Age and Driving Behavior: Contributions from Human Factors

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Abstract

Human factors research regarding age differences and similarities for driving and driving related-behaviors is reviewed. Specifically, cognitive phenomena relevant to driving, such as distraction, memory, navigation, target identification, the legibility of street signs, and judgment of collision are discussed. There is also a discussion of risk assessment and training to improve the useful-field-of view of older drivers, ultimately contributing to improvements in driving skills.

Anecdotal evidence has long confirmed lay theories regarding the driving incompetence of the elderly. But has the scientific community found evidence that driving skills diminish with age? The relationship between crash involvement and driver age is a U-shaped function, where rates are higher for older and younger drivers (Sanders & McCormick, 1993). This would seem to indict the elderly of poorer driving; however, science does not work in this manner.

One specialty that has examined the cognitive processes involved in driving is the area of human factors. The field of human factors is the scientific study of the interaction between a human and a system. Researchers in human factors psychology have examined a variety of questions regarding the relationship of aging to driving behavior, many of which have been studied through testing hypotheses about cognitive processes. While many factors (such as distraction and traffic complexity) can be manipulated in research laboratories, closed-driving courses, and driving simulators, one major component cannot be manipulated—a person's chronological age. Inherent in the cross-sectional nature of many studies (and all of the studies subsequently discussed here) is the fact that there are confounds in comparing abilities of different generations. For example, younger drivers may have been exposed to more video games than older participants before learning to drive. Alternatively, older drivers may have learned to drive in a much different manner, as driver's education programs have developed a more prominent role in driver training. Such confounding variables could contribute to cross-sectional age differences in driving. Thus, it is impossible to use findings with which age has been studied with a cross-sectional design to make definitive statements about age as a causal factor of age differences in driving. Since longitudinal studies of age and driving are expensive and time-consuming, the result is that there are few human factors studies of age differences in driving.

Researchers of human factors have generated a great deal of research on automobile driver behavior, but proportionately little of this research has examined age differences in driving. I suggest that two issues contribute the lack of sufficient research on age differences in driving. First, as discussed above, it is impossible to manipulate the age of the driver. Since many of the human factors researchers who study driving behavior and contribute to basic scientific publication outlets are trained in experimentation, age differences are not an attractive topic due to the lack of experimental control. Second, many of the human factors researchers who study driving behavior work in industry. Their research and solutions to applied problems may not produce publications that are widely available to other scientists. When combined, these issues contribute to a lack of sufficient research on age differences in driving.

Overview

This paper reviews previous research regarding age differences and similarities for driving behaviors as well as driving related-behaviors. It is intended to be a useful summary of human factors research on age differences in driving. This paper basically served as an exhaustive review of human factors research on age differences in driving prior to DeLucia and Mather (2006).

Since there are frequent discrepancies between what researchers classify as "older" among studies, the age ranges are listed for each study discussed whenever possible. I begin by discussing cognitive phenomena relevant to driving, such as distraction, memory, navigation, target identification, the legibility of street signs, and judgment of collision. I conclude with a

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discussion of risk assessment and training to improve the useful-field-of view of older drivers, ultimately contributing to improvements in driving skills.

Distraction

Attention is fundamental to successful driving. A driver must attend to the road and potential dangers that lurk in the roadway and nearby. Recently, increases in mental workload were shown to be detrimental to visual search, as were both verbal production and complex conversations via phone or with a passenger (Recarte & Nunes, 2003). Similarly, Strayer and Drews (2003) examined the effects of cell phone conversations on driving behavior. Older participants were between the ages of 65 and 74 years of age, while younger participants were between the ages of 18 and 25 years of age. Participants performed a driving simulation task in which they were required to follow a pace car. In a dual-task condition, participants conversed with the experimenter by use of a hands-free cell phone. Overall, older participants drove slower and with greater following distance than did younger participants. Additionally, the dual-task condition for older participants increased the onset time of braking, increased following distance, and increased the time required to recover the speed lost by braking over the single-task (driving only) condition.. Braking reaction times of younger participants in the dual-task condition were equivalent to the older participants' braking reaction times in the single-task condition. Thus, cell phone conversations degraded the reaction time of young participants to the same level as older participants who were not engaged in a phone conversation.

