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The impact of urban vs rural environments on driving mobility and safety in older age

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ABSTRACT

Older rural drivers rely more on driving due to limited transportation options, but the impact of cognition on driving in urban versus rural settings is unclear. This study examined whether cognitive changes affect driving mobility and road safety differently across these populations. In a prospective cohort study, 969 older drivers completed driving behaviour and road traffic incident (RTI) history questionnaires, followed by cognitive testing, with a follow-up one year later. We find that older rural drivers have a greater driving mobility than older urban drivers and are less likely to reduce their driving mobility over time, as only urban residents with cognitive decline reduced their driving space. RTI incidence was higher in urban areas, with a stronger link between poor cognition and increased RTI risk in urban residents. This study suggests the interaction between cognitive changes and environmental setting on driving behaviour, providing insights for policy development on driving mobility and safety among older adults.

1. Introduction

Driving mobility is vital for maintaining independence amongst older adults (Eby & Molnar, 2009). This is particularly true for individuals living in rural settings, where reduced public transportation access and greater distances to amenities require greater reliance on personal vehicles for daily activities and social engagements (Arcury et al., 2005; Hamano et al., 2016). However, older adults typically self-regulate and reduce their driving mobility as they age, due to changes to cognitive, physical, and sensory changes (Karthaus & Falkenstein, 2016; Oxley et al., 2010; Payyanadan et al., 2018). With the demographic shift towards an ageing population, and the increase of older adults living in rural areas within Western countries, it is important to understand how changes to cognitive functioning interact with geographical settings to inform how older adults can continue to meet their driving transportation needs whilst maintaining road safety.

Within the UK, a higher proportion of older adults live in rural areas (25.4 %) compared to urban areas (17.1 %) (Office for National Statistics, 2024). Survey findings demonstrate that rural drivers depend substantially more on personal vehicle transportation as their main method of transportation compared to those who live in cities or small towns (Pucher & Renne, 2005; Ritter et al., 2002). This

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greater reliance on personal vehicles in rural areas has been attributed to requiring greater travel distances to reach healthcare services, amenities, and resources; as well as having less access to alternate transportation methods. Within the UK, public transportation has been found to be largely unavailable, unreliable, or deficient in rural areas (Jo et al., 2021), increasing the greater reliance on driving for rural residents. It is therefore of little surprise that driving is regarded more important to individuals living within rural areas (Strogatz et al., 2020), who typically report travelling further distances than urban residents (Payyanadan et al., 2018; Pucher & Renne, 2005).

In addition to the greater reliance of driving in rural areas, data from various national databases show that there is a greater risk of fatalities on rural roads (Department for Transport, 2023; Shrira & Noguchi, 2016; Thompson et al., 2013; Zwerling et al., 2005). Indeed, UK statistics show that although urban roads amount in a greater likelihood of overall road traffic incidents (RTIs), rural roads present a greater risk for fatal RTIs (Department for Transport, 2023). Explicative work has shown that certain features of the environment, such as undivided roads, higher road speeds, and challenges for emergency response teams, are associated with greater risk of road-based fatalities in rural areas (Goldstein et al., 2011; Gonzalez et al., 2009; Thompson et al., 2013). Additionally, predictive work indicates that greater driving dependency in rural areas means that older drivers in these areas may be less able to self-regulate their driving, despite cognitive impairments reducing their driving safety (Byles & Gallienne, 2012; Hanson & Hildebrand, 2011).

During the ageing process, cognitive changes are associated with reduced driving safety (Depestele et al., 2020; Stefanidis et al., 2023). Older drivers typically compensate for these changes by self-regulating their driving, typically by making fewer driving outings, reducing driving distances, and limiting exposure to challenging driving situations (Charlton et al., 2006; Devlin & McGillivray, 2014; Molnar & Eby, 2008). Previous research conducted on the interaction of health impairments on driving mobility within rural and urban environments have focused on physical health, showing that measures of physical functioning were more predictive of driving behaviour in larger urban cities (Anstey et al., 2005; O'Connor et al., 2012). However, research has not yet established how cognitive functioning is associated with driving changes across rural and urban areas. Our research group previously established that spatial orientation is the signature cognitive marker for driving frequency and difficulty in older age (Morrissey et al., 2024), and that use of GPS technology can ameliorate driving mobility for individuals with cognitive impairments (Morrissey et al., 2025). However, it is not yet understood how cognitive impairments may interact with driving mobility and safety across geographical settings. This is important to establish, as individuals who cease driving due to self-regulation from cognitive impairments in rural areas often have less alternate transportation methods to maintain social mobility, and those who do not self-regulate effectively may be at greater risk of RTIs.

