THE EFFECT OF AGE ON DECISION MAKING DURING UNPROTECTED TURNS ACROSS ONCOMING TRAFFIC

Nicholas D. Cassavaugh, Joshua E. Domeyer & Richard W. Backs
Central Michigan University
Department of Psychology
Mount Pleasant, MI USA
Email: cassa1nd@cmich.edu; domey1je@cmich.edu; backs1rw@cmich.edu

Summary: The present study examined whether age-related differences in quantitative measures of left-turn performance could explain older drivers' increased susceptibility to crashing while making unprotected left turns across traffic. Older and younger adults made left turns across traffic in a driving simulator. Time to decide to turn, time to negotiate the turn, the size of the accepted gap, gap clearance, and time to collision with an oncoming vehicle were measured. Significant effects of age were found in decision time, turn time and gap size. A significant interaction between age group and the speed of oncoming traffic was obtained for decision time. Implications for older adult's safety and future directions are discussed.

INTRODUCTION

A large number of crashes occur while drivers are attempting to make turns across traffic and this is especially true for older drivers (Fatality Analysis Reporting System, 2008; *Traffic Safety Facts 2005*, 2006; *Traffic Safety Facts 2006*, 2007). These crashes may be partly due to older adults' decreased ability to accurately estimate the speed of oncoming vehicles and react appropriately for older adults (Andersen, Cisneros, Saidpour, & Atchley, 2000; Andersen & Enriquez, 2006; Scialfa, Guzy, Leibowitz, Garvey, & Tyrrell, 1991). Making unprotected turns across traffic places increased demands on information processing as compared to turns at protected intersections (Hancock, Caird, & Shekhar, 1991). Reduction in information processing capability is one common consequence of aging and manifests in nearly every cognitive process (Craik, 2000; Kramer & Larish, 1996; Kray & Lindenberger, 2000; Salthouse, 1994; Wickens, Braune, & Stokes, 1987).

We examined whether quantitative age-related differences in turn parameters such as time to decide to turn, time to negotiate the turn, size of the accepted gap, or time-to-collision (TTC) with an oncoming vehicle during the turn could explain older drivers' increased susceptibility to crashing while making unprotected turns across traffic.

METHOD

Participants

Thirty-one adults participated in this study. Twenty-one (12 female, 7 male) were undergraduates from the Central Michigan University subject pool who participated for course credit. Age of the younger subjects ranged from 18 to 24 years with a mean of 19.7 years. Ten older adults (7 female, 3 male) from the community participated and were paid $10 per hour for their time. Older subjects' age ranged from 61 to 80 years with a mean age of 70.0 years.

Tasks and Apparatus

A DriveSafety DS-600c simulator with 180º forward field of view was used. The simulator cab is the front passenger section of a Ford Focus and is mounted on a 1.5 degree-of-freedom motion base which provides motion cues in the longitude and pitch axes.

Participant's left-turn decisions were assessed in a scenario which placed them at an unsignalized T-intersection. The task was to execute a safe left turn across oncoming traffic. Oncoming traffic speed was varied across trials and was 48.3, 72.4 or 96.6 km/h (30, 45, 60 miles/h). All oncoming traffic vehicles in a particular trial traveled at the same speed. Gaps between vehicles were set at 2, 3, or 5 seconds, but as vehicles were under autonomous control the gap sizes at the intersection varied. For that reason, the actual gap between oncoming vehicles was used as a dependent measure rather than the original gap. Each participant was asked to make 21 turns across traffic (7 turns at each oncoming speed).

Each trial began with blank screens and the words "Please Wait". This waiting period was to permit the oncoming traffic to accelerate to the target speed and reach the intersection. Participants were asked to keep the vehicle in drive and their foot on the brake pedal until the driving scene appeared. This was done to avoid the need to shift repeatedly between "Park" and "Drive" during the experiment. After approximately 30 s, the driving scene was revealed. Participants were instructed to wait for what they determined to be a safe gap and then execute a left turn. After the left turn, the screens were blanked, the participant's vehicle was returned to the starting point, and a new trial began. Participants were instructed not to wait for the absence of traffic, as there would be no case in which there was no traffic. If participants waited too long, the simulator would move on to the next trial and re-administer the missed trial at the end of the session.

For each trial, participants' performance scores were calculated from the simulator data. The scores included gap size (the size of the gap in seconds between oncoming vehicles), turn time (time from initiating the left turn to clearing the intersection), TTC and the number of gaps presented before turning. Number of gaps was used because the gaps varied in size and rate of occurrence (due to the speed of the oncoming traffic), meaning that a particular unit of time could represent a varying number of turn opportunities. As the intent is to obtain some measure of the information which drivers are extracting from the scene, the relevant measure is not the time spent viewing the scene, but the number of turn opportunities (gaps) viewed by the driver.

