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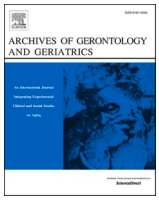

Neighbourhood transportation, elapsed years, and well-being after surrendering the driver's licence in older Japanese adults: The JAGES longitudinal study

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ABSTRACT

This study aimed to examine how the associations between surrendering driving licence and changes in self-rated health and social interactions among older adults differ by the years elapsed since surrendering and the number of public transportation systems (PTS) in the neighbourhood. We used the 2013 and 2016 survey data from the Japan Gerontological Evaluation Study targeting residents aged ≥65 years in 30 municipalities in Japan. Two-waves longitudinal data from 4894 older adults were evaluated. Based on the difference-in-differences method, the interaction terms of respondents' driving status, which was the categorical exposure variable representing respondents' driving status for three years during the study period, and a dummy variable of year (2016) were used as explanatory variables in logistic regression analyses to examine changes in outcomes (poor self-rated health and infrequent meeting with friends) between 2013 and 2016 by driving status during this period. Analyses were stratified based on neighbourhood PTS ('more PTS' and 'fewer PTS' groups). We found that, while surrendering licence within three years was associated with increased probability of poor self-rated health in more PTS group, the confidence interval was large. Although surrendering licence within three years was associated with decreased social interactions, this association weakened if licence was surrendered more than three years ago. These associations were not markedly affected by neighbourhood PTS. Our findings suggested that, regardless of neighbourhood PTS, support and care to promote social interactions at or shortly after surrendering licence may be beneficial to the well-being of older adults who lost their driving licence.

1. Introduction

One of the more psychologically taxing milestones in an older adult's life is the surrender of their driver's licence. Japan, which has a large aging population with 28.7% (2020 national census), particularly has a high number of older drivers on the road, and, consequently, a high number of road traffic collisions involving them (Cabinet Office, 2017).

Driver's Licence Statistics, which is surveyed by the National Police Agency every year in Japan, shows that the proportion of older adults aged 65 and over who had a driver's licence in 2020 was 52.7% (National Police Agency, 2020), which is lower than that of other industrialized countries, such as the US (91.0%) (U.S. Department of Transportation Federal Highway Administration, 2020; United States Census, 2020) and the UK (66.9%) (GOV.UK, 2020a, 2020b). However, in Japan, the proportion of older adults who owns cars and lives in households with only elderly household members ("car-dependent older adults population"), who are considered to be car-dependent in their daily lives, has rapidly increased in recent years: it nearly tripled from 966 thousands in 2005 to 2986 thousands in 2015 among those aged 75 and over (Yakushiji, 2017). In 1998, the Road Traffic Law was amended tougher especially for older adults to renew driver's licence according to the level of cognitive function and driving skills. Since then, surrenders

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by older adults have increased yearly (National Police Agency, 2020); however, there is little discussion on how this has affected their health and social well-being.

There does exist a corpus of literature that has delved into the associations between driving cessation and health among older adults. For example, Chihuri et al. (2016) conducted a systematic review and meta-analysis and showed an increased preponderance of self-reported depressive symptoms after surrendering one's driver's licence. Driving cessation is also known to cause decreased physical activity and frequency of outings (Chihuri et al., 2016; Marottoli et al., 2000) as well as worsened cognitive function, networks of friendship, and social participation (Chihuri et al., 2016; Mezuk & Rebok, 2008). These findings give credence to the belief that driving cessation is a public health issue in this demographic.

There are many reasons why older adults' health is affected after they cease driving – the most obvious being decreased mobility. Once there are restrictions on an older adult's discretionary travel, the decreased mobility as a result has a determinantal effect on health and well-being (Musselwhite, 2017). This also undermines their means of social participation (Liddle et al., 2013). Another reason is the conflict that arises during the decision-making process for surrendering the licence, when older adults face psychological pressure (Musselwhite & Shergold, 2013) and ageism (Drysdale, 2021; Williams, 2000) from family members and society. Finally, driving cessation has psychosocial aspects that affect health, given that driving is not only a means of transportation, but also leads to a sense of independence, freedom, competence, social role, dignity, autonomy and social identity (Liddle & McKenna, 2003, 2004; Pachana et al., 2017; Schwanen & Ziegler, 2011).

Despite this focus on well-being and driving cessation, there remain gaps in the literature, two of which are pertinent to our study. First, the association between decreased mobility and health and social interaction may vary by the number of alternative transportation systems in the neighbourhood. That is, in neighbourhoods with sufficient public transportation systems, the effects of reduced mobility on health and social participation may be mitigated.

Previous studies have focused on family members and friends as the compensators for reduced mobility in older adults. Older adults who ceased driving are likely to rely on rides provided by others as alternative transportation (Adler & Rottunda, 2006; Hendrickson & Mann, 2005). However, using data from the National Health and Aging Trends Study, Lehning et al. (2018) found that older adults who used rides from others as their modes of transportation tended to report higher restrictions on social participation than those who did not. Additionally, Adler and Rottunda's (2006) focus group research showed that many older adults felt uncomfortable about relying on their social partners for transportation and were unwilling to be a burden on them. Therefore, for older adults who ceased driving, depending too much on support from others as a means to compensate social interactions is not necessarily positive for their well-being. In other words, other than transport provided by others, factors that have a protective effect on the mobility of older adults who ceased driving and their subsequent health and social participation should be explored.

