RESEARCH BRIEF

Objectively Derived and Self-Reported Measures of Driving Exposure and Patterns Among Older Adults: AAA LongROAD Study

This research brief used data from the AAA Longitudinal Research on Aging Drivers (LongROAD) study to examine self-reported and objectively derived measures of driving in an older population. Information about older adults' driving exposure and patterns (i.e., when, where and under what conditions they drive) is important for several reasons. Such information contributes to a better understanding of the crash risk of older drivers relative to other age groups. It also provides a context for understanding the process of self-regulation, whereby older drivers reduce their exposure to driving conditions they find challenging (e.g., at night, during rush-hour traffic, on major highways or long distances from home) or decrease their overall amount of driving (see Molnar et al., 2015 for a review of this literature). Such self-regulation of driving may help older drivers compensate for declining driving-related abilities and extend the period over which they can safely drive. Improving our knowledge of older adults' driving exposure and patterns will help inform efforts to develop and strengthen educational and training materials for older drivers.

METHODS

Data for this study came from 2,131 participants in the AAA LongROAD study (see Li et al., 2017 for full study details). LongROAD is a multisite prospective cohort study of drivers ages 65-79. One of the major strengths and unique contributions of LongROAD is the collection of naturalistic driving data from a large cohort of older drivers over several years, coupled with a comprehensive set of questionnaire data on various aspects of driving. The LongROAD data set, therefore, provides an opportunity to compare a set of subjective and objective measures of driving exposure and patterns among a large subset of older drivers.

Objective driving measures were derived from GPS/datalogger data, following procedures described in previous research (Molnar et al., 2013; see Table 1 for list of measures and their descriptions). The devices automatically recorded driving information when the vehicle was turned on, and also determined whether or not it was the participant who was driving. Subjective measures came from a comprehensive questionnaire administered to participants at baseline that asked them to report their driving exposure, patterns and other aspects of driving (Table 3).

The subjective driving avoidance questionnaire items were matched to each appropriate GPS-derived objective variable. Similarly, the questionnaire items related to exposure (e.g., number of miles driven) were matched to GPS-derived objective variables. Several of the GPS-derived variables were recoded from monthly to weekly measures to more closely match the wording used on the questionnaire. Questionnaire items were assessed at a single point in time, but the objective data were collected continuously throughout the study. Only participants with at least 12 months of driving data were included in the analysis for this paper. To account for differences in exposure and seasonality, the analysis only included participants' first 12 months of driving. Finally, the GPS variables were averaged across the 12-month period to compare with each of the subjective measures, and the subjective and objective data sets were merged together. Univariate statistics were generated for each of the variables of interest. The analysis was conducted by fitting a series of separate simple regression models, one for each matched pair of subjective and objective behaviors. For each model, the objective measure served as the independent variable, with the subjective measure as the dependent variable. Linear or logistic models were fit, as appropriate, depending upon the outcome variable type.

Table 1. List of Derived Driving Measures

Measure	Description of the Monthly Variable
Driving Exposure	
Average number of days driven per month	Total number of days with at least one trip
Average number of miles per month	Total number of miles driven
Driving Avoidance	
Average monthly % of trips at night	Percent of all trips during which at least 80% of trip was during nighttime (solar angle greater than 96 degrees)
Average monthly % trips in a.m. rush hour	Percent of trips during 7-9 a.m. on weekdays
Average monthly % trips in p.m. rush hour	Percent of trips during 4-6 p.m. on weekdays
Average monthly % trips on high-speed roads	Percent of trips where 20% of distance traveled was at a speed of 60 mph or greater
Average monthly % trips < 25 miles from home	Percent of trips traveled within 25 miles of home
Average monthly right to left turn ratio	Ratio of all right-hand to left-hand turning events for a driver

Note: A trip is defined as a nonzero distance between vehicle engine on-to-off time.

RESULTS

The mean age of participants was 71.2 years. A total of 48.6% of participants were men and 51.4% were women. The majority were white non-Hispanic (85.7%), followed by black non-Hispanic (6.8%), Hispanic (2.6%), and Asian (2.3%). Participants were well educated: 13.3% had a high school/trade degree or less, 21.2% had some college or an associate degree, 23.8% had a bachelor's degree and 41.7% had an advanced college degree. Annual household incomes were relatively high: 4.3% reported less than $20,000; 21.0% reported $20,000-$49.999; 24.8% reported $50,000-$79,999; 15.0% reported $80,000-$99,999 and 31.4% reported $100,000 or more.

