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The effects of demographics, functioning, and perceptions on the relationship between self-reported and objective measures of driving exposure and patterns among older adults

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Abstract

The exploratory study reported here was intended to examine: how strongly subjectively reported driving avoidance behaviors (commonly referred to as self-regulation) and exposure were related to their objectively measured counterparts and whether it depended on the specific behavior; the extent to which gender and age play a role in the association between subjectively reported driving avoidance behaviors and exposure and their objectively measured counterparts; and the extent to which demographics, health and functioning, driving-related perceptions, and cognition influence the association between subjective and objective driving avoidance behaviors overall. The study used data from the Longitudinal Research on Aging Drivers (LongROAD) study, a multisite, prospective cohort study designed to generate empirical data for understanding the role of medical,

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behavioral, environmental, and technological factors in driving safety during the process of aging. Objective driving measures were derived from GPS/datalogger data from 2131 LongROAD participants' vehicles. The corresponding subjective measures came from a comprehensive questionnaire administered to participants at baseline that asked them to report on their driving exposure, patterns, and other aspects of driving. Several other variables used in the analyses came from the comprehensive questionnaire and an inperson clinical assessment administered to participants at baseline. A series of simple linear and logistic models were fitted to examine the relationship between the subjective and objective driving measures of interest, and a multivariable analysis was conducted to examine the potential role of selected factors in the relationship between objective and subjective driving avoidance behaviors. Results of the models are presented and overall findings are discussed within the context of the existing research literature.

1. Introduction

The collection and analysis of data on older adults' driving exposure and patterns (i.e., how much people drive, as well as when, where, and under what conditions) represents an important first step in understanding the process of driving self-regulation, whereby older adults reduce their exposure to driving conditions considered challenging (e.g., at night, during rush hour, 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). Self-regulation is of particular interest because of its potential to help older drivers compensate for declining driving-related abilities and extend the period over which they can safely drive (Gwyther & Holland, 2012; Wong, Smith, & Sullivan, 2012). However, there is still much we do not understand about the extent to which and conditions under which drivers engage in self-regulation, and the associated safety outcomes (Molnar et al., 2014).

Until recently, most of the available data on self-regulation came from self-reports by older drivers (e.g., Baldock, Mathias, McLean, & Berndt, 2006; DeCarlo, Scilley, Wells, & Owsley, 2003; Sargent-Cox, Windsor, Walker, & Anstey, 2011; Sullivan, Smith, Horswill, & Lurie-Beck, 2011). Although these data can be valuable in understanding driving-related behavior, evidence suggests that older drivers' self-reports do not always align with actual driving (e.g., Blanchard, Myers, & Porter, 2010; Huebner, Porter, & Marshall, 2006). This has led to concerns about the validity and accuracy of self-reported measures of driving (e.g., Huebner et al., 2006; Staplin, Gish, & Joyce, 2008). For example, Agramunt and colleagues (2017) recently found that older drivers with bilateral cataracts significantly underestimated the number of overall trips, weekend trips, and trips during rush hour, and overestimated overall driving duration, based on a comparison of entries in a travel diary to an in-vehicle monitoring device.

It is possible to examine driving exposure and patterns using low cost global positioning system (GPS) technology to record a vehicle's location on a continuous basis along with the date and time (e.g., see Grengs, Wang, & Kostyniuk, 2008), facilitating its use in large scale studies. This presents an opportunity to collect and compare objective and subjective data on older adults' driving patterns and exposure. While there has been some research on this topic (e.g., Blanchard et al., 2010; Huebner et al., 2006; Marshall, Molnar, Man-Son-Hing, Stiell,

& Porter, 2007; Molnar et al., 2013; Myers, Trang, & Crizzle, 2011), results have been mixed and most studies were limited to small samples (e.g., 10 or 20). In addition, none looked beyond overall comparisons between objective and subjective measures to identify various factors that might be affecting the relationship or lack of relationship between these measures.