Some previous studies examined whether frequency of use of public transportation (Schryer et al., 2019) and ability to use it (Mezuk & Rebok, 2008) was associated with changes in social relationships after driving cessation among older adults. However, using data from household-residing older adults in the US, Mezuk and Rebok (2008) examined the mediating effect of ability to use public transportation on the association between driving cessation and decreased friendship network size, but found no mediating effect of this ability. In their study, whether the ability to use public transportation could compensate social interactions among older adults who ceased driving was not investigated. Schryer et al. (2019) asked older adults with vision loss living in New York about their frequency of use of public buses, subways, and paratransit, and examined whether they moderated the association between respondents' driving cessation and their and their social partners' life satisfaction. They demonstrated that while partners of ex-drivers who frequently used public transportation reported higher life satisfaction for social contacts than those of ex-drivers who did not show such tendency, frequent public transportation use was not associated with ex-drivers' own life satisfaction.

Although these previous studies focused on individual characteristics, such as public transportation use and ability to use it, few studies have examined whether the relationships between driving cessation and health/social interactions differ depending on the number of public transportation systems as a neighbourhood environment. From the perspectives of urban planning and public health practices, capturing the number of public transportation systems as a neighbourhood environment within a certain geographic unit and examining how it is associated with health and social interactions of the residents who ceased driving or surrendered their driver's licence are practically useful. This study thus sought to grasp public transportation systems as an overall environmental factor of the neighbourhood in where each individual was embedded, by aggregating the number of public transportation systems perceived by residents at the neighbourhood level and defining neighbourhoods with more and fewer public transportation systems.

Second, the relationship between driving cessation and health may diminish over time. Psychological conflicts that had arisen during the decision-making process of surrendering the driver's licence, and the subsequent psychosocial effects, may adversely affect older adults' health through acute grief (Lindemann, 1944). Although some previous studies examined the association between elapsed time after driving cessation and health outcomes among older adults, they did not clearly distinguish between the short-term and long-term effects of driving cessation. For example, Edwards et al. (2009) used 5-years follow-up data from community-dwelling older adults in the US to examine whether the declining trends of health outcomes over time after driving cessation differed from those before the cessation. They found that the declining trend of general health over time was steeper after the cessation than before the cessation. However, they assumed linear relationships between the elapsed time after driving cessation and health outcomes, and did not examine whether the decline in health outcomes was moderated as time passed after the cessation. Although Freeman et al. (2006) used data from an 8-year follow-up study of 1593 older adults in the US and demonstrated that those who stopped driving at baseline had higher risk of long-term care entry compared to those who continued driving at baseline, they also did not investigate whether the risk immediately after driving cessation differed from that after some time had passed. Therefore, this relationship between elapsed years after cessation and psychosocial effects has also not been empirically tested so far.

We thus examined the relationship between driving status and health and social interactions among older adults. Importantly, we examined if this relationship varied by the number of alternative transportation systems in the neighbourhood and the years elapsed since surrender. We hypothesised that the latter two factors moderate the examined relationship.

2. Methods

2.1. Data

In this study, we used data from the 2013 and 2016 waves of the Japan Gerontological Evaluation Study (JAGES) (Kondo, 2016). The JAGES is a nationwide population-based gerontological cohort in Japan focussing on the social determinants of health. Following the first survey in 1999, five waves have been conducted every three years covering both rural and urban areas.

The JAGES is a self-administered questionnaire mailed to older adults aged 65 years and above who have not been receiving the national long-term care service due to functional independence, both

physical and cognitive. The investigators mailed the questionnaire to 137,736 older adults in 30 municipalities in 2013 and 180,021 in 39 municipalities in 2016. Random sampling was adopted for the municipalities with 5000 or more eligible residents, whilst all residents were recruited in those with fewer than 5000 residents. The response rates were 71.1% ($n = 97,930$) in 2013 and 70.2% ($n = 126,375$) in 2016. The respondents were informed that returning the completed questionnaire implied their full consent to participate in the study. The 2013–2016 JAGES panel data were drawn from respondents who participated in both the 2013 and 2016 waves ($n = 61,267$).

The questionnaire on driving status was randomly distributed to one-eighth of the 2016 survey respondents ($n = 7667$). We excluded those who did not answer any of the questions on self-rated health or frequency of meeting with friends in the 2013 and/or 2016 surveys ($n = 845$), those who provided a contradictory answer to driving status ('never had driver's licence' but 'drive by myself') ($n = 19$), and those who had at least one missing answer for other variables that were used in the analyses ($n = 1909$). In the end, we included 4894 respondents with complete and valid responses in our analyses.

2.2. Measurements

Poor self-rated health and infrequently meeting friends. Our outcome variables were poor self-rated health (hereafter, 'poor SRH') and infrequency of meeting with friends (hereafter, 'infrequent meeting'). Poor SRH was assessed by one question – 'How do you rate your health?' – which is a widely used indicator of an individual's perception of their own health (Mitoku et al., 2006). It was found to be a valid predictor of depression and mortality regardless of other medical, behavioural, or psychosocial factors (Idler & Benyamini, 1997). Respondents chose one of four predetermined categories, namely, 'excellent', 'good', 'fair', and 'poor'. Those who answered 'fair' or 'poor' were coded as 1, and the remaining as 0. The SRH item with four categories has been traditionally used in the General Social Survey in the U.S. A report confirmed that there is no significant difference between the SRH item with four categories and that with five categories ('excellent', 'very good', 'good', 'fair', and 'poor') in correlation with other health-related variables and the distributions of responses in the bottom two categories ('fair' and 'poor') (Smith, 2005). The binarized variable based on the four categories SRH has been used in many previous studies (e.g. Amemiya et al., 2019; Saito et al., 2014; Takesue et al., 2021; Zaitsu et al., 2018).