Analysis of GPS-Derived Measures of Driving Exposure and Patterns

Table 2 provides information on driving exposure and patterns by age and sex. In cases where statistically significant main effects were found for age or sex, the means and SDs are highlighted in boldface. The first set of driving measures in the table is related to driving exposure. Men and women did not differ on the average number of days driven per month, nor were there differences by age. Average number of trips per month differed by age (p=0.0077), with drivers ages 65-69 making significantly more trips than drivers ages 75-79. Trips taken also differed between men and women (p=0.0037), with men taking more trips. Both drivers ages 65-69 and 70-74 drove more miles than ages 75-79 (p<0.0001), and men drove more miles than women (p<0.0001). Both drivers ages 65-69 and 70-74 averaged more miles per trip than those ages 75-79 (p<0.0001), and men averaged more miles per trip than women (p<0.0001). The average number of trip minutes differed by age (p<.0001), with both drivers ages 65-69 and 70-74 driving more minutes than drivers ages 75-79. There were also differences by sex, with men driving more minutes than women (p=0.0010). No interaction effects were found between age and sex for any of the driving exposure variables.

The remaining measures in Table 2 are related to driving patterns. There were differences in night driving by age (p<0.0001) and sex (p<0.0001) with drivers ages 65-69 making a higher percentage of trips at night compared with drivers ages 70-74 and 75-79, and men making a higher percentage of trips at night than women. There were no differences in a.m. rush-hour traffic by age; however, for p.m. rush-hour traffic, drivers ages 65-69 made a higher percentage of trips than those ages 75-79 (p=0.0078). Conversely, there was no difference by sex for p.m. rush-hour traffic, but men made a higher percentage of trips in a.m. rush-hour traffic than women (p=0.0061). Both age and sex differences were found for percentage of trips on high-speed roads (p<0.0001 and p<0.0001, respectively), with drivers ages 65-69 having a higher percentage than those 70-74 or 75-79 years old, drivers ages 70-74 having a higher percentage than those ages 75-79, and men having a higher percentage than women. There were also age and sex differences for average percentage of trips less than 25 miles from home (p<0.0001 and p<0.0001), respectively. Drivers 75-79-years old made a higher percentage of those shorter trips relative to other age groups, and women made a higher percentage of those trips than men.

The average ratio of right to left turns differed by age (p=0.0055); it was higher for drivers ages 75-79 than for those ages 65-69. There were no differences by sex. There were no differences by age or sex for average number of high decelerations. However, both age and sex differences were found for average number of speeding events (p=0.0379 and p=0.0002, respectively); drivers ages 65-69 had more than those who were 75-79 years old, and men had more than women. Similar to the driving exposure variables, there were no interaction effects between age and sex for driving patterns.

Comparative Analysis of Self-Reported and GPS-Derived Driving Measures

We used linear regression analysis to compare a subset of driving behaviors for which we had comparable subjective and objective measures. These measures are highlighted in tables 3 and 4, along with overall descriptive statistics. The subjective questionnaire measures used in the comparative analysis are summarized in Table 3. As a group, participants reported driving 5.6 days per week on average and 121.4

Table 2. Driving Exposure and Patterns by Age Group and Sex* (n=2,131)

Driving Measure	Age			Sex		Total
	65–69	70–74	75–79	Male	Female	
	Mean (SD)	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
Overall Driving Exposure						
Average number of days driven per month	22.7 (5.0)	22.5 (5.0)	22.2 (4.9)	22.5 (5.2)	22.5 (4.8)	22.5 (5.0)
Average number of trips per month [b]	122.4 (57.0)*	119.9 (53.1)*	113.6 (46.9)*	122.8 (59.7)*	116.1 (46.5)*	119.4 (53.4)
Average number of miles per month [b,c]	841.6 (462.6)*	811.7 (456.3)*	677.0 (369.0)*	847.1 (464.3)*	738.6 (417.6)*	791.4 (444.2)
Average number of miles per trip [b,c]	7.1 (3.5)*	6.9 (3.0)*	6.1 (2.7)*	7.2 (3.4)*	6.4 (2.9)*	6.8 (3.2)
Average number of trip minutes per month [b,c]	1,798.3 (886.9)*	1,754.0 (899.2)*	1,551.6 (714.2)*	1,785.7 (920.8)*	1,664.0 (789.6)*	1,723.2 (857.9)
Driving Patterns						
Average % trips at night [a,b]	7.5 (5.5)*	6.4 (4.6)*	5.8 (4.8)*	7.4 (5.5)*	6.1 (4.6)*	6.7 (5.1)
Average % trips in a.m. rush hour	7.4 (4.8)	7.2 (5.0)	6.8 (4.9)	7.5 (5.2)*	6.9 (4.5)*	7.2 (4.9)
Average % trips in p.m. rush hour [b]	9.7 (4.2)*	9.4 (4.6)*	9.0 (4.2)*	9.4 (4.4)	9.4 (4.4)	9.4 (4.4)
Average % trip on high-speed roads [a,b]	14.3 (11.7)*	12.5 (10.5)*	11.0 (9.8)*	14.2 (11.5)*	11.7 (10.1)*	12.9 (10.9)
Average % trips < 25 miles of home [b,c]	74.6 (19.7)*	74.7 (18.9)*	79.4 (16.7)*	74.1 (19.4)*	77.5 (18.2)*	75.8 (18.9)
Average right to left turn ratio [b]	0.92 (0.13)*	0.93 (0.13)*	0.95 (0.14)*	0.93 (0.14)	0.93 (0.13)	0.93 (0.13)
Average number of high deceleration events	4.1 (5.9)	3.9 (5.0)	3.5 (4.3)	4.0 (5.9)	3.8 (4.6)	3.9 (5.3)
Average number of speeding events [b]	8.0 (22.9)*	7.2 (18.4)*	5.4 (13.3)*	8.7 (23.8)*	5.6 (14.0)*	7.1 (19.4)

