck/ Trunk Range of Motion	14. Arm Strength/ Range of Motion/ Speed of Movement	15. Leg Strength/ Range of Motion/ Speed of Movement
A. Refractive Correction (incl. Wavefront technology)	11 (4.0)	11 (3.89)													
B. Cataract Surgery	11 (4.60)	11 (4.56)			11 (4.13)										
C. Avoidance of Challenging Situations (license restriction, or DRS initiated, or self)	11 (2.91)	11 (3.18)	11 (2.91)	11 (3.09)	11 (3.45)	11 (2.82)	11 (2.70)	11 (2.70)							
D. Conformal Vision Enhancement System		11 (3.14)					10 (2.83)								
E. Central Vision Enhancement Systems (Bioptic Telescopic Lenses; Implantable Telescopes)	11 (3.33)	11 (2.78)	11 (3.00)												
F. Visual Field Expansion Systems (Prism, Bioptic Amorphic Lenses, Video Feeds)			11 (3.40)												
G. Training in Compensatory Head/Eye Movements, Scanning Strategies			11 (3.82)										11 (4.0)		
H. Speed of Processing Training						11 (3.64)	10 (3.40)	10 (3.40)							
I. Physical Aerobic Activity/Training						11 (2.91)		11 (2.73)	10 (2.50)	10 (2.50)			11 (3.45)	11 (3.73)	11 (3.73)
J. Strength & Flexibiliy Exercises													11 (4.20)	11 (4.0)	11 (3.90)
K. Visual Perceptual Therapy											11 (3.33)				
L. Driver Safety Education: Theory/classroom only	11 (1.64)	11 (1.82)	11 (1.82)	10 (1.50)	10 (1.80)	10 (2.00)	10 (1.80)	10 (1.80)	10 (1.70)	11 (2.18)	10 (1.80)	11 (3.82)	10 (2.00)	10 (1.70)	10 (1.70)
M. Driver Safety Education: Theory + Behind the Wheel (BTW)	10 (2.10)	11 (2.56)	11 (2.55)	11 (2.36)	10 (2.40)	11 (2.73)	11 (2.45)	11 (2.64)	9 (2.67)	11 (3.00)	10 (2.50)	11 (4.0)	11 (2.91)	10 (2.70)	10 (2.70)
N. Driver Education: Interactive/Computer-Based Technology	10 (2.20)	11 (2.64)	11 (2.73)	11 (2.55)	11 (2.36)	11 (3.27)	11 (3.27)	11 (3.45)	10 (3.40)	11 (2.91)	11 (2.91)	11 (3.82)	11 (2.45)	11 (2.55)	11 (2.55)
O. Education about Driving Aids (Car Fit, Features/Adaptive Equip, Shoes, etc.)			11 (2.55)	10 (1.89)	10 (2.40)							11 (4.0)	11 (3.55)	10 (3.10)	10 (3.10)
P. Collision Warning Systems	11 (3.36)	11 (3.45)				11 (3.45)	11 (3.40)	11 (3.30)					11 (3.09)		
Q. After-Market Non-Planar Driver-Side Mirror													11 (4.11)		
R. Medical Management (incl Pharmacy Review)	11 (3.50)	10 (3.00)	10 (3.0)	10 (2.67)	10 (3.00)	11 (3.18)	11 (3.30)	11 (3.09)	11 (3.20)	11 (3.27)	11 (2.40)	11 (3.30)	10 (3.20)	10 (3.50)	10 (3.50)
S. Cognitive Rehab (incl Memory Training) for Normally Aging							11 (2.89)	11 (2.80)	11 (2.80)	11 (2.80)					
T. Compensatory Cognitive/ Memory Training for Impaired/ MCI Population							11 (2.89)	11 (2.80)	11 (2.90)	11 (2.80)					
U. Pre-Trip Planning									11 (3.09)	11 (3.09)		8 (3.75)			
	Key to color code	Top Third 3.68 to 5.0	Middle Third 2.34 to 3.67	Bottom Third 1 to 2.33											

Figure 4. Number of Panelists in Agreement with Countermeasure-by-Deficit Association, and Mean Likelihood of Effectiveness Ratings.

INTERVIEWS WITH OLDER DRIVERS

A group of 50 older drivers participated in unstructured telephone interviews. Half of these drivers were involved in crashes between 2006 and 2008. The objective of the interviews was to determine whether crash-involved and crash-free drivers differed in factors such as (self-reported) exposure or use of countermeasures. The unstructured interview, as shown in Appendix B, included questions related to (1) current driving status; (2) current driving exposure; (3) difficulties with driving over the past 5 to 10 years; (4) changes in driving habits over the past 5 to 10 years; (5) driver education and professional evaluations over the past 5 years; (6) physical, mental and visual fitness; and (7) driving after alcohol consumption. Participant recruitment methods and a summary of the findings comparing the crash-involved and the crash-free groups are presented below.

Participants

Individuals were recruited by telephone from the sample of 1,722 older drivers who previously consented to telephone interviews during the Maryland Older Driver Pilot Study (Ross et al., 2009; Staplin, Lococo, Gish & Decina, 2003). The crash-involved sample was nearly exhaustive, given attrition from the dates of first recruitment almost a decade earlier. After these 25 phone interviews were completed, a calling list of crash-free participants was generated. After restricting the sample to include active drivers with birth years between 1924 and 1944 (based on driver license information) to match the age range for the crash-involved interviewees, a prospective sample of 592 remained. After sorting by date of birth, every 15th person was selected to create an initial call list (n=39). Two attempts were made to contact those on the list. Two additional call lists were generated selecting every 16th and every 17th person, respectively, until interviews with 25 age-matched, crash-free participants were completed.

The average age of the participants was 76 (range: 62-85). The age difference between the crash-involved sample (mean age=75.4) and the crash-free sample (mean age=76.7) was not significant. Age information for the total sample, crash-involved group, and crash-free group is presented in Table 5.

Participants were primarily white (n=44) and male (n=32). While race was distributed approximately equally across the two samples, gender was not. As shown in Table 6, the crash-free sample included a greater proportion of males (19 males, 6 females) than the crash-involved sample (13 males, 12 females).

Correction for Current Driving Status

Although 50 individuals were interviewed, four of these participants were not currently driving. While all four had been involved in a crash, only one attributed the crash as the reason for driving cessation; the other three indicated they had stopped driving due to stroke or falling. Three participants reported that they stopped driving in 2008; the fourth participant’s driving status had changed within three weeks of the interview due to stroke. Thus, the following summary is based upon 46 individuals, with 21 participants represented in the crash-involved group.

Table 5. Mean Age for the Total Sample, Crash-Involved Drivers, and Crash-Free Drivers.

Crash Status	Mean Age	SD	Range	N
Crash	75.38	5.49	62.26 - 84.83	25
No Crash	76.68	4.99	67.15 - 85.15	25
Total	76.03	5.23	62.26 - 85.15	50

Table 6. Race and Sex by Crash Status.

Prior Crash?	Race	Sex		Total
		Female	Male	
No	African American	1	2	3
	White	4	17	21
	Asian	1	0	1
	Total	6	19	25
Yes	African American	1	0	1
	White	10	13	23
	Asian	1	0	1
	Total	12	13	25

Driving Exposure

Participants responded to the following questions regarding driving exposure:

- How many days per week do you normally drive?
- On a typical day, how many trips do you make?
- How many total miles do you drive in a normal week?
- In a normal week, about what percentage of your overall travel (miles driven) occurs at night?
- Is most of your nighttime travel on lit or unlit roads?
- About how many miles per year do you drive?
- What kind of area do you live in (city, suburban, rural)?
- Do you do most or all of your driving close to home?

- During the past year, have you driven to places that take more than 1/2 hour to get to or are more than 10 miles away?
- During the past year, have you driven to places that take more than 1 hour to get to or are more than 50 miles away?

The categorical variables were interviewees' estimates of miles driven annually (range: 1=less than 1,000 to 12=30,001 or more), estimates of nighttime travel on lit or unlit roads, home area type (city, suburban, rural), and distance driven from home in the past year. The results for the continuous variables, with the exception of miles driven annually, are presented in Table 7 and the results for the categorical variables are presented in Table 8. Summary statistics for annual miles driven are presented in Table 7 both by the category that represents the range of miles driven (i.e., 1 - 12) and by miles, calculated using the midpoint of the mileages listed for each category. Figure 5 presents a histogram of annual miles driven by driver crash status.

The average interviewee reported driving 5 days per week, making 2 trips per day, driving 161 miles per week, and driving between 5,000 to 10,000 miles per year (see Table 7). Regular nighttime driving was reported by 31 (67.4%) interviewees; comprising 11% of their weekly driving. The majority of those that reported driving at night (74.2%) drove on lit roads. The crash-involved reported driving on lit roads 91.7% of the time and the crash-free reported driving on lit roads 63.2% of the time. The majority of the participants reported living in the suburbs (54.3%) and doing most or all of their driving close to home (87%); but most reported driving to places more than 10 miles away (93.5%) and 50 miles away (73.9%) during the past year (see Table 8).

Table 7. Driving Exposure for Variables Overall and by Crash Status.

Exposure Question	Total (*N*=46)		Crash (*n*=21)		No Crash (*n*=25)	
	M	***SD***	***M***	***SD***	***M***	***SD***
How many days per week do you normally drive?	5.04	2.00	4.76	2.17	5.28	1.86
On a typical day, how many trips do you make?	2.13	1.33	2.05	1.28	2.20	1.38
How many total miles do you drive in a normal week?	160.91[a]	229.68	183.38	307.11	141.25[b]	134.33
In a normal week, about what percentage of your overall travel (miles driven) occurs at night?	11.09	14.90	7.67	12.62	13.96	16.28
About how many miles per year do you drive? (categorical response)	4.47[c,e]	2.79	4.57	3.47	4.38[d]	2.08
About how many miles per year do you drive? (estimate derived using midpoint of each category)	8,016	7,915	8,678	10,030	7,437	5,623

[a,c]*N*=45 [b,d]*n*=24 [e]4=5,001 to 7500, 5=7,501 to 10,000

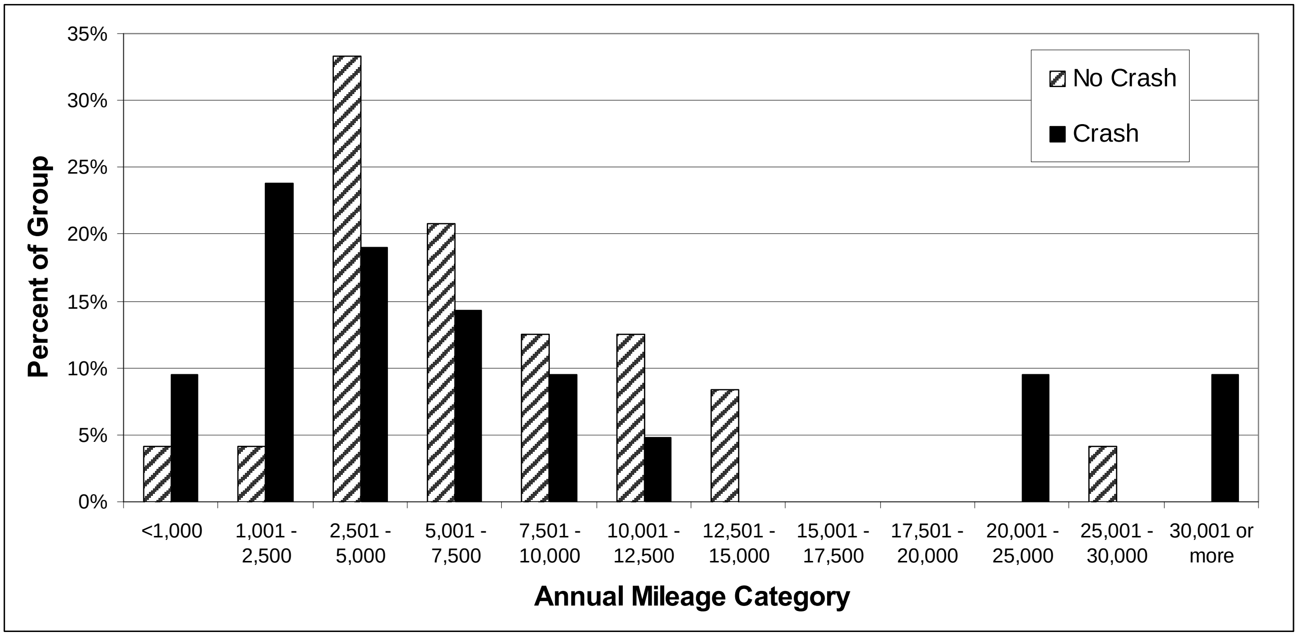

Figure 5. Annual Miles Driven by Driver Crash Status.

Table 8. Driving Exposure for Categorical Variables Overall and by Crash Status.

Exposure Question	Total (*N*=46)	Crash (*n*=21)	No Crash (*n*=25)
Is most of your nighttime travel on lit or unlit roads? (% lit)	74.2[a]	91.7[b]	63.2[c]
What kind of area do you live in? (% suburbs)	54.3	57.1	52
Do you do most or all of your driving close to home? (% yes)	87	90.5	84
During the past year, have you driven to places that take more than 1/2 hour to get to or are more than 10 miles away? (% yes)	93.5	90.5	96
During the past year, have you driven to places that take more than 1 hour to get to or are more than 50 miles away? (% yes)	73.9	71.4	76

[a]*n*=31 [b]*n*=12 [c]*n*=19

A MANOVA revealed no significant differences between crash-involved and crash-free groups for the continuous variables described above. Similarly, there were no differences between these groups indicated by chi-square and Fisher's Exact tests, for responses on the categorical items.

Driving Challenges

This section summarizes the responses to the 19 questions about driving challenges. These questions were structured so that if a participant responded that a given situation had become more challenging over the past 5 or 10 years, the researcher asked whether they continued to drive under those conditions in spite of the difficulty, and if so, how often.

Of the 19 driving situations queried, the top 5 questions for which participants responded that driving situations had become more challenging were:

- Seeing at night (n=21, 45.7%).
- Dealing with bad weather (n=15, 32.6%).
- Turning the head/neck (n=10, 21.7%).
- Judging actions of others/hazard anticipation (n=9, 19.6%).
- Changing lanes/merging (n=6, 13.0%).

For these five situations, only judging the actions of others (hazard anticipation) suggested a potential difference between the crash-involved (n=7) and the crash-free (n=2). Despite difficulty with these driving situations, the majority reported driving anyway. For each of these five situations, the percentage for those who drive anyway despite reporting difficulty follows:

- Seeing at night (14/21, or 67%).
- Dealing with bad weather (9/15, or 60%).
- Turning the head/neck (9/10, or 90%).
- Judging the actions of others/hazard anticipation (8/9, or 89%).
- Changing lanes/merging (5/6, or 83%).

The five situations for which no one reported difficulty were understanding signs, staying in their lane, moving the foot between the brake and gas pedals, knowing which pedal was the brake and which was the gas, and steering when turning. For the remaining 9 situations, the number of participants reporting difficulty ranged from 1 to 4. No other potential trends were observed. These data are summarized in Table 9.

Changes in Driving Habits

Participants were asked whether their driving habits had changed over the past 5 or 10 years for each of 20 driving behaviors including driving fewer miles, making fewer trips, avoiding specific driving situations, or employing strategies such as trip planning or using in-vehicle technologies to make the driving task easier (see Table 10).

Table 9. Frequency and Percentage of Drivers Reporting Difficulties by Crash Status.

Driving Situation	No Crash N=25	Crash N=21
	Number (%) Reporting Difficulty	Number (%) Reporting Difficulty
Seeing at Night	11 (44%)	10 (48%)
Dealing With Bad Weather	7 (28%)	8 (38%)
Judging Actions of Others	2 (8%)	7 (33%)
Turning Head/Neck	4 (16%)	6 (29%)
Changing Lanes / Merging	3 (12%)	3 (14%)
Paying Attention to Everything	1 (4%)	3 (14%)
Getting Tired Easily	1 (4%)	3 (14%)
Judging Gaps	1 (4%)	2 (10%)
Flowing With Traffic	1 (4%)	2 (10%)
Knowing Right of Way	0	2 (10%)
Reading Signs	3 (12%)	1 (5%)
Detecting in Periphery	2 (8%)	1 (5%)
Getting Lost/Disoriented Easily	0	1 (5%)
Understanding Signs	0	0
Staying in Lane	0	0
Moving Foot Between Pedals	0	0
Knowing Pedals	0	0
Steering When Turning	0	0
Other Difficulties	1 (4%)	1 (5%)

As shown in Table 10, there were 14 changes in driving habits (in order of greatest reported change) that more than 25% of either the crash-involved or crash-free drivers reported:

- Making fewer trips per week.
- Driving fewer miles.
- Avoiding or limiting night driving.
- Avoiding or limiting driving at rush hour.
- Avoiding or limiting driving in bad weather.
- Increasing following distance.
- Avoiding or limiting high traffic roads.
- Planning the route before leaving.
- Avoiding or limiting driving in unfamiliar areas.
- Avoiding or limiting driving far from home.
- Avoiding or limiting high speed roads.
- Using in-vehicle technologies.
- Avoiding freeways.
- Limiting driving in other ways.

A higher percentage of the crash-involved drivers reported making each of these changes.

Table 10. Frequency and Percentage of Changes in Driving Habits by Crash Status.

Changes in Driving Habits	No Crash N=25	Crash N=21
	Number (%) Reporting Changes	Number (%) Reporting Changes
Make Fewer Trips per Week	9 (36%)	15 (71%)
Drive Fewer Miles	12 (48%)	14 (67%)
Avoid Night Driving	8 (32%)	14 (67%)
Avoid Driving at Rush Hour	7 (28%)	14 (67%)
Avoid Driving in Bad Weather	10 (40%)	13 (62%)
Increase Following Distance	7 (28%)	10 (48%)
Avoid High Traffic Roads	7 (28%)	9 (43%)
Plan Route Before Leave	4 (16%)	9 (43%)
Avoid Driving Far From Home	6 (24%)	8 (38%)
Avoid Unfamiliar Areas	5 (20%)	8 (38%)
Avoid High Speed Roads	5 (20%)	8 (38%)
Limit Driving in Other Ways	3 (12%)	8 (38%)
Use In-Vehicle Technology	2 (8%)	8 (38%)
Avoid Freeways	5 (20%)	6 (29%)
Avoid Changing Lanes	4 (16%)	5 (24%)
Use Adaptive Equipment	4 (16%)	3 (14%)
Avoid Turning Left	3 (12%)	2 (10%)
Drive Slower Than Speed Limit	2 (8%)	2 (10%)
Drive Only With Passenger	0	1 (5%)
Other Changes	3 (12%)	5 (24%)

Responses for how participants limited driving in other ways included: not going on as many long trips, limiting driving in general, being more careful when changing lanes because of being surprised by a car, planning trips more carefully, preferring lights (versus stop signs) at intersections, driving only in familiar areas in the period before surgery for a cornea transplant, making a right turn if exiting and needing to cross four lanes (judging two gaps in traffic), avoiding busy areas during tourist season, and not driving on ice.

Driver Education and Professional Evaluations

Participants were asked whether, in the past 5 years, they had taken older driver education courses, had cataract surgery, had been counseled by a physician about safe driving, had their driving ability evaluated by an occupational therapist or other driver evaluator, or had been counseled by a pharmacist about the effects of their medications on driving. As shown in Table 11, the number of drivers responding positively to these questions ranged from 1 (physician counseling) to 11 (cataract surgery). Equal percentages of crash-involved and crash-free drivers had undergone cataract surgery, but differences by crash status were seen for the other educational and counseling services. Only crash-free older drivers had taken a driver education course, with all three indicating that the course taken was through AARP. Only crash-involved older drivers had received counseling by a physician (n=1) or undergone a professional driving evaluation (n=2). However, the two participants who had undergone professional driving evaluations completed those evaluations as part of their yearly job requirements (i.e., school bus driver, tour bus driver). Finally, a higher percentage of crash-involved older drivers had received counseling from their pharmacists about the effects of medications on their ability to drive safely. However, pharmacist counseling was not a frequently encountered service (only 5 of the 46 drivers reported receiving such counseling).