Infrequent meeting was assessed by the following question: 'How often do you meet friends or acquaintances?' Respondents marked one of predetermined six categories, namely, 'four times or more a week', 'two or three times a week', 'once a week', '1–3 times a month', 'several times a year', and 'no meeting'. The respondents who answered '1–3 times a month', 'several times a year', or 'no meeting' were coded as 1 (i.e., 'less than once a week'), and the remaining as 0.

Driving status. Japanese Road Traffic Law has a unique provision for retirement from driving. In the framework laid out for voluntary surrender, citizens can surrender their driver's licence at a nearby police station and, in return, acquire an alternative identification card. In recent years, the Japanese government has been more proactive in encouraging older adults with functional decline to voluntarily surrender their licence to drive.

Given that some drivers voluntarily surrender whereas others simply stop driving without surrendering their licence, respondents were categorised into five groups based on driving status at the time of the 2016 survey: 1) those who have never had a driver's licence ('never had'), 2) those who were still driving ('still drive'), 3) those who stopped driving without surrendering their driver's licence ('stopped driving'), 4) those who surrendered their driver's licence within the last three years ('surrendered $\leq$ 3y'), and 5) those who surrendered their driver's licence over three years ago ('surrendered $>$ 3y'). In the JAGES, driving status was measured only in the 2016 survey. We thus used the measurement of driving status in 2016 as an explanatory variable, which can be considered to reflect respondents' driving situation between 2013 and 2016 surveys. For those who stopped driving without surrendering their licence, information was not available on the number of years since they had stopping driving. We distinguished older adults who stopped driving after surrendering their driver's licence and those who did so without surrender as we assumed that the health and social interactions of those who surrendered their driver's licence were more likely to be affected due to loss of identity, psychological conflict, and perceived ageism than those who stopped driving without doing so.

Public transportation systems in the neighbourhood. To examine whether the association between driving status and the outcome variables varied by the available alternative means of mobility, we measured accessibility to public transportation systems (hereafter, PTS) in the neighbourhood. Respondents were asked how many train/subway stations and bus stops existed within walking distance (10–15min by foot) and made to mark one of five predetermined categories, namely, 'many', 'some', 'few', 'none', and 'I'm not sure'. The proportion of those who chose 'many' or 'some' in each school district was used as the PTS accessibility in the neighbourhood. The proportion ranged from 0 to 1 across 455 school districts (mean=0.544, median=0.556). In Japan, each municipality is divided into multiple elementary school districts, which often form the "local community" for older adults, and have a geographical range where they can move on foot or by bicycle. To conduct stratified analyses, we divided school districts in two based on the median of the proportion of those who answered 'many' or 'some' for the PTS question, and grouped respondents into two groups: those who lived in a neighbourhood with 'more PTS' (>median) and those with 'fewer PTS' ($\leq$median).

Covariates. To adjust for demographic factors, physical and psychological health conditions, behavioural characteristic of mobility, we used the following confounders: sex, age, activities of daily living (ADL), depressive symptoms, and means of transportation during outings. For ADL, the respondents were asked whether they needed personal care for basic ADL, such as walking, bathing, urinating, and defecating, and were categorised into three groups: 'no need for care', 'need for care but still independent', and 'need for care and already use'. For depressive symptoms, based on the 15-item version of the Geriatric Depression Scale (GDS-15) score, respondents were categorised into two groups: 'not depressed' (GDS<5) and 'depressive symptoms' (GDS$\geq$5) (Mitoku et al., 2006). For means of transportation, respondents were asked whether they usually used trains and buses for outings; for each, respondents were categorised into 'use' or 'not use'.

2.3. Statistical analysis

The data were analysed in the long format wherein each respondent's variables were measured for both 2013 and 2016, except for sex and age (i.e. totalling 9788 observations by 4894 respondents). Guided by the previous studies (Dimick & Ryan, 2014; Haseda et al., 2019; Nagata et al., 2022; Rose & Bowen, 2019; et al., 2019; Wing et al., 2018), we used the difference-in-differences method to examine whether the change in outcome variables between 2013 and 2016 differed by driving status. The following regression model was specified:

$$Y_{it} = \beta_1(Never\ had)_i + \beta_2(Stopped\ driving)_i + \beta_3(Surrendered \leq 3y)_i + \beta_4(Surrendered > 3y)_i + \beta_5(Year)_t + \delta_1(Never\ had)_i \times (Year)_t + \delta_2(Stopped\ driving)_i \times (Year)_t + \delta_3(Surrendered \leq 3y)_i \times (Year)_t + \delta_4(Surrendered > 3y)_i \times (Year)_t + \beta_6 X_{it} + \beta_7 Z_i + \varepsilon_{it}$$

where Y_{it} represents respondent i's outcome variables, poor self-rated health and infrequent meeting with friends, in survey wave t. $(Never\ had)_i$, $(Stopped\ driving)_i$, $(Surrendered \leq 3y)_i$, and $(Surrendered > 3y)_i$ are dummy variables indicating the driving status category respondent i fell into (a dummy variable indicating 'still drive' was not included in the model, since the category was used as a reference category). The classification of respondents into driving status categories was exclusive, that is, those who were coded as 1 for one of these dummy variables were coded as 0 in the other categories (those who fell into the 'still drive' category were coded as 0 for all four dummy variables). $(Year)_t$ is a dummy variable indicating whether the response was from the 2013 or the 2016 waves of survey (2013 = 0, 2016 = 1). δ_1, δ_2, δ_3, and δ_4, the coefficients of interaction terms of each dummy variable of driving status and year, were the difference-in-differences estimators that indicate how much outcome variables changed between 2013 and 2016 in each driving status group relative to the reference category group ('still drive'). Driving status was measured only in the 2016 wave survey and indicated the driving status of respondent i between 2013 and 2016. Therefore, how this 2013–2016 driving situation was associated with changes in the outcome variables between 2013 and 2016 was examined. X_{it} is a vector of time-varying covariates, including ADL, depressive symptoms, and usual means of transportation, which were measured in both the 2013 and the 2016 waves. Z_i is the variable of sex (male=1, female=0), which was a time-invariant covariate. In addition, since in this study respondents' age increased uniformly from 2013 to 2016, only baseline age was adjusted (i.e. it was included as Z_i). ε_{it} is the error term.

