

Paper presented at the
Association for the Advancement of Automotive Medicine Conference on Aging and Driving,
February 19-20, 2001, Southfield, Michigan

Variations in Task Performance Between Younger and Older Drivers: UMTRI Research on Telematics

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Abstract

This paper describes the effects of age on driver performance reported in recent studies of telematics conducted by the author and suggests what can be done to assure telematics products are safe and easy to use for older drivers. The human factors studies reviewed concern (1) measurements of the visual demand of driving using the visual occlusion method, (2) detecting warnings on head-up displays (HUDs), (3) reading electronic street maps, and (4) entering destinations into navigation systems. In this paper, younger is defined as ages 18-30 and older as 65-75.

As expected, the performance of older drivers was much poorer, though the degree was quite substantial. Depending on the driving situation, the visual demand of older drivers was 15-50% greater. Older drivers required 40% longer to respond to warnings on HUDs, 33-100% longer to read maps in a simulator, 40-70% longer to read maps on the road, and 80% longer to enter destinations.

Therefore, to assure safe and easy use of telematics by all motorists, older drivers, the most challenged users, must serve as subjects in safety and usability evaluations. This will be facilitated by (1) participation of those representing the older population in technical discussions to set safety standards that require the testing of older drivers, (2) support for research on older drivers, especially preliminary evaluations of proposed safety standards, and (3) efforts to make older drivers available to organizations conducting safety and usability evaluations.

Introduction

This paper reviews recent research conducted at the University of Michigan Transportation Research Institute (UMTRI) pertaining to the use of telematics and age differences. Telematics - navigation, entertainment, communications, safety, security, and other computer and communication based services that rely on computer systems – will significantly alter the driving experience, both in the near and far term. These systems have the potential of increasing driving

safety, making trips more productive, and increasing motorist comfort. However, they also have the potential of making the driving situation much worse. To a large degree, the outcome depends on the extent to which safety and usability are an integral part of product design. Key programmatic elements include: (1) following existing design guidelines (Green, Levison, Paelke, and Serafin, 1995; Campbell, Carney, and Kantowitz, 1997; Green, 1999a, b; Japan Automobile Manufacturers Association, 2000; Society of Automotive Engineers, 2000a, b), (2) utilizing and following the advice of well qualified human factors experts, (3) conducting safety and usability evaluations early in design, and (4) supporting research to eliminate knowledge gaps concerning the safety and usability of telematics.

This paper primarily concerns the fourth programmatic element, safety and usability research. At UMTRI, several noteworthy studies of telematics safety and usability have been conducted in which age has been a critical factor. Many other organizations and individuals have done quality research as well (e.g., Waller, 1991; Ball, Owsley, Sloane, Roenker, and Bruni, 1993; Sivak, Campbell, Sprague, Streff, and Waller, 1994; Oxley, 1996; Eby, Kostyniuk, Streff, and Hopp, 1997; Kostyniuk, Eby, Hopp, and Christoff, 1997; Eby, Trombley, Molnar, and Shope, 1998; Llaneras, Swezey, Brock, Rogers, and Van Cott, 1998; Sims, Owsley, Allman, Ball, and Smoot, 1998; Mourant, Tsai, Shibabi, and Jaeger, 2000; Schieber, Holtz, and Myers, 2000). However, given the limited time frame available for developing and delivering this paper and the associated presentation, the author will concentrate on the research he knows best, that of his research team.

Three topics are addressed in this paper: (1) the basic demands of driving, (2) reading displays, and (3) data entry. For each of these 3 topics at least 1 example study is provided

Basic Demands of Driving

There are 4 commonly cited categories of measurements to assess the demands of driving. They include: (1) primary task performance (e.g., standard deviation of lane position), (2) secondary task performance (e.g., response time to a light inside the vehicle), (3) physiological measures (e.g., heart rate variability), and (4) subjective techniques (e.g., workload ratings). None of these measurements is ideal in terms of reliability, ease of measurement, sensitivity, and other desired characteristics. In a recent UMTRI study, a less commonly mentioned approach, visual occlusion, was used (Tsimhoni and Green, 1999, see also Tsimhoni, Yoo, and Green, 1999).