Table 11. Frequency of Driver Education and Professional Evaluations by Crash Status.

Education or Professional Evaluation	No Crash N=25	Crash N=21
	Number (%) Receiving Education or Evaluation	Number (%) Receiving Education or Evaluation
Cataract Surgery	6 (24%)	5 (24%)
Pharmacist Counseling	1 (4%)	4 (19%)
Older Driver Education Courses	3 (12%)	0
Professional Driving Evaluation	0	2 (10%)
Physician Counseling	0	1 (5%)

Physical, Mental and Visual Fitness

Participants were asked whether they regularly do strength and flexibility exercises, aerobic exercises, computer exercises to keep mentally sharp, and receive eye exams/updated corrective lens prescriptions. Higher percentages of participants reported that they did not engage in regular physical (strength and flexibility, aerobic) or mental (computer program) exercise, than those who did. However, of those who regularly engaged in exercise (flexibility and strength, as well as aerobic), higher rates of participation were reported for crash-involved than for crash-free respondents (see Table 12). Approximately equal percentages of crash-involved and crash-free interviewees reported participating in mental exercise programs on the computer. All but two drivers (1 crash-involved and 1 crash-free) reported getting regular eye exams/updated corrective lens prescriptions.

Table 12. Frequency of Regular Physical and Mental Exercise and Eye Exams by Crash Status.

Exercise and Exams	No Crash N=25	Crash N=21
	Number (%) Reporting Regular Participation	Number (%) Reporting Regular Participation
Eye Exams	24 (96%)	21 (100%)
Strength and Flexibility Exercises	5 (20%)	13 (62%)
Aerobic Exercises	5 (20%)	7 (33%)
Computer Exercise Programs	5 (20%)	4 (19%)

Driving After Alcohol Consumption

Participants were asked if on occasion they drink alcohol and then drive, and if so, to estimate the extent of this behavior. The majority (29 of 46, or 63%) reported that they did *not* drink alcohol and then drive. Crash status did not differentiate those reporting having a drink and then driving from those who do not (67% of drivers with crashes did *not* drink alcohol and then drive, compared to 60% of the crash-free drivers who also did *not* drink alcohol and then drive). For the participants who reported driving after drinking alcohol (n=17), most reported engaging in this behavior one to two times per year (6 of 17, or 35%). Twenty-nine percent (5 of 17) reported once per month, 12% (2 of 17) reported doing so three to four times per year, and another 12% indicated they did so once per week. One driver reported driving after drinking once every two months, and another driver reported doing so daily with dinner.

FINDINGS

The principal findings in this study include the interrelationships between functional deficits, driver performance errors and crashes described by the taxonomy table, with explicit links to behavioral countermeasures deemed most likely to be effective in reducing older driver crash risk. Key evidence in support of the taxonomy table is provided by the updated literature review, Taxonomy Table Detail pages, and expert panel discussion results.

The taxonomy table is presented in Figure 6, and the Taxonomy Table Detail pages are included in Appendix C. The five *Crash Types* in which older drivers are most strongly overrepresented; the nine *Critical Driver Performance Errors* highlighted as mediators of these crash types; the 15 age-related functional *Deficits* that contribute to these performance errors, based on the literature review; and the 21 behavioral *Countermeasures* for which there are the strongest expectations of efficacy among the expert panelists, are listed below in Table 13.

Table 13. Crash Types, Performance Errors, Functional Deficits, and Behavioral Countermeasures Included in the Taxonomy Table.

Crash Types	Critical Driver Performance Errors	Deficits	Countermeasures
1. Left Turn at an intersection with stop-sign control for the older driver's approach. Cross traffic does not stop. 2. Left turn at an intersection with signal control. Permissive phase for the older driver's approach. 3. Right turn in a channelized right-turn lane, merging with traffic approaching from the left on a principal arterial (40-45 mph) 4. Merge at a yield sign onto a limited access highway. 5. Lane change on a multilane roadway (4+ lanes).	1. Failure to visually detect potential conflicts, hazards, or traffic control information (without regard to cognitive status). 2. Gap judgment errors (assuming no sensory deficit). 3. Inability to predict the development of future conflicts from current traffic and contextual information (assuming no sensory deficit). 4. Slowed vehicle control response (assuming appropriate response) 5. Inadequate visual search/improper lookout (assuming no sensory deficits) 6. Slowed decision-making (assuming no sensory deficit) 7. Lack of understanding of rules of the road. 8. Lack of understanding of safe driving practices. 9. Inappropriate response selection.	1. Acuity 2. Contrast sensitivity 3. Visual fields 4. Depth & motion perception 5. Dark adaptation and glare recovery 6. Speed of processing 7. Selective attention 8. Divided attention 9. Working memory 10. Executive function (judgment/decision-making) 11. Spatial abilities 12. Knowledge 13. Head/neck/trunk range of motion 14. Arm strength/range of motion/speed of movement 15. Leg strength/range of motion/speed of movement	1. Refractive correction 2. Cataract surgery 3. Avoidance of challenging driving situations 4. Conformal vision enhancement system 5. Central vision enhancement systems 6. Visual field expansion systems 7. Training in compensatory head/eye movements, scanning strategies 8. Speed of processing training 9. Physical aerobic activity/training 10. Strength and flexibility exercises 11. Visual perceptual therapy 12. Driver safety education – theory/classroom only 13. Driver safety education – theory plus behind-the-wheel 14. Driver safety education – interactive/computer-based technology 15. Education about driving aids 16. Collision warning systems 17. After-market non-planar driver side mirror 18. Medical management (incl. pharmacy review) 19. Cognitive rehab (incl. memory training) for normally aging population 20. Compensatory cognitive/memory training for impaired/MCI population 21. Pre-trip planning

CRASH TYPE 1
Left turn at intersection with stop-sign control for older driver's approach. Cross traffic does not stop

CRASH TYPE 2
Left turn at intersection with signal control; permissive phase for older driver's approach

CRASH TYPE 3
Right turn at yield sign in channelized right-turn lane, merging with trafic approaching from the left on principal arterial (40-45 mi/h)

CRASH TYPE 4
Merge at yield sign onto limited access highway

CRASH TYPE 5
Lane change on multilane (4+) roadways

CRITICAL DRIVER PERFORMANCE ERROR 1
Failure to visually detect potential conflicts, hazards, or traffic control information
(without regard to cognitive status)

CRITICAL DRIVER PERFORMANCE ERROR 2
(Assuming no sensory deficit)
Gap judgment errors
(inability to accurately estimate closing speed and distance)

CRITICAL DRIVER PERFORMANCE ERROR 3
(Assuming no sensory deficit)
Inability to predict the development of future conflicts from current traffic & contextual information

CRITICAL DRIVER PERFORMANCE ERROR 4
(Assuming appropriate response)
Slowed vehicle control response

CRITICAL DRIVER PERFORMANCE ERROR 5
(Assuming no sensory deficits)
Inadequate visual search/improper lookout
(attentional failure, includes "looked but didn't see")

CRITICAL DRIVER PERFORMANCE ERROR 6
(Assuming no sensory deficit)
Slowed decision making; traffic situation has changed by the time a maneuver is initiated, resulting in potential conflict

CRITICAL DRIVER PERFORMANCE ERROR 7
Lack of understanding of rules of the road

CRITICAL DRIVER PERFORMANCE ERROR 8
Lack of understanding (leading to failure to apply) safe driving practices (e.g., aiming mirrors, positioning within intersection to increase sight distance)
(not willful or aggressive driving)

CRITICAL DRIVER PERFORMANCE ERROR 9
Inappropriate response selection (pedal errors)

	Critical Driver Performance Error 1					Critical Driver Performance Error 2					Critical Driver Performance Error 3				
DEFICITS															
1. Acuity	X	X	X	X											
2. Contrast Sensitivity	X	X	X	X	X										
3. Visual Fields	X	X	X	X	X										
4. Depth & Motion Perception						X	X	X	X	X	X	X	X	X	X
5. Dark Adaptation & Glare Recovery			X	X	X										
6. Speed of Processing						X	X	X	X	X	X	X	X	X	X
7. Selective Attention						X	X	X	X	X	X	X	X	X	X
8. Divided Attention						X	X	X	X	X	X	X	X	X	X
9. Working Memory						X	X	X	X	X	X	X	X	X	X
10. Executive Function (Judgment/Decision- Making)						X	X	X	X	X	X	X	X	X	X
11. Spatial Abiliies						X	X	X	X	X	X	X	X	X	X
12. Knowledge											X	X	X	X	X
13. Head/Neck/Trunk Range of Motion	X		X	X	X										
14. Arm Strength/Range of Motion/Speed of Movement															
15. Leg Strength/Range of Motion/Speed of Movement															
COUNTERMEASURES															
A. Refractive Correction (inc. wavefront technology)	X	X	X	X	X										
B. Cataract Surgery	X	X	X	X	X										
C. Avoidance of Challenging Situations (License restrictions, DRS Initiated, or Self)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
D. Conformal Vision Enhancement System	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
E. Central Vision Enhancement Systems (Bioptic Telescopic Lenses; Implantable Telescopes)	X	X	X	X	X										
F. Visual Field Expansion Systems (Prism, Bioptic Amorphic Lenses, Video Feeds)	X	X	X	X	X										
G. Training in Compensatory Head/Eye Movements, Scanning Strategies	X	X	X	X	X										
H. Speed of Processing Training						X	X	X	X	X	X	X	X	X	X
I. Physical Aerobic Activity/Training	X		X	X	X	X	X	X	X	X	X	X	X	X	X
J. Strength & Flexibiliy Exercises	X		X	X	X										
K. Visual Perceptual Therapy						X	X	X	X	X	X	X	X	X	X
L. Driver Safety Education - Theory/classroom only	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. Driver Safety Education - Theory + Behind the Wheel (BTW)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
N. Driver Safety Education: Interactive/Computer-Based Technology	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
O. Education about Driving Aids (Car Fit, Features/Adaptive Equip, Shoes, etc.)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P. Collision Warning Systems	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Q. After-Market Non-Planar Driver-Side Mirror	X		X	X	X										
R. Medical Management (incl Pharmacy Review)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. Cognitive Rehab (incl Memory Training) for Normally Aging						X	X	X	X	X	X	X	X	X	X
T. Compensatory Cognitive/Memory Training for Impaired/ MCI Pop						X	X	X	X	X	X	X	X	X	X
U. Pre-Trip Planning						X	X	X	X	X	X	X	X	X	X

	Critical Driver Performance Error 4					Critical Driver Performance Error 5					Critical Driver Performance Error 6				
DEFICITS															
1. Acuity															
2. Contrast Sensitivity															
3. Visual Fields															
4. Depth & Motion Perception															
5. Dark Adaptation & Glare Recovery															
6. Speed of Processing	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7. Selective Attention	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
8. Divided Attention	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9. Working Memory															
10. Executive Function (Judgment/Decision- Making)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
11. Spatial Abiliies						X	X	X	X	X	X	X	X	X	X
12. Knowledge															
13. Head/Neck/Trunk Range of Motion	X		X	X	X										
14. Arm Strength/Range of Motion/Speed of Movement	X	X	X	X	X										
15. Leg Strength/Range of Motion/Speed of Movement	X	X	X	X	X										
COUNTERMEASURES															
A. Refractive Correction (inc. wavefront technology)															
B. Cataract Surgery															
C. Avoidance of Challenging Situations (License restrictions, DRS Initiated, or Self)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
D. Conformal Vision Enhancement System	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
E. Central Vision Enhancement Systems (Bioptic Telescopic Lenses; Implantable Telescopes)															
F. Visual Field Expansion Systems (Prism, Bioptic Amorphic Lenses, Video Feeds)															
G. Training in Compensatory Head/Eye Movements, Scanning Strategies	X		X	X	X										
H. Speed of Processing Training	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
I. Physical Aerobic Activity/Training	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
J. Strength & Flexibiliy Exercises	X	X	X	X	X										
K. Visual Perceptual Therapy						X	X	X	X	X	X	X	X	X	X
L. Driver Safety Education - Theory/classroom only	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. Driver Safety Education - Theory + Behind the Wheel (BTW)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
N. Driver Safety Education: Interactive/Computer-Based Technology	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
O. Education about Driving Aids (Car Fit, Features/Adaptive Equip, Shoes, etc.)	X	X	X	X	X										
P. Collision Warning Systems	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Q. After-Market Non-Planar Driver-Side Mirror	X		X	X	X										
R. Medical Management (incl Pharmacy Review)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. Cognitive Rehab (incl Memory Training) for Normally Aging	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T. Compensatory Cognitive/Memory Training for Impaired/ MCI Pop	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
U. Pre-Trip Planning	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

	Critical Driver Performance Error 7					Critical Driver Performance Error 8					Critical Driver Performance Error 9		
DEFICITS													
1. Acuity													
2. Contrast Sensitivity													
3. Visual Fields													
4. Depth & Motion Perception													
5. Dark Adaptation & Glare Recovery													
6. Speed of Processing											X	X	X
7. Selective Attention											X	X	X
8. Divided Attention											X	X	X
9. Working Memory													
10. Executive Function (Judgment/Decision- Making)											X	X	X
11. Spatial Abiliies													
12. Knowledge	X	X	X	X		X	X	X	X	X			
13. Head/Neck/Trunk Range of Motion													
14. Arm Strength/Range of Motion/Speed of Movement													
15. Leg Strength/Range of Motion/Speed of Movement													
COUNTERMEASURES													
A. Refractive Correction (inc. wavefront technology)													
B. Cataract Surgery													
C. Avoidance of Challenging Situations (License restrictions, DRS Initiated, or Self)											X	X	X
D. Conformal Vision Enhancement System											X	X	X
E. Central Vision Enhancement Systems (Bioptic Telescopic Lenses; Implantable Telescopes)													
F. Visual Field Expansion Systems (Prism, Bioptic Amorphic Lenses, Video Feeds)													
G. Training in Compensatory Head/Eye Movements, Scanning Strategies													
H. Speed of Processing Training											X	X	X
I. Physical Aerobic Activity/Training											X	X	X
J. Strength & Flexibiliy Exercises													
K. Visual Perceptual Therapy													
L. Driver Safety Education - Theory/classroom only	X	X	X	X		X	X	X	X	X	X	X	X
M. Driver Safety Education - Theory + Behind the Wheel (BTW)	X	X	X	X		X	X	X	X	X	X	X	X
N. Driver Safety Education: Interactive/Computer-Based Technology	X	X	X	X		X	X	X	X	X	X	X	X
O. Education about Driving Aids (Car Fit, Features/Adaptive Equip, Shoes, etc.)	X	X	X	X		X	X	X	X	X			
P. Collision Warning Systems											X	X	X
Q. After-Market Non-Planar Driver-Side Mirror													
R. Medical Management (incl Pharmacy Review)	X	X	X	X		X	X	X	X	X	X	X	X
S. Cognitive Rehab (incl Memory Training) for Normally Aging											X	X	X
T. Compensatory Cognitive/Memory Training for Impaired/ MCI Pop											X	X	X
U. Pre-Trip Planning	X	X	X	X		X	X	X	X	X	X	X	X

Figure 6. Taxonomy Table.

The taxonomy table reflects our understanding of how changes in functional ability that occur with normal aging (plus the diseases that more frequently afflict older people and the medications used to treat them) can influence driver performance and crash risk, and ties the development and evaluation of behavioral countermeasures to these associations. At present, there is a dearth of empirical evidence on which to judge countermeasure effectiveness. Accordingly, the collective judgment of the project's expert panel regarding the likely effectiveness of the included interventions to ameliorate the identified functional deficits (shown earlier in Figures 3 and 4), including qualifications and reservations based on their professional experience, represents an additional noteworthy finding in this research.

This information is summarized in the following pages, organized around the 15 age-related functional deficits associated with driver performance errors (shown earlier in Figure 2). Findings from the older driver interviews are also included in this discussion, as appropriate. As noted earlier, a more detailed summary of countermeasure evaluations and panelists' opinions about countermeasure effectiveness for each deficit may be found in Appendix A.

ACUITY

An acuity deficit was associated with a failure to visually detect potential conflicts, hazards, or traffic control information (Critical Performance Error #1). This was the only Critical Performance Error that the expert panelists mapped to an acuity deficit. This could cause a driver to crash as a result of performing any of the first four driving tasks identified as high-risk for older drivers:

1. Turning left at an intersection with stop control on the older driver's approach and where cross traffic does not stop.
2. Turning left at an intersection with permissive signal control for the older driver's approach.
3. Turning right at a yield-controlled intersection in a channelized turn lane and merging with traffic approaching from the left on a principal arterial.
4. Merging at a yield sign upon entrance to a limited access highway.

Nine countermeasures were identified from the literature review and expert panel tasks with varying degrees of effectiveness in remediating an acuity deficit. Those rated by the panelists as most likely to be effective were:

- Refractive correction (including wavefront technology), and
- Cataract surgery.

One panelist with expertise in the area stated that although the ophthalmology literature contains ample research on age and satisfaction for refractive error corrective surgery for improved performance in everyday tasks, it is unknown whether refractive error correction is related to improved driving performance. However, even without research on effectiveness, panelists agreed that refractive correction (lens prescriptions) should be advocated solely on the prevalence of the problem and the low cost of the intervention, particularly as there appears to be a decline in the number of older people who get annual eye exams. Annual eye exams, refractive correction, and early diagnosis of treatable conditions (e.g., cataracts) are inexpensive solutions. Panelists stressed the importance of vision specialists providing feedback to their patients regarding the driver licensing laws in their State, in relation to their level of impairment. They noted that this interaction is rare in practice. Increasing patients' awareness of impairments may lead to appropriate self-restriction.

Panelists rated four of the countermeasures for acuity deficits in the middle third of the effectiveness scale, indicating a need for more information/research before they could endorse the countermeasures:

- Avoidance of challenging driving situations;
- Central vision enhancement systems;
- Collision warning systems; and
- Medical management (including pharmacy review).

The panel noted that avoiding challenging driving situations may be more effective if the driver chooses to adopt the strategy as opposed to a DRS or licensing agency imposing driving restrictions. The extent to which drivers comply with externally imposed restrictions is unknown.

Judgment and self-awareness are critical to selecting and applying an appropriate restriction countermeasure; a client must remember to employ it and believe it is needed. Panelists noted that people try to self-regulate when there are alternative transportation options, but there are times when they feel they must drive even if they'd rather not. This point was underscored in the older driver interviews. However, making people aware of deficits is the first step in getting people to self restrict, if they will self restrict. Ophthalmologists and optometrists need to be included as targets of outreach.

Panelists agreed that central vision enhancement systems[3] have potential if they are accompanied by training, with driving safety assessed after training. Licensing should be recommended only after a driver participates in a low-vision driving rehabilitation program and shows effective and safe use of an apparatus. Drivers should be trained to use the lens only for spotting (5-10% of time). Panelists indicated that the training curriculum and design of lenses need to be validated and standardized. Panelists deemed this countermeasure appropriate only for drivers without cognitive deficits.

With regard to collision warning systems, panelists indicated a need for forward as well as side-collision warning and noted that, in addition to providing a warning, the system should cause the vehicle to brake. A word of caution was provided by an occupational therapist who mentioned that although certain advanced technologies may enable older people to drive more safely for a longer period of time, they also may allow unsafe drivers to continue driving. Panelists voiced concern about drivers relying exclusively on the collision warning technology to

[3] Central vision enhancement systems include bioptic telescopic lenses, which are a lens system with a telescope attached to a pair of glasses, mounted above the normal line of sight. This allows a trained user to detect objects or movement within the driving scene using the wide field of view available through the regular spectacle lens (the "carrier" lens) and to resolve fine details such as road sign messages by glancing briefly and intermittently into and out of the miniature telescopic unit (by a downward tilt of the head).

detect hazards, especially for backing up, where older drivers may perform the maneuver without doing head/shoulder checks. Also, older people may be more distracted than assisted by some of the advanced technologies. Panelists noted that training is a key element in advanced technology countermeasures, particularly for older drivers. A barrier to this training is that adapted cars at most rehabilitation centers do not include high-end/high tech equipment. In the driver interviews conducted in this project, only 10 of the 46 drivers indicated using in-vehicle technology. It is unknown what types of equipment these older drivers used (navigation, collision warning, vision enhancement, etc).