The current study addresses these gaps in knowledge by establishing how driving mobility changes across rural and urban settings over a one-year period within a large sample of community-dwelling older adult drivers. We will further establish how road safety differs across rural and urban environments. Finally, we will explore how cognitive changes over one-year are associated with changes in driving mobility and driving safety across geographical settings. Specifically, we will i) compare driving characteristics and mobility across geographical settings; ii) assess how RTI frequency interacts with cognitive functioning across geographical settings; iii) examine how driving mobility changes over time across geographical settings; and iv) identify whether global cognitive changes are associated with changes to driving mobility within rural and urban areas separately. We hypothesise that i) drivers within rural areas will rely more upon driving their personal vehicles than community transportation or public transport; ii) drivers in rural areas will demonstrate greater driving frequency and space than individuals in urban areas, as they will be more dependent on driving to meet their mobility needs; iii) drivers in urban environments will experience more RTIs due to driving more frequently in more dynamic, high-traffic environments; iv) worse cognitive functioning will be associated with increased RTI risk, with the association being stronger in rural areas due to fewer transport alternatives for self-regulation; v) urban older drivers will show a reduced driving mobility over time, whereas this is maintained in rural older drivers; and vi) older drivers with global cognitive changes living in urban areas will show reduction in their driving mobility. Due to greater reliance on driving, it is predicted that older rural drivers with global cognitive changes will maintain their driving mobility.

2. Methods

2.1. Participant recruitment

969 older adults (mean age: 71.01, 540 female, rural: 296) were recruited between February 2021 and August 2021 to complete the study. The inclusion criteria for the study were being age 65 or older, holding a valid driving license, and being a regular driver (driving at least once per week), and being fluent in written and spoken English. The exclusion criteria for the study were not driving regularly (driving less than once per week), having a medical condition that contraindicates driving, having an untreated significant visual or physical impairment, having a diagnosis of mild cognitive impairment or dementia, taking medications for dementia, and high alcohol consumption ($>$ 45 units per week). Participants were recruited via online and media advertisement. Signed informed consent was obtained from each participant prior to conducting the experimental protocol and data was attributed anonymously. Ethical approval for the study was provided by the Faculty of Medicine and Health Sciences Research Ethics Committee at the University of East Anglia (FMH2019/20–134).

2.2. Procedure

Participants initially completed online questionnaires related to their demographic information, health status, driving history, driving habits (Owsley et al., 1999), and a custom driving-based navigation questionnaire. Following this, participants completed a neuropsychological testing battery assessing cognitive performance across a variety of domains, including reaction speed, processing speed, executive functioning, spatial working memory, episodic memory, visuospatial functioning, and spatial orientation (see Morrissey et al., 2024 for detailed information background on cognitive tests). Participants were then invited to complete a follow-up testing phase one year after baseline data collection, undergoing the same procedure. 574 participants took part in the follow-up testing phase (mean age: 71.95, 314 female, 174 rural).

2.3. Driving mobility and safety measures

Driving mobility and safety measures were derived from the Driving Habits Questionnaire (DHQ), as well as novel Driving History and Road Traffic Incident (RTI) questionnaires (see Supplementary Items 3 and 4, respectively). Driving mobility measures included annual mileage, weekly driving days, driving space (the geographical area in which people drive), weekly trips, maximum weekly trip distance, situation avoidance, driving speed (relative to the general flow of traffic), and transport reference (Drive yourself, Driven by someone else, Public transport). Driving safety was measured by whether someone was in a recent RTI (within the past 3 years). An RTI was defined as being "an incident when you were driving, which could have caused injury or damage, regardless of whether you were at fault". The number of in-vehicle technologies used (parking assistance, cruise control, lane control, sat-nav, and Bluetooth) was collected. Transport preference was measured by asking participants how they prefer to get around (Drive yourself, someone else drives, or public transport/ taxi) (see Supplementary Table 1 for detailed information on mobility and safety measures).

