EXPLORING OLDER DRIVER LATERAL HEAD ROTATIONS AT INTERSECTIONS USING NATURALISTIC DRIVING DATA

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Summary: This study represented a meta-analysis across two naturalistic driving databases which were collected in the same geographic area but focused on distinct age groups. Differences in range of lateral head rotation between older and middle-aged drivers traversing the same pathway through unprotected left turn intersections were examined. These driving scenarios are known to be among the riskiest and most difficult for older drivers, who demonstrated an increased range of head rotation compared to their middle-aged counterparts. These results are interpreted in the context of possible compensation for reduced fields of view.

INTRODUCTION

Safe driving depends on the driver being able to visually gather relevant information from the roadway environment. The prudent driver must perceive and attend to at least each of the following: the forward roadway, nearby as well as oncoming and crossing traffic, other potential obstacles, pedestrians and cyclists, a variety of directional signs and signals, and dashboard displays. Greatly adding to the complexity of the situation are other in-vehicle, as well as external, visual inputs not directly-related to the driving task which compete for attention, such as an infotainment system or the scene of a recent crash. It is also well understood that our visual and related cognitive capabilities tend to decline with age (Bohensky, Charlton, Odell, and Keeffe, 2008). The question becomes, how much do the various types of visually-related impairment affect behavior, and possibly risk, for the aging driver in particular driving scenarios?

Intersections

Several researchers have noted that one of the riskiest of regularly-encountered scenarios for older drivers to negotiate is intersection crossings, especially turns across path - left turns in the U.S. (LTAP). Stamatiadis et al. (2003) investigated the relationship between crashes involving older drivers and intersections using the relative accident involvement rate (RAIR) for drivers in the state of Michigan from 1983 to 1985. They investigated the ratio of at-fault crashes with the percentage of crashes where a driver from an age-matched control was not at fault. They found that drivers aged 70 and older exhibited a significantly higher RAIR than their younger counterparts for complex intersections (i.e., those with more than two traffic signals).

Chandraratna and Stamatiadis (2003) used 1995-1999 crash data from Kentucky to investigate crash rates in various situations. Both gap estimations and LTAPs were found to have a higher crash rate for drivers over 65. Odds ratios comparing older to younger drivers were found to be 3.20 for left turns against oncoming traffic and 1.87 for gap acceptance. Their analysis suggests that issues for older drivers may arise from LTAP intersections which often require the driver to estimate gaps between oncoming vehicles. Charlton, Oxley, Fildes, and Les (2001) administered a survey to older drivers (85-96 years old) which consisted of several questions about self-regulation. Only 5.6 % of drivers noted always avoiding LTAP intersections while 59.3% never did. The relatively high percentage of drivers who never avoided turning across traffic suggests they were either unaware of the risks, that they still felt confident in such situations, or that such scenarios were not easily avoided. Stutts, Martell and Staplin (2009) analyzed both FARS and GES data for the years 2002 to 2006 and found that left-turning movements were one of the most problematic situations for older drivers. They also noted that such situations often include complex visual searches and information from multiple sources that must be processed rapidly under divided attention conditions. These studies indicate that left turn intersections and the resulting gap estimations for oncoming (and sometimes crossing) traffic are the cause of much concern for older drivers and an area where further research is required.

Glance Related Behaviors at Intersections. Isler, Parsonson, and Hansson (1997) evaluated the age-related restriction of head movements on the useful field of view (UFOV) of drivers. Eighty drivers in four groups of twenty were sampled: < 30, 40-59, 60-69, and 70+. In a test of head rotation, the oldest drivers had lost about 1/3 of range of motion relative to the younger age groups. The loss of head rotation was most-evident in males. The authors also note that many of the drivers in the two oldest age groups had severely restricted head rotation abilities. In a more recent study, differences in visual scanning were evaluated among 60 drivers in three separate age groups: 18-25, 35-55, and 65-80 (Bao and Boyle, 2009). Participants performed various driving maneuvers at different intersection types. The proportion of time they visually sampled towards the left, right, and rear-view mirror were measured. Results showed that older drivers performed a smaller proportion of sampling to the left and right during intersection crossings.

Angell, Antin, Wotring, and Aich (2010) performed a pilot study whereby head rotation behavior at intersections was compared across teen, middle-aged, and older drivers. Intersections were broken out into zones functionally defined as follows: (1) initiation zone – from first behavioral indication of the intention to make a turn to the entrance to the conflict zone; (2) conflict zone – the area within the intersection where the participant’s vehicle could come into conflict with other oncoming or crossing traffic; and (3) completion zone – from the end of the conflict zone to the completion of the turn (defined in terms of vehicle kinematics). VTTI’s machine vision based automated head position tracking tool was applied post-hoc to the driver face video, and preliminary results indicated that the methods were promising.