Panelists indicated that medical management was an appropriate countermeasure for all 15 listed functional deficits, including acuity deficits. They stated that medical management leads to early detection of impairments and remediation, and as such, it is important for researchers/sponsors of research to provide education to physicians, pharmacists, and eyecare specialists linking medical conditions to functional impairments and driving risk, so they can educate their patients. Patients rely on their healthcare providers to diagnose, treat, and counsel, so their physicians and pharmacists also need to be educated. Of the 46 older drivers interviewed in this project, only 1 reported receiving advice from a physician about driving, and only 5 had been counseled by their pharmacist about the effects of medication on their ability to drive safely.

The three countermeasures rated as the least likely to effectively remediate an acuity deficit, given the present state-of-the-knowledge, were the three driver safety education countermeasures:

- Theory/classroom only;
- Theory plus behind-the-wheel training; and
- Interactive/computer-based technology.

CONTRAST SENSITIVITY

A contrast sensitivity deficit was associated with a failure to visually detect potential conflicts, hazards, or traffic control information (Critical Performance Error #1). As with an acuity deficit, this was the only Critical Performance Error that the expert panelists mapped to a contrast sensitivity deficit. This driver performance error could cause an older driver to be involved in a crash in any of the five driving situations prioritized as high-risk for older drivers, including making a lane change on a multilane roadway.

Ten countermeasures were identified from the literature review and expert panel tasks with varying degrees of likelihood to remediate a contrast sensitivity deficit. Those rated by the panelists as most likely to be effective were the same as for an acuity deficit:

- Refractive correction (including wavefront technology); and
- Cataract surgery.

Panelists agreed that cataract surgery is a relatively inexpensive treatment, and resulting visual improvements have been shown to result in crash reduction. Cataracts are often the only medical condition affecting driving performance. Even if the crash reduction benefit is small, cataract surgery may provide a large public health benefit because of the large number of people affected. Interestingly, of the 46 drivers interviewed in this project, 45 reported having a regular eye exam/updated corrective lens prescription, and 11 reported having cataract surgery.

Seven of the 10 countermeasures were rated in the middle third of the effectiveness scale, indicating a need for more information/research before panelists could endorse them as likely to be effective for a contrast sensitivity deficit. These were:

- Avoidance of challenging driving situations;
- Conformal vision enhancement systems;
- Central vision enhancement systems;
- Driver education that incorporates theory plus behind-the-wheel training;
- Driver education using interactive/computer-based technology;
- Collision warning systems; and
- Medical management (including pharmacy review).

Regarding avoidance of challenging driving situations, driver awareness of visual impairments is a key to getting drivers to restrict their driving. This underscores the need to educate eyecare professionals about contrast sensitivity deficits and driver performance and include them as targets for outreach to their patients. Decina and Staplin (1993) found that older drivers who could pass the State acuity standard for driving but who suffered impairment in contrast sensitivity were at the highest risk of crashing. Counseling by an optometrist or ophthalmologist about avoiding driving during periods of reduced lighting could encourage such drivers to self restrict appropriately.

The two driver education interventions received higher effectiveness ratings to remediate a contrast sensitivity deficit than an acuity deficit. Comments and concerns for all countermeasures were discussed above (in relation to acuity deficits) with the exception of conformal vision enhancement systems.

A conformal vision enhancement system overlays an image on the windshield (as a head's-up display) that is directly superimposed on the object it is providing information about. Panelists stated that older drivers in focus groups have indicated that they don't like anything in their cars that takes their focus away from the road, either on the windshield or on a head's-down display in the vehicle. These drivers would choose not to drive in challenging situations rather than use a device that may take their attention from the road, or that may be more difficult to operate. Another panelist indicated that following training in equipment use, older drivers have accepted such countermeasures; emphasizing that training is a critical component for new technologies to assist older drivers. Panelists indicated that conformal vision enhancement systems are a logical countermeasure for a contrast sensitivity deficit, pending further research.

Driver safety education providing only theory received a likelihood of effectiveness rating in the bottom third of the scale for drivers with a contrast sensitivity deficit.

VISUAL FIELDS

A visual fields deficit was associated with a failure to detect potential conflicts, hazards, or traffic control information (Critical Performance Error #1). As with acuity and contrast sensitivity deficits, this was the only Critical Performance Error that the expert panelists mapped to a deficit in visual fields. This performance error could cause an older driver to be involved in a crash in any of the five driving situations prioritized as high-risk for older drivers.

Nine countermeasures were identified from the literature review and expert panel tasks with varying degrees of likelihood to remediate a visual fields deficit. Only one was rated by the panelists as highly likely to be effective: training in compensatory head/eye movements (scanning strategies). Panelists agreed that although this is an appropriate countermeasure for visual field deficits, it is not appropriate for drivers with cognitive impairment. This type of training has been used for telescopic and amorphic lens drivers and has been effective in improving peripheral visual detection.

Panelists rated seven of the nine countermeasures in the middle third of the effectiveness scale, indicating a need for more information/research before they could endorse the interventions for drivers with visual fields deficits. These were:

- Avoidance of challenging driving situations;
- Central vision enhancement systems;
- Visual field expansion systems;
- Driver safety education incorporating theory plus behind-the-wheel-training;
- Driver safety education delivered via interactive/computer-based technology;
- Education about driving aids (e.g., CarFit); and
- Medical management (including pharmacy review).

Comments and concerns for visual field expansion systems and education about driving aids are presented below; discussion for the other five countermeasures was presented earlier.

Panelists indicated that visual field expansion systems have a lot of promise for remediation of visual field deficits (based on small-scale studies); however, larger studies need to be conducted and there is a need for the OT and rehabilitation communities to define and develop the curricula. Panelists considered prisms and other technologies for addressing visual field loss not appropriate for drivers with cognitive deficits. They indicated that a 100-degree binocular field is a good minimum standard; if a driver has less than 100 degrees and is adamant about driving, the standard of care should be to offer these systems to see if the driver can adapt. Further, a video feed may be better than amorphic lenses to expand the visual field, because the peripheral extent required for driving is incorporated in the lens. [4]

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[4] For patients with tunnel vision, Peli, Luo, Bowers, and Rensing (2007) describe an augmented-vision system using a miniature video camera that provides minified edge images of the scene shown on a head-mounted display. This enables patients to see and detect potential obstacles and locate other objects that, without the minification, would fall outside of their residual visual field. Once an object is detected in the head-mounted display, patients can view it directly though the see-through display with the full resolution and color sensitivity of their natural vision, without limiting the clarity of the see-through view.

With regard to education about driving aids, Panelists stated that many vehicles have safety features that need to be adjusted to meet the needs of the driver, and older drivers often do not know how to make these adjustments. Thus, education in fitting safety equipment to the driver has the potential to help older drivers stay on the road longer. This countermeasure merits further research. Several panelists (OTs) indicated that some CarFit event staff remove mirrors from their example bag because they don't want to be liable for somebody getting a mirror, not understanding how to use it, and having a crash. Using adaptations and mirrors requires training and practice. At CarFit, an OT may adjust a mirror for a driver and explain how the new setting eliminates blind spots. The OT will then set the mirrors back as they were when the driver arrived at the event. This is required to prevent OTs from being liable for making a change; the driver must make the change. In general, more research is needed to determine optimal mirror positions, driver training required to use them safely, and the professionals qualified to deliver the training.

Driver safety education providing only theory received a likelihood of effectiveness rating in the bottom third of the scale for drivers with a visual field deficit.

DEPTH AND MOTION PERCEPTION

A deficit in depth or motion perception was associated with two of the nine Critical Performance Errors: a gap-judgment error, where a driver is not able to accurately estimate closing speed and distance (Critical Performance Error #2); and an inability to predict the development of future conflicts from current traffic and contextual information (Critical Performance Error #3). Both errors assume there is no sensory deficit. Each of these Critical Performance Errors could result in any of the five crash types in which older drivers are most strongly overrepresented, as highlighted in the taxonomy table (see Figure 6).

Six countermeasures were identified from the literature review and expert panel tasks with varying degrees of likelihood to remediate a depth or motion perception deficit. None were rated as highly likely to be effective, given the present state of the knowledge.

Four received likelihood-of-effectiveness ratings in the middle of the scale, indicating a need for more research:

- Avoidance of challenging driving situations.
- Driver safety education incorporating theory with behind-the-wheel instruction.
- Driver safety education delivered via interactive/computer-based technology.
- Medical management (including pharmacy review).

Two countermeasure options received ratings at the bottom of the likelihood-of-effectiveness scale:

- Driver education-theory/classroom only; and
- Education about driving aids.

DARK ADAPTATION AND GLARE RECOVERY

A deficit in dark adaptation and glare recovery was associated with a failure to visually detect potential conflicts, hazards, or traffic control information (Critical Performance Error #1). This was the only Critical Performance Error that the expert panelists mapped to this deficit. This driver performance error could cause a crash in three of the five driving situations identified as high-risk for older drivers: turning right at a yield-controlled intersection in a channelized turn lane and merging with traffic approaching from the left on a principal arterial (Crash Type #3); merging at a yield sign upon entrance to a limited access highway (Crash Type #4); and making a lane change on a multilane roadway (Crash Type #5).

Seven countermeasures were identified from the literature review and expert panel tasks with varying degrees of likelihood of effectiveness to remediate a dark adaptation and glare recovery deficit. Only one was rated by panelists as highly likely to be effective: cataract surgery.

Four were rated in the middle of the scale, indicating the need for more research:

- Avoidance of challenging driving situations;
- Driver safety education incorporating theory with behind-the-wheel instruction;
- Driver safety education delivered via interactive/computer-based technology; and
- Medical management (including pharmacy review).

Two potential countermeasures received ratings at the bottom of the likelihood-of-effectiveness scale:

- Driver education-theory/classroom only; and
- Education about driving aids.

SPEED OF PROCESSING

A deficit in speed of processing was associated with six of the nine Critical Performance Errors: a gap-judgment error, (Critical Performance Error #2); an inability to predict the development of future conflicts from current traffic and contextual information (Critical Performance Error #3); slowed vehicle control response (Critical Performance Error #4); inadequate visual search/improper lookout (Critical Performance Error #5); slowed decision-making, where the traffic situation has changed by the time a maneuver is initiated, resulting in a potential conflict (Critical Performance Error#6); and inappropriate response selection (Critical Performance Error #9). All Critical Performance Errors with the exception of inappropriate response selection could lead to any of the five high-priority crash types listed at the top level of the taxonomy table in Figure 8. Inappropriate response selection could lead to crashes at intersections involving a left turn at a stop sign (Crash Type 1), a left turn at a permissive signal (Crash Type 2), or a crash when turning right at a yield sign in a channelized right-turn lane (Crash Type 3).

Eight countermeasures were identified from the literature review and expert panel tasks with varying degrees of likelihood to remediate a speed of processing deficit. None were rated as highly likely to be effective, given the present state of the knowledge.

Panelists rated seven of these eight countermeasures in the middle third of the effectiveness scale, indicating that there was a need for more information/research before they could be endorsed as likely to remediate a speed of processing deficit. These were:

- Avoidance of challenging driving situations;
- Speed of processing training;
- Physical aerobic/activity training;
- Driver safety education incorporating theory plus behind-the-wheel-training;
- Driver safety education delivered via interactive/computer-based technology;
- Collision warning systems; and
- Medical management (including pharmacy review).

Comments and concerns for all countermeasures with the exception of speed of processing training and physical aerobic/activity training were discussed above for contrast sensitivity deficits.

With regard to speed of processing training, panelists agreed this may be a viable countermeasure, but there is a need to establish the link between training on the task and transfer to driving. Prior work has demonstrated that speed-of-processing training improves speed-of-processing performance on the trained task, but the question of how well such training transfers to the speed at which people perform everyday tasks with real-world stimuli has not yet been answered satisfactorily. Pending the emergence of such evidence, the duration or sustainability of training effects also need more research; and, the depth of training (time course, number of trials) needed to produce operationally significant improvements in performance is unknown. Because of hypothesized mobility benefits, a determination of whether speed-of-processing gains are associated with changes in driver exposure is also of interest. New findings from the ACTIVE trial may shed light on the impact of speed of processing training on driving outcomes at six years after entry into the study, according to one panelist; but these findings were not published as of the date of this report.

With regard to physical aerobic activity/training, panelists noted that the literature in the area of exercise and cognitive function is mixed, with some studies showing improvement and others showing no effect. One problem may be that the exercise interventions are too brief to result in an improvement. Of the 46 drivers interviewed in this project, only 12 reported that they participate in regular aerobic exercise.

Driver safety education providing only theory received a likelihood of effectiveness rating in the bottom third of the scale for drivers with a speed of processing deficit.

SELECTIVE ATTENTION

Critical Performance Errors associated with a deficit in selective attention mirror those associated with a deficit in speed of processing (namely, #2, 3, 4, 5, and 6), leading to any of the five prioritized Crash Types in the taxonomy table; and Critical Performance Error #9, leading to Crash Types 1, 2, and 3.

Ten countermeasures were identified from the literature review and expert panel tasks with varying degrees of likelihood to remediate a selective attention deficit. None were rated as highly likely to be effective, given the present state of the knowledge.

Nine of the ten countermeasures were rated in the middle third of the effectiveness scale, indicating that there was a need for more information/research before they could be endorsed by the panelists as likely to be effective for a selective attention deficit. These were:

- Avoidance of challenging situations;
- Conformal vision enhancement systems;
- Speed of processing training;
- Driver safety education incorporating theory plus behind-the-wheel-training;
- Driver safety education delivered via interactive/computer-based technology;
- Collision warning systems;
- Medical management (including pharmacy review);
- Cognitive rehabilitation (including memory training) for the normally aging population; and
- Compensatory cognitive/memory training for the mildly cognitively impaired (MCI) population.

Comments and concerns for all countermeasures, with the two exceptions of cognitive rehabilitation (including memory training) for the normally aging population and compensatory cognitive/memory training for the mildly cognitively impaired population, were discussed above for contrast sensitivity and speed of processing deficits.

With regard to cognitive rehabilitation (and memory training) for the normally aging population, panelists indicated that cognitive rehabilitation builds subskills for the driving task, but OT's must explain how the skill a client has learned in the clinic could be applied to everyday practical situations such as driving. Panelists agreed that cognitive rehabilitation has real promise as a countermeasure, but is in its infancy as far as developing the training protocols and guidelines to make sure the training is appropriate for the individual, including preventative, restorative, and maintenance interventions. Also, few cognitive rehabilitation specialists also specialize in driving rehabilitation. Because many of the current tools are untested, panelists expressed concern with marketing cognitive retraining tools to the public, as opposed to their application by experts who can make informed decisions. Panelists indicated that cognitive rehabilitation and memory training are not appropriate for the dementia population, because dementia is progressive; clients with dementia cannot learn and remember the strategies.

The panel considered compensatory strategies/memory training that target the strategic level of driving performance to be appropriate for the MCI population. Panelists were cautious about recommending cognitive interventions for people with early stage dementia, and ruled out restorative interventions for this group. Someone with early stage dementia may have good situational awareness and operational control of a vehicle, but could have a memory deficit that would manifest in navigational difficulties. A panelist who is a physician indicated that it is difficult to define where MCI begins and where it ends. It is unknown whether drivers with MCI can benefit from interventions because, historically, they have been excluded from studies so as not to confound the study results.

One countermeasure, driver education-theory/classroom only, received a rating at the bottom of the likelihood-of-effectiveness scale for drivers with selective attention deficits.

DIVIDED ATTENTION

Critical Performance Errors associated with a deficit in divided attention mirror those associated with a deficit in selective attention and speed of processing (namely, #2, 3, 4, 5, and 6), leading to any of the five Crash Types highlighted in the taxonomy table; and Critical Performance Error #9, leading to Crash Types 1, 2, and 3.

Ten countermeasures were identified from the literature review and expert panel tasks with varying degrees of likelihood to remediate a divided attention deficit. None were rated as highly likely to be effective, given the present state of the knowledge.

Nine of the ten countermeasures were rated in the middle third of the effectiveness scale, indicating that there was a need for more information/research before they could be endorsed by the panelists as likely to be effective for a divided attention deficit. These were:

- Avoidance of challenging situations;
- Speed of processing training;
- Physical aerobic activity/training;
- Driver safety education incorporating theory plus behind-the-wheel-training;
- Driver safety education delivered via interactive/computer-based technology;
- Collision warning systems;
- Medical management (including pharmacy review);
- Cognitive rehabilitation (including memory training) for the normally aging population; and
- Compensatory cognitive/memory training for the mildly cognitively impaired (MCI) population.

One countermeasure, driver education-theory/classroom only, received a rating at the bottom of the likelihood-of-effectiveness scale for drivers with divided attention deficits.

WORKING MEMORY

A deficit in working memory was associated with two of the nine Critical Performance Errors: a gap-judgment error (Critical Performance Error #2); and an inability to predict the development of future conflicts from current traffic and contextual information (Critical Performance Error #3). Both errors could lead to any of the five Crash Types highlighted in the taxonomy table in which older drivers are over-involved.

Eight countermeasures were identified from the literature review and expert panel tasks with varying degrees of likelihood to remediate a working memory deficit. None were rated as highly likely to be effective, given the present state of the knowledge.

Seven of the eight countermeasures were rated in the middle third of the effectiveness scale, indicating that there was a need for more information/research before they could be endorsed by the panelists as likely to be effective for a working memory deficit. These were:

- Physical aerobic activity/training;
- Driver safety education incorporating theory plus behind-the-wheel-training;
- Driver safety education delivered via interactive/computer-based technology;
- Medical management (including pharmacy review);
- Cognitive rehabilitation (including memory training) for the normally aging population;
- Compensatory cognitive/memory training for the mildly cognitively impaired (MCI) population; and
- Pre-trip planning.

Comments and concerns for all countermeasures with the exception of pre-trip planning were discussed earlier.

Pre-trip planning is at the strategic level in hierarchical models of driver behavior (cf. Michon, 1985). It involves a conscious decision to plan the intended driving route, including avoiding challenging or difficult intersections, and could also include other self-imposed restrictions relating to time of day (daytime rather than night), type of weather (dry versus in the rain or snow) and subjective health conditions (e.g., avoiding driving when fatigued, or when impaired by medication-side effects, or impairing symptoms of medical conditions). The expert panelists added this countermeasure to the taxonomy table. They agreed that it merits further research for deficits in working memory and executive function, as well as for knowledge deficits. Because it requires practice, pre-trip planning may also help with memory deficits.

Panelists indicated that trip planning ties in with mobility management counseling—the idea of introducing other modes of transportation for those times that a driver shouldn't drive, because of functional impairments. This strategy may extend driving, to the extent that near-misses or confusion while driving can result from being lost. If people can learn an intervention like memorizing or previewing a (novel) route, it could translate to greater capacity for serial processing of the moment-to-moment demands of traffic conditions. In the older driver interviews conducted in this project, 43% of the crash-involved sample and 16% of the crash-free sample reported that they plan their route before they leave, and that this is a change in driving habits made over the past 5- to 10-year period.

One countermeasure, driver education-theory/classroom only, received a rating at the bottom of the likelihood-of-effectiveness scale for drivers with working memory deficits.

EXECUTIVE FUNCTION (JUDGMENT AND DECISION-MAKING)

Critical Performance Errors associated with a deficit in executive function mirror those associated with a deficit in selective attention, divided attention, and speed of processing (namely, #2, 3, 4, 5, and 6), leading to any of the five Crash Types highlighted in the taxonomy table; and Critical Performance Error #9, leading to Crash Types 1, 2, and 3.