2.4. Rural/Urban classification

Participants were classified into rural or urban residency groups. depending on the outward code (the first part) of their postcode location, based on the 2011 Rural-Urban classification data (Department for Environment, Food & Rural Affairs, 2021). Urban areas consisted of major and minor conurbation, and city & town, whereas rural areas consisted of town & fringe, villages, and hamlets & isolated dwellings.

3. Cognitive measures

3.1. Baseline global cognitive functioning

A composite global cognitive functioning measure was developed to establish whether cognitive performance moderates the relationship between driving mobility and environmental settings. This was developed by averaging Z-scores for neuropsychological test measures (reaction time, processing speed, executive functioning, spatial working memory, episodic memory) after reversing necessary variables to ensure they followed consistent directionality. Spatial orientation measures (allocentric & egocentric orientation) were not included within the global composite measure as fewer participants completed spatial orientation tests and therefore this would have reduced global cognitive datapoints significantly (644 participants without spatial orientation tests compared to 391 with spatial orientation tests). Spatial orientation measures were therefore included separately for post-hoc analyses.

3.2. Longitudinal cognitive change

For longitudinal analyses, a cognitive change measure was developed to establish whether change in global cognitive functioning over a one-year period moderated changes to driving mobility across environmental settings. To develop a global cognitive change score, cognitive data was standardised within each cognitive measure using the grand mean from both timepoints, and average performance across all tasks was derived across baseline and follow-up test phases. Cognitive change was established by subtracting follow-up global cognition from baseline global cognition. Spatial orientation measures were again omitted for the global cognitive change measurement as fewer participants completed these tests across both testing phases and therefore there would have been a substantive reduction in data (172 participants with spatial orientation measures included compared to 311 participants without spatial orientation measures).

3.3. Statistical analysis

Differences in driving characteristics between people living in rural and urban areas were established using two sample t-tests and chi-squared tests for continuous and categorical variables respectively. Analyses of Covariances (ANCOVAs) were conducted to assess whether driving mobility differed across environmental locations after controlling for age as a covariate. In assessing how avoidance of driving situations differed across environmental locations, weekly driving days were added to the model as a covariate. A Pearson's chi-square test was conducted to establish whether there were differences in transport preferences across environmental locations. A binary logistic regression was used to assess whether environmental location predicted whether individuals were more likely to have a recent RTI after accounting for age and annual mileage as covariates as they have previously been associated with increased RTI risk. Post-hoc logistic regression analyses were then conducted to assess whether global cognitive functioning was associated with recent RTIs between rural and urban environments separately after controlling for age and mileage. Individual spatial orientation tests were not assessed with recent RTIs due to few rural residents with a recent RTI completing spatial orientation tests. A post-hoc independent samples *t*-test analysis was then conducted to assess whether the annual mileage for individuals who had experienced a recent RTI differed across rural and urban residents. We then assessed whether driving mobility changes over a one-year period were associated with environmental location using linear mixed effect (LME) modelling. For LME analysis, difference in driving mobility was calculated by subtracting the baseline score from the follow-up score. Age was included as a covariate and a random intercept term was added to the model to account for individual variability.

We then assessed whether global cognitive performance was associated with driving mobility variables using linear regression models within geographical settings, separately. Cognitive functioning across both geographical settings was comparable as a Mann-Whitney *U* test revealed that there was no significant difference in global cognitive performance between rural and urban areas ($W = 39425$, $p = 0.14$). Following this, we assessed whether cognitive change over time was associated with change in driving mobility within environmental locations separately. Post-hoc analysis was therefore conducted to establish whether spatial orientation performance change over time was associated with change in driving mobility changes across environmental locations separately. Spatial orientation change over time was calculated in the same approach as global cognitive change, but with egocentric and allocentric orientation measures analysed separately.

To account for potential measurement error of online testing, outliers were assessed for baseline and follow-up data using boxplots, Q-Q plots, and histograms. For online cognitive data, extreme outliers outside of 3 *SD* were removed for reaction time (baseline: 8, follow-up: 6), trail-making test – A(10, 6), trail-making test – B (16, 8), spatial working memory (5, 0), allocentric orientation (2, 0), egocentric orientation (2, 0), and subjective sense of direction (5, 3). Extreme values above and below the 99th percentile were removed for recognition memory (8, 5) and source memory (8, 5). For self-reported driving data, extreme outliers were also removed for typical annual mileage (18), driving space (1, 0), weekly trips (13, 2), and weekly trip distance (11, 12), number of passengers (7), years spent with current car (8), and cars regularly driven (8). Weekly trips and maximum weekly trip distance variables were given a logarithmic transformation for analysis due to high positive skewness. For ANCOVA and LME analysis, checking normality of outcome variables was conducted using visual inspection of histograms and normality of residuals was conducted by QQ-Plots. Linearity assumptions and multicollinearity were checked for regression analyses. A significance threshold of 0.05 was used to assess statistical significance. All analysis was carried out in R (version 4.3.1) using car, lme4, and nlme packages.