Memory

Since distraction impairs driving and there is a short amount of time to process information while driving, does memory during driving differ with age? Bao, Kiss, and Wittmann (2002) examined the effects of a visual memory task on a simulated driving task. Older participants were between the ages of 60 and 80 years of age, while younger participants were between the ages of 20 and 31 years of age. Participants sat in a car and viewed a car simulation projected on a screen. Participants performed one of three tasks: a memory task (in which German words were presented with variously manipulated groupings), a driving task (in which they were instructed to stay in the right lane and brake upon seeing a red light), or a dual task (in which both the memory and driving tasks were performed at the same time). Older participants remembered fewer words on the memory task than did younger participants. Younger participants recalled more words when the words were presented in shape groups rather than not grouped, but this effect was not present for the older participants. The type of memory task affected older participants' reaction times to the red light and number of driving errors, while younger participants were unaffected. Bao et al. discussed the fact that their findings had implications for engineering instruments in cars to better disseminate information to both older and younger drivers.

Wayfinding and Navigation

Similar to the memory research, others have examined more complex forms of spatial memory used during driving. de Ridder, Elieff, Diesch, Gershenson, and Pick (2002) examined the spatial orientation of older and younger participants. Older participants were above 60 years of age (M = 71.3), while younger participants were between the ages of 24 and 40 years of age (M = 27.4). Participants drove a set route through a neighborhood with instructions to recall the route, while the experimenter pointed out particular landmarks. After practicing the route, participants drove to various stations and pointed to where they believed the landmarks to be in the route. Older participants had larger errors when pointing to the intersections and landmarks from the station points than did younger participants. A second study using a driving simulation revealed that older participants again had larger errors when pointing to the intersections from the station points than did younger participants, thus generalizing the findings to a virtual driving task where the experimenters had more control over extraneous variables.

Driving Performance and Target Identification

Given what we know about attention and memory age differences in driving, it is logical to examine visual memory in the periphery of the visual field during a complex driving task, which is important to anticipating collisions in driving. Chaparro and Alton (2000) examined age differences in driving performance and peripheral letter identification. Older participants were between the ages of 64 and 85 years of age, while younger participants were between the ages of 18 and 41 years of age. Using a driving simulator, participants drove in either a high complexity or a low complexity traffic condition. The number of stoplights that could potentially turn red and the number of obstacles in the road defined the complexity of the traffic condition. Older participants drove slower, had more accidents, showed more difficulty in turning, and correctly identified fewer letters in the accompanying peripheral letter task. The older participants' higher accident rate and lower correct letter identification rate were both amplified by increasing scene complexity. It should be noted that these differences could also have manifested from the cross-sectional design, where older participants actually had more difficulty within the confines of the driving simulator than younger participants, perhaps due to the older participants' lack of experience with video simulations.

Legibility of Street Signs

One way in which both older and younger drivers receive information while driving is through street signs. Sivak, Olson, and Pastalan (1981) examined the relationship of a driver's age to the legibility of a highway sign at night. Older participants were between the ages of 62 and 74 years of age, while younger participants were between the ages of 18 and 24 years of age. All participants were matched for high-luminance far acuity (how well they see for well-lit moderate distances). Participants rode in a car at night and pressed a switch to indicate when they perceived the orientation of a letter on the sign. It was found that older drivers required closer distances to correctly perceive the orientation of the letter on the nighttime highway sign. Thus, older drivers effectively have less time to react to the information on a highway sign when approaching it. Sivak et al. suggested that the legibility of highway signs be calibrated specifically for both night driving conditions and older drivers, where they are currently calibrated for young drivers under daytime conditions.

Chrysler, Stackhouse, Tranchida, and Arthur (2001) examined what improves street sign legibility. All participants were between the ages of 62 and 83 years of age. Participants drove through three intersections in St. Paul, Minnesota. Each of the intersections was classified as high complexity, medium complexity, or low complexity, based on the intersection's usual traffic flow. Different types of retroreflective material were used. Participants drove to the intersection and verbally read the sign when it became legible. The experimenter pressed a button that recorded the distance from the sign when the sign was read. Results indicated that brighter signs facilitated legibility to the greatest degree in the highly complex traffic situations, that this effect was increased when signs were mounted on the left side of the road rather than on the right side, and that certain types of retroreflective materials increased the distance at which the older drivers could read the sign.