The same eight countermeasures identified to remediate a working memory deficit were identified as appropriate for remediating a deficit in executive function, with varying degrees of effectiveness. None were rated as highly likely to be effective, given the present state of the knowledge.

Seven of the eight countermeasures were rated in the middle third of the effectiveness scale, indicating that there was a need for more information/research before they could be endorsed by the panelists as likely to be effective for a deficit in executive function. These were:

- Physical aerobic activity/training;
- Driver safety education incorporating theory plus behind-the-wheel-training;
- Driver safety education delivered via interactive/computer-based technology;
- Medical management (including pharmacy review);
- Cognitive rehabilitation (including memory training) for the normally aging population;
- Compensatory cognitive/memory training for the mildly cognitively impaired (MCI) population; and
- Pre-trip planning.

One countermeasure, driver education-theory/classroom only, received a rating at the bottom of the likelihood-of-effectiveness scale for drivers with deficits in executive functioning.

SPATIAL ABILITIES

A deficit in spatial abilities was associated with four of the nine Critical Performance Errors: a gap-judgment error (Critical Performance Error #2); an inability to predict the development of future conflicts from current traffic and contextual information (Critical Performance Error #3); inadequate visual search/improper lookout (Critical Performance Error #5); and slowed decision-making, where the traffic situation has changed by the time a maneuver is initiated, resulting in a potential conflict (Critical Performance Error #6). All four errors could lead to any of the five Crash Types highlighted in the taxonomy table in which older drivers are over-involved.

Five countermeasures were identified from the literature review and expert panel tasks with varying degrees of likelihood to remediate a deficit in spatial abilities. None were rated as highly likely to be effective, given the present state of the knowledge. In addition, the panelists who are OTs noted a serious deficit in spatial abilities should categorically rule out driving, as such deficits manifest themselves in lane control difficulty.

Four of the five countermeasures were rated in the middle third of the effectiveness scale, indicating that there was a need for more information/research before they could be endorsed by the panelists as likely to be effective for a spatial abilities deficit. These were:

- Visual perceptual therapy;
- Driver safety education incorporating theory plus behind-the-wheel-training;
- Driver safety education delivered via interactive/computer-based technology; and
- Medical management (including pharmacy review).

One countermeasure, driver education-theory/classroom only, received a rating at the bottom of the likelihood-of-effectiveness scale for drivers with deficits in spatial ability.

KNOWLEDGE

A knowledge deficit was associated with three of the nine Critical Performance Errors: an inability to predict the development of future conflicts from current traffic and contextual information (Critical Performance Error #3); a lack of understanding of rules of the road (Critical Performance Error #7), or a lack of understanding of safe driving practices (Critical Performance Error #8). Errors 3 and 8 could result in any of the five Crash Types highlighted in the taxonomy table in which older drivers are overrepresented. Error 7 could lead to four of the five (the exception being a crash associated with a lane-change maneuver).

Six countermeasures were identified from the literature review and expert panel tasks with varying degrees of likelihood to remediate a knowledge deficit. Five of the six were rated as highly likely to be effective, given the present state of the knowledge. These included:

- Driver safety education: theory/classroom only;
- Driver safety education incorporating theory plus behind-the-wheel-training;
- Driver safety education delivered via interactive/computer-based technology;
- Education about driving aids (such as CarFit); and
- Pre-trip planning.

Knowledge deficits were the only type of deficit for which driver education was rated highly likely to be effective. For knowledge deficits, there was a general consensus that it makes sense to provide education, despite mixed results in the research literature, since it is likely to work for some drivers.

One countermeasure, medical management (including pharmacy review), was rated in the middle third of the effectiveness scale, indicating that there was a need for more information/research before they could be endorsed by the panelists as likely to be effective for a knowledge deficit.

HEAD/NECK/TRUNK RANGE OF MOTION

A deficit in head/neck/trunk range of motion was associated with two of the nine Critical Performance Errors: failure to visually detect potential conflicts, hazards, or traffic control information (Critical Driver Performance Error #1); and slowed vehicle control response (Critical Driver Performance Error #4). Each of these errors could lead to four of the five Crash Types highlighted in the taxonomy table in which older drivers are over-involved. The only exception is Crash Type 2, because in that scenario a driver would be looking straight ahead at the signal and/or assessing gaps in oncoming traffic. This contrasts with Crash Types 1 and 3, where a driver needs to scan left and right for traffic approaching on a cross street; with Crash Type 4, where the conflict arises from traffic merging from the sides; and with Crash Type 5, where conflicts involve vehicles approaching from the rear.

Ten countermeasures were identified from the literature review and expert panel tasks with varying degrees of likelihood to remediate a deficit in head/neck/trunk range of motion. Three were rated as highly likely to be effective, given the present state of the knowledge. These were:

- Training in compensatory head/eye movements (scanning strategies);
- Strength and flexibility exercises; and
- An aftermarket, non-planar driver side mirror.

A panelist who is a vision specialist also indicated that eye movement training would be important for someone who can't move his or her neck.

With regard to strength and flexibility exercises, countermeasure evaluations have demonstrated improvements in on-road driving performance, and panelists agreed that this was an appropriate countermeasure with a high likelihood of effectiveness. In the older driver interviews conducted in this project, 62% of the crash-involved and 20% of the crash-free sample indicated that they regularly participated in strength and flexibility exercises.

With regard to the use of non-planar mirrors, while panelists judged this intervention as likely to be effective, participating OTs were concerned that this practice could incur liability in a rehabilitation context. They noted that (re-)aiming mirrors for drivers during a CarFit event incurs liability. So, after instructing drivers about proper aiming techniques, OTs put the mirrors back to their original position, i.e., as they were aimed when the driver arrived at the evaluation. Current standards require the driver side mirror to be planar (flat), while the passenger side mirror may be convex or planar; however, aftermarket "bulls eye" convex mirrors are available that can be applied to the planar mirror. No evaluations of this countermeasure were uncovered in the literature review, specific to older drivers. Prior evaluations by NHTSA have found that detection of adjacent-lane vehicles can be enhanced by the use of driver's side non-planar mirrors, but the image distortions they introduce can render drivers' gap and distance judgments for vehicles approaching/overtaking from the rear inaccurate (Staplin, Lococo, Sim, & Gish, 1998). Thus, non-planar mirrors would require optical distortion training, but there is no standard for providing such instruction.

Six of the 10 countermeasures were rated in the middle third of the effectiveness scale, indicating a need for more information/research before panelists could endorse them as likely to be effective for a deficit in head/neck/trunk range of motion. These were:

- Physical aerobic activity/training.
- Driver safety education incorporating theory plus behind-the-wheel-training.
- Driver safety education delivered via interactive/computer-based technology.
- Education about driving aids.
- Collision warning systems.
- Medical management (including pharmacy review).

One countermeasure, driver education-theory/classroom only, received a rating at the bottom of the likelihood-of-effectiveness scale for drivers with head/neck/trunk range of motion deficits.

For all three physical deficits listed in the taxonomy table (restrictions in head/neck/trunk range of motion; arm strength range of motion/speed of movement; and leg strength range of motion/speed of movement), panelists stated that classroom driver education may be useful as it raises awareness of deficit so drivers can self restrict, and may also motivate individuals to initiate activity (e.g., to exercise). Panelists deemed education alone as unlikely to be effective.

ARM STRENGTH/RANGE OF MOTION/SPEED OF MOVEMENT AND LEG STRENGTH RANGE OF MOTION/SPEED OF MOVEMENT

These two deficits are grouped together for discussion because they underlie the same Critical Driver Performance Error and resulting crash types, and may be remediated with the same behavioral countermeasures.

A deficit in arm or leg strength/speed of movement/range of motion was associated with one of the nine Critical Performance Errors: slowed vehicle control response (Critical Driver Performance Error #4). This error could lead to any of the five Crash Types highlighted in the taxonomy table in which older drivers are over-involved.

Seven countermeasures were identified from the literature review and expert panel tasks with varying degrees of likelihood to remediate these deficits. Two, physical aerobic activity/training and strength and flexibility exercises, were rated as highly likely to be effective, given the present state of the knowledge.

Four were rated in the middle third of the effectiveness scale, indicating a need for more information/research before they could be endorsed by the panelists as likely to be effective for these deficits. These were:

- Driver safety education incorporating theory plus behind-the-wheel-training;

- Driver safety education delivered via interactive/computer-based technology;
- Education about driving aids (e.g., CarFit); and
- Medical management (including pharmacy review).

One countermeasure, driver education-theory/classroom only, received a rating at the bottom of the likelihood-of-effectiveness scale for drivers with deficits in arm or leg strength/speed of movement/range of motion.

DISCUSSION AND CONCLUSIONS

This study addressed the role of specific age-related functional deficits as contributing factors in selected types of motor vehicle crashes by older drivers, via their potential to influence the probability and/or severity of critical driver performance errors. To the extent these connections are sound, they underscore the potential for behavioral countermeasures targeted to the remediation or accommodation of such deficits to attenuate critical errors in performance, and thus reduce crash risk. The following discussion highlights several conclusions from this work, and identifies opportunities to advance older driver safety and mobility through continuing research and program development based on present findings.

One conclusion derives from examination of the linkages of the five prioritized Crash Types to the nine Critical Driver Performance Errors (see Figure 6). All but two Critical Driver Performance Errors (which in turn manifest age-related functional deficits) could result in any of the major Crash Types. The only exceptions are for Error 7 (lack of understanding of rules of the road), which lacks a tie to Crash Type 5, and Error 9 (inappropriate response selection), which lacks ties to Crash Types 4 and 5. This suggests that *remediation of functional deficits has broad potential for crash reduction*; it is not specific to any particular crash type.

Another conclusion may be drawn from a comparison of the driver interview data on driving difficulties and the Critical Driver Performance Errors listed in the taxonomy table. Overall, few drivers reported difficulty with any of the queried driving situations, with the exception of difficulty seeing at night (44% of the crash-free sample and 48% of the crash-involved sample). Difficulty seeing at night could lead to Critical Driver Performance Error 1: failure to visually detect potential conflicts. Notably, 67% of those who indicated they had difficulty driving at night reported driving at night anyway. At the same time, self-reports indicated that two-thirds of the crash-involved drivers and a third of the crash-free drivers avoided night driving. And, 44 of 46 drivers interviewed (96%) indicated that they regularly have an eye exam, and 24% of this sample reported having cataract surgery. These data reveal that *when older drivers are aware of a functional impairment, they will make an effort to compensate or correct it, but are likely to continue to drive in some instances.*

A high percentage of drivers reported <u>no difficulty</u> with the following situations: judging gaps (93%), detecting traffic in the periphery (93%), judging the actions of others (80%), and changing lanes/merging (87%). These difficulties feed directly into the Critical Driver Performance Errors listed in the taxonomy table (specifically #2, 3, and 5), which were associated with all five Crash Types in which older drivers are overrepresented. Very few of the older drivers interviewed reported avoiding the driving situations that are associated with the greatest increase in crash risk for this group (only 11% avoided left turns and 20% avoided changing lanes). This suggests that *many older drivers are unaware of these consequences of functional aging on driving task performance, presenting a significant opportunity to improve safety through appropriate educational interventions.*

As emphasized in this report, determinations of the likely effectiveness of the included behavioral countermeasures are based largely on expert opinion, with only limited evaluation data available, and must therefore be regarded as preliminary. Nevertheless, the experience of the participating clinicians provides valuable guidance for developing and implementing behavioral countermeasures, even as evaluation studies proceed.

One unavoidable conclusion is that *self-awareness drives the application of any strategy or countermeasure unless it is absolutely passive to the client's will.* Passive measures may be employed without dependence on the person's will or awareness. But if an individual must remember to employ a countermeasure or believe it is needed, then a rehabilitation professional should be involved in determining if a particular intervention is appropriate.

In this regard, the role of the professional in implementing the specialized training and/or adaptive equipment associated with many potential countermeasures to preserve or restore function among older drivers needs to be clearly stated. Attempts to keep impaired drivers on the road longer with devices or strategies that improve competence in very specific areas carry significant risk. The fact that a professional driving evaluation costs several hundred dollars, in most cases not reimbursable by insurance, may be cited as a rationale for the narrow application of a countermeasure instead of a more comprehensive approach. *Research is needed to define the boundaries of what can be responsibly prescribed or advocated as a countermeasure for age-related diminished capabilities outside of a formal rehabilitation context, and what interventions should or shall only be administered with the guidance and supervision of a driving rehabilitation professional.*

This study has for the most part excluded adaptive equipment in its consideration of behavioral countermeasures—at least the most common examples: spinner knobs, pedal extenders, left foot accelerators, and seat cushions. As noted earlier, research findings that document the effectiveness of such devices are elusive. But the manner in which these aids are prescribed further underscores the role of rehabilitation professionals. Under best practice, a driver would go to a driving rehabilitation specialist (DRS) who would consider their vehicle model and all the types of adaptations that might work, and tailor their choice to the individual's needs. Then, the driver would purchase the adaptation that was recommended by the DRS, and would have it installed in their vehicle. The DRS would then inspect the installation and train the driver in the use of the equipment. In reality, adaptive equipment is readily available for purchase via the Internet or in auto parts stores, and people buy it without being evaluated for their need, or trained in its use; and, there are no controls for proper installation. *Research is needed to develop standards of care for adaptive equipment installation and training.*

The work in this project provides additional guidance for behavioral countermeasures in two specific areas. First, *the vision countermeasures require intact cognition, to realize the desired safety and performance gains.* If cognition is not intact, then vision measures must be supplemented by other strategies that address the cognitive deficit. Also, some countermeasures are used in combination with legal restrictions on driving. *Judgment and self-awareness are critical to the effectiveness of a restriction countermeasure.*

Finally, there is a clear need for continuing research to understand the extent to which age-related functional change places older drivers (and all motorists) at risk, and the extent to which existing or innovative countermeasures can compensate for such changes. In developing this taxonomy of older driver behaviors and crash risk, the current study has provided important insights about the operating conditions and traffic situations where crashes involving older drivers are most prevalent. Yet there is a critical gap in knowledge about how often older drivers are exposed to the most risky situations, either relative to the exposure of all drivers or to their own exposure at younger ages when they were functionally intact. Notwithstanding our efforts to apply induced exposure methods, without this information it will remain extremely problematic to apportion safety gains to interventions that preserve or restore function, or that compensate for functional loss, versus a simple restriction in exposure—self-imposed or otherwise.

Similarly, significant gaps in knowledge exist with respect to the role of functional deficits in older driver crashes. The most extensive and rigorous study to date linking functional status to safety outcomes (Staplin, Lococo, Gish, & Decina, 2003b) has focused attention on a core set of capacities that, when in decline, place older drivers at significantly higher risk of causing a crash. Subsequent research to refine and expand the evidence base for predicting crash risk through functional assessment is now underway (Staplin et al., n.a.). But an understanding of how specific deficits mediate crash risk that is sufficient to establish benchmarks for countermeasure development will not result solely from case-control investigations; it requires at least some knowledge of the driving contexts in which performance errors reflecting those deficits are manifested. Again, a lack of exposure information is a major barrier.

Consequently, *there is a need to collect functional status data for a large group of (older) drivers whose exposure can be characterized in terms of road, traffic, and environmental characteristics, and for whom reliable crash data can be obtained over a multi-year interval*. Any State that introduces even limited functional screening at license renewal would be an ideal venue for such research. Failing this, appropriate incentives coupled with a credible guarantee of confidentiality must be offered to recruit study participants. The administrative as well as the technical hurdles involved in a project of this magnitude would be substantial. However, this integration of function, exposure, and safety data would not only describe a true taxonomy of older driver problems, it would permit evaluations of countermeasure effectiveness that are free of the most serious confounds in work performed to date.

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Appendix A:

Expert Panel Commentary for Countermeasures

Appendix A: Expert Panel Commentary for Countermeasures.

Countermeasure A: Refractive Correction (Including Wavefront Technology)	
Description	Refractive examination by optometrist or ophthalmologist and prescription for corrective lenses. A panel member (vision specialist) recommended inclusion of Wavefront technology as part of refractive correction. Wavefront technology diagnoses higher-order vision errors represented by the way the eye refracts or focuses light; such aberrations defocus images even with 20/40 acuity. Wavefront guided lenses can reduce certain higher-order aberrations, which potentially can improve low light image quality during activities such as driving at night.
Countermeasure Evaluation	No before-after studies on refraction correction (updating prescription for corrective glasses) and driving safety uncovered. Studies on effectiveness of Wavefront technology are currently limited to that conducted by lens manufacturer (so caution must be exercised in interpreting the results; see Haddrill, 2007). Another caution noted by the panelist regarding the lens company research is that improvements in vision with the wavefront lenses were compared to patients' vision as they appeared for the study. But it is well known that many patients, especially those over age 60, haven't had regular eye check-ups or new prescriptions. Haddrill (2007): Ophthonix founder A. Dreher reports that Ophthonix iZon wavefront guided lenses provide higher definition vision in the daytime and significantly improve night driving responses when compared with conventional lenses. Night vision improved a driver's ability to identify pedestrians by an average of 330 ms (30 ft sooner at 55 mi/h) when compared to conventional lenses. www.allaboutvision.com/lenses/wavefront-lenses.htm; http://ophthonix.izonlens.com/globals/faqs.asp; www.allaboutvision.com/whatsnew/lenses1.htm.
Expert Commentary	Panelist with expertise in the area stated that in the ophthalmology literature there is quite a bit of research on age and satisfaction for refractive errors corrective surgery. There is actually quite ample literature on people's feelings about their improved performance in everyday tasks there, discussing the clarity with which they can see things. It would seem reasonable that one would have asked the question about improved driving performance as a result of refractive error correction, but the panelist was not aware of anything done. Even without research on effectiveness, panelists agreed that refractive correction should be advocated just on the prevalence of the problem and the inexpensiveness of the solution, particularly as there appears to be a decline in the number of older people who get annual eye exams. Annual eye exams, refractive correction, and sooner diagnosis of treatable conditions (e.g., cataracts) are inexpensive solutions for reaching a substantial number of people for remediation. Vision specialist feedback to drivers regarding the driver licensing laws in their State in relation to their own level of impairment is important (and presently rare in practice); increasing awareness of impairments may lead to appropriate self-restriction. One of the early findings of the Salisbury Eye Study was that among the proportion of older individuals who had worse than 20/40 vision, more than half of them could be corrected just with glasses.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Acuity: 11/11 panelists; (MLE = 4.0) • Contrast Sensitivity: 11/11 panelists; (MLE = 3.89) MLE ratings for both functional deficits indicate panelists' confidence that countermeasure is likely to be effective as an intervention for these deficits, in promoting safe driving practices (MLE ratings in the top third).

Countermeasure B: Cataract Surgery	
Description	Cataracts cause acuity and contrast sensitivity deficits, and increased disability glare (Owsley, McGwin, Sloane, Wells, Stalvey, & Gauthereaux, 2002). They are treatable by surgical removal of the crystalline lens followed by intraocular lens (IOL) insertion.
Countermeasure Evaluation	McGwin, Scilley, Brown, and Owsley (2003) found improvements in acuity with cataract surgery, and that improvement in visual acuity had a significant, independent association with the change in activities of daily vision scale (that includes daytime and nighttime driving). Wood and Carberry (2006) found that improvement in acuity that accompanied cataract surgery was related to improvement in overall driving score. Monestam and Wachtmeister (1997): Self reported problems with distance judgment declined from 37% to 6% of sample following cataract surgery. McGwin et al. (2003): contrast sensitivity improved significantly in the sample that underwent surgery, and day and night driving scores on Activities of Daily Vision Scale significantly improved post-operatively in surgery group. McGwin et al. (2003): disability glare improved significantly post surgery in group of patients with cataract. First surgery eye improvement in acuity significantly related to change in overall activities of daily vision scale and night driving and glare disability subscales. Change in disability glare in second surgery eye significantly assoc. w/change in ADVS score as well as change scores in night driving, near vision, and disability glare subscales. Owsley et al. (2002): Patients with a cataract who underwent surgery and IOL implantation had half the crash rate of drivers with cataract who did not undergo surgery (4.74 crashes per million miles of travel vs. 8.95). Wood and Caraberry (2006): Bilateral cataract surgery resulted in significant improvements in on-road performance, related to improvements in CS.
Expert Commentary	Panelists agree this is a relatively inexpensive treatment and improvements result in crash reduction. Cataracts are often the only medical condition affecting driving performance. Even if crash reduction benefit is small, cataract surgery may provide a large public health benefit because of the large number of people affected by cataracts.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Acuity: 11/11 panelists; (MLE = 4.60) • Contrast Sensitivity: 11/11 panelists; (MLE = 4.56) • Dark Adaptation and Glare Recovery: 11/11 Panelists; (MLE = 4.14) MLE ratings for all three functional deficits indicate panelists' confidence that countermeasure is likely to be effective as an intervention for these deficits, in promoting safe driving practices (MLE ratings in the top third).