4. Results

4.1. Driving characteristics of older rural and urban residents in the UK

Within our cohort, individuals living in rural environments had more years of driving experience ($p < 0.05$), and less use of in-vehicle technology than urban drivers ($p < 0.05$) (see Table 1). 125 participants self-reported recent RTIs (95 living in urban locations) (see Fig. 1).

4.2. The impact of urban and rural environments on driving mobility

Rural residents showed a significantly greater driving space (M = 10.12, CI [9.79, 10.45] compared to (M = 9.62, CI [9.40, 9.84]; $F(1, 939) = 6.164$, $p < 0.05$, η_p^2 (partial eta squared) = 0.01); typical annual mileage (M = 7582, CI [7196, 7969] compared to M = 6429, [6170, 6688]; $F(1, 924) = 23.684$, $p < 0.001$, $\eta_p^2 = 0.02$); higher maximum weekly trip distance (M = 2.03 miles, CI [1.88, 2.17] compared to M = 1.66 miles, CI [1.56, 1.75]; $F(1, 554) = 17.960$, $p < 0.001$, $\eta_p^2 = 0.03$), but made less weekly driving trips (M = 0.26, 95 % CI [0.15, 0.37]) than urban residents (M = 0.42, CI [0.35, 0.49]; $F(1, 588) = 5.886$, $p < 0.05$, $\eta_p^2 = 0.01$) (see Fig. 2). Rural residents (M = 1.31, CI [1.17, 1.45] avoided more driving situations than urban residents (M = 1.04, CI [0.94, 1.13]; $F(1, 943) =$

Table 1
Baseline participant demographic and driving characteristics.

Variable	Environment			
	Rural	Urban	*p*-value	Effect size *(d)*
Participants	296	673		
Age (years)	71.38 (5.30)	70.85 (4.78)	0.14	0.11
Gender (% female)	52.36	57.21	0.18	0.94
Education (years)	14.78 (2.85)	14.90 (2.71)	0.54	0.04
Driving experience (years)	50.27 (7.13)	48.96 (7.52)	0.01	0.18
Subjective driving ability	3.79 (0.62)	3.79 (0.65)	0.99	0.00
Cars regularly driven	1.34 (0.57)	1.31 (0.51)	0.45	0.06
Time with current vehicle (years)	2.82 (3.45)	3.23 (3.80)	0.11	0.11
N. of regular passengers	1.07 (1.11)	1.18 (1.19)	0.20	0.09
Use of in-vehicle technology	0.91 (0.69)	1.03 (0.81)	0.02	0.16
Sat-Nav use	1.01 (1.02)	1.18 (1.04)	0.14	0.16
Driving speed	3.03 (0.49)	2.99 (0.43)	0.18	0.10
Recent Road Traffic Incidents	0.10 (0.30)	0.14 (0.35)	0.07	0.12

Note.
[a]Road Traffic Incidents is displaying the average number of individuals who had experienced a Road Traffic Incident since 2018.
[b]Welch's two sample *t* test conducted for group differences. Chi squared test of independence used for Gender analysis.
[c]Cramér's V effect size used for Gender analysis. Cohen's D effect sizes calculated for other variables.

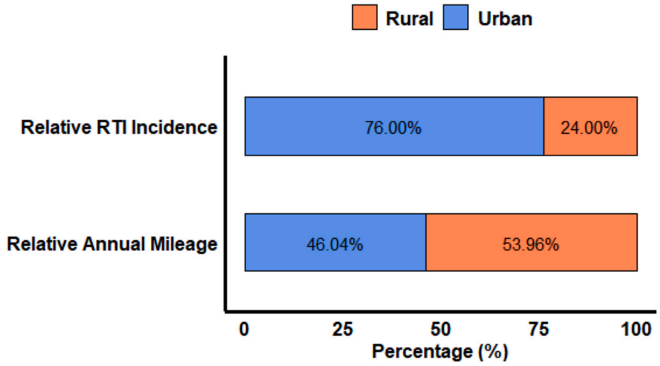

Fig. 1. Baseline relative road traffic incident incidence and relative annual mileage across rural and urban areas. This figure presents the percentage of recent RTIs (within 3 years prior to data collection), and the percentage of total annual mileage, stratified by rural and urban residency in the present sample. RTI percentages are calculated only among individuals who reported a recent RTI.

