DOI:
10.1136/jech-2017-210038

Document Version
Peer reviewed version

Public transport policy, social engagement, and mental health in older age: A quasi-experimental evaluation of free bus passes in England

Erica Reinhard*[1,2], Emilie Courtin[1, 3], Frank van Lenthe[2,4], Mauricio Avendano[1,5]

Affiliations:

1. King's College London, Department of Global Health and Social Medicine, London, UK
2. Erasmus University Medical Center Rotterdam, Department of Public Health, Rotterdam, Netherlands
3. London School of Economics and Political Science, Personal Social Services Research Unit, London, UK
4. Utrecht University, Department of Human Geography and Spatial Planning, Faculty of Geosciences, Utrecht, Netherlands
5. Harvard T.H. Chan School of Public Health, Department of Social and Behavioral Sciences, Boston, USA

***Corresponding Author:**

Erica Reinhard

Department of Global Health and Social Medicine

King's College London

Strand, London WC2R 2LS

United Kingdom

Email: erica.reinhard@kcl.ac.uk

Phone: +44 0207 848 7893

Publisher Version:
Reinhard E, Courtin E, van Lenthe FJ, Avendano, M. Public transport policy, social engagement and mental health in older age: a quasi-experimental evaluation of free bus passes in England. *J Epidemiol Community Health*. Published Online First: 19 January 2018. doi: 10.1136/jech-2017-210038

What is already known on this topic

-Free bus travel for older people in England, an age-friendly transportation policy, is associated with increased public transport use and lower rates of obesity

-Social engagement, social isolation, and loneliness are key determinants of mental health in older age, yet there is limited evidence on whether transportation policies can reduce isolation, promote engagement, and improve mental health

What this study adds

- Increased public transportation use as a result of the free bus passes was associated with a decline in depressive symptoms among English older adults

- Increased transportation use was also associated with reductions in loneliness and increases in social engagement, in the form of volunteering and contact with children and friends

- Transportation subsides may be a public health policy instrument to improve the mental health and social engagement of older people

ABSTRACT

Background: Social engagement and social isolation are key determinants of mental health in older age, yet there is limited evidence on how public policies may contribute to reducing isolation, promoting social engagement, and improving mental health among older people. This study examines the impact of the introduction of an age friendly transportation policy, free bus passes, on the mental health of older people in England.

Methods: We use an instrumental variable approach that exploits eligibility criteria for free bus passes to estimate the impact of increased public transportation use on depressive symptoms, loneliness, social isolation, and social engagement.

Results: Eligibility for the free bus travel pass was associated with an 8% (95% confidence interval [CI]: 6.4% to 9.6%) increase in the use of public transportation among older people. The IV model suggests that using public transport reduces depressive symptoms by 0.952 points (95% CI: -1.712 to -0.192) on the CES-D scale. IV models also suggest that using public transport reduces feelings of loneliness (β: -0.794, 95% CI: -1.528 to -0.061), increases volunteering at least monthly (β: 0.237, 95% CI: 0.059 to 0.414), and increases having regular contact with children (β: 0.480, 95% CI: 0.208 to 0.752) and friends (β: 0.311, 95% CI: 0.109 to 0.513).

Conclusion: Free bus travel is associated with reductions in depressive symptoms and feelings of loneliness among older people. Transportation policies may increase older people's social engagement and consequently deliver significant benefits to mental health.

Key Words: Mental Health, Depression, Loneliness, Ageing, Transportation, Policy

INTRODUCTION

Depressive disorders as the second leading cause of disability worldwide.[1] Social isolation,[2] loneliness,[3] and social engagement[4] have been identified as critical risk factors for depression in older age, and the World Health Organisation [5] has emphasised the need for age-friendly policies to promote social inclusion and engagement among older people. However, there is limited evidence of how specific policies targeted at older people may promote social engagement, reduce loneliness and isolation, and in turn influence mental health.

Evidence suggests that access to public transportation may promote social engagement in older age.[6, 7] In April 2006, the government implemented a policy of free bus travel on local services for people aged 60 and older in England.[8] In April 2008, the concessionary fare was extended to free bus travel nationwide.[8] Recent research suggests the bus passes have been associated with increases in public transportation use[9, 10] and physical activity levels,[11] and with lower rates of obesity.[10] Findings from qualitative studies suggest the free bus passes may have also improved quality of life and increased social engagement.[12-15] However, to our knowledge, no quantitative study has examined the effects of the free bus pass policy on mental health.

In this paper, we exploit the natural experiment provided by the introduction of free bus passes and data from a large, representative cohort of older people in England to examine the impact of increased public transport use on depressive symptoms. In addition, we explore whether social isolation, loneliness, and social engagement may explain the link between transport use and depressive symptoms.

METHODS

Data

We used data from 7 waves of the English Longitudinal Study of Ageing [ELSA], a representative cohort of residents of England aged 50 years and above and their younger partners.[16] The sample consisted of 18,453 participants residing in England who were surveyed at one or more time points between 2002 and 2014.