Objective

The objective of the current study was to build on the efforts of Angell, Antin, Wotring, and Aich (2010) by using naturalistic driving data to compare the lateral head rotations of middle-aged and older drivers as they negotiated many more unprotected left turns. The middle-aged drivers are believed to represent a baseline against which the older driver behaviors can be compared.

METHODS

This study represents a meta-analysis across two naturalistic driving studies: the Older Driver Study (Antin, 2007) and the 40-Teen Study (Lee, Klauer, Olsen, Simons-Morton, Dingus, Ramsey, and Ouimet, 2008). Note that the 40-Teen Study also included data collection on the parents of the teens. The current study encompasses data from the older drivers in the Older Driver Study and *only* data from the middle-aged parents in the 40-Teen Study.

Participants and Intersections

Fourteen older drivers included nine men and five women ranging in age from 71 to 84. The 13 middle-aged drivers consisted of four men and nine women ranging in age from 42 to 53. All participants were recruited from the vicinity of the New River Valley area of Virginia. Note: there were more participants in these naturalistic data collections than are represented in the current study. The ones included here are ones where a screening process revealed at least three unprotected left turn intersection pathway traversals by both older and middle-aged participants. Both LTAP and "T" intersections were included. All intersection crossings were considered successful, that is, no crashes or near-crashes were included in the analyses.

Instrumentation in the Original Data Collection Efforts

The drivers' vehicles were instrumented with a data acquisition system (DAS) that continuously recorded data whenever the vehicle was running (less a brief warm-up period at the outset of each trip). The DAS included several cameras and sensors, most notably GPS for the current analyses.

Experimental Design and Variables

A mixed-factors experimental design was used. The within-subject factor was intersection zone with three levels: initiation, conflict, and completion. The between-subjects factor was age group with two levels: middle-aged and older. Dependent variables included the following: Lateral-right – the farthest lateral head rotation to the right in degrees; Lateral-left – the farthest lateral head rotation to the left in degrees; Lateral-range – the range of lateral head position in degrees; and Lateral-SD – the standard deviation of lateral head rotations, in degrees.

VTTI's machine vision based automated head position tracking tool was applied post-hoc to the driver face video for 226 intersection pathway traversals at four different unprotected left turn intersections. An intersection pathway is defined not only by a particular intersection but also a particular pathway through that intersection.

Table 1 shows the total number of passes and unique participants per intersection pathway for both age groups. Note that in several cases, participants are represented in more than one intersection pathway and multiple times within a single pathway.

Table 1. Total Number of Participants and Unique Passes by Age Group

	Number of Unique Participants		Total Number of Passes	
Intersection Pathway	Middle-Aged	Older	Middle-Aged	Older
A (LTAP)	7	4	7	5
B (LTAP)	5	3	8	3
C (T)	6	7	20	23
D (LTAP)	8	7	104	56

RESULTS AND DISCUSSION

ANOVAs were conducted on each of the four variables described above, and the statistically significant results are presented in Table 2.

Table 2. Statistically-significant lateral head position effects

Dependent Variable	Factor	Error Term Used	*F* Value	*p* <
Lateral-right	Zone	Zone*Participant (Age Group)	17.24	0.001
Lateral-left	Zone	Zone*Participant (Age Group)	15.39	0.001
Lateral-range	Zone	Zone*Participant (Age Group)	23.47	0.001
Lateral-SD	Zone	Zone*Participant (Age Group)	11.15	0.001
Lateral-range	Age Group	Participant (Age Group)	6.07	0.022

$\alpha = 0.05$

The means for the significant dependent measures are summarized in Table 3. All post-hoc testing was executed using the Student-Newman-Keuls correction for multiple tests.