9.701, $p < 0.01$, $\eta_p^2 = 0.01$). There were no significant differences in driving days or relative driving speed between groups.

Significant differences in transport preferences were found between rural and urban residents, ($\chi2 = 7.27$, df = 2, $p < 0.05$), with rural residents less likely to use public transport or rely upon a friend to drive them than people living in urban areas.

4.3. The impact of urban and rural environments road traffic incident occurrence

Urban residents were more likely to have been in a recent RTI than rural residents (OR = 1.57, $p < 0.05$, CI[1.02, 2.48]). Worse global cognitive functioning was predictive of a greater incidence of RTIs within urban residents (OR = 1.98, $p < 0.05$, CI[1.00, 3.88]),

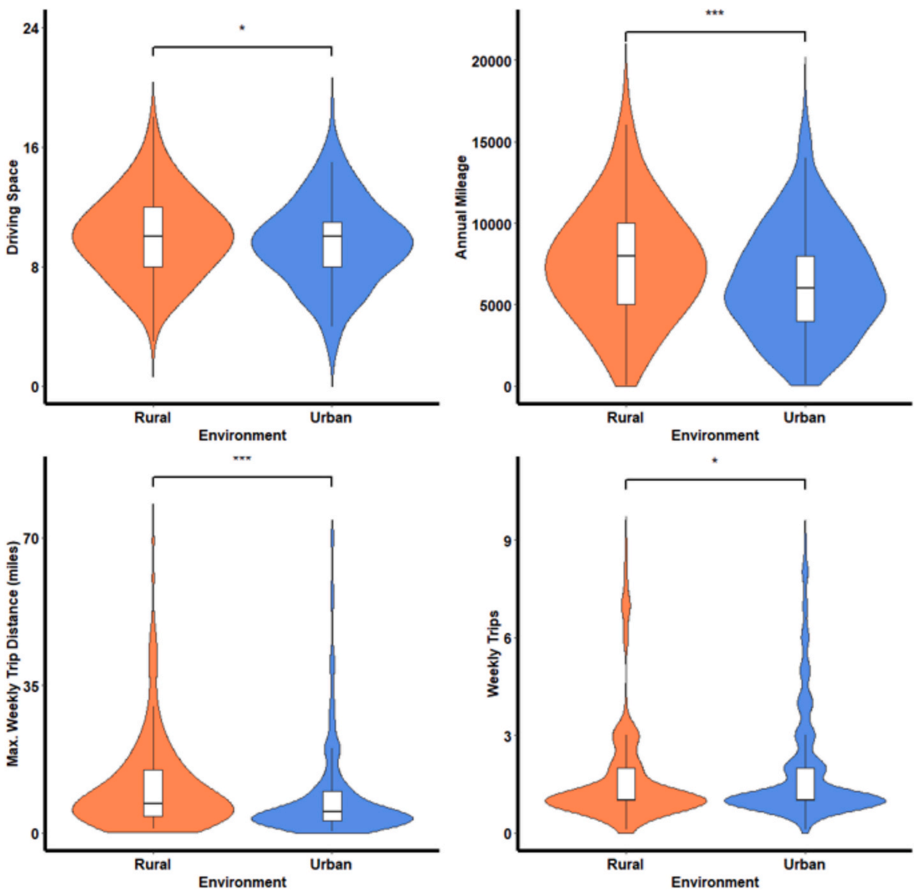

Fig. 2. Baseline driving mobility differences across rural and urban settings.

but not rural residents (see Table 2). Among individuals involved in a recent RTI, there was no significant difference in typical annual mileage between rural and urban residents.

The impact of cognitive performance on driving mobility within urban and rural environments.