Further research in this area is clearly warranted. In particular, given evidence of gender and age differences in self-regulation, and driving exposure and patterns more generally (e.g., Charlton et al., 2006; Gwyther & Holland, 2012; Kostyniuk & Molnar, 2008; Naumann, Dellinger, & Kresnow, 2011; Sargent-Cox et al., 2011; Unsworth, Wells, Browning, Thoman, & Kendig, 2007), it seems reasonable that these might be useful characteristics to examine in comparing objective and subjective driving measures. For example, studies suggest that women are more likely to avoid challenging driving situations than men, and such avoidance increases with age. Similarly, it could prove fruitful to examine the effects of other factors that have been found to affect self-regulation such as perceived driving ability and comfort, or health and functioning (e.g., see Baldock et al., 2006; Blanchard & Myers, 2010; Molnar & Eby, 2008; Rudman, Friedland, Chipman, & Sciortino, 2006; Siren & Meng, 2013). Finally, as evidence has accumulated that awareness of and insight into declining functional abilities is a necessary first step in driving self-regulation (e.g., Freund, Colgrove, Burke, & McLeod, 2005; Molnar et al., 2015; Owsley, McGwin, Phillips, McNeal, & Stalvey, 2004), it makes sense that cognitive functioning may also play a role in the extent to which individuals' self-reports of avoidance correspond to their actual driving.

2. Study purpose and aims

The exploratory study reported here was intended to examine: how strongly subjectively reported driving avoidance behaviors and exposure were related to their objectively measured counterparts and whether it depended on the specific behavior; the extent to which gender and age play a role in the association between subjectively reported driving avoidance behaviors and exposure and their objectively measured counterparts; and the extent to which demographics, health and functioning, driving-related perceptions, and cognition influence the association between subjective and objective driving avoidance behaviors overall. We assessed four hypotheses in this study: (1) each objectively measured and subjectively reported driving behavior will be statistically significantly related to each other; (2) women's subjectively reported driving avoidance behaviors and exposure will be more closely related to their objective behaviors than will men's; (3) no significant differences will be observed by age in the association between subjective and objective driving avoidance behaviors and exposure, given the limited range of ages of participants in our study; and 4) in the multivariable context, the relationship between subjective and objective driving avoidance behaviors will be significantly stronger among women, participants with no cognitive decline, participants with more health or functioning problems, and those with lower perceived driving ability and comfort. While this study was exploratory in nature, our thinking in developing the last two components of the fourth hypothesis was that participants with the poorer physical functioning and less confidence in their driving would be more sensitive to the declines they were experiencing, and therefore have a better match between their subjective and objective measures.

3. Methods

This study used data from the Longitudinal Research on Aging Drivers (LongROAD) study, a multisite, prospective cohort study designed to generate empirical data for understanding the role of medical, behavioral, environmental, and technological factors in driving safety during the process of aging. Full details on the study methods can be found elsewhere (Li et al., 2017). A short overview is presented here.

The LongROAD project includes five data collection sites: Ann Arbor, MI; Baltimore, MD; Cooperstown, NY; Denver, CO; and San Diego, CA. Participants in the project were recruited from health clinics associated with the respective health systems at each site. To be eligible for the study, participants needed to meet the following criteria: be age 65–79 at enrollment; have a valid driver license; drive at least 1 day per week by self-report; score at least 4 on the Six Item Screener (Callahan, Unverzagt, Hui, Perkins, & Hendrie, 2002) to make sure they had the capacity to consent to be in the study; drive a primary vehicle of model year 1996 or newer; drive that vehicle at least 80% of the time if they also drove other vehicles; have no plans to be outside the study area for more than 2 months each year; and plan to remain in the study area for the next several years. Eligible, interested individuals were scheduled for an in-person baseline visit, during which written informed consent was obtained, driving, health, and functioning data were collected, and the vehicle of each participant was inspected by a trained researcher and installed with a device for collecting objective driving data. Each site received approval from its respective institutional review board for study procedures and protocols.