We applied logistic regression analyses to calculate the odds ratio (OR) and 95% confidence interval (CI) for poor SRH and infrequent meeting. Additionally, to address the underestimation of standard errors, we calculated robust standard errors clustered on respondents. Analyses were stratified by the number of PTS in a neighbourhood ('more PTS' and 'fewer PTS').

Although logistic regression analysis does not directly yield diagnostic information for multicollinearity (i.e. VIF), guided by Menard (2002), we ran Ordinary Least Square using the same outcomes and explanatory variables as our logistic regression models, calculated VIF, and checked for multicollinearity. According to the previous studies (Giancristofaro & Salmaso, 2003; Lubelski et al., 2021; Steyerberg et al., 2001), we assessed model performance by using area under the curves (AUC) of receiver operating curve (ROC), overfitting by checking for optimism using the bootstrapping method with 1000 replications, and goodness-of-fit of the models by using the Hosmer-Lemeshow test.

Finally, to help the interpretations of the interaction effects (i.e. the difference-in-differences estimates), we calculated the predicted probabilities of poor SRH and infrequent meeting by driving status and year (2013 and 2016), based on the estimates of logistic regression analyses. When calculating the predicted values, other covariates were set as their mean value. The software used was Stata 16.1 (StataCorp, Texas, USA).

3. Results

Descriptive statistics showed the highest mean age for 'surrendered > 3y' (mean 78.5, standard deviation 5.9) (Table 1). The proportions of men largely differed for driving status – from 10.1% for 'never had' to 62.1% for 'still drive'. Current drivers ('still drive') tended to live with someone, had less access to public transportation, and were less likely to use it than former and non-drivers. For 'surrendered ≤ 3y', increases in the proportions of poor SRH and infrequent meeting from 2013 to 2016 were more marked than other driving statuses (from 19.8% to 24.6% for poor SHR and from 52.4% to 60.3% for infrequent meeting).

Logistic regression analyses showed that the main effects of driving

Table 1
Descriptive statistics at baseline (2013) and follow-up survey (2016) by driving status at 2016.

	Never had[a] (n = 1100)		Still drive[b] (n = 3170)		Stopped driving[c] (n = 159)		Surrendered ≤ 3 years[d] (n = 126)		Surrendered > 3 years[e] (n = 339)	
	N	%	n	%	n	%	n	%	n	%
Male	111	10.1	1967	62.1	71	44.7	48	38.1	128	37.8
Poor self-rated health (2013)	166	15.1	393	12.4	30	18.9	25	19.8	70	20.7
Poor self-rated health (2016)	176	16.0	402	12.7	34	21.4	31	24.6	78	23.0
Infrequent meeting with friends (2013)	483	43.9	1517	47.9	85	53.5	66	52.4	194	57.2
Infrequent meeting with friends (2016)	498	45.3	1409	44.5	85	53.5	76	60.3	190	56.1
Need for care (2013)	28	2.6	28	0.9	1	0.6	1	0.8	12	3.5
Need for care (2016)	97	8.8	117	3.7	18	11.3	17	13.5	49	14.5
Depressive symptoms (2013)	248	22.6	611	19.3	39	24.5	31	24.6	98	28.9
Depressive symptoms (2016)	242	22.0	593	18.7	54	34.0	29	23.0	102	30.1
Living alone (2013)	203	18.5	297	9.4	30	18.9	23	18.3	78	23.0
Living alone (2016)	229	20.8	355	11.2	34	21.4	27	21.4	90	26.6
Use train when going out (2013)	342	31.1	657	20.7	50	31.5	32	25.4	103	30.4
Use train when going out (2016)	463	42.1	874	27.6	75	47.2	54	42.9	164	48.4
Use bus when going out (2013)	421	38.3	426	13.4	50	31.5	42	33.3	140	41.3
Use bus when going out (2016)	449	40.8	418	13.2	67	42.1	52	41.3	149	44.0
Living in neighbourhood with less PTS[f]	789	71.7	2681	84.6	102	64.2	88	69.8	212	62.5
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (2016)	77.8	5.7	74.5	5.0	74.4	5.7	77.2	6.0	78.5	5.9

[a] Those who never had driver's license.
[b] Those who had the licence and drove a car at the time of 2016 survey.
[c] Those who had the licence but did not drive a car at the time of 2016 survey.
[d] Those who surrendered the license within 3 years at the time of 2016 survey.
[e] Those who surrendered the license over 3 years ago at the time of 2016 survey.
[f] PTS: public transportation system.

Table 2
Logistic regression estimates for poor self-rated health.