* Statistically significant differences.
[a] 65-69-year-olds differed from 70-74-year-olds.
[b] 65-69-year-olds differed from 75-79-year-olds.
[c] 70-74-year-olds differed from 75-79-year-olds.

miles per week. In terms of driving patterns, self-reported avoidance was highest for driving during rush-hour traffic (55.9%), followed by driving at night (35.7%), driving in unfamiliar areas (17.3%), making unprotected left turns across traffic (12.9%) and driving on the freeway (10.2%).

The GPS-derived driving measures used in the comparative analysis are summarized in Table 4. Participants drove an average of 5.6 days per week and 197.8 miles per week. The selected driving patterns highlighted in the table are those for which there were comparable questionnaire measures. Among participants as a group, the lowest percent of trips were taken at night (6.7%), followed by those on high-speed roads (a proxy for freeways; 12.9%), in rush-hour traffic (16.6%) and within 25 miles of home (a proxy for familiar areas; 75.8%). Participants made, on average, about the same number of right turns as left turns across all of their trips (a proxy for making left turns at unprotected intersections).

For the comparative analysis, simple linear regressions were used to model the relationship between comparable GPS-derived and questionnaire combinations that were related to driving exposure and patterns (e.g., days per week). In each case, the GPS-derived driving measure was used as the independent variable and the corresponding questionnaire measure was used as the dependent variable. The purpose of the modeling was to predict, for each combination, the outcome of the questionnaire, based on the corresponding GPS-derived driving behavior measure.

Summary information for the linear regressions for driving exposure is presented in Table 5. Both objective measures of driving exposure were significantly related to subjectively reported measures. That is, for each additional day that participants drove per week (measured objectively), the number of days they reported driving per week increased by 0.575 days, and for each additional mile per week that participants drove (measured objectively), the number of miles they reported driving per week increased by 0.439 miles.

Summary information for the logistic regressions is presented in Table 6 for driving patterns. All objective and subjective avoidance behaviors were significantly related with the exception of making left turns. That is, for every percentage point increase in trips made at night, during rush hour traffic and on high-speed roads (measured objectively), the odds of participants reporting that they avoided those situations decreased by 10.2%, 3.4% and 1.3%, respectively (calculated as 1 minus the OR). For every percentage point increase in trips made within 25 miles of home (measured objectively), the odds of participants reporting that they avoided unfamiliar areas increased by 2%.

Table 3. Self-Reported Driving Behaviors from Questionnaire

Question	Outcome	Percent
Driving Exposure	***Mean (SD)***	
How many days per week do you normally drive?	5.6 (1.6)	
How many miles do you drive in a normal week?	121.4 (104.0)	
Driving Patterns	***Number Responding Yes***	
Do you try to avoid driving at night?	759	35.7%
Do you try to avoid making unprotected left hand turns?	274	12.9%
Do you try to avoid driving in an unfamiliar area?	367	17.3%
Do you try to avoid driving during rush-hour traffic?	1183	55.9%
Do you try to avoid driving on the freeway?	216	10.2%

Note: SD = standard deviation.