The rationale for the visual occlusion method is that one must see in order to drive, and the more demanding the driving situation, the more often the driver must look at the road. In the simplest implementation of this approach, the driver is instructed to drive safely but close their eyes whenever they can. The percentage of time their eyes are open is a measure of the visual demand of driving. For ease of recording, this data is often collected in a driving simulator, with the subject pressing a button each time they want a 0.5 second glimpse of the road (approximately a typical eye fixation).

In the study just mentioned, subjects drove a road consisting of straight and curved sections (3, 6, 9, and 12 degrees of curvature – radii of 582 to 146 m) and 3 deflection angles, 20, 45, and 90 degrees). Figure 1 shows the mean visual demand as a function of curve radius and driver age.

Notice the consistent age effects (except for the middle-aged drivers with the largest curve and the straight sections). In general, visual demand increased with age, with the value for older drivers being about 15-50% greater than younger drivers. Thus, older drivers felt they needed to see the road much more frequently than younger drivers and therefore have much less time to look away from the road at telematics.

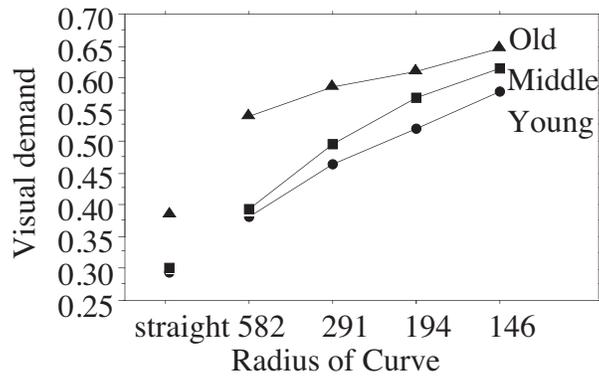


Figure 1. Visual Demand as a Function of Curve Radius and Driver Age Group
 Note: Young = 18-24, Middle =35-54, Old = 55+
 Source: Tsimhoni and Green (1999)

The author would like to emphasize that in this and all of the other studies cited in this paper, there is nothing categorically different between younger and older drivers evaluated other than their age. Both groups included people who were either acquaintances of the experimenters or lived in the Ann Arbor area (and were recruited via a newspaper ad). All were licensed drivers, drove regularly, and were in good health.

Reading Displays

There have been several recent UMTRI studies concerning reading head-up displays (HUDs). In the initial experiment (Watanabe, Tsimhoni, Yoo, and Green, 1999, see also Yoo, Tsimhoni, Watanabe, Green, and Shah, 1999), 24 drivers (16 ages 20-29, 16 ages 65-78) watched a videotape of a driver’s eye view of an expressway scene while seated in a vehicle mockup. To encourage the natural eye scan patterns of driving, subjects pressed a key when the lead vehicle’s brake or turn signal lights illuminated, when a road sign was observed, or when the lead vehicle was passed by a vehicle on the left. In addition, a warning icon (a triangle) randomly appeared on a HUD, to which the subject pressed a key.

Figure 2 shows the mean response times to warnings as a function of the horizontal location of the warning relative to the driver’s line of sight. The mean response time was about 830 ms for younger drivers, 1150 ms for older drivers, with older drivers requiring 40% more time than younger drivers. Even more striking were the age differences in the extreme positive tails of cumulative response time distributions as shown in Table 1. These instances are expected to be most crash provocative.

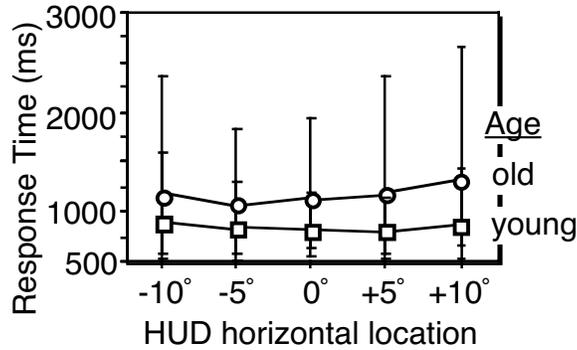


Figure 2. Response Time as a function of HUD Horizontal Location
 Source: Yoo, Tsimhoni, Watanabe, Green, and Shah, 1999, p .iv.