Countermeasure C: Avoidance of Challenging Driving Situations (Includes License Restriction, Driver Rehabilitation Specialist Initiated, and Self-Restriction)	
Description	Avoidance of (or restricted exposure to) situations that are difficult or challenging for older drivers, such as night, high-traffic roads, rush-hour traffic, high-speed interstates/ expressways, driving alone, making left-hand turns across oncoming traffic, and rain. May also include restrictions imposed by a licensing agency such as driving only within a prescribed distance from home.
Countermeasure Evaluation	Gallo, Rebok, and Lesikar (1999). Self-reported vision impairment was related to avoidance of challenging driving situations, but not to self-reported citations or crashes in prior 2 years. Authors conclude that vision impaired drivers who self restrict are less likely to crash. Vision impairment categories: no trouble seeing; a little trouble, a lot of trouble (i.e., may not be specific to acuity). Ball, Owsley, Stalvey, Roenker, Sloane, and Graves (1998): No relationship between avoidance score and crashes in subsequent 3 year period. De Raedt and Ponjaert-Kristoffersen (2000): poor performers on a road test but were free of (self-reported) at-fault crashes (prior 12 mo) used significantly more strategic compensation tactics (avoidance of challenging situations) than poor-performing drivers with a history of at-fault crashes. Hennessy (1995): poorer visual field ability (modified Synemed perimeter) was significantly associated with greater avoidance of driving at night, rain, dusk, dawn, and making left turns, but the predictive value of visual fields performance on crash rate (prior 3 yrs) was mediated only for avoidance of left turns; But avoidance did not reduce risk, it increased it (inadequate compensation). Hennessy (1995): older drivers with poor contrast sensitivity (CS) and who (sometimes or often) avoided heavy traffic had a reduced crash risk compared to those with poor CS who did not avoid heavy traffic. Avoidance brought risk equal to that of drivers with good CS. Avoidance of the other situations did not moderate the relationship between CS and crash risk. Hennessy (1995): poorer speed of processing (SOP) ability was significantly associated with greater avoidance of driving at night, rain, dusk, dawn, alone, left turns, and heavy traffic, but the predictive value of the SOP subtask on crash rate (prior 3 yrs) was mediated only for avoidance of left turns; But avoidance did not reduce risk, it increased it (inadequate compensation). Hennessy (1995): poorer divided attention ability was significantly associated with greater avoidance of driving at night, rain, dusk, dawn, alone, left turns, and heavy traffic, but the predictive value of the divided attention subtask of UFOV on crash rate (prior 3 yrs) was not mediated by any of the forms of self restriction. Owsley et al. (1998) found that older drivers with UFOV reduction of 40% or more and who reported driving fewer than 7 days per week had a 45% decreased crash risk compared to older drivers with a 40% or more reduction in UFOV who reported driving 7 days/week.

Countermeasure C: Avoidance of Challenging Driving Situations (Includes License Restriction, Driver Rehabilitation Specialist Initiated, and Self-Restriction)	
Expert Commentary	Panelists indicate this may or may not be effective; "we don't know if this works." People try to self-regulate when there are alternative transportation options, but there are times when they feel they must drive even if they'd rather not (e.g., winter when it gets dark earlier, or no other driver to take them). Making people aware of deficits is the first step in getting people to self restrict, if they will self restrict. Studies show that there are many unaware vision-impaired drivers. Ophthalmologists and optometrists need to be included as targets of outreach, similarly to the AMA guide, and other outreach efforts that NHTSA has done for specialized populations because, eyecare specialists are a group that does not know their red flags to tell patients that "these are the laws in our state and this is what you need to be concerned about." For depth and motion perception deficits, panelists indicated that drivers could choose the route that has a protected turn. The effectiveness really depends on which avoidance behavior is being used and how well it fits with the functional decline for which the driver is trying to compensate. If a person is having difficulty with dark adaptation and glare recovery, choosing to avoid driving at night and in inclement weather would be very effective. However, if he or she chooses to limit driving to familiar areas, that would be less effective in addressing that specific functional decline. So, particularly for this category (avoiding challenging situations), one panelist specifically noted that rating effectiveness it was not at all clear cut. One panelist indicated that effectiveness ratings would be higher with self-regulation than with DRS initiated or licensing agency imposed restrictions, because driver compliance with externally imposed restrictions is unknown. Another noted that a driver must have adequate judgment, memory and self awareness to appropriately employ a restriction and believe it is needed.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Acuity: 11/11 panelists; (MLE = 2.91) • Contrast Sensitivity: 11/11 panelists; (MLE = 3.18) • Visual Fields: 11/11 panelists; (MLE = 2.91) • Depth and Motion Perception: 11/11 panelists; (MLE = 3.09) • Dark Adaptation and Glare Recovery: 11/11 panelists; (MLE = 3.45) • Speed of Processing: 11/11 panelists; (MLE = 2.82) • Selective Attention: 11/11 panelists; (MLE = 2.70) • Divided Attention: 11/11 panelists; (MLE = 2.70) MLE ratings for all eight functional deficits indicate a need for more information/research (MLE ratings in the middle third).

Countermeasure D: Conformal Vision Enhancement System	
Description	An in-vehicle vision enhancement system that overlays an image (on the windshield, in the case of a head-up display) that is directly superimposed on the object it is providing information about. For example, conformal vision enhancement of moving and parked vehicles may consist of a horizontal blue bar superimposed on the bumpers of other vehicles. As the vehicles approach, the blue bar would increase in size (corresponding to the increasing size of the bumper). Conformal enhancement of a traffic light at an intersection may be accomplished by placing a blue bar behind the traffic light, such that it surrounds the light with a sort of halo.
Countermeasure Evaluation	Caird, Horey, and Edwards (2001). Simulator study with 24 younger and 24 older drivers. Conformal enhancement of a traffic light resulted in fewer drivers running the light. Drivers indicated conformal vision enhancement system (VES) would be helpful when environmental conditions restrict visibility, but not under heavy traffic, cluttered environments, or in daytime. Less than 25% indicated they would use VES regularly if available. Oxley and Mitchell (1995) reported that in a sample of older 31 ultraviolet vision enhancement systems (UVES) and 15 infrared vision enhancement systems IVES users, 100% found it easy to use, and 60-73% indicated it would encourage them to drive outside of their usual driving situations. Gish, Staplin, and Perel (1999) found that 3 of 4 older drivers did not use VES to detect targets, but instead used it to detect curves in the road (controlled field study).
Expert Commentary	Panelists stated that older drivers in focus group studies have indicated that they don't like anything in their cars that takes their focus away from the road (either on the windshield or on a heads-down display in the vehicle). They would choose not to drive in challenging situations rather than to use a device that may take their attention from the road, or that may be difficult to operate. Another panelist indicated that following training in equipment use, older drivers are ok with such countermeasures; emphasizing that training is a critical component for new technologies to assist older drivers. Panelists indicated that this countermeasure is logical for a contrast sensitivity deficit, and may be relevant for selective attention deficits pending the results of research on its effectiveness.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Contrast Sensitivity: 11/11 panelists; (MLE = 3.14) • Selective Attention: 10/11 panelists; (MLE = 2.83) MLE ratings for both functional deficits indicate a need for more information/research (MLE ratings in the middle third).

Countermeasure E. Central Vision Enhancement Systems (Bioptic Telescopic Lenses; Implantable Telescopes)	
Description	A bioptic telescopic lens (BTL) is a lens system with a telescope attached to a pair of glasses, mounted above the normal line of sight. This allows a trained user the opportunity to detect objects or movement within the driving scene using the wide field of view available through the regular spectacle lens (the "carrier" lens) and to resolve fine details such as road sign messages and traffic light status by glancing briefly and intermittently into and out of the miniature telescopic unit (by a downward tilt of the head).
Countermeasure Evaluation	Janke and Kazarian (1983): Crash rate in users is 1.5 times higher than population rate, but less than the crash rate of drivers licensed with other medical conditions. Clark (1996): Crash rates for BTL users 1.9 times higher than comparison group, but citation rates 0.7 of that for comparison group. Szlyk et al. (2000): Training in the use of BTL lenses (both lab and on-road) significantly increased performance in recognition, peripheral identification, and scanning compared to performance of non-trained BTL users.
Expert Commentary	Panelists supported the countermeasure if accompanied by training and assessment of driving safety after training. Recommend licensing with restrictions after low-vision driving program/rehab. Use lens only for spotting (5-10% of time). Training curriculum and design of lenses needs to be standardized. Training curriculum needs to be developed by Occupational Therapists. Countermeasure appropriate if no cognitive deficit.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Acuity: 11/11 panelists; (MLE = 3.33) • Contrast Sensitivity: 11/11 panelists (MLE = 2.78) • Visual Fields: 11/11 panelists; (MLE = 3.00) MLE ratings for all three functional deficits indicate a need for more information/research (MLE ratings in the middle third).

Countermeasure F: Visual Field Expansion Systems (Prism, Bioptic Amorphic Lenses, Video Feeds)	
Description	Amorphic lenses are spectacle-mounted cylindrical reversed telescopes that increase the peripheral visual field by minifying the horizontal meridian. Other field expansion systems include video feeds and prisms ground into the lens (although optometrists do not often prescribe them; it is not part of most optometry curricula), and according to one panelist, there are only one or two clinicians applying prism lenses to low vision driving (Eli Peli, O.D., a low-vision clinician for 20 years who heads a large research team at the Schepens Eye Institute, Harvard Medical School, and Evelyn Koenig).
Countermeasure Evaluation	Szlyk et al. (1998) used a bioptic form of an amorphic lens system, with the amorphic lens mounted inferiorly on both the left and right carrier lenses, and provided a 12-week training curriculum in the use of the amorphic system for navigation, mobility, and driving an automobile. Patients' distance prescriptions were incorporated into the carrier lens as well as into the amorphic lens. The study included 15 patients ages 27 to 67. Following training with the lenses (lab and on-road), patients showed improvements in all visual skill categories, including peripheral detection and selecting appropriate gaps. Specific effects of the lenses and training on driving skills *per se* (i.e., as opposed to the visual skills noted above), or on a global driving score, were not reported. However, 86 percent of the subjects in this study reported that they were "satisfied to extremely satisfied" with their lenses and improvement in visual function, although they expressed concerns with their weight and cosmetic appearance, and high cost if they had to be replaced. Authors note further research is necessary to determine safety while driving. Bowers, Keeney, and Peli (2008) evaluated peripheral prism glasses for their ability to improve a patient's walking mobility, which includes obstacle avoidance. Forty-three patients were fitted with prism glasses in 15 community-based clinics around the country. The clinicians interviewed them at six weeks and after 12 months. Success was measured by how many patients continued wearing the prism glasses and by their ranking of the prisms' effectiveness in assisting with obstacle avoidance while walking. Thirty-two participants (74 percent) continued wearing the glasses at week six. At 12 months, 20 (47 percent) were still wearing the spectacles eight hours a day and rating them as "very helpful" for obstacle avoidance. These 12-month-plus patients reported significant benefits for a variety of obstacle avoidance scenarios (e.g. walking in crowded areas, unfamiliar places, shopping malls). A new, higher power, version of the permanent prism glasses recently developed by Chadwick Optical should further expand the visual field and be even more beneficial for patients' mobility, according to Peli. The prototype used in the study expanded the peripheral upper and lower visual fields by 20 degrees without obstructing central vision. The new glasses expand the field by 30 degrees.
Expert Commentary	Panelist stated that 100 degree binocular field is a good minimum standard; if < 100 degrees and adamant about driving, a driver should be offered these systems to see if he/she can adapt to it (should be the standard of care). Target audience would be a driver with 50 degree binocular fields in a State with no visual field requirement, and prisms (ref. Eli Peli) could be used to expand the field to 100 degrees to make driving safer. Video feed may be better than amorphic lenses, because the peripheral extent required for driving is incorporated in the lens. Visual field expansion systems show promise in small-scale studies, however, larger studies need to be conducted and the OT community and rehab community needs to develop curricula. Prisms and other technologies for drivers with visual field loss would not be appropriate countermeasures if the driver also has cognitive deficits.

Countermeasure F: Visual Field Expansion Systems (Prism, Bioptic Amorphic Lenses, Video Feeds)	
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Visual Fields: 11/11 panelists; (MLE = 3.40) MLE rating indicates a need for more information/research (MLE ratings in the middle third).

Countermeasure G: Training in Compensatory Head/Eye Movements, Scanning Strategies	
Description	Compensatory viewing strategies for drivers with peripheral visual field defects (inability to notice objects in the periphery) consist of scanning to enlarge the field of view. Compensatory viewing strategies for drivers with central visual field defects (inability to notice objects in the fixation area) consists of eccentric fixation as well as scanning to assure that no information is concealed by the area of decreased vision.
Countermeasure Evaluation	Coeckelbergh et al. (2001): Training in compensatory viewing strategies, particularly on-road training, improved viewing behavior for people with central or peripheral visual field constriction, and increased the number of subjects who passed a road test who previously failed. Subjects had visual field defects due to ocular pathology; those with severe cognitive impairments were excluded from participation. Laderman, Szlyk, Kelsch, and Seiple (2000): Conducted a 4-week training program on a task in a rehab center setting to teach peripheral detection, scanning, and tracking. Clients sat close to a screen and detected slide images in the periphery using amorphic lenses, then turned their heads toward the object to identify it more clearly through the carrier. Following the rehab center training, an 8-week training program was conducted in-vehicle on a closed course with driving instructor to practice the skills. Before-after training results indicated 39% improvement in tasks involving peripheral detection, and 27% improvement in scanning tasks. Authors note further research is needed to define standards and evaluation methods for training curricula. Dynavision apparatus has been used in office rehabilitation settings to train compensatory scanning strategies for visual inattention and visual field deficit in people with intact attentional mechanisms. Klavora et al. (1995) found that Dynavision training with 10 older (age 46-73) post-CVA individuals resulted in significantly improved behind-the-wheel driving performance when compared with expected outcomes. All failed their first BTW assessment pre-Dynavision training. Training involved three 40-minute Dynavision Training sessions per week for 6 weeks. On the second BTW assessment, 6 of the 10 subjects earned a “safe to resume driving and/or receive on-road driving lessons.”
Expert Commentary	Panelists agreed that this is an appropriate countermeasure for visual field deficits, but candidates must be cognitively intact. This type of training has been used for telescopic and amorphic lens drivers ("search and destroy" method referred to by panelist, described by Laderman et al, 2000) and has been effective in improving peripheral visual detection. It was noted that Mary Warren has a compensatory training program for drivers with visual field defects, but none of the panelists thinks she has published anything. In a follow-up with Mary Warren, she indicated she does not have a specific protocol for behind-the-wheel training that emphasizes head turning, but during pre-driver training, she set a Dynavision criterion of 1 light per second and a score of over 200 on the 4 minute test (based on the Klavora research), and concentrated heavily on divided attention tasks on the apparatus. She also discussed a lot of cognitive strategies with the client in terms of predicting where they were likely to experience difficulty because of hemianopsia: turns and merges towards the deficit side, evasive maneuvers towards the side of the deficit (how to avoid them), parking lots and unpredictable traffic flow. She looked at where they drove, and evaluated those areas for potential threats and looked for alternative routes. She also considered vehicle modifications, such as mirrors. One panelist mentioned a book that may be useful in this training older adults to scan effectively by Ken Mills "Disciplined Attention: How to Improve Your Visual Attention When You Drive." The book (directed toward young driver training) is not a countermeasure that's ready to go, but it's one ready to be researched. The vision specialist panelist indicated that training eye movements would be important for someone who can’t move their neck.

Countermeasure G: Training in Compensatory Head/Eye Movements, Scanning Strategies	
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Visual Fields: 11/11 panelists; (MLE=3.82) • Head/Neck/Trunk Range of Motion: 11/11 panelists; (MLE = 4.0) MLE ratings for both functional deficits indicate panelists' confidence that countermeasure is likely to be effective as an intervention for these deficits, in promoting safe driving practices (MLE ratings in the top third).

Countermeasure H: Speed of Processing Training	
Description	Visual search skills and the ability to identify and locate visual information quickly in a divided attention format.
Countermeasure Evaluation	Roenker et al. (2003): Speed of processing (SOP) training using all 3 subtests of UFOV compared to Doron simulator training and untrained reference group. Global ratings of on-road driving performance improved for both training groups, but only SOP group maintained performance at 18 mo. For "dangerous maneuvers" component, both training groups showed improvements, but only SOP training maintained improvement at 18 mo. Dangerous maneuvers included 6 opportunities for unprotected turns across traffic and 9 left-turn entrances to a high-traffic road.
Expert Commentary	Panelists agreed this may be a viable countermeasure for cognitive rehabilitation, but there is a need to establish the link between training on the task and transfer to driving. A panelist indicated that data were recently presented at a Gerontological Society of America meeting describing speed of processing training on outcomes such as driving frequency, driving exposure, driving difficulty, and crashes. The training was part of an ACTIVE trial described by Ball, Berch, Helmers, Jobe, Leveck, et al., 2002) that found that SOP training improved SOP performance, but that did not transfer to everyday speed at which participants interacted with real-world stimuli (e.g., looking up a telephone number, finding food items on a crowded shelf, etc.). New findings presented at GSA showed an impact for speed of processing training on driving outcomes, at 6 years after entry into the study. The training was associated with increased frequency of driving and increased exposure, prolonged duration of driving in the people that received this kind of training (they ceased driving later than people who did not receive this training), they perceived that they had less driving difficulty and, for the first time, a reduction in crash rate risk was demonstrated prospectively six years after entry into the study.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Speed of Processing: 11/11 panelists (MLE = 3.64) • Selective Attention: 10/11 panelists; (MLE = 3.40) • Divided Attention: 10/11 panelists; (MLE = 3.40) MLE rating for all three deficits indicates a need for more information/research (MLE ratings in the middle third).