3.1. Data sources and measures

Objective driving measures were derived from GPS/datalogger data from 2131 LongROAD participants' vehicles. 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. Because raw GPS data do not allow examination of driving patterns directly, we derived the measures of interest for the study following procedures described in previous research (Molnar et al., 2013). Travel patterns were determined primarily based on GPS measurements that included location, time of day, vehicle speed, heading, and GPS quality indicators. Several measures were normalized by the exposure variable of trips undertaken by the driver. This was done because many decisions about self-regulation are made by drivers on a trip-by-trip basis (e.g., avoidance of nighttime driving is typically manifested as not taking a trip during nighttime hours rather than generally limiting the number of miles or days driven at night). Information on solar angle (based on latitude/longitude coordinates and GPS time) was used to determine daylight, twilight, and nighttime. Daylight was defined as 0–89 deg solar angle, civil twilight as 90–96 deg solar angle, and nighttime as solar angle greater than 96 deg. Percent of trips during nighttime was determined based on the percent of trips during which at least 80% of the trip was during nighttime. Rush hour driving was defined as driving between the hours of 7:00–9:00 AM or 4:00–6:00 PM. Driving within 25 miles of home was examined as proxy for driving in familiar areas. High speed driving (a proxy for freeway driving) was defined as speeds of 60 miles per hour or higher for at least 20% of the trip taken. The process of determining the ratio of left to right turns involved several steps. The first step was to identify turns by taking the vehicle heading data from the GPS and developing a yaw rate (rate of change of heading). Yaw rate was derived from the GPS heading data at times when the vehicle was moving and GPS fixed quality was considered good (i.e., at least three satellites). The yaw rate was then smoothed using a binomial filter over a 5-s period. Yaw rate was used to identify periods when a vehicle was turning or in a curve; these were defined by having an absolute value of yaw greater than 0.09 deg/s. Vehicle speed was then divided by yaw rate to obtain instantaneous turn radius. Turning events were defined as those with a heading change of between 70 deg and 110 deg with the sign of the heading indicating the direction of the turn. Further description of the derived driving variables can be found in Table 1. The table also lists the corresponding subjective measures which came from a comprehensive questionnaire administered to participants at baseline that asked them to report on their driving exposure, patterns, and other aspects of driving. For more detailed information on the development and testing of the questionnaire from which these items were taken, see Molnar, Eby, Roberts, Louis, and Langford (2009).

Several other variables used in the analysis came from the comprehensive questionnaire and an in-person clinical assessment administered to participants at baseline. Demographic variables included gender (male or female), age (measured as a continuous variable ranging from 65 to 79 years), race (White, African American, Hispanic, other), marital/relationship status (married or partnered, separated or divorced, widowed, never married), educational attainment (less than high school, high school and anything after high school but no bachelor's degree, bachelor's degree, graduate degree), household income (less than $20,000, $20,000–$49,999, $50,000–$79,999, $80,000–$99,999, and $100,000 or more), and work for pay (measured by the questionnaire item 'Did you do any work for pay at any time in the last month?'; yes or no). Three driving related variables from the questionnaire (in addition to those shown in Table 1) were included in the analysis. Perceived importance of driving was measured by the item 'How important is driving to you?'; using a scale of one (not at all) to seven (completely). 'Driving ability' was calculated by averaging participants' responses to a number of items assessing their perceived ability in several factors important to driving, including: their ability to see during the day; to see at night; to remember things; to concentrate on more than one thing at a time; and their strength/ flexibility/general mobility. Responses for each item (and the composite variable) ranged from one (poor) to seven (excellent). 'Driving comfort' was created by averaging participants' responses to items assessing their comfort with potentially difficult driving conditions, including: driving at night, in bad weather, on busy roads, in unfamiliar areas, alone, at night in bad weather, in rush hour traffic, and on the freeway; backing up; and making unprotected left turns. Responses for each item (and the composite variable mean) ranged from one (not at all) to seven (completely). Physical function was measured by the rapid pace walk test (seconds) from the in-person assessment. Finally, three variables from the in-person assessment were used to measure cognition: a delayed recall test to assess memory (number incorrect); Trail Making Part B to assess attention/concentration ability and executive functions (seconds to complete test); and a retrieval fluency test to assess vocabulary and processing speed (total number of animals named within 60 s maximum period).

3.2. Data management and analysis

Several of the GPS-derived variables were re-coded from monthly to weekly measures, to more closely match the wording used on the corresponding questionnaire item. Questionnaire items were assessed at a single point in time, but the objective data were collected continuously throughout the study. To account for differences in exposure among the participants (i.e., some had been in the study for more months than others), and to remove the potential for seasonal differences in the data, adjustments were made to the GPS-derived variables. Any participant who did not have at least 12 months of driving data was removed from the analyses. For participants who had more than 12 months of driving data, only their first 12 months were used. These adjustments resulted in an equal amount of exposure data for all participants. Finally, the GPS variables were averaged across the 12 month period to compare with each of the subjective measures.