Table 1. Response Time Distributions to HUD Warnings

Percentile	Young (ms)	Old (ms)
5	540	647
10	571	708
25	637	795
50	745	943
75	901	1248
90	1277	2827
95	1930	6678

Source: Yoo, Tsimhoni, Watanabe, Green, and Shah (1999)

In Brooks and Green (1998), 20 drivers (10 ages 18-30, 10 over age 65) drove the UMTRI simulator while searching a simulated electronic map for a navigation system. Figure 3 shows a sample map. Tasks involved (1) identifying the street driven, (2) identifying the cross street a specified number of streets ahead, or (3) locating a particular street. In the street-driven task, subjects pressed 1 or 2 keys depending upon if the name of the street driven was male or female. In the cross-street task, subjects indicated if a particular cross street for that trial (e.g., the third one) had a male name, a female name, or was not on the map. In the find-the-street task, subjects indicated if the street specified was ahead, behind, to the left, to the right, or not shown. In this experiment, the number of streets displayed, the percentage of streets labeled, the label size, and the display location were varied.

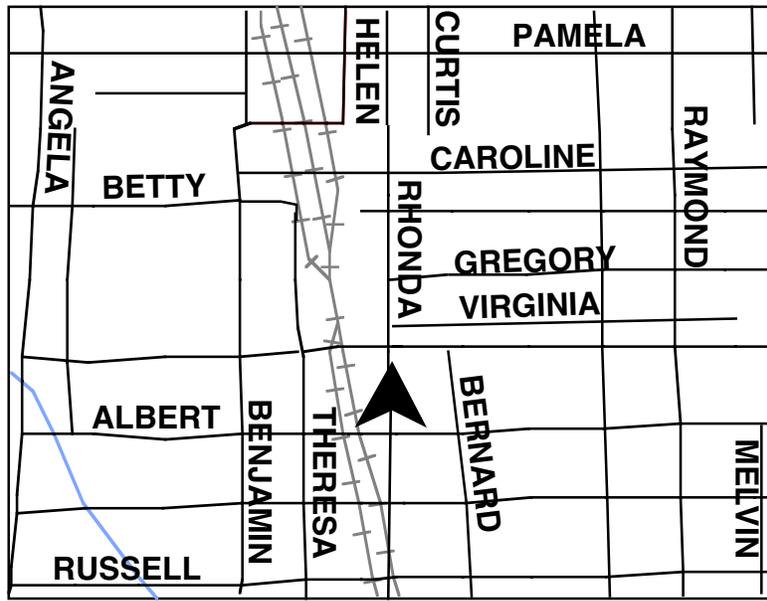


Figure 3. Sample Map from Brooks and Green (1998), p 57.
(24 streets, 66% Labeled, 12 point)

As shown in Figure 4, the difference between younger and older drivers depended upon the viewing conditions. For the very simple driven-street task, the mean response time when the point size was 14 or larger was approximately 1600 ms for older drivers and just under 1200 ms for younger drivers, a 33% increase. For smaller point sizes sometimes found in production navigation systems, the difference was much greater. For example, for 10 point, the response time of older drivers was about double that of younger drivers. This is an indication of the problems older drivers have of reading small print, even with proper corrective lenses. These problems were exacerbated by the need to rapidly re-accommodating from the road scene (at optical infinity) to in-vehicle displays (at less than a meter).

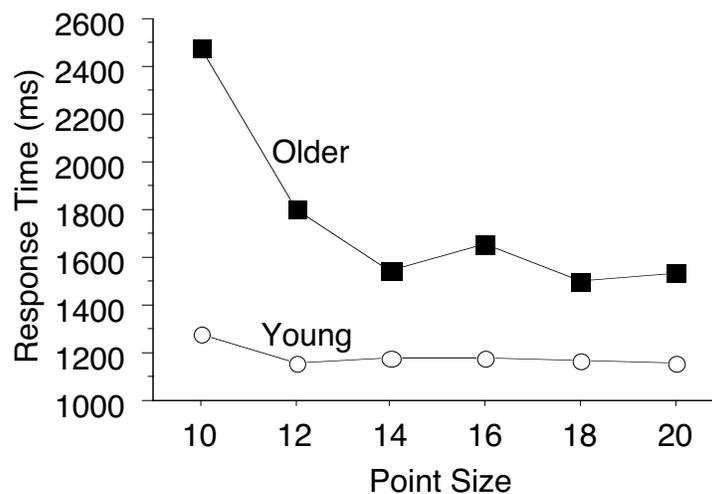


Figure 4. Response Time as a Function of Point Size and Age, 33% of the Streets Are Labeled
Source: Brooks and Green (1998), p. 19