Countermeasure I: Physical Aerobic Activity/Training	
Description	Evidence is mounting that physical aerobic activity can increase cognitive function, and provide a protective effect against dementia. An example of a physical aerobic activity intervention in the research is walking for 45-minute periods 3 times per week (Colcombe et al., 2006). In another study, exercise was defined as leisure time physical activity lasting at least 20 to 30 minutes at least twice a week and intense enough to cause breathlessness and sweating (Rovio et al., 2005).
Countermeasure Evaluation	No studies on improvement in driving. In a study by Colcombe et al. (2006), subjects who participated in aerobic exercise showed increased brain volumes in regions associated with age-related decline in both structure and cognition. In their study, 59 healthy but sedentary community-dwelling volunteers ages 60 to 79 participated in a 6-month randomized clinical trial. Half of the older adults were assigned to an aerobic training group and the other half participated in a toning and stretching control group (non-aerobic stretching exercises 3 times per week). Twenty younger adults served as controls on the measure of effectiveness (magnetic resonance imaging) and did not participate in the exercise intervention. Significant increases in brain volume, in both gray and white matter regions were found in the older adults who participated in the aerobic fitness training, but not in the adults who participated in the stretching and toning exercises (nonaerobic) or in the younger controls. During their magnetic resonance imaging protocol, participants performed a focused attention task which required them to focus on a single central object while ignoring irrelevant distractor objects that flanked the target item. Older adults who participated in the aerobic walking protocol were better able to ignore the misleading flanking items, but the control adults were not (Kramer, Erickson, and Colcombe, 2006). Rovio et al. (2005) studied 1,449 older people found that those who exercised during their middle-life (age 30, 40, and 50) were 60 percent less likely to develop Alzheimer's disease in old age (65 to 79) than sedentary adults, and 50 percent less likely to develop other forms of dementia and memory loss. The benefits were apparent even after adjusting for medical and lifestyle factors such as heart/blood vessel disease, locomotor disorders, smoking, alcohol consumption, age, gender, education. The benefits were especially pronounced among those who carried the APO-E4 gene—an inherited trait that increases a person's risk of developing Alzheimer's disease in old age. Colcombe and Kramer (2003) found the largest positive effects of fitness training and cognitive functioning in older (non-demented) adults was on executive control processes. Programs combining aerobic training with strength and flexibility training had the largest effects. Conflicting evidence was found by Marmeleira, Godinho, and Fernandes (2008); an exercise program incorporating walking with cognitive and perceptual tasks resulted in no improvement on tests of executive function (Stroop or Trails B) from baseline to 12-weeks post intervention. Marmeleira, Godinho, and Fernandes (2008) found that a 12-week exercise program with 3, 60-min sessions per week improved visual attention in speed of processing and divided attention (using the UFOV protocol) at 12 weeks follow-up in adults 60 to 81. The intervention incorporated perceptual and cognitive tasks (problem solving and responding to challenging situations) with aerobic activity. Examples are: walking while listening for auditory cues to perform fast and specific psychomotor responses). At 12 weeks, speed of processing and divided attention were significantly improved compared to baseline for the exercise group; at baseline, there was no difference between groups. Driving performance was not studied, and there was no exercise-only group to determine the contribution of physical activity alone on speed of processing or divided attention.

Countermeasure I: Physical Aerobic Activity/Training	
Expert Commentary	Panelists indicated this countermeasure merits further research for remediation of working memory deficits, stating a large body of research showing aerobic exercise results in alertness--hippocampul regeneration. Panelists indicated this may be an appropriate countermeasure for deficits in executive function, but requires further research. A panelist mentioned that the literature in the area of exercise and cognitive function is mixed, with some studies showing improvement and others showing no effect. One problem with the research may be that the exercise interventions are too brief to result in an improvement.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Speed of Processing: 11/11 panelists; (MLE = 2.91) • Divided Attention: 11/11 panelists; (MLE = 2.73) • Working Memory: 10/11 panelists; (MLE = 2.50) • Executive Function: 10/11 panelists; (MLE = 2.50) • Head/Neck/Trunk Range of Motion: 11/11 panelists; (MLE = 3.45) • Arm Strength/Range of Motion/Speed of Movement: 11/11 panelists; (MLE = 3.73) • Leg Strength/Range of Motion/Speed of Movement: 11/11 panelists; (MLE = 3.73) MLE ratings for cognitive deficits and one of the three physical deficits (head/neck/trunk) indicate a need for more information/research (MLE ratings in the middle third). MLE ratings for arm and leg strength/range of motion/speed of motion deficits indicate panelists' confidence that countermeasure is likely to be effective as an intervention for these deficits, in promoting safe driving practices (MLE ratings in the top third).

Countermeasure J: Strength and Flexibility Exercises	
Description	The intervention described in the research performed by Marottoli et al. (2007) was a weekly in-home visit by a physical therapist for 12 weeks, who guided participants through a graduated exercise program targeting the following physical domains and abilities potentially relevant to driving: • Axial/extremity conditioning (cervical, trunk, and axial rotation; cervical flexion and extension; shoulder flexion and abduction; hip flexion and abduction; knee flexion and extension; ankle dorisflexion and plantarflexion). • Upper extremity coordination/dexterity and hand strength. • Gait and foot abnormalties. Each of the coordination domains consisted of three progressive levels of exercises. The therapist gradually increased the number of repetitions for each exercise, once the participant demonstrated the ability to perform the exercises safely and correctly. Exercise programs were designed to take 15 minutes and participants were asked to perform the exercises once daily for 7 days each week. Intervention participants reported completing the exercises a median of 5.4 days per week. The control group received monthly in-home education modules about home safety, fall prevention, and vehicle care. The intervention group also received these modules to ensure that the materials did not influence study outcomes. The exercise program employed by Ostrow, Shaffron, and McPherson (1992) was an 8-week range of motion exercise program that could be practiced at home, consisting of chin flexion/extension, neck rotations, head side bending, chin tucks, rotating the shoulders backward, and trunk rotations. Drivers in the experimental (exercise) group met weekly with a clinician who introduced new elements of the exercise program, reviewed previously learned skills, and monitored the subjects' compliance with the program. They also kept a daily log to record their compliance, and the frequency and extent of their driving. Subjects in the control group did not receive the exercise intervention. Instead, they kept a log of the frequency and extent of their driving, and as an incentive to participate in the study, received in-car instruction after the project was completed. The physical therapy intervention implemented by McCoy, Tarawneh, Bishu, Ashman, and Foster (1993) consisted of a set of seven self-administered, home-based exercises designed to improve posture, trunk rotation, neck flexibility, and shoulder flexibility. The exercises were done 4 times per week for 8 weeks, following a 1-hour training session.
Countermeasure Evaluation	Marottoli et al. (2007): On-road driving performance was measured at baseline and post-intervention for treatment and control group. Significant improvement for treatment group compared to control group translated to 8 to 16% lower crash occurrence over 2 year period. Treatment group also made 37% fewer critical errors (inattention, turning or changing lanes w/o looking, and disobeying signs or signals) than control group at follow up. Ostrow et al. (1992): Significant improvements in trunk rotation and shoulder flexibility across experimental subjects' 3 testing sessions (baseline, 8 and 11 weeks). Subjects in experimental group showed improvements in field-based assessment of driving skill: looked more frequently to the sides and rear of their vehicle than control drivers who did not participate in program. McCoy et al. (1993): Post intervention on-road drive test performance improved by 6.8 percentage points (significant) for the exercise group, and when physical therapy was combined with driver education, improvement increased by 8.7 percent.
Expert Commentary	Panelists agreed that this is an appropriate countermeasure for head/neck/trunk range of motion; arm strength/range of motion/speed of movement; and leg strength/range of motion/speed of movement.

Countermeasure J: Strength and Flexibility Exercises	
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Head/Neck/Trunk Range of Motion: 11/11 panelists; (MLE = 4.20) • Arm Strength/Range of Motion/Speed of Movement: 11/11 panelists; (MLE = 4.0) • Leg Strength/Range of Motion/Speed of Movement: 11/11 panelists; (MLE = 3.90) MLE ratings for all three deficits indicate panelists' confidence that countermeasure is likely to be effective as an intervention, in promoting safe driving practices (MLE ratings in the top third).

Countermeasure K: Visual Perceptual Therapy	
Description	The visual perceptual therapy intervention employed by McCoy et al. (1993) consisted of a set of self-administered home-based exercises designed to improve the following five components of visual perception: spatial relationships, visual discrimination, figure-ground, visual closure, and visual memory. The therapy consisted of 568 exercises, organized into five sections in a workbook, one for each component of visual perception, arranged in order of degree of difficulty, from the simplest to the most difficult. The subjects were instructed to spend about 4 minutes on each section during a 20-minute session, doing as many exercises as possible working at their own pace. The exercises were to be done for 20-minutes, four times a week, for 8 weeks. If they completed the exercises in one of the sections before the end of 8 weeks, they were instructed to start the section over from the beginning. Before the start of the exercise program, subjects were given a 1-hour training session, during which time they practiced the exercises for each of the five components.
Countermeasure Evaluation	McCoy et al. (1993) evaluated the effectiveness of a perceptual therapy intervention for 9 older drivers (ages 65 to 88) in improving their on-road driving performance, compared to a control group of 9 older subjects who did not receive the intervention. Baseline driving performance and follow-performance at 2 months post-intervention were assessed using the Driver Performance Measurement (DPM) technique developed at Michigan State University. The mean difference in DPM was 7.7 percentage points higher at follow-up than at baseline, indicating an improvement in performance for the perceptual therapy intervention group. The mean difference for the control group was -0.4 (no improvement in performance). A pair-wise comparison showed these differences to be statistically significant, indicating that visual perceptual therapy was effective in improving driving performance for the intervention group, relative to the control group.
Expert Commentary	Panelists indicated this countermeasure merits further research for remediation of deficits in spatial abilities.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Spatial Abilities: 11/11 panelists: (MLE = 3.33) MLE rating indicates a need for more information/research (MLE rating in the middle third).

Countermeasure L: Driver Safety Education: Theory/Classroom Only	
Description	This intervention includes programs such as the AARP Driver Safety Program and the AAA Safe Driving for Mature Operators program that are taught in a classroom setting, with no on-road/behind-the-wheel component. Most AARP Driver Safety Program (DSP) courses are taught in two, 4-hour sessions, although an on-line course is available for those wishing to take the course over the Internet. The course teaches participants the effects of aging on driving behaviors and how to adjust driving behaviors to accommodate these changes. Safe Driving for Mature Operators program delivers tips and techniques to help experienced drivers compensate for changing vision, reflexes and response time; understand how prescription medications may affect driving; and drive defensively in a variety of situations. It can be presented over 4 hours, 6 hours or 8 hours.
Countermeasure Evaluation	• Owsley, McGwin, Phillips, McNeal, and Stalvey (2004) found no difference in crash rate during 2 year follow up period for drivers with 40% or more reduction in UFOV or a visual acuity deficit (20/30 to 20/60) in an educational intervention group ("Knowledge Enhances Your Safety") who reduced their overall exposure and avoided driving at night, in the rain, in rush hour, and made right turns around the block to avoid left turns across traffic. Avoidance and exposure were self-reported, so social desirability may have been operative; or restriction was not frequent enough to be protective. Also, crash type was not restricted to at-fault in the study. • Eby, Molnar, Shope, Vivoda, and Fordyce (2003): Driving Decisions Workbook (a self assessment tool) was effective in increasing older drivers' awareness of changes in driving abilities related to aging, and effects of changes on driving. Participants stated they would seek 2nd tier assessment and change driving habits. • Skufca (2008): AARP DSP participants indicated course encouraged them to change certain driving behaviors (20% indicated avoiding left turns as a new behavior). • Kutner (2006): No difference in crash rate (self reported) in prior 12-month period for AARP Driver Safety program participants and comparison group of non-AARP DSP participants. • Bedard et al. (2004): Canadian Safety Council adaptation of AARP DSP evaluated for treatment and comparison group using an on-road evaluation at baseline and post-treatment. On-road evaluation scores improved significantly for treatment and control group from baseline to post-intervention; no significant difference between treatment and comparison group on mean change score from the first to second evaluation. • Janke (1994): Completion of Mature Driver Improvement Program was associated with more total fatal injury crashes and fewer citations compared with group who did not attend course. • McCoy et al. (1993): Completion of AAA Safe Driving for Mature Operators was associated with a significant increase in on-road driving performance (baseline and post intervention road test using DPM technique) of 3.7 percentage points. Education plus physical therapy increased score by 8.7 percentage points; education plus perceptual therapy increased score by 13.9 percentage points. • Nasvadi and Vavrik (2007): Evaluation of British Columbia Safety Council adaptation of AARP DSP comparing police-reported at-fault crash and violation rate for participants vs. non-participants in prior 2-year period, to determine whether self-selection bias exists for those who attend remedial safety courses. Significantly more participants than controls had crashed, but there was no difference in violation rate. A follow-up comparison of crash rate for subsequent 2-year period for attendees and controls with matched pre-course crash rate showed that more attendees had crashes than non-attendees, but the difference was not significant. However, when stratifying by age group and gender, males age 75+ who attended the course were 3.8 times more likely to be involved in a crash than controls who did not attend class. No difference in crash rate for men 55 to 74 or women 55 to 74 and those 75+.

Countermeasure L: Driver Safety Education: Theory/Classroom Only	
Expert Commentary	Panelists stated driver safety education/theory may be useful for the visual deficits including acuity, contrast sensitivity, visual field, dark adaptation/glare recovery, and depth/ motion perception deficits, because it raises awareness of the deficit so drivers can self restrict. Also important is to provide education to physicians and eyecare specialists so they can educate their patients. Education by OT may be a reimbursable intervention. Education alone may never be enough, however; it may need to be coupled with skills training. Panelist (a KEYS study author) noted that he has always questioned whether those self reported changes in driving habits were real; people may have been invested due to time spent in intervention and reported more avoidance than they really engaged in. Also, candidates for education intervention should not have advanced cognitive deficits (e.g., dementia). Similarly, for all the cognitive deficits, panelists stated that classroom driver education may be useful to raise awareness of deficit so drivers self restrict, and again, panelists agreed that education alone may never be enough; it may need to be coupled with skills training. OTs use commentary driving and building skills through progressively more challenging situations. In the case of spatial abilities, the OT panelists noted that if there is a serious deficit, driving should be ruled out. Spatial abilities deficits manifest themselves in lane control difficulty. OTs will start with easy situations and progress to more difficult situations if there is improvement. For knowledge deficits, there was a general consensus that it makes sense to provide education, even if it isn't adequate; people will be people, and it may work for some and not others. Education (theory) alone may never be enough; may need to be coupled with skills training. For all three physical deficits, panelists stated that classroom driver education may be useful as it raises awareness of deficit so drivers can self restrict. Education by OT may be a reimbursable intervention. Education alone may never be enough; may need to be coupled with skills training. OTs use commentary driving and building skills through progressively more challenging situations.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Acuity: 11/11 panelists; (MLE = 1.64) • Contrast Sensitivity: 11/11 panelists; (MLE = 1.82) • Visual Fields: 11/11 panelists; (MLE = 1.82) • Depth and Motion Perception: 10/11 panelists; (MLE = 1.50) • Dark Adaptation/Glare Recovery: 10/11 panelists; (MLE = 1.80) • Speed of Processing: 10/11 panelists; (MLE = 2.00) • Selective Attention: 10/11 panelists; (MLE = 1.80) • Divided Attention: 10/11 panelists; (MLE = 1.80) • Working Memory: 10/11 panelists; (MLE = 1.70) • Executive Function: 11/11 panelists; (MLE = 2.18) • Spatial Abilities: 10/11 panelists; (MLE = 1.80) • Knowledge: 11/11 panelists; (MLE = 3.82) • Head/Neck/Trunk ROM: 10/11 panelists; (MLE = 2.00) • Arm Strength/ROM/Speed: 10/11 panelists; (MLE = 1.70) • Leg Strength/ROM Speed:10/11 panelists; (MLE = 1.70) With the exception of knowledge deficits, MLE scores indicate that driver safety education (theory/classroom alone) is not likely to be an effective intervention for promoting safe driving practices (scores in the bottom third). For knowledge deficits, the MLE ratings indicate panel members' confidence that driver safety education (theory/classroom alone) can be an effective intervention (scores in the top third).

Countermeasure M: Driver Safety Education: Theory Plus Behind the Wheel	
Description	This countermeasure involves providing driver safety education, such as that provided in the AAA and AARP classroom programs, but supplementing what is taught in the classroom with actual on-road instruction, to reinforce concepts learned in class. The intervention in the Bédard et al. (2008) study consisted of the Canadian Safety Council's adaptation of the AARP 55-Alive Mature Driving Program, presented in two sessions that lasted for 4 hours. In addition, participants were given the opportunity to reinforce the concepts learned in the classroom by engaging in two 30- to 40-minute sessions with a certified instructor, driving either in their own vehicles or in a dual-brake vehicle. The instructor provided participants with constructive feedback on their driving habits. Intervention drivers in the Marottoli (2007) study participated in two, 4-hour classroom sessions based on the AAA Driver Improvement Program (Safe Driving for Mature Operators) and two 1-hour on-road driving sessions focused on common problem driving areas for older drivers. The classroom sessions followed the outline and videos of the AAA program, but were supplemented with the following additional topics: a review of all road signs, neck rotation for head checks, checking blind spots, the use of side mirrors, steering-wheel hand placement, steps for changing lanes and merging in traffic, right-on-red rules, limiting distractions and focusing on driving, search strategies for intersections, scanning to the rear, backing-up strategies, the consistent use of turn signals, and strategies for left turns across traffic or how to avoid such turns. The on-road instruction was based on common errors made by older drivers, which included failure to scan side to side, to the rear, and make head checks; failure to use a seat belt, keep the car centered in the lane, maintain a safe following distance, and use directional signals; and errors in backing up, making lane changes, and in speed regulation. The topics therefore that were included in the on-road instruction were vehicle orientation (adjusting seat position and mirrors, seat belt, head restraints, hand position, and distance from wheel); parking lot maneuvers (parking, backing up, using mirrors, looking over shoulder); maneuvers for low volume streets (K-turns, intersection strategies such as stopping position, search strategies, signaling, yielding to pedestrians, and left turns across traffic); maneuvers for moderate- and high-volume roads (looking 30 seconds ahead, watching for pedestrians and vehicles changing directions or slowing down, strategies for stop lights, turning strategies, lane change strategies, speed and space management, mirrors and head checks, and signaling); and maneuvers on highways (entering, exiting, merging, changing lanes, mirror and head checks, blind spots, speed regulation, space management). The first session also addressed any errors the driver made during the baseline assessment.
Countermeasure Evaluation	The measures of effectiveness in the Bédard et al. (2008) study were (1) scores on a 15-item multiple choice safe driving knowledge questionnaire given before the classroom session and again after completion of the classroom sessions, but before the on-road training sessions (for the treatment group); and (2) performance on a standardized on-road driving evaluation given before the intervention and again 4- to 8-weeks post-intervention (both the treatment and control group). Five driving actions were evaluated: (1) starting/stopping/slowing; (2) signal violations/right of way/inattention; (3) moving in the roadway; (4) speed/passing; and (5) turning. Bédard et al. (2008) found a significant improvement in knowledge of safe driving practices, with an increase from 61 percent of the questions answered correctly at baseline to 81 percent answered correctly at follow-up. Driving performance improved significantly for the intervention group (fewer violations were made) compared to the control group, but only for the category of moving in the roadway. Examples of violations in this category included straddling the traffic lane, failing to check traffic when changing lanes, wandering, and failing to drive in the proper lane.

Countermeasure M: Driver Safety Education: Theory Plus Behind the Wheel	
Countermeasure Evaluation (Cont'd)	Marottoli (2007) conducted a randomized, controlled trial with blinded endpoint assessment to determine whether an educational intervention consisting of classroom and on-road training focused on commonly encountered problem areas for older drivers, could enhance driving performance among 126 active drivers age 70 or older. Control drivers received one-on-one sessions about vehicle maintenance and safety devices, home safety, and environmental safety. These were conducted in the participants' homes and included education on falls and tripping hazards, lighting, handrails, appropriate footwear, crime prevention, tire pressure, vehicle lights and mirrors, pedestrian issues, etc. BTW performance was assessed at baseline and 8 weeks post-intervention. The road test covered 10 miles, included a 1.7-mile highway segment, and took 45 minutes to complete. It included urban and residential areas with low- medium- and high-traffic densities, with speed limits ranging from 10 to 35 mi/h on access roads and city streets to 55 mi/h on the highway. There were 63 intersections on the route (32 crossing and 31 T-type); 45 were signalized, 2 were controlled by flashing lights, and 11 were controlled by stop signs. There were 15 right and 15 left turns, 12 merges, and several opportunities to make a right on red at a traffic signal. Mean baseline road test scores were comparable in the intervention and control groups, for those who drove daily or less than daily (60.9 vs. 60.7, respectively, out of 72 points). Intervention drivers showed a mean increase in road test score of 8.5 percent compared to a 4.2 percent increase for control subjects. The improvement in on-road test performance at 8 weeks for the intervention group was 2.87 points higher (least-squares mean change) on a 72-point scale than that in the control group. This difference was significant, and translates to a 9.5 percent decrease in crash risk over a 2-year period. The items showing the most improvement with intervention were: scanning to the rear, lane selection, right turns, and judgment. Intervention drivers showed a mean increase in knowledge test score of 22.5 percent compared to a 6.2 percent increase for control subjects. The improvement in written-test performance at 8 weeks was 3.45 points higher (least-squares mean change) on a 28-point scale for the intervention group than for the control group, which was also significant.
Expert Commentary	Panelists stated driver safety education (theory plus behind the wheel) may be useful for the visual deficits including acuity, contrast sensitivity, visual field, dark adaptation/glare recovery, and depth/ motion perception deficits, because it raises awareness of the deficit so drivers can self restrict. Also important is to provide education to physicians and eyecare specialists so they can educate their patients. Education by OT may be a reimbursable intervention. Education alone may never be enough, however; it may need to be coupled with skills training. Similarly, for all the cognitive deficits, panelists stated that classroom driver education combined with a behind the wheel component may be useful to raise awareness of deficit so drivers self restrict. It was reinforced that education alone may never be enough; it may need to be coupled with skills training. OTs use commentary driving and building skills through progressively more challenging situations. In the case of spatial abilities, the OT panelists noted that if there is a serious deficit, driving should be ruled out. Spatial abilities deficits manifest themselves in lane control difficulty. OTs will start with easy situations and progress to more difficult situations if there is improvement. For knowledge deficits, there was a general consensus that it makes sense to provide education, even if it isn't adequate; it may work for some and not others. Education should be coupled with skills training. For all three physical deficits, panelists stated that classroom driver education with a behind-the-wheel component may be useful as it raises awareness of deficit so drivers can self restrict.