Univariate statistics were generated for each of the variables of interest. The four study hypotheses were tested using the following statistical analyses. Hypothesis 1 was assessed 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, following the procedures described by Molnar et al. (2013). Linear or logistic models were fitted, as appropriate, depending upon the outcome variable type. Hypothesis 2 was assessed in the same manner, but with the addition of gender, and an interaction term between gender and the objective measure, as independent variables. When a significant interaction term was observed, separate parameter estimates (betas and/or odds ratios) were calculated to illustrate the differences. The same procedures were used to assess Hypothesis 3, replacing gender with age in those models. Finally, Hypothesis 4 was assessed by calculating a single dependent variable to represent the overall match between subjective and objective avoidance behaviors. To do so, the five subjectively reported driving avoidance behaviors (final column in Table 1) were summed for each participant. The five objective behaviors were based upon actual driving, so the following procedure was used to develop a closely matching measure. First, each variable was assessed or converted such that a higher value represented greater avoidance (e.g., % of trips at night was converted to % of trips NOT at night). Next, the maximum value (the highest observed value in the dataset) of each objectively measured avoidance behavior was identified (e.g., across all participants, the highest % of trips NOT at night was 100% so that value was used as the maximum). Each participant's value was then divided by that maximum to create a proportion for every individual that could range from zero to one (to more closely align with the subjective measure). The proportions for each avoidance behavior were then summed to create a total avoidance measure from the objective variables. Lastly, the subjective and objective measures were combined together by subtracting the smaller of those values from the larger, to create the final dependent variable. That variable was intended to represent a match between subjective and objective avoidance behaviors, with larger values denoting a greater discrepancy between subjectively reported and objectively measured behaviors.

4. 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 (85.7%), followed by African American (6.8%), Hispanic (2.6%), and other (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 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.

4.1. Comparative analyses of self-reported avoidance behaviors and GPS-derived driving exposure measures

Simple linear regressions were used to model the relationship between comparable GPS-derived and questionnaire combinations related to driving exposure (e.g., days driven per week). As noted earlier, 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. The analyses also tested for separate interaction effects for age and gender.

Summary information for the linear regressions is presented in Table 2. 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. Gender played a role in both of these relationships, but in different ways. For days per week driving, women's objective and subjective measures matched more closely than men's, but for miles per week driving, men had a better match. Age did not play a significant role in the match between objective and subjective exposure measures.

4.2. Comparative analyses of self-reported avoidance behaviors and GPS-derived driving pattern measures

Simple logistic regressions were used to model the relationship between comparable GPS-derived and questionnaire combinations related to driving patterns (e.g., % trips at night and try to avoid driving at night). Summary information for the logistic regressions is presented in Table 3. 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, and on high speed roads (measured objectively), the odds of participants reporting that they tried to avoid 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 tried to avoid unfamiliar areas increased by 2.0%. Gender played a role in how well the objective behavior predicted the subjective behavior for the following: unfamiliar areas, rush hour (marginally significant), and freeways. As the percentage of driving during rush hour and on high speed roadways increased, the odds of reporting trying to avoid those behaviors were significantly lower, respectively, for women than for men. The odds of reporting trying to avoid driving in unfamiliar areas were significantly higher for men than for women, as the percentage of trips close to home (less than 25 miles) increased. However, as discussed later, the underlying probability of reporting avoidance in this situation was higher for women than for men (Fig. 1).

Age played a role in how well the objective behavior predicted the subjective behavior only for rush hour travel. Age was included as a continuous variable, so odds ratios (and predicted probabilities; see Fig. 3) were calculated for the two ends of the age spectrum (65 and 79) to illustrate the difference. For every percentage point increase in trips made during rush hour, the odds of reporting avoiding traveling during rush hour decreased by 5.9% for 65 year old participants. In general, as age increased the odds ratios moved closer to one, and no significant relationships were observed between the objective and subjective variables for the oldest participants.

In addition to presenting odds ratios in the table above, a series of figures were produced to illustrate the predicted probabilities of responding “yes” to the subjective measure, given the objective data, for each of the significant interactions (Figs. 1–4). The shaded area in each figure represents the 95% confidence interval for each predicted value. As noted earlier, we selected the ages at the ends of the age spectrum (65 and 79) as the specific ages to report for significant age interaction (given that the original age variable was continuous).

Fig. 1 shows that overall, as the percent of short trips (<25 miles) increased, the probability of participants saying they tried to avoid driving in unfamiliar areas increased. At any given percentage point of short trips, the underlying probability of reporting this avoidance behavior was higher for women than for men, but the relationship increased more for men as the percent of short trips increased. Fig. 2 shows that overall, as the percent of trips made during rush hour increased, the probability of participants saying they tried to avoid driving during rush hour decreased. This relationship was more pronounced among women than men. Fig. 3 shows that among the youngest age versus oldest age participants, as the percent of trips made during rush hour increased, the probability of participants reporting that they tried to avoid driving during rush hour decreased. This relationship became less pronounced as age increased, and no significant relationship was observed at the oldest age. Fig. 4 shows that overall, as the percent of trips made on freeways increased, the probability of participants saying they tried to avoid driving on the freeway decreased. This relationship was more pronounced among women than men, with a notably higher probability of reporting this behavior among women who took relatively few freeway trips, compared to men with similar freeway driving patterns.