Worse global cognitive functioning was associated with a smaller driving space (β = -1.12, $p < 0.05$, CI[-2.04, −0.20]) and slower driving speed (β = -0.22, $p < 0.05$, CI[-0.39, −0.05]) among rural residents, and less annual mileage amongst urban residents (β = -803.09, $p < 0.05$, CI[-1581.20, −24.98]). Post-hoc spatial orientation tests revealed that worse allocentric orientation was associated with less annual mileage (β = -596.41, $p < 0.001$, CI[-943.17, −249.66]) and smaller driving space (β = -0.361, $p < 0.01$, CI[-0.62, −0.10]) within rural areas, and greater avoidance of driving situations (β = 0.115, $p < 0.01$, CI[0.03, 0.20]) within urban residents. Worse egocentric orientation performance was associated with reduced driving space (β = -0.01, $p < 0.05$, CI[-0.02, −0.00]) and greater avoidance of driving situations (β = 0.006, $p < 0.01$, CI[0.00, 0.01]) in urban residents (see Table 3).

4.4. Longitudinal driving changes across urban and rural environments

Urban residents exhibited a greater decline in their driving space over time (β = −0.652, $p < 0.01$, CI[−1.10, −0.21]), and were more likely to avoid more driving behaviours over time than rural residents (β = 0.334, $p < 0.001$, CI[0.138, 0.530]). No significant differences were found in driving days, weekly trips, maximum weekly trip distance, or driving speed (see Supplementary Table 2).

No significant associations were found between global cognitive changes and driving mobility over time across environmental location. Post-hoc analysis of the association between spatial orientation performance and driving mobility across rural and urban locations showed that in urban residents the decline in allocentric orientation performance predicted reduced driving space over time (β = 0.338, $p < 0.05$, CI[0.02, 0.65]).

5. Discussion

Within a large sample of healthy older adults, the present study examined how driving mobility and safety differ across rural and urban environments over a one-year period and establishes how this relates to cognitive functioning. Overall, we found that rural residents show a greater driving mobility than urban residents and were less likely to decrease their driving mobility over time. We also demonstrate that worse cognitive performance is associated with lower driving mobility in both rural and urban areas, but only urban residents with decline in spatial orientation ability reduced their driving space over time. Importantly, we corroborate previous findings showing that urban residents were more likely to be in a recent collision than rural residents and build upon previous findings to show that people with worse global cognition are more likely to be in RTIs within urban areas.

Within our sample, approximately 14 % of urban residents and 10 % of rural residents self-reported a recent RTI, supporting previous evidence that RTIs are more common in urban environments (Merlin et al., 2020). Worse cognitive functioning has previously been associated with an increased presence of RTIs within older age (Ball et al., 2006; Emerson et al., 2012; Fraade-Blanar et al., 2018; Kosuge et al., 2017), however this study is the first to our knowledge to show that worse cognitive functioning is associated with increased RTI risk amongst urban but not rural residents. Urban road environments present greater hazards due to a more dynamic road environment, and cognitive deficits in healthy ageing have previously been associated with experiencing challenges for road features common in urban road environments, such as intersections and higher traffic volume (Morrissey et al., 2024; Son et al., 2011; Swain et al., 2021). The heightened risk of RTIs among urban residents may therefore be attributed in part to the interaction between cognitive decline in ageing individuals and the complexities of navigating urban road environments. In support of this, we found that urban residents were less likely to avoid challenging driving situations than rural residents, and therefore may have higher exposure to more at-risk driving than rural residents. This interpretation is consistent with prior qualitative findings, where older urban drivers reported more difficulty with aspects of the road environment, such as traffic congestion (Payyanadan et al., 2018).

Aligning with our hypotheses, rural residents demonstrated a greater driving mobility than urban residents: driving at a greater annual mileage, covering greater driving space, and having a higher distance in weekly trips. In reverse, urban residents reported a greater number of weekly trips. The greater reliance on driving in rural areas is consistent with previous US and Australia based findings that older rural drivers show greater mobility than the urban population (Byles & Gallienne, 2012; Payyanadan et al., 2018; Pucher & Renne, 2005). Differences found in weekly trip frequency across geographical settings may be related to accessibility of amenities and local services, as urban households living closer to intended destinations would be more likely to take shorter, more frequent trips than more isolated rural residents, who may be less inclined to be on the road again after travelling farther distances to reach their destination and may conduct multiple stops in one trip.

Table 2
Multiple logistic regression analysis comparing predictors of recent road traffic incident (RTI) occurrence across rural and urban environments.