Table 4. GPS-Derived Driving Measures

Measure	Mean	SD	Range
Driving Exposure			
Average number of days driving per week	5.6	1.2	1.0-7.6
Average number of miles per week	197.8	111.0	11.3-860.1
Driving Patterns			
Average % trips at night	6.7	5.1	0-39.3
Average right to left turn ratio	0.93	0.1	0.4-1.5
Average % trips less than 25 miles from home	75.8	18.9	5.4-99.7
Average % trips in rush-hour traffic	16.6	5.6	3.7-49.0
Average % trips on high-speed roads	12.9	10.9	10.9-75.8

Table 5. Simple Linear Regression Results Comparing Self-Reported and GPS-Derived Driving Exposure Measures

Subjective Exposure (DV)	Objective/GPS (IV)	β	SE
Days per week driving	Days in month with >= 1 trip / 4	0.575***	0.025
Miles per week driving	Miles in month / 4	0.439***	0.018

Note: DV = dependent variable, IV = independent variable, SE = standard error. Separate models fitted for each pair of data.
* p < 0.05. ** p < 0.01. *** p < 0.001.

Table 6. Unadjusted Logistic Regression Results Comparing Self-Reported Avoidance and GPS-Derived Driving Patterns

Subjective Exposure (DV)	Objective/GPS (IV)	β	SE	OR	OR 95% CI	
					Lower	Upper
Driving at night	% trips at night	-0.108***	0.011	0.898	0.878	0.918
Making left turns	Right to left turn ratio	-0.090	0.485	0.914	0.353	2.366
Unfamiliar areas	% trips < 25 miles	0.019***	0.004	1.020	1.013	1.027
Rush-hour traffic	% trips during a.m./p.m. rush hour	-0.035***	0.008	0.966	0.951	0.981
Freeway	% trips including 60 mph	-0.109***	0.012	0.897	0.875	0.919

Note: DV = dependent variable, IV = independent variable, SE = standard error; OR = odds ratio. Separate models fitted for each pair of data.
* p < 0.05. ** p < 0.01. *** p < 0.001.

DISCUSSION

When looking just at the objective driving measures, the oldest age group (75-79 years old) had the lowest overall driving exposure, in general, of the three age groups. They drove fewer miles and minutes per month, and fewer miles per trip than either of the younger age groups (65-69 and 70-74 years old). They also made fewer trips per month than the youngest age group. In terms of driving patterns, they took a lower percentage of trips on high-speed roads and a higher percentage of trips within 25 miles of home than either of the younger age groups. They also made a lower percentage of trips at night and in p.m. rush-hour traffic than the youngest age group.

Women had lower overall driving exposure than men, driving fewer trips, miles, and minutes per month, and fewer miles per trip. They also made a lower percentage of trips at night, in a.m. rush-hour traffic and on high-speed roads. They also had fewer speeding events and a higher percentage of trips within 25 miles of home than men. These results are consistent with several self-report studies that have found that women restrict their driving more than men (e.g., Charlton et al., 2006; Kostyniuk & Molnar, 2008; Naumann, Dellinger, & Kresnow, 2011; Unsworth et al., 2007) and that such restriction increases with age (e.g., Charlton et al., 2006; Donorfio, Mohyde, Coughlin, & D'Ambrosio, 2008; Gwyther & Holland, 2012; Sargent-Cox, Windsor, Walker & Anstey, 2011; Unsworth et al., 2007).

We also compared the objective measures of a subset of driving exposure and patterns to subjective measures based on drivers' self-reports. An important strength of the study was the large sample size (n=2,131) relative to the few studies of this type that have been conducted to date. With one exception, the results supported our assumption going into the study that for each driving behavior of interest, the subjective measure and its comparable objective measure would be related. For driving exposure, comparisons were statistically significant for both days driving per week and miles driving per week. In both cases, actual driving predicted self-reported driving, albeit not perfectly. For driving patterns, comparisons were statistically significant for driving at night, in unfamiliar areas, during rush-hour traffic and on high-speed roads. For each driving situation, participants' actual driving predicted the likelihood of reporting trying to avoid that situation. However, the objective measure of the ratio of right to left turns was not significantly related to the subjective measure of avoidance of unprotected left turns. The lack of correspondence between the subjective and objective measures related to right and left turns may have been due, in part, to the necessity of using the ratio of right to left hand turns as a proxy measure for making left turns across unprotected intersections, based on the idea that drivers who tried to avoid such turns would be more likely to have a higher ratio of right to left hand turns. However, we were not able to identify whether left hand turns occurred at protected or unprotected intersections, although the algorithm did limit turns to intersections and not roundabouts. It is also important to note that the avoidance items in the questionnaire focused on participants' intent rather than actual behavior; thus, the subjective and objective measures were not identical. However, the significant relationships between the subjective and objective measures for avoidance of driving at night, in unfamiliar areas and on high-speed roads suggest that there is an opportunity to use both types of data in combination to better understand these driving patterns. Improving our knowledge of older adults' driving exposure and patterns will help inform efforts to develop and strengthen educational and training materials for older drivers.