We also conducted a multivariable analysis to examine the potential role of selected factors in the relationship between objective and subjective driving avoidance behaviors. In addition to gender and age, several variables from the questionnaire and an in-person clinical assessment administered to all participants at enrollment were used in the models. Preliminary models included educational attainment, income, relationship status, rapid pace walk, delayed memory recall, Trail Making Part B, and the perceived importance of driving. These variables showed no significant relationship with the dependent variable and were not retained in the final models. Variables retained in the final models included gender, age, race, work for pay, retrieval fluency (the only remaining cognition variable), driving ability, and driving comfort (see methods section for variable descriptions).

Results are presented in Table 4. Because the dependent variable was created by subtracting the smaller value from the larger value (between the subjective and objective measures of driving avoidance), the positive and negative values in the betas are not interpretable; rather a larger difference represents greater discrepancy between the two. The variance explained by gender was subsumed by the driving comfort variable. Age was not significant in any of the models. African American participants and those who identified as some other race had significantly greater discrepancy between subjective and objective avoidance behaviors. The significant, independent contribution of work for pay was attenuated as the driving ability and comfort variables were added to the model. The opposite effect was observed for the retrieval fluency score that represented cognition. However, its effect on the dependent variable was small. Perceived driving ability was highly significant in both models, with a substantial beta value that attenuated with the addition of driving comfort. Driving comfort had the largest influence on the discrepancy between objectively measured and subjectively reported driving avoidance behaviors. For every one-unit increase in driving comfort, the discrepancy increased by about three-quarters of a point.

5. Discussion

Comparisons between objectively measured and subjectively reported driving exposure were statistically significant for both days driving per week and miles driving per week, consistent with Hypothesis 1. In each case, actual driving predicted self-reported driving, albeit not perfectly. For driving patterns, comparisons were statistically significant for driving at night, driving in unfamiliar areas, and on high-speed roads. For each driving situation, participants' actual driving predicted the likelihood of reporting trying to avoid that situation. However, even those that were significantly related were not close to "perfect" correlations/associations. In addition, 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. The objective data could be used to determine the rates of driving that actually occur in these situations, and the subjective data could be used to understand the context of driving or non-driving in these situations.

We hypothesized that women's objective driving behavior would more strongly predict their subjectively reported avoidance behaviors and exposure than would men's (Hypothesis 2), which was partially supported by the linear and logistic regression results. In terms of driving exposure, women's objective and subjective measures were more closely related than men's for days driven per week but not miles driven per week. In terms of driving patterns, the odds of reporting trying to avoid driving during rush hour and on freeways were significantly higher for women than men, as the percentage of trips driven in these situations increased (Table 3). Women also had greater probabilities of reporting that they tried to avoid these situations than men (Figs. 2 and 4). Although the odds of reporting trying to avoid driving in unfamiliar areas were significantly higher for men than for women, as the percentage of trips close to home (less than 25 miles) increased (Table 3), the underlying probability of reporting avoidance in this situation was higher for women than for men (Fig. 1). Collectively, women appeared to be better at assessing (or admitting) that they tried to avoid certain challenging situations. However, results from the multivariable analysis yielded different results with regard to gender (Table 4). Gender, while significant in the early models, was no longer significant once the driving comfort variable was added; that is, the variance explained by gender was subsumed by driving comfort. These results suggest that gender may have been serving as a proxy for driving comfort in the unadjusted models. This result is consistent with the conclusion reached by other studies that perceived driving comfort or confidence may mediate the relationship between gender and self-regulation (e.g., Charlton et al., 2006; Kostyniuk & Molnar, 2008). More research in this area would be beneficial to further explore these relationships.

As hypothesized, no significant differences by age were observed in the relationships between subjective and objective driving avoidance behaviors and exposure (Hypothesis 3), with the exception of rush hour in the simple regression analysis. However, the relationship between the subjective and objective rush hour measure was only significant for the youngest age participants. It could be that the youngest participants were most likely to still be in the workforce and may have had less choice about when they could drive. Therefore they could have been more aware of consciously avoiding rush hour because of their requirement to drive in that situation. The lack of age effects are not surprising given that the LongROAD sample, at enrollment, was relatively young and healthy. Given the longitudinal nature of the study, we expect that there may be greater age effects as some participants begin to move into the older age groups (e.g., 80 and over).