<table>
<tr><th colspan="2">Countermeasure M: Driver Safety Education: Theory Plus Behind the Wheel</th></tr>
<tr><td>Functional Deficits Targeted by this Countermeasure

Mean likelihood of effectiveness (MLE) ratings
1=extremely unlikely to
5= extremely likely

Top third: 3.68 – 5.0
Middle third: 2.34 – 3.67
Bottom third: 1.0 – 2.33</td><td>• Acuity: 10/11 panelists; (MLE = 2.10)
• Contrast Sensitivity: 11/11 panelists; (MLE = 2.56)
• Visual Fields: 11/11 panelists; (MLE = 2.55)
• Depth and Motion Perception: 11/11 panelists; (MLE = 2.36)
• Dark Adaptation/Glare Recovery: 10/11 panelists; (MLE = 2.40)
• Speed of Processing: 11/11 panelists; (MLE = 2.73)
• Selective Attention: 11/11 panelists; (MLE = 2.45)
• Divided Attention: 11/11 panelists; (MLE = 2.64)
• Working Memory: 9/11 panelists; (MLE = 2.67)
• Executive Function: 11/11 panelists; (MLE = 3.0)
• Spatial Abilities: 10/11 panelists; (MLE = 2.50)
• Knowledge: 11/11 panelists; (MLE = 4.0)
• Head/Neck/Trunk ROM: 11/11 panelists; (MLE = 2.91)
• Arm Strength/ROM/Speed: 10/11 panelists; (MLE = 2.70)
• Leg Strength/ROM Speed:10/11 panelists; (MLE = 2.70)

With the exception of acuity and knowledge deficits, MLE scores indicate a need for more information/research (MLE rating in the middle third) to determine whether driver safety education theory/classroom combined with a behind-the-wheel component will be effective as an intervention in promoting safe driving practices.

MLE rating in the bottom third for acuity deficits indicates that this countermeasure is not likely to be an effective intervention for promoting safe driving practices.

MLE rating in the top third for knowledge deficits indicates panel members' confidence that driver safety education theory/classroom with a BTW component can be an effective intervention for promoting safe driving practices.</td></tr>
</table>

Countermeasure N: Driver Safety Education: Interactive/Computer-Based Technology	
Description	This countermeasure was added by panelists as an outgrowth of the discussions on classroom/theory driver education and on-road/behind the wheel driver training. Interactive/computer-based technology is a new approach to driver education being used with teens, and also with seniors that addresses all of the listed deficits. It could include driver simulator training, or computer-based training on a desk-top platform with a steering wheel for input. But the computer-based, interactive component addresses the attentional and cognitive aspects of driving, as well as imparting knowledge/theory.
Countermeasure Evaluation	None uncovered in the literature (with the interactive component), and none offered by the panelists.
Expert Commentary	This is an emerging application that needs more research, and could apply to all listed deficits.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Acuity: 10/11; (MLE = 2.20) • Contrast Sensitivity: 11/11 panelists; (MLE = 2.64) • Visual Fields: 11/11 panelists; (MLE = 2.73) • Depth and Motion Perception: 11/11 panelists; (MLE = 2.55) • Dark Adaptation/Glare Recovery: 11/11 panelists; (MLE = 2.36) • Speed of Processing: 11/11 panelists; (MLE = 3.27) • Selective Attention: 11/11 panelists; (MLE = 3.27) • Divided Attention: 11/11 panelists; (MLE = 3.45) • Working Memory: 10/11 panelists; (MLE = 3.40) • Executive Function: 11/11 panelists; (MLE = 2.91) • Spatial Abilities: 11/11 panelists; (MLE = 2.91) • Knowledge: 11/11 panelists; (MLE = 3.82) • Head/Neck/Trunk ROM: 11/11 panelists; (MLE = 2.45) • Arm Strength/ROM/Speed: 11/11 panelists; (MLE = 2.55) • Leg Strength/ROM Speed:11/11 panelists; (MLE = 2.55) With the exception of acuity and knowledge deficits, MLE scores indicate a need for more information/research (MLE rating in the middle third) to determine whether interactive/computer-based driver education will be effective as an intervention in promoting safe driving practices. MLE rating in the bottom third for acuity deficits indicates that this countermeasure is not likely to be an effective intervention for promoting safe driving practices. MLE rating in the top third for knowledge deficits indicates panel members' confidence that interactive/computer-based driver safety education can be an effective intervention for promoting safe driving practices.

Countermeasure O: Education about Driving Aids (CarFit, Features, Adaptive Equipment, Diabetic Shoes, etc.)	
Description	CarFit is an in-car safety program that teaches older drivers how to adjust their vehicles to help reduce crashes and injuries. It was developed through collaboration among the American Society on Aging, AARP, the American Occupational Therapy Association, and AAA. It includes a 12-point checklist to ensure that senior drivers are sitting properly in their vehicle and that the driver's seat, seat belts, mirrors, steering wheel, head rest, gas/brake pedals, and other controls are properly positioned. Each CarFit evaluation takes approximately 15 minutes, and is administered by specially trained volunteers and health professionals such as occupational therapists.
Countermeasure Evaluation	None published to date. A panelist indicated that there was one initial preliminary study that people had retained the knowledge imparted during the session, making some changes following the session. The panelist also indicated that there's a proposal in from UCLA to do a bigger study of it if they get funded (but they haven't heard yet). The panelist indicated there have been some small studies that have not been compiled in any way. Different master's level OT students have done a number of small studies at different CarFit events; she stated that we could use more research on CarFit. Smart, Safe, and Sober Newsletter (2007) indicates that a trial version of the program was administered in 2006 with over 300 senior citizens and found that: 37% had at least one 'red flag" issue; 10% did not have the right spacing between their steering wheel and chest; and almost 20% did not have the right line of sight over their steering wheel.
Expert Commentary	Panelists state that vehicles have safety features but many need to be adjusted, and older drivers don't know how to do this. Education about driving aids is a positive theme to staying on the road longer. Countermeasure merits further research. Another panelist indicated that there's some interesting work that's being done in Australia in terms of developing and evaluating educational programs. There is some work by an occupational therapist named Liddle, who has developed a program using the public health behavioral change theory of stages of change. This has been a successful approach in smoking cessation programs, for example, that takes into account the stage at which people are active and respond to their readiness to change. Several panelists (OTs) indicated that at CarFit events, they have been removing the mirrors from their example bag because they don't want to be liable for somebody getting a mirror and not having enough training in its use, and then getting in a crash. There's a lot of learning involved in using adaptations and mirrors. At CarFit, if a mirror is adjusted for a driver (and the explanation provided about elimination of blind spots), the OT sets the mirrors back as they were when the driver arrived at the event. That is a requirement, because OTs can't be liable for making a change; the driver must make the change. There are other concerns with adaptive equipment. With adaptations, theoretically, a driver would go to a driving specialist who would look at their model of car and all the types of adaptations that might work and recommend the one that would work for their car and the individual. Then the driver would get the device the specialist indicated and would have it installed. The specialist would check and make sure that the device is installed the right way and then train the driver in its use. OTs voiced concern about adaptive equipment being readily available from the internet or in car parts stores, and people buying it without being evaluated for their need or trained in its use. Panelists were concerned about who installs the equipment; is the mechanic down the street putting the equipment in, and is it being installed correctly? There needs to be a standard of care. Ideally, devices would be available to those who need them, but a professional should be involved in selecting a device and training the driver to use it. There is no standard of care; more research is needed on mirrors, the training required to use them safely, and the professionals qualified to deliver the training.

Countermeasure O: Education about Driving Aids (CarFit, Features, Adaptive Equipment, Diabetic Shoes, etc.)	
(Cont'd)	More research is needed to identify unintended consequences of safety devices, including submarining under the seatbelt if a seat cushion is used and effects of aftermarket add-ons to the seat belt to make it comfortable across the neck. There is dissention between automakers and OTs and even among the OTs themselves with regard to aftermarket devices such as seat cushions and seat belt adjustors. One panelist raised the issue of pedal confusion among drivers with diabetes and neuropathy, related to the characteristics of therapeutic shoes that reduce a driver's ability to feel the pedals. She stated that there are not studies for OTs to turn to for support in guiding their clients.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Visual Fields: 11/11 panelists; (MLE = 2.55) • Depth and Motion Perception: 10/11 panelists; (MLE = 1.89) • Dark Adaptation/Glare Recovery: 10/11 panelists; (MLE = 2.40) • Knowledge: 11/11 panelists; (MLE = 4.0) • Head/Neck/Trunk ROM: 11/11 panelists; (MLE = 3.55) • Arm Strength/ROM/Speed: 10/11 panelists; (MLE = 3.10) • Leg Strength/ROM Speed:10/11 panelists; (MLE = 3.10) MLE scores for visual fields, and all three physical abilities indicate a need for more information/research (MLE rating in the middle third) to determine whether education about driving aids will be effective as an intervention in promoting safe driving practices. MLE ratings in the bottom third for depth/motion perception and dark adaptation/glare recovery indicate that this countermeasure is not likely to be an effective intervention for promoting safe driving practices. MLE rating in the top third for knowledge deficits indicates panel members' confidence that education about driving aids can be an effective intervention for promoting safe driving practices.

Countermeasure P: Collision Warning Systems	
Description	Collision warning systems provide an audio warning to the driver in advance of an impending emergency event.
Countermeasure Evaluation	Caird (2004) notes that few evaluation studies have included a sample of older drivers, and those that do, don’t analyze age effects. Maltz, Sun, Wu, and Mourant (2004) found that drivers, both younger and older, benefited from the use of a headway and detection alerting device. Age had no effect on the amount of time drivers spent in the optimal following distance zone (2 to 4 seconds). Older drivers were less likely to respond to false alarms when they were distracted by an auditory task (listening to a book on tape) than when they were not distracted. However, younger drivers responded *more* to false alarms when they were distracted than when they were not distracted. This age effect occurred only when the headway and detection alerting device was highly reliable. Maltz et al. indicate that the explanation for older drivers ignoring more false alarms when they were distracted may be due to their greater difficulty dividing attention, particularly when the two tasks share the same output modality (auditory stimuli, in this case). Oxley and Mitchell (1995): collision warning system tested in a simulator was effective in preventing older drivers from turning across traffic through gaps that were dangerously short. They found that this technology was even more effective for a small sample of younger drivers than for the main sample of older drivers.
Expert Commentary	Suggested by panelists as countermeasure that merits further research. Need forward as well as side-collision warning. Would be helpful if it caused the vehicle to brake, in addition to providing a warning. An OT mentioned that although adaptive cruise control systems might enable elders to drive safer for a longer period of time, they also may allow unsafe drivers to drive for a longer period of time. If the person has a system in the car that is going to drive the car for them, it may enable them to drive past the time they should have stopped. Panelists were concerned about drivers relying completely on the technology to detect hazards (esp. for backing up). Older drivers who have backed up without doing head/shoulder checks and have backed into (and killed) pedestrians. Also older people may be more distracted rather than assisted by some of the advanced technologies. And, most rehab centers’ adapted cars are not high-end/high tech, so it would be difficult for OTs to train people to use these technologies. Panelists noted that training is a key element with advanced technology countermeasures, particularly for older drivers. One panelist noted that collision warning systems aren’t a panacea for drivers with visual decline; in combination with other countermeasures, they may be helpful, but shouldn’t be relied on to prevent crashes for drivers who don’t see well. Several panelists discussed the fact that some higher-end vehicles (e.g., 7 Series BMW) have a display on the dashboard or on the mirrors that shows if you are getting too close to someone or if someone is in your blind spot. However, the systems aren’t always reliable; they may miss detecting a following vehicle in an adjacent lane, resulting in a driver who does not also do a head check changing lanes and colliding with the adjacent-lane vehicle. Another problem is that due to the display being visual, drivers may be distracted by looking at the display instead of the actual traffic scene. One panelist who has looked at auto insurance claims found that blind spot detection systems have resulted in a reduction in severity but not in frequency of crashes (which is not what would be expected).

Countermeasure P: Collision Warning Systems	
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Acuity: 11/11 panelists; (MLE = 3.36) • Contrast Sensitivity: 11/11 panelists; (MLE = 3.45) • Speed of Processing: 11/11 panelists; (MLE = 3.45) • Selective Attention: 11/11 panelists; (MLE = 3.40) • Divided Attention: 11/11 panelists; (MLE = 3.30) • Head/Neck/Trunk Range of Motion: 11/11 panelists; (MLE = 3.09 MLE scores for all listed functional deficits abilities indicate a need for more information/research (MLE rating in the middle third) to determine whether collision warning systems will be effective as an intervention in promoting safe driving practices.

Countermeasure Q: After-Market Non-Planar Driver-Side Mirror	
Description	Title 49, Part 571, Standard Number 111 of the Code of Federal Regulations requires the driver side mirror to be planar (flat), while the passenger side mirror may be convex or planar. In Europe, non-planar rearview mirrors are allowed on both the driver's and passenger's side of the vehicle. There is anecdotal evidence that drivers attach after-market convex mirrors on the driver side mirror to eliminate the blind spot, and there are multiple vendors who provide such after-market mirrors. Convex mirrors provide a wider field of view, but produce a minified image that may cause inaccurate judgments about the speed and distance of following/overtaking vehicles. No research was uncovered on the effectiveness or safety benefit of this behavioral adaptation, but research has been performed in the U.S. and Europe on the benefits and difficulties experienced by drivers using convex and multiradius mirrors on the driver's side.
Countermeasure Evaluation	No research on "bullseye" convex mirror affixed to standard planar mirror, however Staplin et al. (1998) found that approx 13% of older driver sample in laboratory simulator study made unsafe gap acceptance judgments to change lanes in front of an adjacent-lane vehicle overtaking at 25 mi/h differential while using full-sized non-planar mirrors. Also one-third of sample indicated sole reliance on mirror when changing lanes. De Vos (2000) reported that older drivers look over their shoulders less frequently than younger drivers when changing lanes. Drivers accepted smaller gaps when using non-planar mirrors, due to image minification.
Expert Commentary	Panelist OTs were concerned that the recommendation could pose a liability, but merits further research. Even aiming mirrors for drivers during CarFit is a liability and OTs put the mirrors back to their original position (as they were aimed when the drivers arrived at the evaluation). Non-planar mirrors would require optical distortion training, and there is currently no standard of care.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Head/Neck/Trunk Range of Motion: 11/11 panelists; (MLE = 4.11) MLE rating in the top third for this deficit indicates panel members' confidence that this countermeasure can be an effective intervention for promoting safe driving practices.

Countermeasure R: Medical Management (Including Pharmacy Review)	
Description	This countermeasure arose from discussions among the expert panelists that physicians and other healthcare providers need to have the information linking medical conditions and medications to crash risk, so they can provide remediation when possible, and educate their patients (leading to self-restriction when necessary). This began as extension of the discussion of cataract surgery as a remediation for contrast sensitivity and acuity deficits. So, in addition to older drivers being the targets of brochures describing driving with certain medical conditions, physicians must also be the targets of such interventions. Allard, Hébert, Rioux, Asselin, and Voyer (2001) found that the consumption of 3 or more drugs per day increased the risk of functional decline in elderly people by 60 percent. Decreases in functional ability brought on by polypharmacy have been associated with an increased risk of motor vehicle crashes (LeRoy, 2004), raising public health and safety concerns. Therefore, pharmacy reviews can serve to educate patients about the potential driver impairing effects of medications, leading to better decisions about when and if it is safe to drive. Pharmacy reviews can also be beneficial in reducing crash risk, because they uncover dangerous drug interactions, redundant prescriptions, unnecessary prescriptions, and dosing problems.
Countermeasure Evaluation	Sleep apnea has been associated with a 2- to a 7-fold increase in crash risk (Teran-Santos, Jimenez-Gomez, and Cordero-Guevara, 1999). Sleep apnea/sleep deprivation is an active area of research. One investigator (Maycock, 1996) has correlated scores on the Epworth sleepiness scale with crash risk. Many additional studies have documented increased crash risk or impaired driver performance due to fatigue; and it has been shown that treatment for sleep disorders can reduce crash risk to baseline levels (George, 2001). Nathan, Goodyer, Lovejoy, and Rashid (1999) reported on medication use of 205 patients (mean age 64.5 years) who volunteered to participate in a pharmacist-led brown-bag review. The number of drugs reviewed per patient ranged from 1 to 14, with an average of 6.2. Pharmacists made interventions in 87 percent of the reviews. Interventions included: providing information about the purpose of at least one medication (65% of the reviews); improving or correcting usage of at least one medication (46%); providing knowledge on common or important adverse drug reactions or side effects (52% of reviews). Fifty-eight percent of patients admitted to or were suspected of either not using at least one of their medications at all or not using them according to prescribed directions. Interactions between medications (sometimes between prescribed and over-the-counter medicines) were identified in 4 percent of the reviews. Fillit, Futterman, Orland, et al., (1999) conducted a prospective study with a follow-up survey to examine the effects of a brown bag review by primary care physicians on prescriptions written for elderly members of a Medicare managed care organization who were at risk of risk related to polypharmacy. Ninety-six percent of the 1,087 members who participated in the medication review reported that they had a discussion concerning prescription medications and 72% indicated that nonprescription medications were also discussed. As a result of the medication review, 20% indicated that the doctor stopped or discontinued a medication, 29% indicated that the doctor changed the dosage of medication, 11% indicated that the doctor discovered medications purchased without a prescription that he or she did not know the patient was taking, and 17% indicated that the doctor discovered medications prescribed by another physician that he or she did not know the patient was taking.
Expert Commentary	Panelists stated that medical management leads to early detection of impairments and remediation. They indicated that it is important for researchers/sponsors of research to provide education to physicians, pharmacists, and eyecare specialists linking medical conditions to functional impairments and driving risk so they can educate their patients. They pointed to cataract surgery as a remediation for acuity and contrast sensitivity deficits; patients rely on their healthcare providers to diagnose, treat, and counsel, so the physicians need to be educated. Panelists provided examples of arthritis and sleep apnea. Impairments in psychomotor functioning may result from musculoskeletal disease leading to weakening, frailty, and/or restricted range of motion. Medical management of arthritis is important. Medical management of sleep apnea is another countermeasure to promote safe driving, but the panelist didn't know if there was a model for a sound medical management of sleep apnea.