Scialfa, Ho, Caird, and Graw (1999) examined the effects of sign clutter on older drivers. In the first experiment, older participants (M = 64.7 years) and younger participants (M = 23.4 years) viewed slides of various traffic signs and judged them as either high or low clutter. In the second experiment, scenes were used that were categorized as high and low in the first experiment. Participants were either older (M = 63.9) or younger (M = 24.1), and viewed a traffic sign and subsequent traffic scene on a monitor. Eye gaze was recorded, and their task was to indicate whether the traffic sign was present in the traffic scene. Results indicated that older participants used more eye movements (and thus more time) to locate traffic signs. Additionally, both older and younger participants were detrimentally affected by clutter. Scialfa et al. (1999) suggested that older participants might have developed expertise over their lifetimes that negated age differences in susceptibility to clutter.

Judgments of Collision

When driving, both older and younger drivers must calculate how fast they are approaching other cars, pedestrians, turns, etc. Such calculations are not explicit, and occur very rapidly. Judgments of collision often use time-to-contact (TTC) measurements to examine a person's perception of an approaching object. Specifically, TTC refers to the rate of optical expansion, which is called tau (DeLucia, Kaiser, Bush, Meyer, & Sweet, 2003). Such estimates can be affected by self-motion (DeLucia & Lidell, 1998), which occurs when the observer moves or perceives that they move when making the judgment. The studies discussed represented both self-motion (e.g., DeLucia & Mather, 2006; Kennedy, Jentsch, & Smither, 2001), a lack of self-motion (Scialfa, Kline, Lyman, & Kosnik, 1987), and both (DeLucia, Bleckley, Meyer, & Bush, 2003).

Scialfa et al. (1987) examined judgments of the estimated velocity of an oncoming vehicle. Older participants were between the ages of 54 and 79 years of age, while younger participants were between the ages of 16 and 45 years of age. Participants viewed brief video clips of a car approaching from the left from a variety of different speeds and distances. All participants made a judgment of both distance and velocity for each trial. Results indicated that older females overestimated the velocity of the car more than did males or younger females. In addition, older males overestimated the distance of nonmoving vehicles relative to the estimates of females or young males. The fact that older males overestimate the distances of vehicles may lead to problems for older males as both drivers and pedestrians. For example, an older male driver who overestimates the distance of an oncoming vehicle when pulling into traffic is at risk for collision. Similarly, an older male pedestrian who overestimates the distance of an oncoming vehicle when crossing a street is at risk for a collision.

Scialfa, Guzy, Leibowitz, Garvey, and Tyrrell (1991) further examined the role that judgments of velocity play in driving behavior by employing an actual car on a test track as the stimulus. Older participants were between the ages of 55 and 74 years of age, middle-aged participants were between the ages of 40 and 54 years of age, while younger participants were between the ages of 20 and 27 years of age. Participants were instructed to view through their windshield a car that was moving on the track and to estimate the car's velocity. The speed of the stimulus car varied. Results indicated that: 1) participants can scale the velocity of an approaching car, as all judgments were made in miles-per-hour (mph) rather than the traditional use of a neutral metric, 2) participants did not accurately estimate velocity, overestimating at higher velocities and underestimating at lower velocities, and 3) compared to the young participants, the older participants overestimated at lower velocities and underestimated at higher velocities. These results suggest that participants make errors that bias their driving toward conservative behavior (i.e., overestimating at higher velocity). However, the fact that older participants overestimated at lower velocities and underestimated at higher velocities compared to younger participants indicated that the older participants might be more at risk for accidents than the younger participants, based on judgments of velocity.

Schiff, Oldak, and Shah (1992) examined the age differences in the estimated arrival times of vehicles. In Experiment 1, older participants were between the ages of 65 and 83 years of age, while younger participants were between the ages of 20 and 45 years of age. Participants viewed films of a car approaching either on course for collision or a near miss. The scene vanished during the approach, and the participants' task was to press a button when they judged that the car would have reached them or passed them had the motion continued (direct response) or to estimate the velocity and distance (verbal response). Older participants made higher estimates of velocity than did younger participants. Older female participants made higher estimates of velocity than did younger females, or older and younger males. Across two experiments, Schiff et al. found that verbal estimates of arrival time were less accurate than direct estimates.