Our fourth hypothesis, that the relationship between subjective and objective driving avoidance behaviors would be significantly better among women, participants with more health or functioning problems, no cognitive decline, and those with lower perceived driving ability and comfort, was only partially support by the study results. In multivariable models, gender did not affect the relationship, while cognition had only a small (albeit significant) effect. The effect of perceived driving ability was influenced by driving comfort. Driving comfort clearly had the largest influence on the discrepancy between objectively measured and subjectively reported driving avoidance behaviors. As noted earlier, for every one-unit increase in driving comfort, the discrepancy increased by about three-quarters of a point. These results suggest that those who are more comfortable in the driving situations examined in this study may not perceive themselves to be avoiding anything, even if their objective behaviors suggest otherwise. The importance of driving comfort in self-regulatory behaviors is well established in the literature as noted in the introduction to this paper, so it is not surprising that it also plays an important role in the match between objective and subjective measures of driving exposure and patterns.

We also found that African American participants and those who identified as some other race had a significantly greater discrepancy between subjective and objective avoidance behaviors. Further investigation of this result is needed. One area of inquiry might focus on individual differences in driving needs or lifestyle which could make it difficult to carry out avoidance behaviors or recognize them as actual avoidance. Such differences may have accounted for the effects of race that were found. This study used self-reported avoidance of certain driving situations as the first step in examining self-regulation among older adults. However, drivers may choose not to drive in various situations for other reasons such as changes in preferences or lifestyles resulting in greater flexibility in scheduling trips or simply less need to travel under certain conditions (e.g., Ball et al., 1998; Blanchard & Myers, 2010; Charlton et al., 2006; Hassan, King, & Watt, 2015). Further research in the LongROAD study is underway to explore the motivations drivers have for avoiding certain situations to determine whether or not avoidance is in fact self-regulation.

This study had some limitations. As noted in Li et al. (2017), LongROAD participants are better educated, have higher household incomes, and are less racially diverse than the general population of older adults in the United States. In addition, because they had to volunteer to participate in the project, they are likely to be healthier. Also, given that the questionnaire was administered at baseline and the objective driving data were collected over the following 12-month period, participants could have experienced declines in functioning that led to changes in driving behavior, thereby reducing the match between subjective and objective measures. Because the questionnaire will be repeated later in the study, we will have an opportunity to examine the match between subjective and objective driving behaviors, using repeated measures. Finally, while study sites represent a wide range of communities with diverse geography, population density and racial, ethnic, and socioeconomic distribution, they were not selected to specifically generate a geographically representative sample of older adult drivers and therefore the results may not necessarily be generalizable to other areas of the country.

This study had several unique strengths that help advance the state of knowledge about older adults' driving exposure and patterns. First, it included a very large sample (n = 2131) which greatly increased our ability to compare objective GPS-derived driving measures and their corresponding subjective questionnaire measures. Other studies of older adults using GPS-derived driving data have generally been limited to a few dozen or at most, a few hundred participants in their analyses. We also had a long data collection or exposure period over which to measure driving, and our restriction of our analyses to only those participants with a full 12 months of data reduced the possibility of confounding effects from seasonal differences. As our study progresses, the longitudinal cohort design of the LongROAD project will allow us to follow participants over time to assess changes in their objective and subjective driving as their health and functioning change with age.

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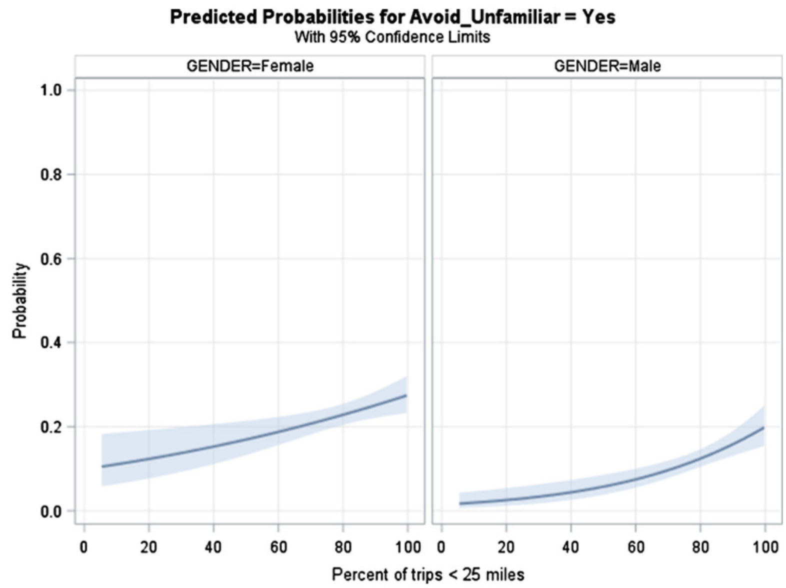

Fig. 1.
Avoid unfamiliar areas by gender.