Variable	Global Cognition	Age	Mileage
Rural – Recent RTI	0.96 (0.29–2.98)	1.05 (0.94–1.67)	1.00 (1.00–1.00)
Urban – Recent RTI	**1.98* (1.00–3.88)**	1.02 (0.96–1.08)	1.00 (1.00–1.00)

Note.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
[a]Displaying Odds Ratios and 95% Confidence Intervals.
[b]Analysis pertains to baseline road traffic incident data.

Table 3
Multiple linear regression analysis establishing how cognitive performance interacts with driving mobility within rural and urban environments.

Variable	Driving days	Driving space	Annual mileage	Weekly trips	Max. trip distance	Situational avoidance	Driving speed
Rural							
Global cognition	−0.46	**−1.12***	−900.02	0.12	−0.21	0.19	**−0.22***
Allocentric orientation	−0.10	**−0.36****	**−596.41*****	−0.03	0.00	0.09	−0.01
Egocentric orientation	0.00	0.01	−7.85	0.00	0.00	0.00	0.00
Urban							
Global cognition	−0.15	−0.00	**−803.09***	−0.12	0.22	0.12	−0.04
Allocentric orientation	−0.01	−0.11	−169.73	0.02	0.00	**0.11****	−0.01
Egocentric orientation	−0.00	**−0.01***	−7.61	0.00	0.00	**0.01****	0.00

Note.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
[a]Displaying unstandardised beta coefficients.
[b]Analysis pertains to baseline driving mobility data.

The greater reluctance of rural residents to reduce their driving mobility over time may be related to a greater reliance on driving as a transportation method to meet their mobility needs. Rural residents were less likely to rely upon alternate forms of transportation than urban residents, including public transport or relying upon a friend to drive them. Therefore, whilst community transportation is common amongst older adult populations (Davey, 2007; Kerschner & Rousseau, 2008), it may be that this is less prevalent within rural areas and potentially a less viable transportation alternative. Among our sample, however, we found no significant differences in the number of regular driving passengers for rural and urban drivers, indicating that despite potential disparities in transportation options, both rural and urban residents maintain similar levels of social engagement and support through shared mobility experiences.

Within both rural and urban areas, we observe that worse global cognitive functioning was associated with reduced driving mobility. Longitudinally, however, only urban residents with declining allocentric spatial orientation ability reduced their driving mobility, showing a smaller driving space over time. Rural residents with cognitive impairments may therefore be less inclined to reduce their driving than urban residents, possibly due to fewer transportation alternatives to meet their mobility needs. Interestingly, however, our findings show that rural residents with worse cognitive functioning showed slower driving speeds relative to other drivers on the road while there was no significant difference among urban residents. Rural residents may therefore be compensating for cognitive impairments by driving slower on the road, whereas urban residents with worse cognitive performance may self-regulate their driving by reducing their overall mobility. This differential response may be linked to the perception that altering speed limits poses a greater risk on urban roads compared to rural roads, possibly due to greater environmental complexity on urban roads requiring more attentional resources (Cox et al., 2017). The less congested nature of rural roads may consequently afford for cognitively impaired rural drivers to compensate by reducing their travel speed.

There is a potential bidirectional component to the relationship between allocentric orientation decline and reduced driving space, as it is unclear whether individuals may show reduced driving space because of cognitive decline, or whether individuals are experiencing cognitive decline due to reduced hippocampal activation involved in allocentric spatial processing. Successful allocentric spatial orientation is highly dependent on cognitive mapping within the medial temporal lobe, which is one of the earliest brain areas to undergo neurophysiological changes in advanced normative ageing (Raz et al., 2004). It is possible that due to being more closely located to amenities and services, older urban residents travel less frequently to distant locations over time and engage less with hippocampal-based cognitive mapping processes, reducing their allocentric spatial orientation ability. Maintaining driving in older age and living in more spatially complex environments has previously been associated with reductions in hippocampal brain atrophy in older age (Shimada et al., 2023; Shin et al., 2024). Reducing one's driving space, and keeping to familiar routes, may therefore result in declining allocentric spatial orientation performance over time due to hippocampal atrophy. Furthermore, as allocentric spatial orientation was the only cognitive modality associated with reductions in driving mobility over time, this is supportive of previous work showing that allocentric orientation is a key cognitive marker toward driving changes in healthy ageing (Morrissey et al., 2024).