	Participants in neighbourhood with more PTS[a] ($n = 2044$)[b]			Participants in neighbourhood with fewer PTS[a] ($n = 7744$)[c]		
	OR[d]		95% CI[e]	OR[d]		95% CI[e]
Male	1.40		(0.93, 2.11)	1.19		(1.00, 1.42)
Age	1.00		(0.96, 1.03)	1.02	*	(1.01, 1.04)
Need for care	7.49	*	(3.91, 14.38)	5.34	*	(4.02, 7.10)
Depressive symptoms	5.24	*	(3.90, 7.05)	4.65	*	(4.00, 5.41)
Living alone	0.78		(0.52, 1.16)	0.89		(0.70, 1.13)
Use train when going out	0.68	*	(0.49, 0.95)	0.53	*	(0.43, 0.65)
Use bus when going out	0.92		(0.66, 1.26)	0.83		(0.65, 1.07)
Driving status						
Never had[f]	1.33		(0.76, 2.34)	1.37	*	(1.06, 1.77)
Still drive[g]	Ref			Ref		
Stopped driving[h]	1.02		(0.40, 2.59)	2.21	*	(1.34, 3.64)
Surrendered ≤ 3 years ago[i]	1.60		(0.56, 4.55)	1.89	*	(1.04, 3.43)
Surrendered > 3 years ago[j]	2.27	*	(1.25, 4.14)	1.49		(1.00, 2.22)
Year (2016)	1.13		(0.77, 1.66)	0.95		(0.82, 1.09)
Interactions						
Never had × year (2016)	1.02		(0.58, 1.81)	0.93		(0.70, 1.24)
Stopped driving × year (2016)	1.06		(0.33, 3.41)	0.71		(0.38, 1.32)
Surrendered ≤ 3 years ago × year (2016)	1.67		(0.54, 5.10)	1.01		(0.50, 2.02)
Surrendered > 3 years ago × year (2016)	0.91		(0.46, 1.82)	0.92		(0.58, 1.45)

* $p < 0.05$.
[a] PTS: public transportation system.
[b] Total observations from 2013 to 2016 wave surveys, which were clustered on 1022 respondents.
[c] Total observations from 2013 to 2016 wave surveys, which were clustered on 3872 respondents.
[d] OR: odds ratio.
[e] 95% CI: 95% confidence interval.
[f] Those who never had driver's license.
[g] Those who had the licence and drove a car at the time of 2016 survey.
[h] Those who had the licence but did not drive a car at the time of 2016 survey.
[i] Those who surrendered the license within 3 years at the time of 2016 survey.
[j] Those who surrendered the license over 3 years ago at the time of 2016 survey.

Table 3
Logistic regression estimates for infrequent meeting with friends.

	Participants in neighbourhood with more PTS[a] ($n = 2044$)[b]			Participants in neighbourhood with fewer PTS[a] ($n = 7744$)[c]		
	OR[d]		95% CI[e]	OR[d]		95% CI[e]
Male	2.54	*	(1.92, 3.35)	2.28	*	(2.01, 2.58)
Age	0.98		(0.96, 1.00)	0.99		(0.98, 1.00)
Need for care	1.31		(0.70, 2.40)	1.43	*	(1.11, 1.84)
Depressive symptoms	1.76	*	(1.34, 2.30)	1.89	*	(1.67, 2.14)
Living alone	0.60	*	(0.45, 0.79)	0.56	*	(0.47, 0.67)
Use train when going out	0.78	*	(0.63, 0.97)	0.86	*	(0.76, 0.97)
Use bus when going out	0.82		(0.66, 1.01)	1.10		(0.93, 1.29)
Driving status						
Never had[f]	1.78	*	(1.24, 2.56)	1.28	*	(1.06, 1.54)
Still drive[g]	Ref			Ref		
Stopped driving[h]	1.23		(0.70, 2.18)	1.66	*	(1.10, 2.50)
Surrendered ≤ 3 years ago[i]	2.09	*	(1.03, 4.21)	1.35		(0.87, 2.10)
Surrendered > 3 years ago[j]	2.16	*	(1.41, 3.32)	1.81	*	(1.34, 2.45)
Year (2016)	1.01		(0.82, 1.24)	0.86	*	(0.79, 0.94)
Interactions						
Never had × year (2016)	1.16		(0.86, 1.56)	1.22	*	(1.02, 1.45)
Stopped driving × year (2016)	1.29		(0.65, 2.57)	0.95		(0.63, 1.43)
Surrendered ≤ 3 years ago × year (2016)	1.51		(0.70, 3.29)	1.66	*	(1.02, 2.69)
Surrendered > 3 years ago × year (2016)	1.16		(0.79, 1.71)	1.01		(0.73, 1.39)

* $p < 0.05$.
[a] PTS: public transportation system.
[b] Total observations from 2013 to 2016 wave surveys, which were clustered on 1022 respondents.
[c] Total observations from 2013 to 2016 wave surveys, which were clustered on 3872 respondents.
[d] OR: odds ratio.
[e] 95% CI: 95% confidence interval.
[f] Those who never had driver's license.
[g] Those who had the licence and drove a car at the time of 2016 survey.
[h] Those who had the licence but did not drive a car at the time of 2016 survey.
[i] Those who surrendered the license within 3 years at the time of 2016 survey.
[j] Those who surrendered the license over 3 years ago at the time of 2016 survey.

statuses indicated higher odds of poor SRH compared with 'still drive' among those in neighbourhoods with fewer PTS (Table 2). Those in neighbourhoods with more PTS also showed that non-driving categories were positively associated with poor SRH, except for the almost null OR of 'stopped driving'. Although the interaction term of 'surrendered ≤ 3y' × year showed a positive interaction effect in neighbourhoods with more PTS, the 95% CI was large (OR 1.67, 95%CI 0.54–5.10). Other interaction effects were not marked.

Table 3 shows that, compared with 'still drive', the odds of infrequent meeting were higher among all other driving statuses in neighbourhoods with both more and fewer PTS. The interaction effects of driving status and year were statistically significant for 'never had' (OR 1.22, 95% CI 1.02–1.45) and 'surrendered ≤ 3y' (OR 1.66, 95% CI 1.02–2.69) among those in neighbourhoods with fewer PTS. For those in neighbourhoods with more PTS, these interaction effects were not statistically significant.