Hancock and Manser (1997) tested the effects of varying how the target disappeared from the video. In the first experiment, older participants were between the ages of 50 and 70 years of age, while younger participants were between the ages of 18 and 30 years of age. Participants were seated in a high-fidelity wrap-around environment simulator, which was a car with a screen that wrapped around the vehicle. On the screen, three images were projected so that it appeared as though the driving scene was one image. Participants then viewed a scene where an oncoming car either disappeared or was occluded by a bush. Their task was to press a button when they believed that the oncoming vehicle would have reached them after its disappearance. Judgments of collision were more accurate as the velocity of the oncoming car increased, and when the oncoming car was occluded as opposed to simply vanishing. Older participants made less accurate TTC estimates than younger participants. This difference was highest at 40 mph (versus 35 and 45 mph).

In Hancock and Manser's (1997) second experiment, older participants were between the ages of 55 and 83 years of age, while younger participants were between the ages of 19 and 27 years of age. Again, judgments of collision were more accurate as the velocity of the oncoming car increased, and when the oncoming car was occluded as opposed to simply vanishing. Older participants again made less accurate TTC estimates than younger participants. This difference decreased as the velocity of the oncoming car (either 6, 9, 15, or 44 mph) increased. The results of both Experiment 1 and Experiment 2 indicated that older females made more errors at lower oncoming velocities than older and younger males or younger females.

Lee (2001) examined age differences in ability to estimate distance using car lengths. Older participants were between the ages of 64 and 76 years of age, while younger participants were between the ages of 19 and 28 years of age. Participants drove their own cars to a course where lines were marked from 0 to 250 feet. Each participant placed their car on the "0" line, and was asked to estimate in feet (from the driver's seat) the length of their own vehicle. Following this, they were asked to estimate (in both feet and car lengths) the distance from their car to another car on the course. Results indicated that participants underestimated distances, and that older participants did so more than younger participants at distances greater than 100 feet. Additionally, estimates of linear length in feet were more accurate than estimates that used car length as the unit of measure.

Kennedy et al. (2001) examined older and younger participants' ability to detect when they, as the driver of a car, are closing in on another car. In such a situation, the detection of the change of optical size of the approaching object is called looming. Older participants were between the ages of 60 and 80, middle-aged participants were between the ages of 40 and 55, and younger participants were between the ages of 18 and 35. Participants were tested on a variety of tasks, and driving errors were assessed through a driving simulator game on a PC. Results indicated that older participants performed worse than middle-aged and younger participants for several measures of looming detection, time to navigate the course, and number of violations (such as departures from the assigned driving lane) in the driving simulation. Additionally, middle-aged participants performed worse than younger participants for some measures of looming detection. Kennedy et al. also found that their looming detection task system had test-retest reliability, and advocated its development as a tool for use in driver research.

In three experiments, DeLucia, Bleckley, et al. (2003) examined age differences in judgments about potential collision (TTC). In Experiment 1, the authors examined the idea that older drivers are more conservative than younger drivers in judgments about when objects will collide. Older participants were between the ages of 50 and 64 years, while younger participants were between the ages of 18 and 29 years. Computer-displayed scenes showed a rectangular object that moved toward a pole. The scenes showed the objects from both moving and stationary observation positions.

In Experiment 2, the authors examined the idea that older drivers make less accurate TTC judgments than younger drivers. Older participants were between the ages of 55 and 76 years, while younger participants were between the ages of 18 and 20 years. Computer-displayed scenes showed two cubes, either on course to collide or not to collide. The scenes showed the cubes both from moving and stationary observation positions, and a condition of correct ground-intercept information was also present.

In Experiment 3, the authors examined the idea that older drivers have higher thresholds for TTC than younger drivers. Older participants were between the ages of 51 and 75 years, while younger participants were between the ages of 18 and 23 years. Computer-displayed scenes showed square objects that approached the observer and appeared for both moving and stationary observation positions.

Older participants had smaller TTC judgments than younger participants. Younger participants had a higher percentage correct than older participants. It was also found that both older and younger drivers used the same visual information in performing the task. Younger drivers performed the driving task more effectively than older drivers. Younger drivers performed better than chance for nearly all conditions, while older drivers only did so when multiple cues provided the same information (and indicated confidence in their ratings). Older drivers had more difficulty with the task when TTC was large. Age differences also affected female participants more then male participants for the point of subjective equality (PSE), which varies the horizontal position and speed of an object to vary factors that determine whether or not an object will collide with an observer. Declines in the thresholds for collision detection were found, indicating that general declines in cognitive functioning occur with age. Evidence for this came from the fact that older and younger drivers had similar judgments when TTC was small, but older drivers had worse judgments as TTC increased.