Strengths of this study included the large sample size and collection of both subjective and objective data on driving exposure and patterns over a full 12 months. A limitation of the study is that the sample may not be representative of all older drivers across the United States. However, the study sites do represent a wide range of communities with diverse geography, population density, and racial, ethnic, and socioeconomic distribution (Li et al., 2017), and the longitudinal cohort design will allow us to follow these participants over time to assess changes in driving as their health and functioning change with age. Further studies of this cohort are planned to more closely examine individual characteristics that might help us understand the relationship between subjective and objective measures of driving exposure and patterns.

REFERENCES

Blanchard, R. A., Myers, A. M. & Porter, M. M. (2010). Correspondence between self-reported and objective measures of driving exposure and patterns in older drivers. Accident Analysis and Prevention, 42, 523–529.

Charlton, J.L, Oxley, J., Fildes, B., Oxley, P., Newstead, S., Koppel, S. & O'Hare, M. (2006). Characteristics of older drivers who adopt self-regulatory driving behaviors, Transportation Research Part F, 9, 363-373.

Donorfio, L.K.M., Mohyde, M., Coughlin, J.F. & D'Ambrosio, L.A. (2008). A qualitative exploration of self-regulation behaviors among older drivers. Journal of Aging & Social Policy, 20, 323-339.

Grengs, J., Wang, X. & Kostyniuk, L. (2008). Using GPS data to understand driving behavior. Journal of Urban Technology, 15, 33-53.

Gwyther, H. & Holland, C. (2012). The effect of age, gender and attitudes on self-regulation in driving. Accident Analysis and Prevention, 45, 19-28.

Huebner, K. D., Porter, M. M. & Marshall, S. C. (2006). Validation of an electronic device for measuring driving exposure. Traffic Injury Prevention, 7, 76–80.

Kostyniuk, L.P & Molnar, L.J. (2008). Driving self-restriction among older adults: Health, age, and sex effects. Accident Analysis and Prevention, 40, 1576-1580.

Li, G., Eby, D.W., Santos, R., Mielenz, T.J., Molnar, L.J., Strogatz, D., Betz, M., DiGuiseppi, C., Ryan, L.H., Jones, V., Pitts, S.I., Hill, L.L., DiMaggio, C., LeBlanc, D. & Andrews, H.F. for the LongROAD Research Team. (2017). Longitudinal Research on Aging Drivers (LongROAD): Study design and methods. Injury Epidemiology, 4, 22.

Molnar, L.J., Charlton, J.L., Eby, D.W., Bogard, S.E., Langford, J., Koppel, S., Kolenic, G., Marshall, S. & Man-Son-Hing, M. (2013). Self-regulation of driving by older adults: Comparison of self-report and objective driving data. Transportation Research Part F, 20, 29-38.

Molnar, L.J., Eby, D.E., Zhang, L., Zanier, N., St. Louis, R.M. & Kostyniuk, L.P. (2015). Self-Regulation of Driving by Older Adults: A Synthesis of the Literature and Framework for Future Research. Washington D.C.: AAA Foundation for Traffic Safety.

Naumann, R.B., Dellinger, A.M. & Kresnow, M.J. (2011). Driving self-restriction in high-risk conditions: How do older drivers compare to others? Journal of Safety Research, 42, 67-71.

Sargent-Cox, K. A., Windsor, T., Walker, J. & Anstey, K. J. (2011). Health literacy of older drivers and the importance of health experience for self-regulation of driving behaviour. Accident Analysis and Prevention, 43, 898–905.

Unsworth, C.A., Wells, Y., Browning, C., Thoman, S.A. & Kendig, H. (2007). To continue, modify or relinquish driving: Findings from a longitudinal study of healthy ageing. Gerontology, 53, 423-431.

ABOUT AAA FOUNDATION FOR TRAFFIC SAFETY

The AAA Foundation for Traffic Safety is a 501(c)(3) nonprofit, publicly supported charitable research and education organization. It was founded in 1947 by the American Automobile Association to conduct research to address growing highway safety issues. The organization's mission is to identify traffic safety problems, foster research that seeks solutions, and disseminate information and educational materials. AAA Foundation funding comes from voluntary, tax-deductible contributions from motor clubs associated with the American Automobile Association and the Canadian Automobile Association, individual AAA club members, insurance companies and other individuals or groups.

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