This study provided valuable insights into the interaction between cognition and environment on driving mobility and safety that have several important implications for policymakers and future investigation. Environmentally tailored interventions may be needed to address the specific challenges faced by older drivers in urban and rural settings. For example, urban-focused interventions should emphasise cognitive screening for older drivers and education campaigns on navigating complex urban traffic patterns. Urban design should focus on understanding how cities can support older adults ageing in place and undertake more local activities, as they are more likely to reduce their driving space over time (Vivoda et al., 2017; Wang et al., 2021). In rural areas, interventions should focus on strategies for maintaining mobility and independence while acknowledging the limited availability of alternative transportation options. As rural drivers rely more upon driving to meet their transportation needs, cessation is potentially deeply impactful for their community participation and mobility (Mielenz et al., 2024; Strogatz et al., 2020). Rural communities may therefore benefit from increased support and resources for older adults who face challenges in accessing transportation alternatives. Potential initiatives may include volunteer driver programs, expanded access to public transportation services, and community-based transportation solutions to reduce the impact of driving cessation in older age.

Despite the important findings in our study, there are some limitations. Firstly, in using postcode data to infer urban/rural status, we use between-subject comparisons (alike many driving-environment studies (Dunsire & Baldwin, 1999; Payyanadan et al., 2018; Pucher & Renne, 2005) and do not account for the extent to which individuals drive within rural or urban environments. Future research measuring naturalistic driving can more granularly delineate driving mobility and safety differences across rural and urban environments, establishing how driving mobility changes across the rural–urban scale. Nonetheless, our sample is representable across the UK, as there are approximately 2.5 million older adults living in rural areas and 8 million living in urban areas. Our sample consisted of a similar proportional disparity between rural (296) and urban (673) dwellers. Secondly, as driving mobility and RTI data were self-reported within our study, it is possible that they were prone to inaccuracy and/or bias, as self-report data has been found to differ from objective mobility and crash statistics (McGwin et al., 1998). Using naturalistic driving data to measure driving mobility and objective RTI data provided by crash reports can provide objective and accurate data with which responsibility and cause of the RTI can be ascertained, which will allow for more in-depth analysis on how cognitive functioning interacts with road safety risk. Thirdly, there was significant attrition from baseline (969 older adults) and follow-up testing (574), likely due to our sampling approach (participants were recruited for follow-up testing via opportunity sampling). Whilst longitudinal analysis was conducted among only participants with baseline and follow-up data, this could introduce a selection bias to our longitudinal results which may limit generalisability. It is important also to note that analyses establishing how cognitive performance interacts with environmental settings was conducted within environmental settings separately, and while we found that there were no significant differences in global cognitive performance across rural and urban areas, it is possible that other characteristics of the rural and urban participant samples in this study may influence the relationship between cognitive performance and driving settings. Future research should therefore look to establish how external sample characteristics, such as health status and socioeconomic background, moderate the relationship between cognitive performance across environmental settings. Furthermore, including interaction terms in a unified model would further establish how cognitive performance interacts with environmental settings in impacting driving mobility. Lastly, the number of self-reported RTIs was low, particularly for rural older adults (30), and did not enable for longitudinal testing of road safety risk. By sampling for participants who had been involved in RTIs in the future, this will enable for a greater number of participants with which to compare to a non-RTI control group. One potential method would be recruiting participants via Police databases, which provide access to RTI involvement records.

In conclusion, the present study establishes the differential impact of age-related cognitive changes on driving mobility and safety within rural and urban areas over time, emphasising the importance of considering the interaction between cognitive functioning with regional setting in managing changes to driving safety and mobility in older age. We discuss the implications on maintaining independence in older age, and present future research directions and policymaking options to address the evolving needs of older drivers to promote a safer and sustainable transportation model.

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CRediT authorship contribution statement

Sol Morrissey: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Stephen Jeffs:** Writing – review & editing, Project administration. **Rachel Gillings:** Writing – review & editing, Project administration. **Mizanur Khondoker:** Writing – review & editing. **Mary Fisher-Morris:** Writing – review & editing. **Ed Manley:** Writing – review & editing, Supervision. **Michael Hornberger:** Writing – review & editing, Writing – original draft, Supervision, Resources, Methodology, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data used for analysis will be made available upon request. This study was not pre-registered.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trf.2025.07.005.

Data availability

Data will be made available on request.

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