DeLucia, Bleckley, et al. (2003) also found that age differences in TTC judgments were not significant factors in older drivers' higher accident rate, thus judgment about when two objects would collide did not correlate with performance. Judgment about whether two objects would collide was not correlated with performance. It was found that more accurate judgments were associated with a higher frequency of police stops. This may have been due to the fact that drivers with more accurate judgments engage in more risky behaviors because they are more accurate in knowing their own driving capabilities. Additionally, younger drivers showed a positive correlation between PSE and the frequency of accidents, while older drivers showed a negative correlation.

Additional measures indicated that older drivers were more conservative in terms of driving behavior. Minor accidents and major accidents were positively correlated for older but not for younger drivers. Major accidents and the frequency of being stopped by the police were positively correlated for older but not for younger drivers. Scores on the driving behavior questionnaire that examined errors and the frequency of being stopped were positively correlated for older but not for younger drivers. Major accidents and speed violations were correlated for younger but not older drivers.

Horizontal position of PSE was negatively related to the participant's performance on a mental rotation task. Reaction time was positively related to both horizontal position and horizontal speed of PSE. Age was negatively related to reaction time.

Older drivers underestimated TTC more than younger drivers, ultimately judging collisions to occur earlier than they would actually occur. Older drivers were also less accurate in their judgments about whether a collision would occur. Older drivers performed most accurately when they had both optical expansion and ground-intercept information, while young drivers performed accurately with ground-intercept alone. Delucia, Bleckley, et al. (2003) suggested that the ability to judge potential collision may be useful for driving licensure tests to assess risk of accident among elderly drivers.

Risk Assessment, Training, and Field-of-View

Along the lines of developing a test for driving licensure, much research has been dedicated to accident prevention. The research on accident prevention among the elderly has generally centered on either assessing a person's risk for an accident or developing a training program to improve driving skills. The role of a variety of cognitive abilities has been examined in both assessment and training program development.

Van Elslande and Fleury (2000) suggested a model with which to classify errors committed by older drivers in accidents. These classifications were constructed to use in scenarios representative of typical driving, and ultimately to lead to a tool to use in training drivers. Van Elslande and Fleury suggested that such training might teach appropriate safety maneuvers designed to avoid accident outcomes in the selected scenarios.

Lee, Drake, and Cameron (2002) used a driving simulator to identify criteria that older drivers need to be successful drivers. Participants were between the ages of 65 and 85 years of age. Results indicated that performance indicators were related to age, such that the length of the simulated drive was positively related to age, and speed violation, proper signaling, divided attention task, and off-road accident were all negatively related to age. Operational parameters (e.g., head angle error, lane position) were not related to age. Lee et al. suggested that the operational parameters represented well-learned automatic processes that were not subject to deterioration with age, while the performance indicators were not subject to automatic processes. They concluded that based on the performance indicators effectiveness as predictors, their driving simulator can be used to evaluate the driving skills of older people.

Marottoli et al. (1998) developed tests designed to relate functional abilities of older drivers with self-reported driving behavior. These tests were designed to be easy to administer by a clinician to identify older drivers at risk of impaired driving ability. All participants were 72 years of age and above. Factors associated with self-reported history of adverse driving events were poor near visual acuity (ability to see clearly at close distances), visual attention, and neck rotation. Decreased neck rotation might be an especially dangerous impairment, as decreased field-of-view accompanies increased age (Sifrit, Chaparro, & Stumpfhauser, 2003).

Roenker, Cissell, Ball, Wadley, and Edwards (2003) tested the effectiveness of speed-of-processing training on actual driving behavior. Participants were between the ages of 48 and 94 years of age. Participants were assigned to speed-of-processing training, driving simulator training, or a low-risk control group. The speed-of-processing training consisted of the participant performing a variety of tasks on a computer in which they identified items embedded among distracters, or simply identifying central and peripherally located targets. The driving simulator training consisted of an instructor reviewing basic driving rules and techniques for crash prevention, all practiced by the participant in a simulator. An open-road (14 mile) driving task was used to assess driving behavior on three different occasions for each participant: pretraining, posttraining, and an 18-month follow-up. The speed-of-processing training resulted in fewer dangerous maneuvers and a faster reaction time in the visual task (related to useful field of view; see below for a description of useful field of view), both of which were maintained for an 18-month follow-up. The simulator training improved the participants' use of turning into the correct lane and proper signal use, neither of which showed a maintained improvement at an 18-month follow-up. This research suggested that the driving behavior of older drivers could be improved through a speed-of-processing training program.