Checks of VIF showed that even the highest VIF value was 2.85 of the 'Never had' variable in the models for poor SRH and infrequent meeting with fewer PTS. This is due to the interaction term of this variable and Year included in the models. While the stability of the model also depends on sample size and distribution of explanatory variables (O'Brien, 2007) and there is no formal criteria for VIF, given the suggested cut-off values of VIF ≥ 5 or VIF ≥ 10 for potential multicollinearity (Kutner et al., 2005), it was suggested that no serious multicollinearity occurred in our analyses.

For model performance, AUCs for models for poor SRH (0.747 [95% CI 0.731–0.764] for fewer PTS group; 0.751 [95% CI 0.718–0.785] for more PTS group) indicated moderate accuracy. In contrast, those of models for infrequent meeting with friends (0.647 [95% CI 0.634–0.659] for fewer PTS group; 0.655 [95% CI 0.632–0.679] for more PTS group) indicated low accuracy (Hosmer & Lemeshow, 2000). This suggested that we should consider other explanatory variables than

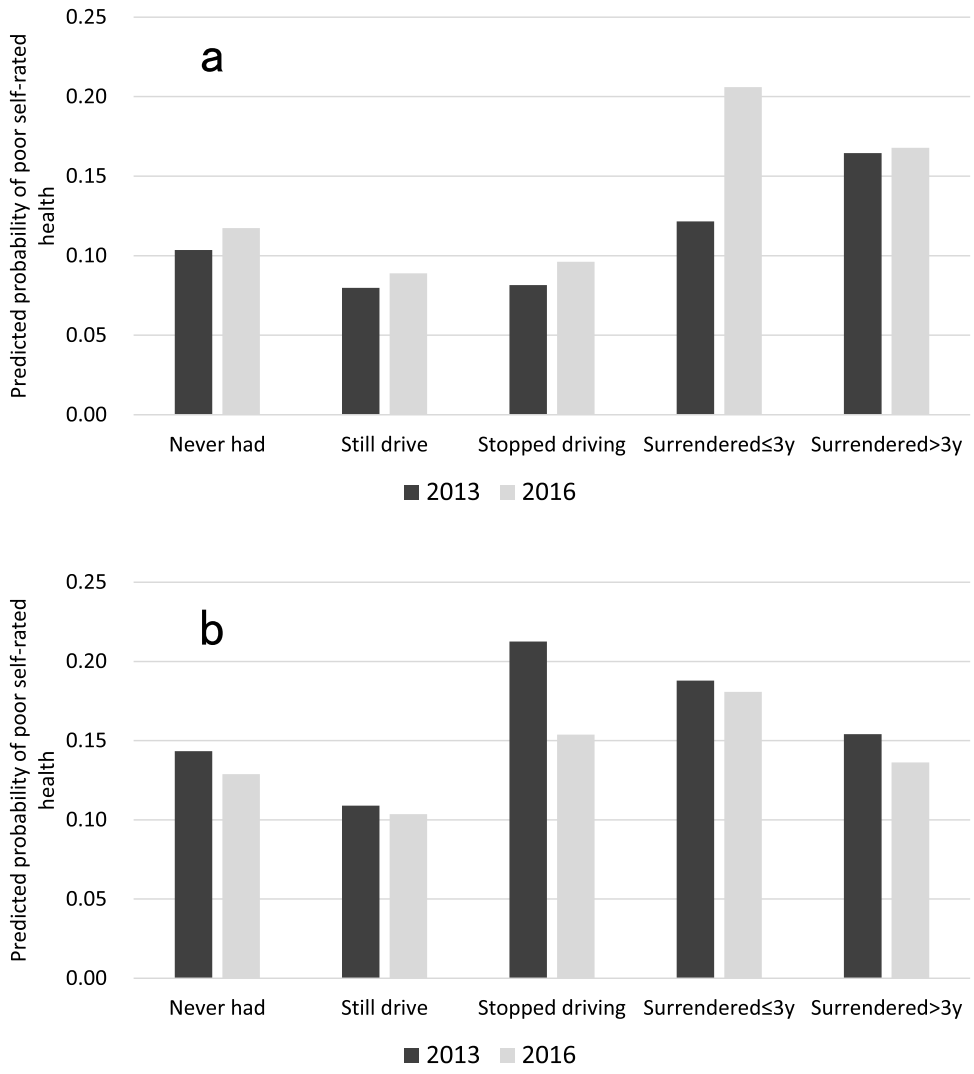

Fig. 1. Predicted probabilities of poor self-rated health by driving status categories and survey years. *Note.* (a) represents the predicted values among those in neighbourhoods with more public transportation systems (PTS); (b) represents those in neighbourhoods with fewer PTS.

driving status, which were not included in our models, for more accurate prediction of the trend of infrequent meeting with friends.

From the perspective of model validation, too many covariates relative to the number of respondents results in overfitting. As a result of overfitting, model performance is overestimated, that is, optimism occurs. In this study, estimates of optimism for each model, calculated as the average of differences in performance (i.e. AUC) between the original data and the 1000 data generated by bootstrapping (Steyerberg et al., 2001), were 0.018 (model for poor SRH for fewer PTS group), 0.072 (model for poor SRH for more PTS group), 0.031 (model for infrequent meeting for fewer PTS group), and 0.092 (model for infrequent meeting for more PTS group), which were all less than 0.2, indicating absence of significant overfitting (Audureau et al., 2018; Kosoku et al., 2020; Sato et al., 2021).