Figure 5 shows the age differences for the find the cross street task, in this case as a function of the number of streets labeled. For this task, the mean time for older drivers was 3100 ms versus only 2200 for younger drivers, an increase of about 40%. This difference was not due to older drivers trading speed for accuracy. Their error rate was 18%, much greater than the 4+% of younger drivers.

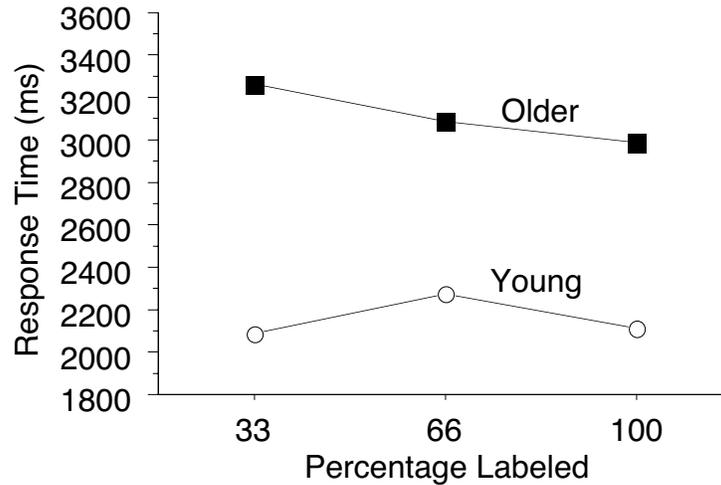


Figure 5. Response Time as a Function of Percentage Labeled and Age
 Source: Brooks and Green (1998), p. 25.

Figure 6 shows the age differences for the find-the-street task. The mean response time for older drivers was about 6710 ms versus 4040 for younger drivers, an increase of 66%. The pattern of the results is typical of what has been found in many UMTRI studies. In the younger age group, the men are strongly motivated to show they are best, so their response times are generally shorter than women of the same age (“the testosterone effect”). In contrast, mortality is an issue among older subjects, where the number of surviving women exceed the number of surviving men. Furthermore, among those surviving, the average woman is healthier than the average man (“the survival effect”). This leads to the interaction shown in the figure.

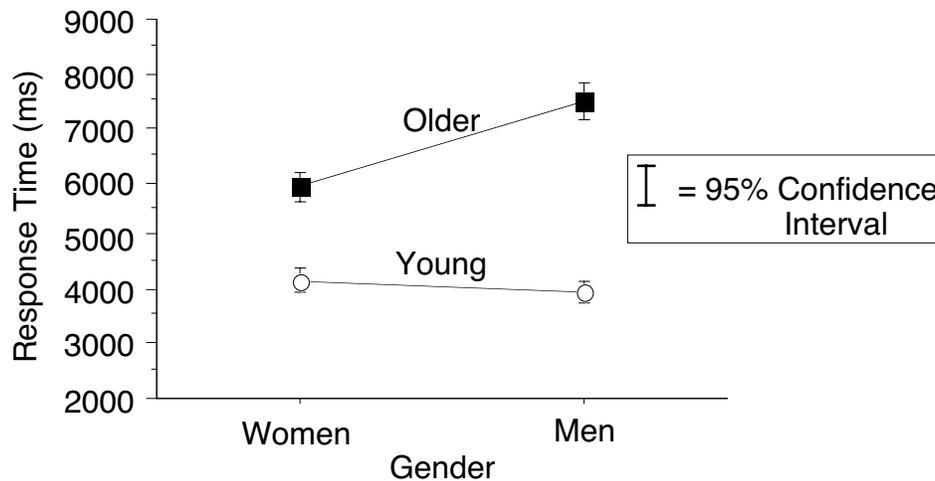


Figure 6. Relationship between Age and Response Time as a Function of Sex
 Source: Brooks and Green (1998), p. 30.