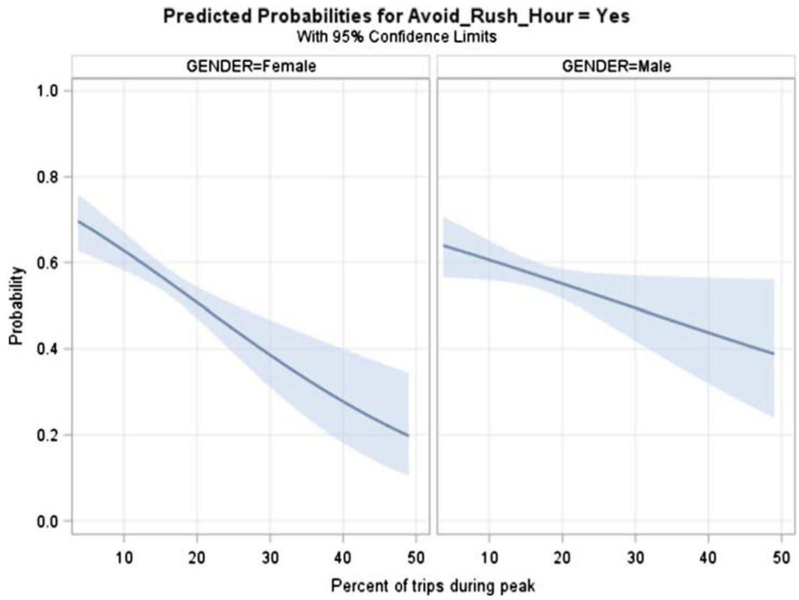

Fig. 2.
Avoid rush hour traffic by gender.

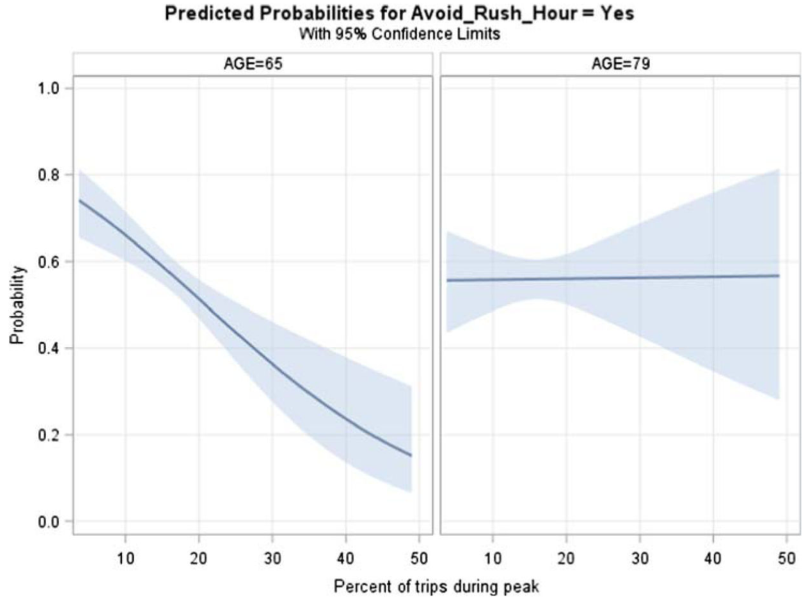

Fig. 3.
Avoid rush hour traffic by age (ends of the age spectrum).

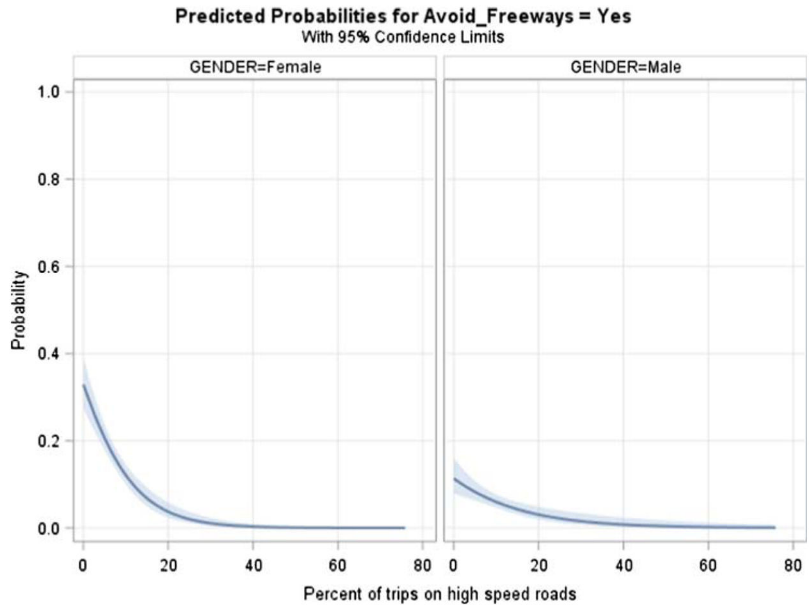

Fig. 4.
Avoid freeway by gender.