Finally, the Hosmer-Lemeshow χ^2 of each model to check goodness-of-fit were not statistically significant for all models (5.39 [$P = 0.715$], 13.45 [$P = 0.097$], 7.89 [$P = 0.444$], and 9.21 [$P = 0.325$], respectively), indicating adequate goodness-of-fit (Hosmer & Lemeshow, 2000).

As shown in Fig. 1(a), whilst the predicted probability of poor SRH increased between 2013 and 2016 among 'surrendered ≤ 3y' in neighbourhoods with more PTS, this interaction effect was not statistically significant, as shown in Table 2. The change in poor SHR between 2013 and 2016 was not notable for other driving statuses.

Fig. 2(b) shows that the probability of infrequent meeting with friends increased between 2013 and 2016 for 'surrendered ≤ 3y' in neighbourhoods with fewer PTS, and the corresponding interaction term was statistically significant. For 'never had', the interaction effect was also statistically significant (Table 3) but shows a less marked increase in infrequent meeting in Fig. 2(b). In neighbourhoods with more PTS, although the interaction effects were not statistically significant, as shown in Table 3, all driving statuses, except for 'still drive', showed increased infrequent meeting with friends between 2013 and 2016 as shown in Fig. 2(a).

4. Discussion

The literature, as we explain in the introduction, does demonstrate that driving cessation or surrendering one's driver's licence is associated with health (Chihuri et al., 2016), health-related behaviours (Chihuri et al., 2016; Marottoli et al., 2000), and social participation (Chihuri et al., 2016; Mezuk & Rebok, 2008) among older adults. Our findings contribute new evidence suggesting that the association between the surrender and a decrease in social interactions with friends was more marked in neighbourhoods with fewer PTS than in those with more PTS. However, based on the point estimates, the difference between two areas was not large – that is, social interaction decreased in both areas. Further, the association between the surrender and social interactions

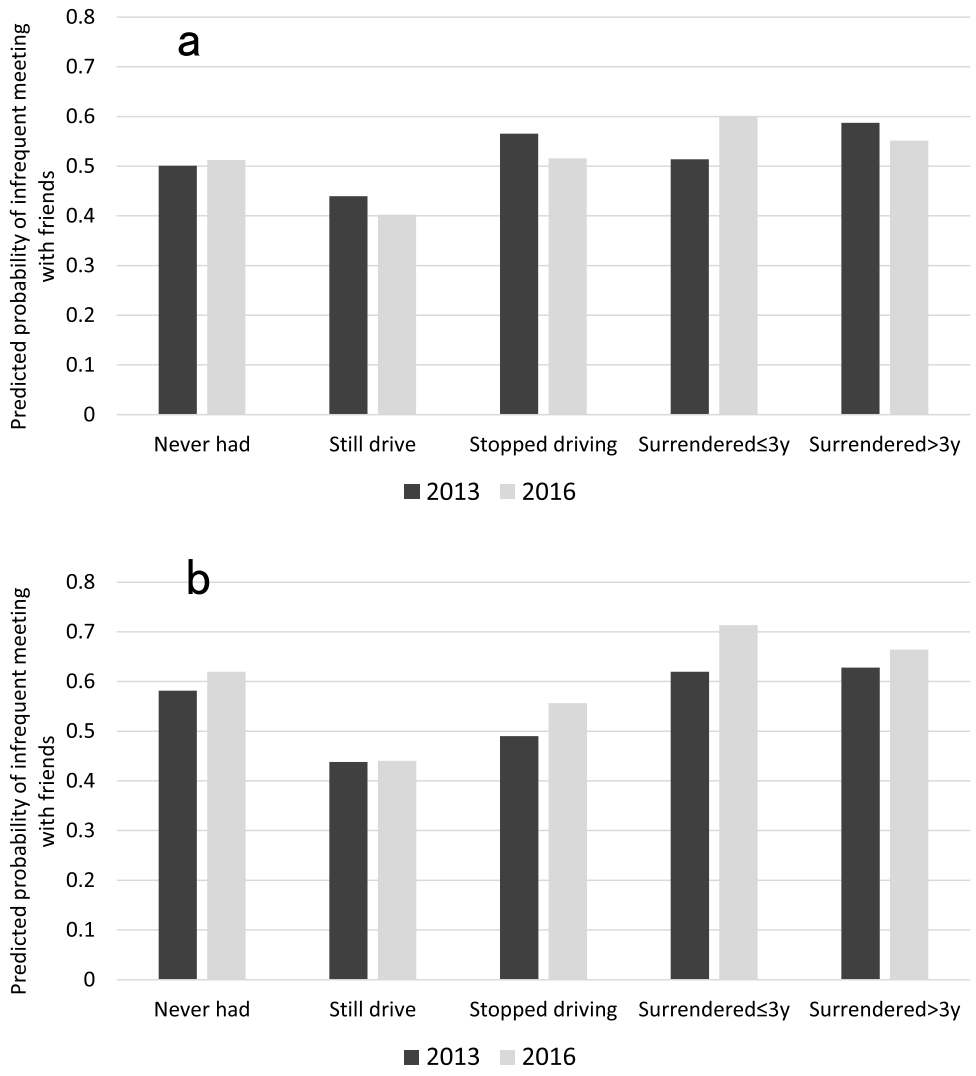

Fig. 2. Predicted probabilities of infrequent meeting with friends by driving status categories and survey years. *Note.* (a) represents the predicted values among those in neighbourhoods with more public transportation systems (PTS); (b) represents those in neighbourhoods with fewer PTS.

varied by the number of years elapsed since the surrender.