Nowakowski and Green (1998) report a partial on-road replication of Brooks and Green (1998) using the same tasks, but explored a subset of the test combinations (e.g., all streets were labeled). A total of 16 subjects participated in the on-road experiment (8 ages 19-25, 8 ages 65-75). There was no effort to quantify the difficulty of the simulated driving task or precisely duplicate the visual demand of a real road (an expressway with light traffic). Younger versus older driver differences of 1500 versus 2200 ms (47%) were reported for the on-street task, 2800 versus 4000 ms (43%) for the cross-street task, and 4000 versus 6800 ms (70%) for the find-the-street task. As an aside, the means also differed from those of the prior experiment because the difficulty of the in-vehicle tasks was not perfectly matched.

Data Entry

Manes, Green, and Hunter (1998) reanalyzed data reported in Steinfeld, Manes, Green, and Hunter (1996). In the original experiment there were 36 subjects, 12 ages 18-30, 12 ages 40-55, and 12 over age 65. Subjects entered and retrieved destinations into a real and simulated Siemens Ali-Scout navigation system while seated in a driving simulator. The simulator was “parked.” All actions were videotaped and the videotapes were played back frame by frame to determine the interkeystroke intervals. Figure 7 shows the mean time per keystroke as a function of keystroke type and driver age. The mean times were 1.13 seconds/keystroke for young drivers, 1.64 for middle-aged drivers, and 2.48 for older drivers. These result in middle:young ratios of 1.45 and old:young ratios of 2.19. The ratios of the total task times (approximately 1.5 and 1.8) differed from those just given because the shift and enter keystrokes were relatively uncommon in most entry sequences.

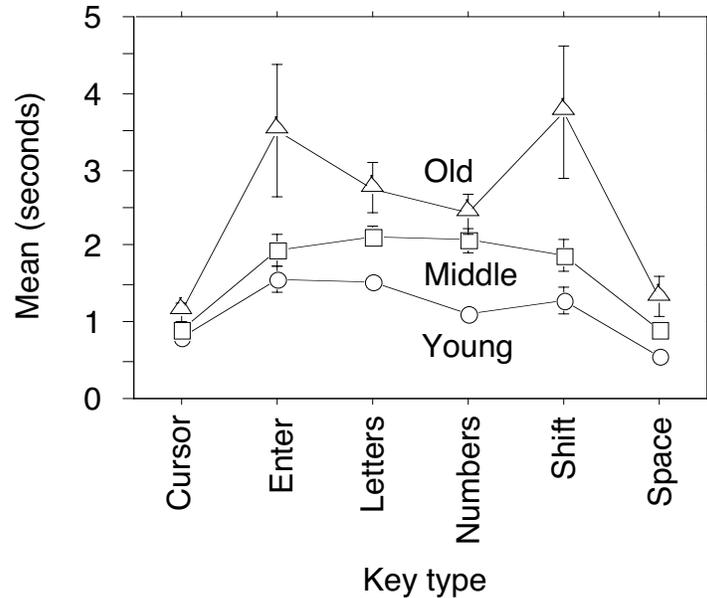


Figure 7. Mean Keystroke Times for Real Interfaces for Various Key Types and Driver Ages
 Source: Manes, Green and Hunter (1998), p. 25.

Conclusions, Recommendations, and Comments

As the driving population matures, there will be increasing focus on older drivers. In recognition of the statistical and practical importance of age differences on driver performance, almost every UMTRI interface study over the last decade has included both older and younger drivers. The author can recall only 1 study conducted by his research team where scheduling and funding limited the sample size to 8 subjects, so only younger drivers were recruited.

Recruiting has proven to be a challenge and mechanisms other than advertisements for subjects in the local paper, the Ann Arbor News, should be examined. There is a strong temptation to make excessive use of drivers who have participated in prior studies. Suggestions for recruiting are welcome. Although UMTRI could extend the distance over which recruiting occurs, that tends to significantly increase the cancellation and no-show rates, creating major logistical and cost problems for projects.