Countermeasure R: Medical Management (Including Pharmacy Review)	
	The panelists also proposed the idea of a model stroke rehab program, as stroke was another medical condition associated with high crash risk. Panelists indicated that medical management was an appropriate countermeasure for all 15 listed functional deficits.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Acuity: 11/11 panelists; (MLE = 3.50) • Contrast Sensitivity: 10/11 panelists; (MLE = 3.0) • Visual Fields: 10/11 panelists; (MLE = 3.0) • Depth and Motion Perception: 10/11 panelists; (MLE = 2.67) • Dark Adaptation/Glare Recovery: 10/11 panelists; (MLE = 3.0) • Speed of Processing: 11/11 panelists; (MLE = 3.18) • Selective Attention: 11/11 panelists; (MLE = 3.30) • Divided Attention: 11/11 panelists; (MLE = 3.09) • Working Memory: 11/11 panelists; (MLE = 3.20) • Executive Function: 11/11 panelists; (MLE = 3.27) • Spatial Abilities: 11/11 panelists; (MLE = 2.40) • Knowledge: 11/11 panelists; (MLE = 3.30) • Head/Neck/Trunk ROM: 10/11 panelists; (MLE = 3.20) • Arm Strength/ROM/Speed: 10/11 panelists; (MLE = 3.50) • Leg Strength/ROM Speed:10/11 panelists; (MLE = 3.50) MLE scores for all listed functional deficits abilities indicate a need for more information/research (MLE rating in the middle third) to determine whether medical management can be effective as an intervention in promoting safe driving practices.

Countermeasure S: Cognitive Rehabilitation (Including Memory Training) for the Normally Aging Population	
Description	Cognitive rehabilitation was added to the list of countermeasures by expert panelists as an outgrowth of the discussion about divided attention. This could include reasoning training and memory training such as that included in the ACTIVE trial (Ball et al., 2002). The memory training was focused on verbal episodic memory; participants were taught mnemonic strategies for remembering word lists and sequences of items. The exercises involved laboratory memory tasks (recalling a list of nouns, recalling a paragraph) and memory tasks related to cognitive activities of daily life (recalling a shopping list, recalling the details of a prescription label). The reasoning training focused on the ability to solve problems that follow a serial pattern; the exercises involved abstract reasoning tasks (e.g., letter series) and reasoning problems related to activities of daily living.
Countermeasure Evaluation	Ball et al. (2002) found that the reasoning training improved reasoning ability (tasks requiring identification of patterns in letter or word series problems) and the memory training improved performance on episodic verbal memory tasks, durable to 2 years. Subjects were volunteers ages 65 to 94; with approximately 700 in each training group. Training effects were of a magnitude equal to the amount of decline expected in older people without dementia over 7 to 14 year intervals. No training effects were found on everyday functioning tasks (paper and pencil tests and behavioral simulations of everyday tasks) at 2 years following enrollment. Preliminary findings from the ACTIVE trial evaluating cognitive interventions and crash risk 5 years prospectively are pending. Laderman, Szlyk, Kelsch, and Seiple (2000) found improvement in visual memory (remembering store names subjects had walked past) after practice in the laboratory recalling sequences of numbers, letters, and shapes presented briefly on 35-mm slides. This practice was part of a protocol for amorphic lens wearers, prior to participating in a driver training protocol on a closed course and riding as passengers in traffic. The purpose of the driving protocol was to learn how to incorporate the search and scanning techniques learned in the laboratory into the driving task. The finding that visual memory showed significant improvement indicated that patients realized the importance of exiting the amorphic lenses as quickly as possible and the necessity of remembering what was just seen through them.
Expert Commentary	Panelists indicated that cognitive rehabilitation is really building subskills for the driving task. An OT panelist noted that you cannot just do a lot of the cognitive retraining tasks and assume that it will generalize to driving. You need to make that part of the therapy program. Therapists need to "connect-the-dots" for their patients when doing cognitive therapy for driving; explain how the skill they just developed during the last hour in the clinic could be applied to everyday practical situations (in this case, driving). This makes it more likely that they will show functional improvement. One cognitive rehabilitation model, recommended by an OT for its application to behavior change and driving, is the "Trans-Theoretical" model of change, which focuses on the decision making of the individual. It has been the basis for developing effective interventions to promote health behavior change such as smoking cessation and low fat diets, and could help drivers make decisions about reducing risk when driving with functional deficits. It is described at www.uri.edu/research/cprc/TTM/detailedoverview.htm. Another pertinent model is 'Motivational Interviewing.' It helps the client achieve the "ah ha" moment, where s/he develops insight into the existence and nature of a (driving) problem, and what can be done to deal with it. It is described at www.motivationalinterview.org/clinical/interaction.html.

Countermeasure S: Cognitive Rehabilitation (Including Memory Training) for the Normally Aging Population	
Expert Commentary (Cont'd)	Panelists agreed that cognitive rehabilitation has tremendous promise as a countermeasure but it is in its infancy; training protocols and validation testing are not yet complete. Protocols and treatments differ based on the clinicians and therapy settings. There is a need for good research to make sure that rehab specialists use this appropriately. Current treatment protocols for cognitive rehab vary from simple exercises, to counseling, to computer-based drills and video games; and rehabilitation specialists from multi-disciplinary fields (psychologists, neuropsychologists, speech pathologists, OTs, PTs, etc) are using the method. There aren't many cognitive rehabilitation specialists who also specialize in driving rehabilitation. An OT indicated that cognitive rehab has a history that is tainted by excitement over new protocols such as video games, so it is important that good research is performed to determine its efficacy, and that it is used appropriately. These tools tend to be marketed to the public rather than to the experts who can make informed decisions. Many of the current tools are untested. There is a proliferation of memory training programs on the Internet, according to one panelist. OTs noted that there are protocols and treatments for retraining concentration and attention, and the cognitive rehab literature shows efficacy of attentional therapy in the broader rehab area ("Society for Cognitive Rehab"). Cognitive rehab doesn't directly address driving, but builds subskills for the driving task. The panelist noted that since improved attention has an impact on driving, and the broad rehab area shows efficacy in training attention, then it makes sense to consider improving attention through rehab to improve driving ability. A panelist noted that interventions can be enhanced by cross training/packaging interventions, rather than thinking of them as single interventions. As an example, combine skill-based targeted training with educational training. One panelist noted that reasoning training conducted as part of the ACTIVE trial described by Ball, Berch, Helmers, Jobe, Leveck, et al.(2002) showed an effect of decreased driving difficulty in the 6 years following enrollment in the study. These findings were presented at the 2008 GSA meeting. Panelists indicated that cognitive rehab (preventative, restorative, maintenance) and memory training are not appropriate for the dementia population, because dementia is progressive; they can't learn and remember the strategies. The dementia population can be abused by being sold restorative interventions.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Selective Attention: 11/11 panelists; (MLE = 2.89) • Divided Attention: 11/11 panelists; (MLE = 2.80) • Working Memory: 11/11 panelists (MLE = 2.80) • Executive Function: 11/11 panelists; (MLE = 2.80) MLE scores for all listed functional deficits abilities indicate a need for more information/research (MLE rating in the middle third) to determine whether cognitive rehabilitation (for the normally aging population) can be effective as an intervention in promoting safe driving practices.

Countermeasure T: Compensatory Cognitive/Memory Training for Impaired/MCI Population	
Description	Compensatory strategies/memory training that the panelists deemed appropriate for the mild cognitive impairment (MCI) population are at the strategic level of Michon's hierarchical model of driver behavior. Examples include trip planning: planning the route ahead of actually driving it, using tools like MapQuest, and possibly practicing the route ahead of time (if the trip involves an appointment in an unfamiliar area), and may include avoiding challenging situations such as rush hour and complex intersections, depending on the nature of the individual's impairment. It may include strategies such as allowing more time to get to a location, increasing following distance to provide more time to react/respond to situations, using a GPS with auditory output for navigation assistance, and driving only in familiar areas.
Countermeasure Evaluation	No research studies were uncovered to evaluate the effectiveness of the strategic compensatory strategies. Unverzagt et al. (2007) reported on a subset of the ACTIVE trial population (193 subjects) who had mild cognitive impairment (MCI), who underwent the memory and reasoning cognitive interventions described by Ball et al. (2002) . MCI was defined as Rey Auditory Verbal Learning Test (AVLT) sum recall score 1.5 sd or more below predicted AVLT sum recall. Subjects had intact intellectual function (normal range MMSE) and normal ADLs at baseline. The training was conducted in 10 sessions lasting 60 to 75 minutes over a 5- to 6-week period. Participants were instructed in strategies for recalling word lists and short narratives for the memory training. Reasoning training focused on improving the ability to solve problems that contained a serial pattern. Memory training outcomes were measured by verbal memory tasks; reasoning training outcomes were measured by tasks requiring the identification of patterns in letter and word series problems. Memory training showed no benefit at post test, nor after 1 year or after 2 years post training for the memory-impaired subjects relative to a no-contact control group. However, reasoning training was effective for the memory-impaired subjects at post test and at 2-years following training. The memory training was focused on verbal episodic memory; participants were taught mnemonic strategies for remembering word lists and sequences of items. The reasoning training focused on the ability to solve problems that follow a serial pattern; the exercises involved abstract reasoning tasks. Preliminary findings from the ACTIVE trial evaluating cognitive interventions and crash risk 5 years prospectively are pending. In a small sample study of 20 subjects with MCI and 9 controls, Belleville at al. (2006) found that adults with MCI benefited from training on some immediate post-test measures of face-name associations but not on measures of paragraph recall or immediate word list recall. The training consisted of mnemonic training techniques similar to those used in ACTIVE (imagery, organization, method of loci) that were imbedded within dual-task attention training. Thus, improvement in memory function in those with MCI may require a more multi-factorial approach than that employed by the ACTIVE training. It is unknown whether such training would transfer to improvements in safe driving ability.
Expert Commentary	Panelists were cautious about recommending cognitive interventions for people with early stage dementia, and indicated that strategies must be compensatory rather than restorative for this group. Because dementia is progressive, cognitive rehab is not recommended; it is not beneficial because people can't learn and remember the strategies. The dementia population can be abused by being sold restorative interventions. Someone with early stage dementia may have good situational awareness and operational control of a vehicle, but could have a memory deficit that would manifest in navigational difficulties. A panelist who is a physician indicated that it is difficult to define where MCI (Mild Cognitive Impairment) begins and where it ends. It is unknown whether the MCI group can benefit from interventions because historically, they have been excluded from studies so as not to confound the study results. A panelist who is an author on the MCI ACTIVE report indicated that memory training strategies

Countermeasure T: Compensatory Cognitive/Memory Training for Impaired/MCI Population	
	used with MCI and Alzheimer's patients should be different from those used with someone whose cognitive neurofunctioning is intact. One panelist noted that not all people with MCI progress to Alzheimer's Disease, this may be appropriate for MCI (however, more research is needed). However, as AD progressively worsens, it is difficult to see how this countermeasure would be effective beyond the earliest AD stages, and would need to be reviewed for its appropriateness on a regular/frequent basis.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Selective Attention: 11/11 panelists; (MLE = 2.89) • Divided Attention: 11/11 panelists; (MLE = 2.80) • Working Memory: 11/11 panelists (MLE = 2.90) • Executive Function: 11/11 panelists; (MLE = 2.80) MLE scores for all listed functional deficits abilities indicate a need for more information/research (MLE rating in the middle third) to determine whether compensatory cognitive/memory training for MCI population will be effective as an intervention in promoting safe driving practices.

Countermeasure U: Pre-Trip Planning	
Description	Pre-trip planning is at Michon's strategic level in his hierarchical model of driver behavior. It involves a conscious decision to plan the intended driving route (including avoiding challenging or difficult intersections), and could also include other self-imposed restrictions, such as time of day (daytime rather than night), type of weather (dry vs. in the rain or snow) and under optimal health conditions (e.g., avoiding driving when fatigued, or when impaired by medication-side effects, or impairing symptoms of medical conditions).
Countermeasure Evaluation	Has not been evaluated, as far as panelists know
Expert Commentary	Panelists added this countermeasure and agreed that it merits further research for drivers with deficits in working memory and executive function, as well as for knowledge deficits. They indicated it may help with memory deficits, because it requires practice. Panelists indicated that trip planning ties in with management mobility counseling; introducing other modes of transportation for those times that a driver shouldn't drive because of functional impairments. This may be a strategy to extend driving, because trip planning could prevent near-misses, misinterpretation or confusion that could result from being lost. If people can learn an intervention like memorizing or previewing a route, it could help them drive safer longer.
Functional Deficits Targeted by this Countermeasure Mean likelihood of effectiveness (MLE) ratings 1=extremely unlikely to 5= extremely likely Top third: 3.68 – 5.0 Middle third: 2.34 – 3.67 Bottom third: 1.0 – 2.33	• Working Memory: 11/11 panelists; (MLE = 3.09) • Executive Function: 11/11 panelists; (MLE = 3.09) • Knowledge: 8/11 panelists; (MLE = 3.75) MLE scores for deficits in working memory and executive function indicate a need for more information/research (MLE rating in the middle third) to determine whether pre-trip planning can be effective as an intervention in promoting safe driving practices. MLE rating in the top third for knowledge deficits indicates panel members' confidence that this countermeasure can be an effective intervention for promoting safe driving practices.

"Taxonomy of Older Driver Behaviors and Crash Risk"
Contract Number DTNH22-05-D-05043, Task Order 08
Task 7 – Unstructured Interviews of Older Drivers

Driver Name: ___________________________ DL Number: _____________________
Date of Birth: ________________ Prior crash? ____ (1) Yes ____ (0) No
Interview Date: ________________

Current Driving

1. Do you currently drive?
   _____ (1) yes *(go to question 4.)*
   _____ (0) no (*ask questions #2 and #3 and then stop interview*).

2. Why did you stop driving?
____
____
____
____
____

3. When is the last time you drove? (month/day/year)
____

4. How many days per week do you normally drive? (*circle one*)

   1 2 3 4 5 6 7

5. On a typical day, how many trips do you make? _____________________

6. How many total miles do you drive in a normal week? ________

7. In a normal week, about what percent of your overall travel (miles driven) occurs at night?
   ________ *(if >0%, ask Q. 8)*

   7a. Is most of your nighttime travel on lit or unlit roads?
      (1)_______ lit
      (0)_______ unlit

8. About how many miles per year do you drive? (*circle one*)

Less than 1,000	1,001 to 2,500	2,501 to 5,000	5,001 to 7,500	7,501 to 10,000	10,001 to 12,500	12,501 to 15,000	15,001 to 17,500	17,501 to 20,000	20,001 to 25,000	25,001 to 30,000	30,001 or more
1	2	3	4	5	6	7	8	9	10	11	12

9. What kind of area do you live in: *(circle one)*
   1) the city
   2) the suburbs
   3) a rural area

10. Do you do most or all of your driving close to home?
    (1)_______ yes
    (0)_______ no

11. During the past year, have you driven to places that take more than ½ hour to get to or are more than 10 miles away?
    (1)_______ yes
    (0)_______ no

12. During the past year, have you driven to places that take more than 1 hour to get to or are more than 50 miles away?
    (1)_______ yes
    (0)_______ no

13. When driving, have any of the following situations become more difficult or challenging over the past 5 or 10 years?

    13a. *(Check "yes" or "no" for each item in the table below.)*
    13b. *For each item to which they respond "yes", then ask* "Are there certain kinds of trips or certain destinations you would drive to, in spite of this difficulty?" *And if so, ask:* "How often do you do this?" *If they volunteer other info. such as certain destinations or situations, record this under "Other comments."*

13a. Check "*Yes" or "No" for each of the following potential difficulties.*	13b. *Drive anyway, despite difficulty? – Check "Yes" or "No." If 'yes,' how often?*
13a(1). Harder to see at night (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(2). Harder to read signs or see traffic signals (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(3). Harder to understand the meaning of signs and signals (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:

13a. Check "*Yes" or "No" for each of the following potential difficulties.*	13b. *Drive anyway, despite difficulty? – Check "Yes" or "No." If 'yes,' how often?*
13a(4). Harder to know when you have the right-of-way to proceed at an intersection (through or turn). (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(5). Harder to judge gaps in traffic (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(6). Harder to detect other vehicles or pedestrians in the periphery (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(7). Harder to keep up with the flow of traffic (on high speed roads) (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(8). Harder to judge what other drivers are going to do in traffic (hazard anticipation) (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(9). Harder to change lanes or merge (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(10). Harder to pay attention to everything at the same time (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(11). Harder to turn head/neck to look for traffic to the sides or rear of the car (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often?
13a(12). Harder to stay in your lane (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(13). Harder to move your foot between gas and brake pedals (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:

13a. Check *"Yes" or "No" for each of the following potential difficulties.*	13b. *Drive anyway, despite difficulty? – Check "Yes" or "No." If 'yes,' how often?*
13a(14). Harder to know which pedal is the brake pedal and which is the gas (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(15). Harder to steer when making left or right turns (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(16). Get tired easily (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(17). Get lost or disoriented easily (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(18). Harder to deal with bad weather (rain, snow, fog) (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:
13a(19). Other (Fill in, if yes) (1) ___ yes (0) ___ no	(1) ___ yes (0) ___ no How often? Other Comments:

14. Have you changed your driving habits over the past 5 or 10 years in any of the following ways ? *(Check "yes" or "no" for each item)*

14a.	Drive fewer miles	(1) ___ yes (0) ___ no
14b(1).	Make fewer trips per week?	(1) ___ yes (0) ___ no
14b(2).	Avoid or limit night driving?	(1) ___ yes (0) ___ no
14b(3).	Avoid or limit driving in unfamiliar areas?	(1) ___ yes (0) ___ no
14b(4).	Avoid or limit driving far from home?	(1) ___ yes (0) ___ no
14b(5).	Avoid or limit high speed roads?	(1) ___ yes (0) ___ no
14b(6).	Avoid or limit freeways/expressways	(1) ___ yes (0) ___ no

14b(7).	Avoid or limit high traffic roads?	(1) ___ yes (0) ___ no
14b(8).	Avoid or limit driving at rush hour?	(1) ___ yes (0) ___ no
14b(9).	Avoid or limit changing lanes?	(1) ___ yes (0) ___ no
14b(10).	Avoid or limit driving in bad weather (rain, snow, fog)?	(1) ___ yes (0) ___ no
14b(11).	Avoid or limit turning left at intersections, unless there is a green arrow to tell you that it is safe to go.	(1) ___ yes (0) ___ no
14b(12).	Limit where/when you drive in other ways? ______________________________	(1) ___ yes (0) ___ no
14c.	Drive only with a passenger	(1) ___ yes (0) ___ no
14d.	Drive slower than the speed limit	(1) ___ yes (0) ___ no
14e.	Use adaptive equipment (Fill in. e.g., seat cushions, spinner knobs, special mirrors, etc.) ____________________	(1) ___ yes (0) ___ no
14f.	Use in-vehicle technologies (Fill in. e.g., navigation systems, collision avoidance technology). ________________	(1) ___ yes (0) ___ no
14g.	Leave more room between your car and the car ahead (increase following distance)	(1) ___ yes (0) ___ no
14h.	You plan the route you're going to take before you leave	(1) ___ yes (0) ___ no
14i.	Other changes in driving habits Fill in: ______________________________	(1) ___ yes (0) ___ no

15. In the past 5 years, have any of the following occurred:

15a.	You took older driver education courses (fill in type) ____________________	(1) ___ yes (0) ___ no
15b.	You had cataract surgery	(1) ___ yes (0) ___ no
15c.	Your physician counseled you about safe driving	(1) ___ yes (0) ___ no
15d.	You had your driving ability evaluated by an occupational therapist or other driver evaluator	(1) ___ yes (0) ___ no
15e.	Your pharmacist counseled you about the effects of your medications on driving	(1) ___ yes (0) ___ no

16. Do you regularly do any of the following?

16a.	Strength and flexibility exercises	(1) ___ yes (0) ___ no
16b.	Aerobic exercises	(1) ___ yes (0) ___ no
16c.	Computer exercise program to keep mentally sharp	(1) ___ yes (0) ___ no
16d.	Get regular eye exams/ updated corrective lens prescription	(1) ___ yes (0) ___ no

17. Are there social events or other occasions where you have a drink of alcohol, and then drive?" (1) ___ yes (0) ___ no

If "yes," ask: "How often does this happen?" ___________________________________

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