RESULTS

Data were analyzed with repeated-measures analysis of variance (ANOVA) with oncoming-vehicle speed (48.3, 72.4 or 96.6 km/h; 30, 45, 50 miles/h) as a within-subjects variable and age group (old vs. young) as a between-subjects variable. Greenhouse-Geisser corrections for nonsphericity were used for within-subjects variables.

Decision Time

As shown in Table 1, a main effects of oncoming traffic speed (F(2,58)=14.8; p<.001) and age group (F(1,29)=208.1, p<.001) were obtained for decision time. There was no significant interaction of speed and age group (F(2, 58)=2.313; p=.134). Older drivers took slightly longer to make the decision to turn at lower speeds. Both older and younger drivers made the decision to turn more quickly as the speed of oncoming traffic increased.

Table 1. Decision time (# of gaps presented) by speed and age group

	Speed of oncoming traffic							
	48.3 km/h		72.4 km/h		96.6 km/h		Overall	
	M	SE	M	SE	M	SE	M	SE
Old	5.092	.755	3.380	.343	2.622	.193	3.698	.376
Young	3.487	.521	2.771	.237	2.407	.133	2.888	.259
Overall	4.290	.458	3.076	.209	2.514	.117	3.293	.228

Gap Size

Main effects of age group (F(1,29)=8.60; p<.01) and oncoming traffic speed (F(2,58)=46.9; p<.001) were obtained for gap size. There was no interaction of speed and age group (F(2, 58)=1.10; p=.340). As can be seen in Table 2, older adults accepted slightly larger gaps than did younger adults; however, the actual differences were small, ranging from 80 ms to 310 ms. The accepted gap tended to be the largest available gap in the trial. Both groups accepted smaller gaps as the speed of oncoming vehicles increased but again the differences in the means were small.

Table 2. Mean accepted gap size (s) by speed and age group

	Speed of oncoming traffic							
	48.3 km/h		72.4 km/h		96.6 km/h		Overall	
	M	SE	M	SE	M	SE	M	SE
Old	6.14	.074	5.53	.098	5.48	.100	5.714	.053
Young	5.95	.051	5.45	.067	5.17	.069	5.523	.037
Overall	6.042	.045	5.49	.059	5.321	.061	5.618	.032

Turn Time

A main effect of age group (F(1,29)=15.241; p<.002) was obtained for turn time., but there was no effect of oncoming traffic speed (F(2,58)=.567; p=.570). However, the interaction of speed and age group approached significance (F(2, 58)=3.302; p=.076). Turn time data are presented in Table 3 and Figure 1.

Table 3. Mean turn time (s) by speed and age group

	Speed of oncoming traffic							
	48.3 km/h		72.4 km/h		96.6 km/h		Overall	
	M	SE	M	SE	M	SE	M	SE
Old	4.55	.355	4.03	.243	4.04	.270	4.20	.248
Young	2.89	.245	3.08	.168	3.13	.186	3.03	.171
Overall	3.72	.216	3.55	.148	3.58	.164	3.61	.150

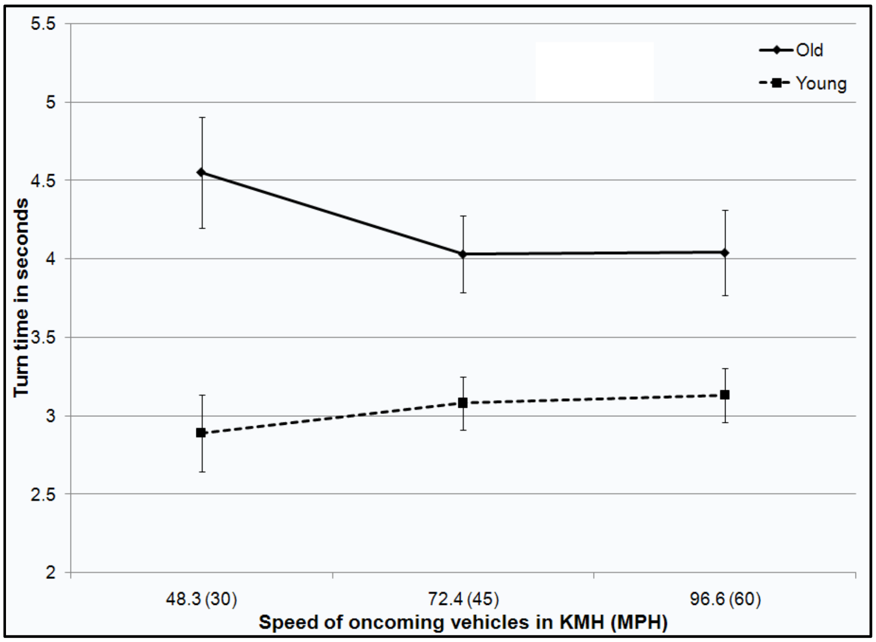

Figure 1. Mean time to negotiate the turn by age group and oncoming vehicle speed