The experience of the UMTRI Driver Interface team in utilizing older drivers, those over age 65, as test subjects in research projects has been positive. Older drivers have proven to be the most dependable subjects, often showing up early, and they are well motivated. Their primary reason for participation often is a desire to do something interesting, not financial remuneration. However, their performance is quite different from that of younger drivers.

From the studies reviewed in this paper, there were 5 key findings with regard to age differences:

1. Depending upon the driving situation, the visual demand of driving for older drivers (as measured by visual occlusion) is 15-50% greater than younger drivers.

2. On average, older drivers took 40% longer to respond to warnings on HUDs, with differences in the most crash provocative situations being a factor of 2-3.
3. For map reading performed while driving in the simulator, older drivers took 33-100% longer to complete tasks, with the difference increasing with task difficulty. Older drivers often made more errors as well.
4. On the road, older drivers took 40-70% longer to complete the same map reading tasks, with the difference generally increasing as task difficulty increased.
5. For data entry tasks performed while parked, older drivers took almost 80% more time, with the time increase depending upon the character to be typed.

Thus, by itself, the basic task of “plain old driving” imposes relatively greater workload on older drivers than young drivers. However, much larger differences are often found when common telematics tasks are added (such as responding to warnings, reading complex displays, and entering data). This increase is of particular concern because some task times reported for older drivers in the literature (Tijerina, Parmer, and Goodman, 1998) are on the order of minutes, and distractions of that duration can expose older drivers to unacceptable levels of risk.

Furthermore, readers should keep in mind that the differences reported here underestimate the differences likely for the most vulnerable drivers. Though this may not be phrased in a politically correct manner, cost constraints have limited UMTRI studies from distinguishing between “old” drivers (ages 65-74) and “old-old” drivers (age 75 and older). Most of the drivers in UMTRI studies are in the 65-74 category.

Since older drivers are both purchasers and users of motor vehicles, suppliers and manufacturers must assure that telematics products are safe and easy for them to use. As the studies reviewed here have shown, older drivers experience considerably more difficulty in completing telematics tasks, and therefore it is essential that safety and usability evaluations focus on them. If the older drivers are able to complete a task safely and easily, then other drivers will be able to as well.

The author has heard the argument that older drivers should not be considered when they are not the target market for a motor vehicle product. Regardless of market intentions, older drivers will nonetheless purchase and use those products unless prohibited. The author cannot foresee a situation where a sale would be contingent upon the motorist’s age. Accordingly, safety and usability evaluations of telematics products must include and target older drivers.

As an example of concerns, the current safety regulations for navigation systems, SAE Recommended Practice J2364 (“the 15-Second Rule,” Green, 1999a,b; Society of Automotive Engineers, 2000a,b), originally called for testing drivers ages 60-65, which was revised to 55-60 and then later revised to over 45 without a change in the performance criteria (a maximum task time of 15 seconds). This change could put older drivers at risk. The rationale for the change was the need achieve a consensus sufficient for approval and satisfy concerns that “older drivers were too difficult to obtain.”

This outcome suggests a need for groups representing older drivers to find ways to assist organizations conducting safety and usability evaluations in recruiting older drivers. They may also need to provide professional expertise to standards development organizations so there will be fewer compromises detrimental to their constituents. Technical contributions such as (1) general research on older drivers, (2) pilot tests of draft standards using older drivers as subjects, (3) commentaries on the language of standards, and so forth (but not lobbying) will help assure older drivers are included in safety and usability evaluations. In this manner, the safety of older drivers will be assured.

In many industrialized countries, but especially in North America, people depend on private motor vehicles for transportation, even in many urban centers. For those individuals, the loss of mobility resulting from the inability to drive can be as traumatic and damaging to health and well being as the most serious diseases. Thus, it is critical that motor vehicles and telematics products for vehicles be designed so that they are safe and easy to use for elderly drivers. This will be achieved by assuring that validation protocols in telematics standards make use of older drivers. Organizations representing older drivers should therefore seek ways to provide technical input to standards development and facilitate the availability of elderly drivers for safety and usability evaluations.

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