For poor SRH, the ORs of driving statuses (i.e., main effects), except for 'stopped driving' in neighbourhoods with more PTS, were positive compared with the reference category ('still drive'). This result likely reflects that the health condition of older adults is determined by driving status and *vice versa*. However, the interaction effects of driving status and year showed that the probability of poor SRH increased between 2013 and 2016 among those who surrendered less than three years ago since the survey in neighbourhoods with more transport amenities (however, the 95% CI was large). Neighbourhoods with more PTS are relatively more urban areas, where people are less likely to have a driving licence and/or cars than in neighbourhoods with fewer PTS. Therefore, older adults may not be able to rely on relatives' and neighbours' cars after surrendering their driver's licence, and a modal shift from cars is likely to be needed in such neighbourhoods, which may be difficult for older adults. However, this assumption requires further investigation.

For the model of infrequent meeting, the main effects of driving statuses were positive, suggesting that those who did not drive a car infrequently met their friends in neighbourhoods with both more and fewer PTS compared with those who 'still drive'. Importantly, the interaction effect of 'surrendered $\leq$ 3y' $\times$ year was positive and statistically significant only in neighbourhoods with fewer PTS, which is in line with our hypothesis. However, even in neighbourhoods with more PTS, although not statistically significant, the point estimate of 'surrendered $\leq$ 3y' $\times$ year was comparable to that in neighbourhoods with fewer PTS, suggesting that the neighbourhood difference may not so glaring. Liddle et al. (2014) intervention study, for instance, suggests that psychoeducation programmes, including how to use PTS, promote a greater frequency of outings and more self-efficacy in going out. Knowledge and self-efficacy about travelling without a car, rather than the number of PTS in the neighbourhood, may be more effective in mitigating the adverse effects that occur after surrendering the licence. Additionally, in the current society, other than neighbourhood public transportation systems, the role of Information and Communication Technology (ICT), which was not considered in this study, might have been examined as a factor influencing social interactions among older adults who lost mobility. Although ICT can reduce the time and distance constraints contingent to communications and help people maintain existing social ties (Mesch, 2019; Wellman et al., 2001), further research is needed to reveal whether ICT can contribute to mitigating the decline in face-to-face contacts, which was the outcome of this study, immediately after licence surrender in older adults.

Interestingly, the interaction effect of 'surrendered > 3y' $\times$ year was null, suggesting that, while those who surrender their driver's licence lose their mobility and the opportunities of social interactions, the declining trend weakens over time. This may be due to the positive acquirement of or resigning themselves negatively to new lifestyles,

however, further research is needed to buttress this claim with empirical evidence.

Nevertheless, early support/care for older adults and their family members may be important. As mentioned above, qualitative studies do suggest that driving has complex meanings related to human identity (Liddle & McKenna, 2003). Driving cessation is thus not only a loss of means of mobility but also signifies a loss of sense of self, independence, freedom, competence, social role, dignity, and social identity (Liddle et al., 2004; Pachana et al., 2017; Yano & Hashimoto, 2020; Yassuda et al., 1997; Ziegler & Schwanen, 2011). Such an extensive loss may deplete the health of older adults in the long run. These long-term effects of psychosocial losses on the health of older adults who have surrendered their licence as well as the strategies and effects of support/care thereof deserve further investigation.

Despite the above findings, our study has some limitations. First, some categories of driving status had a small number of observations which led to large standard errors of the estimates. Second, we could not identify the causal association between driving status and outcomes. Especially for those who surrendered their driving licence within three years of the survey, we could not determine whether this act deteriorated health and social interactions during 2013–2016 or if the deterioration in health during this period determined the surrender. The 'stopped driving' category may also include those who stopped driving between 2013 and 2016, which led to the difficulty of causal inference. Third, the generalisability of our findings is limited because the JAGES survey did not randomly or probabilistically select the participating municipalities, and data collected were not nationally representative. Fourth, as respondents of this study were relatively healthy older adults who were able to participate in both the 2013 and 2016 surveys, the changes in the outcome variables observed might be an underestimation. Fifth, although different decision-making processes of surrendering the driver's licence (i.e. voluntary or involuntary surrender; Jett et al., 2005) may affect the association between surrendering the licence and its outcomes, information on the surrendering process of each respondent was not available in this study. Sixth, although we used PTS as a variable for public transport availability in the neighbourhood, this might reflect other urban characteristics, such as the convenience of the city and higher education and income among residents. Seventh, our measurement of neighbourhood PTS was solely derived from respondents' subjective five-scale estimation. Previous built environment studies used both objective and subjective measurements. Although Giles-Corti et al. (2005) suggested that respondents' perception of the environment might be more related to their actual action such as health-related behaviours than objectively measured environment, some studies showed that results were mixed depending on outcomes (Tani et al., 2019; Zhang et al., 2019). Therefore, for public health practices, further research should compare between objective and subjective measurements on psychosocial outcomes due to driving cessation.

In conclusion, our findings indicate that surrendering the driver's licence may reduce social interactions in older adults, regardless of the amount of neighbourhood PTS, and that this change is noticeable within a few years of surrendering the licence. Therefore, providing support/care to prevent the decrease in social interactions at or shortly after surrendering the licence may be beneficial to the well-being of older adults who have lost their driving ability. Future research should feature a greater focus on the factors mitigating the association between surrendering one's driver's licence and social interactions.

5. Author contributions

All authors contributed to the analysis and interpretation of data, and to the drafting and revision of the article critically for intellectual content. All the authors approved the version to be published.

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5.2. Ethical standards

The JAGES survey protocol was approved by the Nihon Fukushi University ethics committee on research into human subjects (approval No. 13–14), Chiba University (approval No. 2493), and the National Centre for Geriatrics and Gerontology (approval No. 992). Data utilization for this study was approved by the University of Tokyo Faculty of Medicine ethics committee (approval No. 10555).

Declaration of Competing Interest

The authors declare no conflicts of interest.

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