Time-to-collision

With a single lane of oncoming traffic, the accepted gap is bounded by the vehicle which has most recently passed the participant's vehicle and the nearest oncoming vehicle. We examined time-to-collision (TTC) with the nearest oncoming vehicle when the participant's vehicle was in the center of the opposing lane of traffic during the turn. These data are presented in Table 4. There were no significant effects or interactions.

Table 4. Mean TTC (s) by speed and age group

	Speed of oncoming traffic							
	48.3 km/h		72.4 km/h		96.6 km/h		Overall	
	M	SE	M	SE	M	SE	M	SE
Old	.920	.094	.932	.072	.971	.067	.941	.065
Young	1.023	.065	1.084	.049	.996	.046	1.035	.045
Overall	.972	.057	1.008	.043	.984	.041	.988	.040

TTC values were then examined in terms of the proportion of the actual gap they represented. That is, we asked what proportion of the accepted gap remained as the participant's vehicle passed between the gap-bounding vehicles (gap clearance, see Figure 2). The gap clearance data are presented in Table 5. Note that as with TTC values, lower gap clearance values represent more dangerous behavior. The effect of speed of oncoming traffic was significant ($F(2,58)=7.86$; $p=.002$), but neither the effect of age group ($F(1,29)=2.79$; $p=.105$) nor the age group by speed interaction ($F(2,58)=.629$; $p=.519$) were significant.

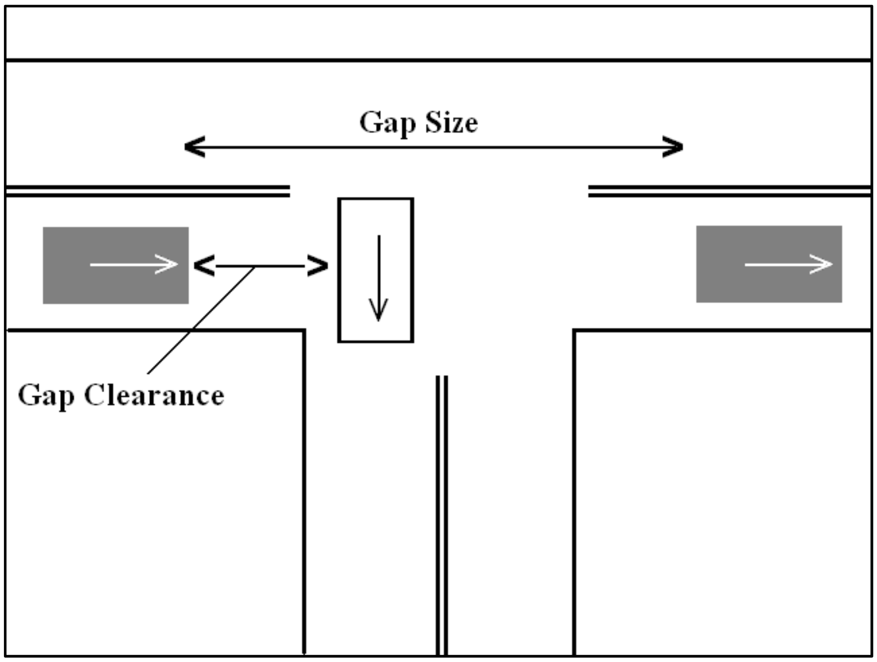

Figure 2. Overhead representation of the intersection in the present study illustrating gap size and gap clearance measures. Dark grey blocks represent oncoming traffic. The white block represents the participant vehicle. Arrows indicate general direction of travel.

Table 5. Mean gap clearance by speed and age group

	Speed of oncoming traffic							
	48.3 km/h		72.4 km/h		96.6 km/h		Overall	
	M	SE	M	SE	M	SE	M	SE
Old	.146	.015	.166	.012	.173	.011	.162	.011
Young	.169	.010	.195	.008	.188	.008	.184	.008
Overall	.158	.009	.180	.007	.180	.007	.173	.007

DISCUSSION

The present study investigated the behavior of older and younger adults while making unprotected left turns across oncoming traffic. Older drivers observed more gaps before deciding to turn and took longer to negotiate the turn than younger adults. Both groups waited for the largest openings in traffic regardless of the speed of oncoming traffic. Effects of age and oncoming vehicle speed on gap acceptance were significant, but quantitatively small.