Table 1

List of derived driving measures and corresponding questionnaire items.

Measure	Description of the Monthly Variable	Corresponding Questionnaire Item
Driving Exposure		
Average # days driven per month	Total number of days with at least one trip	How many days per week do you normally drive?
Average # miles per month	Total number of miles driven	How many miles do you drive in a normal week?
Driving Avoidance		
Average monthly % trips at night	Percent of all trips during which at least 80% of trip was during nighttime (solar angle greater than 96 degrees)	Do you try to avoid driving at night?
Average monthly % trips in AM rush hour	Percent of trips during 7–9 AM on weekdays	Do you try to avoid driving in rush hour traffic?
Average monthly % trips in PM rush hour	Percent of trips during 4–6 PM on weekdays	Do you try to avoid driving in rush hour traffic?
Average monthly % trip on high speed roads	Percent of trips where 20% of distance travelled was at a speed of 60 MPH or greater	Do you try to avoid driving on the freeway?
Average monthly % trips < 25 miles of home	Percent of trips traveled within 25 miles of home	Do you try to avoid driving in unfamiliar areas?
Average monthly right to left turn ratio	Ratio of all right-hand to left-hand turning events for a driver	Do you try to avoid making unprotected left turns?

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

Table 2

Linear regression results comparing subjective to objective exposure in simple models, and when significant gender or age interactions were observed.

Subjective Exposure (DV)	Sig int	Objective/GPS (IV)	β	SE
Days per week driving		Days in month with ≥ 1 trip/4***	0.575	0.025
	**	Male	0.512	0.033
		Female	0.643	0.037
Miles per week driving		Miles in month/4***	0.439	0.018
	*	Male	0.457	0.027
		Female	0.376	0.024

Note. DV = dependent variable; Sig int = significance level of interaction; IV = independent variable; SE = standard error.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

Table 3

Logistic regression results comparing subjective to objective avoidance behaviors in simple models, and when significant gender or age interactions were observed.

Subjective Avoidance (DV)	Sig int	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
	*	Male			1.029	1.016	1.041
		Female			1.012	1.004	1.021
Rush hour		% trips during rush hour***	−0.035	0.008	0.966	0.951	0.981
	†	Male			0.978	0.957	0.999
		Female			0.952	0.930	0.974
	*	At age 65			0.941	0.914	0.968
		At age 79			1.001	0.965	1.038
Freeway		% trips including 60 MPH***	−0.109	0.012	0.897	0.875	0.919
	*	Male			0.932	0.900	0.966
		Female			0.881	0.853	0.910

Note. DV = dependent variable; Sig int = Significance level of interaction; IV = independent variable; SE = standard error; OR = odds ratio.

† $p < 0.10$.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

Table 4

Linear regression results assessing the role played by demographics, cognition, and driving factors in the relationship between total self-reported driving reduction and objective measures.

	Model 1: Demographics & cognition (R^2 = 0.04)		Model 2: Demographics, cognition, & driving ability (R^2 = 0.11)		Model 3: Demographics, cognition, and driving ability and comfort (R^2 = 0.36)	
	β	SE	β	SE	β	SE
Female gender	−0.280***	0.047	−0.284***	0.046	−0.008	0.040
Age (5 years)	−0.006	0.030	0.018	0.029	0.041	0.025
Race (ref = White)						
African American	−0.402***	0.095	−0.412***	0.092	−0.270***	0.079
Other	−0.445***	0.110	−0.453***	0.107	−0.242**	0.091
Hispanic	0.052	0.149	−0.043	0.144	0.027	0.122
Work for pay	0.207***	0.053	0.185***	0.051	0.086*	0.043
Cognition (fluency score)	0.001	0.004	−0.003	0.004	−0.009**	0.003
Driving ability			0.435***	0.034	30.129***	0.035
Driving comfort					0.745***	0.026

Note. SE = standard error.

† $p < 0.10$.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.