Table 3. Means in Degrees

	Intersection Zone			Age Group	
Factor	Initiation	Conflict	Completion	Middle-Aged	Older
Lateral-right	74.7 (C)	89.0 (A)	84.7 (B)	-	-
Lateral-left	115.6 (A)	117.4 (A)	100.8 (B)	-	-
Lateral-range	41.0 (A)	28.4 (B)	16.1 (C)	27.7 (A)	30.6 (B)
Lateral-SD	9.4 (A)	9.5 (A)	5.4 (B)	-	-

Note: Different letters denote significant differences across each row

Intersection Zone

Looking at right and left glance behaviors permits a more detailed examination of what is seen in the range results. The average extents of the Lateral-right and Lateral-left for each zone are illustrated in

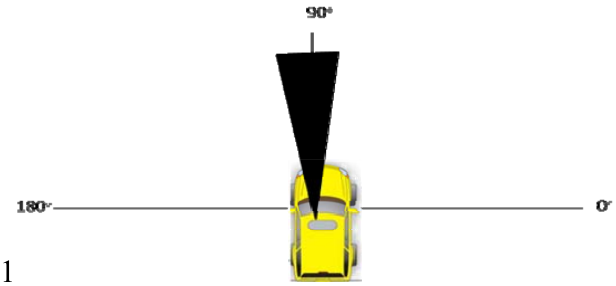
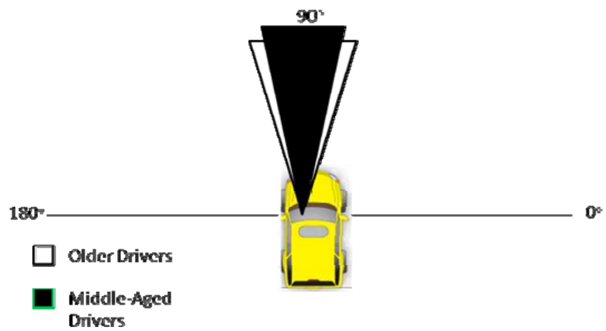


Figure 1



, and Figure 3.

Figure 1. Lateral-right and left – Initiation Zone

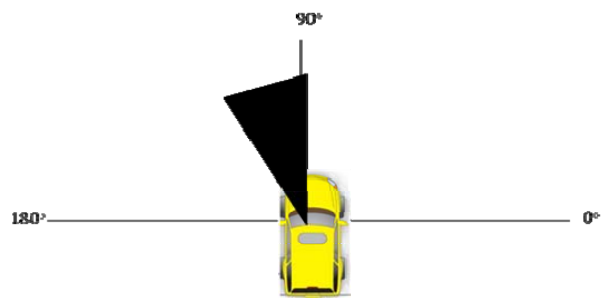


Figure 2. Lateral-right and left – Conflict Zone

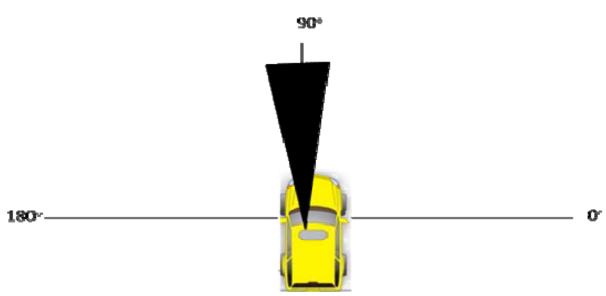


Figure 3. Lateral-right and left – Completion Zone

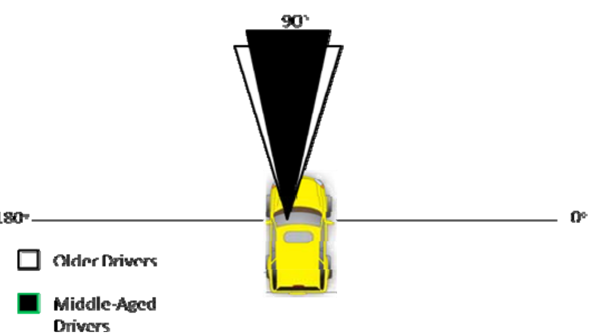


Figure 4. Range of lateral head rotation by age group

A significant difference between the age groups was seen with the range of lateral head movements. The magnitude of the difference, approximately 10% (30.6% for older drivers vs 27.7% for middle-aged drivers), with the older drivers demonstrating the greater range of head rotation (see Figure 4).

Conclusions

This study represented a meta-analysis across two naturalistic driving data databases which were collected in the same geographic area. Differences in lateral head rotation between older and middle-aged drivers were examined as they traversed particular unprotected left turn intersections, driving scenarios known to be among the riskiest and most difficult for older drivers to safely execute.

Analyses showed that the range of lateral head rotation decreased significantly as the driver passed through the intersection zones: from initiation to conflict to completion. This corresponds with the notion that degree of lateral head rotation generally indicates the degree to which the driver is visually scanning to gather relevant traffic information. This is most important during the initiation zone in which the driver must make the decision of when to initiate the crossing of the intersection and enter the potentially dangerous conflict zone.