Similarly, Sifrit et al. (2003) sought to improve visual attention skills of older drivers though a training program. Participants were between the ages of 60 and 81 years of age. Participants were pretested on the Useful Field of View (UFOV) test, in which processing speed, divided and selective attention were measured. UFOV is "the area within the visual field from which information can be obtained rapidly without moving the eyes or head" (p. 253). The experimental group received five training sessions designed to improve the UFOV, while the control group received no training. All participants were tested again on the UFOV after five weeks. Results indicated that improvements in selective attention and divided attention occurred for participants with initially poor selective/divided attention, but not for those with initially high selective/divided attention. Thus, Sifrit et al. found evidence that UFOV training can improve visual attention in older drivers.

Discussion

Human factors research is unique in that it is comprised of practitioners employed in both industry and academia. Since many researchers in human factors are practitioners in industry, the *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* is an important outlet for this research and has been cited in many mainstream psychological journals. For an example of a research summary on driving behavior in young drivers that cites the *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, see Pollatsek, Fisher, and Pradham (2006). As a survey of the human factors research on age differences in driving, it was necessary to leave no stone unturned—hence the use of several articles from the *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. The fact is that although there is much human factors research available, much human factors research never leaves industrial circles and there is certainly a shortage of human factors research on age differences and driving behavior.

Summary

As the population grows and becomes increasingly urbanized, research on age differences in driving will become more important. Previous research has demonstrated that cell phone conversations degrade the reaction times of young participants to the same level as older participants who were not engaged in a phone conversation (Strayer & Drews, 2003), and the type of memory task affects older participants' reaction times in a driving task but not younger participants (Bao et al., 2002). Also, older participants had larger errors when pointing to intersections and landmarks than did younger participants in both real and simulated driving tasks (de Ridder et al., 2002), and scene complexity amplifies older participants' higher accident rates and lower correct letter identification rates in a driving simulation (Chaparro & Alton, 2000). Additionally, older drivers require closer distances to correctly perceive the orientation of the letter on the nighttime highway sign (Sivak et al., 1981). Finally, older participants overestimate speed at lower velocities (Scialfa et al., 1991), underestimate speed at higher velocities (Scialfa et al., 1991), and underestimate TTC more than younger drivers (DeLucia, Bleckley, et al., 2003), ultimately judging collisions to occur earlier than they would actually occur. Various types of training, such as speed-of-processing training (Roenker et al., 2003) and Useful Field of View training (Sifrit et al., 2003) have been shown to improve upon these deficiencies in older drivers. These human factors findings regarding age differences in driving behavior are an important first step for improving traffic safety.

Future Directions

While it is necessary to study actual driving behavior during different stages of the lifespan, it is equally important to conduct basic laboratory research on the cognitive and perceptual processes that relate to driving. Such in vivo studies accentuate applied studies. For instance, DeLucia and Mather (2006) used a computer-driving simulator and a cross-sectional design to examine age difference in motion extrapolation. While such studies did not allow the authors to draw conclusions about the causal nature of age in the design, it was a powerful design that was much safer than manipulating actual car-following behaviors in a longitudinal design. In fact, the cross-sectional design allowed the researchers to answer basic questions about age differences in motion extrapolation of car-following without the 40-year delay of a longitudinal study! This review is designed to increase awareness to human factors researchers that: 1) it is important to study age differences in driving, 2) it is important to answer first generation basic questions about cognitive processes involved in driving with a cross-sectional design, and 3) it is important to conduct subsequent research on cognitive processes involved in driving with longitudinal designs.

Conclusions

Solutions to problems of age differences in driving exist, including risk assessment and training to improve the useful-field-of view of older drivers. The reality is that there are indeed many age differences in driving, including distraction, memory, navigation, target identification, the perception of street signs, and judgment of collision. Many of these are attributable to cognitive differences between the age groups studied. However, it has yet to be determined the degree to which these differences are attributable to the aging process or to environmental learning differences between the age groups. Future research should employ longitudinal designs to compliment basic cross-sectional laboratory research that closely examines cognitive processes. Only by formulating research hypotheses from longitudinal and cross-sectional perspectives will science gain a more comprehensive understanding of the effects of age on driving abilities, skills, and behaviors.

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