Of particular note is that although older adults tended to turn more quickly in response to faster oncoming traffic, there were no effects on TTC in the intersection. On the other hand, there was a significant effect of gap clearance. Both older and younger adults adjusted their turn in response to the speed of oncoming traffic such that more of the total gap remained when oncoming traffic was traveling faster. One way this might be accomplished would be to start the turn sooner relative to the start of the approaching gap.

Traffic statistics have established that older adults are at increased risk of collision when making left turns across traffic. In addition, Andersen and Enriquez (2006) have shown that older adults are less capable of judging TTC, and that the degree of impairment increases with increasing speed of the moving objects. The present findings suggest this impairment can lead to an increase in collisions because older adults fail to adequately account for the speed of oncoming traffic by executing the left turn more quickly. The result is a reduction in the safety margin for older drivers as compared to younger drivers. It is interesting to note that in the present study, no participants were involved in a collision.

One limitation with the present study is that only 10 older adults were able to complete the experiment, those who did not finish often terminated the session because of simulator discomfort. Therefore, external validity may be affected in unknown ways if those older adults who can tolerate the simulator were in some way also better able to judge TTC or to execute the turn. Another potential limitation to external validity is the absence of incentive to make the turn more quickly. In many cases there is traffic behind the driver who is attempting to turn left, which provides an additional incentive to turn, either implicitly by the existence of other drivers and/or explicitly due to expressions of impatience by other drivers. A potential limitation to internal validity arises because the effect of oncoming vehicle speed on the size of the accepted gaps (drivers accepted smaller gaps at higher speeds) may be due to an artifact of the autonomous control of the oncoming vehicles. The oncoming vehicles were initially created with the desired gap at some distance from the intersection in order to prevent the participant from observing their sudden appearance; however, they were under some degree of autonomous control while traveling along the roadway toward the intersection. This may have caused the gaps to open up over time. Vehicles traveling at faster speeds would have less time for the gaps to widen than those traveling at lower speeds. Thus, the speed effect on gap might be due to this particular issue. For this reason, it appears that the gap clearance measure provides a more sensitive measure than gap size. Future studies will take further steps to reduce these potential limitations.

ACKNOWLEDGEMENTS

This work was supported by a Faculty Research and Creative Endeavors grant to the first author from the Office of Research and Sponsored Programs at Central Michigan University.

REFERENCES

Andersen, G. J., Cisneros, J., Saidpour, A., & Atchley, P. (2000). Age-Related Differences in Collision Detection During Deceleration. *Psychology and Aging, 15*(2), 241-252.

Andersen, G. J., & Enriquez, A. (2006). Aging and the detection of observer and moving object collisions. *Psychology and Aging, 21*(1), 74-85.

Craik, F. I. M. (2000). Age-related changes in human memory. In D. Park & N. Schwarz (Eds.), *Cognitive Aging: A Primer*. Philadelphia, PA: Psychology Press.

Fatality Analysis Reporting System (2008). (Publication. Retrieved October 15, 2008, from National Highway Transportation Safety Administration: http://www-fars.nhtsa.dot.gov/Main/index.aspx

Hancock, P. A., Caird, J. K., & Shekhar, S. (1991). *Factors influencing drivers' left turn decisions.* Paper presented at the 35th annual meeting of the human factors society, San Francisco, CA.

Kramer, A. F., & Larish, J. L. (1996). Aging and dual-task performance. In W. R. Rogers, A. D. Fisk & N. Walker (Eds.), *Aging and skilled performance* (pp. 83-112). Hillsdale, NJ: Lawrence Earlbaum Associates.

Kray, J., & Lindenberger, U. (2000). Adult Age Differences in Task Switching. *Psychology and Aging, 15*(1), 126-147.

Salthouse, T. A. (1994). The aging of working memory. *Neuropsychology, 8*(4), 535-543.

Scialfa, C. T., Guzy, L. T., Leibowitz, H. W., Garvey, P. M., & Tyrrell, R. A. (1991). Age Differences in Estimating Vehicle Velocity. *Psychology and Aging, 6*(1), 60-66.

Traffic Safety Facts 2005. (2006). (No. DOT HS 810 631). Washington, D.C.: National Highway Traffic Safety Administration.

Traffic Safety Facts 2006. (2007). Washington, D.C.: National Highway Traffic Safety Administration.

Wickens, C. D., Braune, R., & Stokes, A. (1987). Age Differences in the Speed and Capacity of Information Processing: 1. A Dual-Task Approach. *Psychology and Aging, 2*(1), 70-78.