In addition, the older drivers in the current study demonstrated a significant (approximately 10%) increase in the range of lateral head rotation compared with their middle-aged counterparts during intersection negotiation. This was initially counter to what was expected given the reduced range of motion results noted by Isler, Parsonson, and Hansson (1997) and the behavioral narrowing of scanning behavior at intersections noted by Bao and Boyle (2009). Related research has shown that UFOV may typically be reduced on the order of 30% for drivers aged 55 and older (Ball, Owsley, Sloane, Roenker, and Bruni, 1993; Hennessey, 1995). In addition to a loss in UFOV, a reduction of peripheral vision has also been noted in older individuals (Tielsche, Sommer, Witt, Katz and Royall, 1990). Taken together, these decrements clearly demonstrate the disadvantages that an older individual may face when taking in visual information across the spatial expanse of a busy or complex intersection. In this context, the greater degree of lateral head rotation demonstrated by the older drivers in this study may be interpreted as their compensating for generally-reduced fields of view. That is, a reduced field of view would require an older driver to rotate his or her head *more* than the middle-aged drivers to gather the required information (see Figure 5). Negotiating an unprotected left turn is the ideal time to execute such compensation, when the driver has an unspecified amount of time to scan for traffic hazards before deciding when to proceed. Hennessey (1995) reported that losses in UFOV in older drivers were highly-associated with self-restriction of left turns. An increase in lateral head rotation may just be another form of compensation for the same functional deficit.

Further research is required to replicate these findings which could have implications for the implementation of various countermeasures, including forms of training for older drivers. For instance, driver training could be focused on optimizing scan behaviors at intersections, physical training could be applied to increase flexibility, and brain training may improve older drivers' UFOV.

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REFERENCES

Angell, L., Antin, J.F., Wotring, B., and Aich, S. (2010). National Surface Transportation Safety Center for Excellence Naturalistic Driving Research Update. Panel discussion at the Second International Symposium on Naturalistic Driving Research, Aug 31-Sep 2, 2010, Blacksburg, VA.

Antin, J. F. (2007). Virginia's older driver: assessment and naturalistic observation methods. Presentation given at the Virginia Transportation Conference, Roanoke, VA.

Bao, S., Boyle, L. (2009). Age-related differences in visual scanning at median-divided highway intersections in rural areas, *Accident Analysis and Prevention,* 41, 146-152.

Ball, K., Owsley, C., Sloane, M. E., Roenker, D.L., and Bruni, J.R. (1993). Visual attention problems as a predictor of vehicle crashes in older drivers, *Investigative Ophthalmology and Visual Science,* 34 (11), 3110-3123.

Bohensky, M., Charlton, J., Odell, M., and Keeffe, J. (2008). Implications of vision testing for older driver licensing, *Traffic Injury Prevention*, *9*(4), 304-13.

Chandraratna, S. and Stamatiadis, S. (2003). Problem driving maneuvers of elderly drivers, *Transportation Research Record: Journal of the Transportation Research Record, 1843*, 89-95.

Charlton, J. Oxley, J., Fildes, B. and Les, M. (2001). Self-regulatory behaviour of older drivers, *Paper presented at the Road Safety Research, Policing and Education Conference* Melbourne, Victoria, Australia (2001).

Hennessy, D.F. (1995). Vision testing of renewal applicants: crashes predicted when compensation for impairment is inadequate, Research and Development Section, California Department of Motor Vehicles, Sacramento, CA, Report No: RSS-95-152.

Isler, R., Parsonson, B., and Hansson, G. (1997). Age related effects of restricted head movements on the useful field of view of drivers, *Accident Analysis and Prevention*, 29(6), 793-801.

Lee, S. E., Klauer, S. G., Olsen, E. C. B., Simons-Morton, B. G., Dingus, T. A., Ramsey, D. J., and Ouimet, M. C. (2008). Detection of Road Hazards by Novice Teen and Experienced Adult Drivers. *Transportation Research Record: Journal of the Transportation Research Board, No. 2078,* pp. 26–32.

Stamatiadis, N., Agent, K. R., and Ridgeway, M. (2003). Driver license renewal for the elderly: a case study, *The Journal of Applied Gerontology, 22(1)*, 42-56.

Stutts, J.,. Martell, C. and Staplin, L. (2009) Identifying Behaviors and Situations Associated With Increased Crash Risk for Older Drivers. NHTSA DOT HS 811 093.

Tielsche, J.M., Sommer, A., Witt, K., Katz, J., and Royall, R.M. (1990). Blindness and visual impairment in an American urban population: the Baltimore Eye Survey, Archives of Ophthalmology, 108 (2), 286-290.