Statistical Analysis

We used two-stage least squares [2SLS] instrumental variable [IV] regression models,[17-19] a common econometric technique used to examine the relationship between an outcome and an 'endogenous' exposure— a variable determined by other variables in the model.[20] An endogeneity test indicated IV was preferable to ordinary least squares [OLS] (Appendix Table 1). The IV model exploits the semi-random variation in public transport use generated by the introduction of the policy and the age-eligibility threshold. Appendix Figure 1 illustrates the two stages in the IV models. In the first stage equation, the endogenous exposure (public transport use) is regressed on the instrument (eligibility for free bus travel) and all control variables. In the second stage equation, the outcome (depressive symptoms) is regressed on the predicted values of transport use derived from the first stage and all control variables. Analyses were conducted in Stata, version 14,[21] using the ivreg and ivreg2[22] commands.

The Instrument: Free Bus Pass Eligibility

We used a binary variable to indicate whether individuals were eligible for free bus travel at each wave, based on government eligibility criteria: people aged 60 years or older were classified as eligible between April 2006 and March 2010. Since April 2010, the eligibility age has been increasing in monthly increments in accordance with the increases in women's state pension age.[8] As birth month is not publicly available in ELSA, , we rounded up the eligibility age between April 2010 and 2014 as follows: 61 (2010-2012), 62 (2012-2013), and 63 (2014). Between 2010 and 2014, there were 1,892 individuals who were not eligible based on our rounded-up eligibility ages, but who may have met the government's actual age criteria. We excluded these individuals from the main analyses during the years their eligibility statuses were potentially misclassified, but we incorporated them under various eligibility assumptions in sensitivity analyses.

Three assumptions about the instrument (eligibility for free bus passes) must be met for the IV model to yield unbiased estimates; it must (1) be associated with the endogenous exposure variable (public transport use) in the first stage, (2) be uncorrelated with the outcome (depressive symptoms) except through its impact on public transport use, and (3) be independent of unmeasured confounders. F-statistics from the first stage of the 2SLS model were greater than 10, confirming that bus pass eligibility is strongly associated with public transport, meeting the first condition.[23] The

introduction of the bus pass and the age eligibility threshold were exogenous policy changes. However, a potential concern is that many individuals eligible for the bus pass were also eligible for state pensions. We therefore adjust for receipt of pensions in all models to control for their potential effect on depressive symptoms. Conditional on pension receipt and other observed covariates, we do not expect eligibility for free bus travel to influence depressive symptoms other than by increasing transport use.

Public Transportation Use

In 2002 and 2004, participants were asked: "Do you use public transport… a lot, quite often, sometimes, rarely, or never." In 2006, this question changed to: "How often do you use public transport… every day or nearly every day, 2 or 3 times a week, once a week, 2 or 3 times a month, once a month or less, or never." As never was the only consistent category, a binary variable was created that assigned a 1 to users of public transportation and a 0 to non/never users at each wave. In sensitivity analyses, we tested different cut-off points for the binary variable. We also restricted the range of data to 2006 through 2014, after the change in questionnaire, to confirm our main results were not an artefact of the question change.

Depressive Symptoms, Loneliness, Social Isolation, and Social Engagement

We used the total 8-item Center for Epidemiologic Studies Depression Scale [CES-D] score to assess depressive symptoms.[24, 25] The CES-D scale assesses interpersonal relations, positive affect, depressed affect, and somatic activity. Each item was scored as 1 if the participant has the depressive symptom, with reverse coding used for the 2 positive affect items. This resulted in a CES-D score ranging from 0 to 8.

We also examined potential mechanisms linking transport use and depressive symptoms, including loneliness, social isolation, and social engagement. Loneliness was evaluated using the 3-item University of California Los Angeles [UCLA] Loneliness scale.[26] The items included in the UCLA Loneliness Scale are how often the respondent feels (1) they lack companionship, (2) left out, and (3) isolated from others. These items were scored as 1 for a response of "hardly ever or never," as 2 for "some of the time," and as 3 for "often" and then summed for a score ranging from 3 (not lonely) to 9 (very lonely). Social isolation was assessed using the 5-item scale developed by Shankar

et al[27] with each of the following items scored as 1: (1) Not married or cohabitating, (2) Less than monthly contact (including face-to-face, telephone or written/e-mail contact) with children, (3) Less than monthly contact with other immediate family, (4) Less than monthly contact with friends, (5) Does not participate in any organisations, religious groups, or committees. These items are summed for a score ranging from 0 (not socially isolated) to 5 (very socially isolated).

For social engagement measures, we created binary variables to indicate whether respondents volunteered at least monthly, were a member of any group/club/organisation, and whether they had a least monthly face to face contact with children, other immediate family members, and friends.

Controls

We controlled for age, gender, at least one limitation in the activities of daily living [ADL's], at least one limitation in the instrumental activities of daily living [IADL's], car ownership, the natural log of net total non-pension household wealth, the natural log of equivalised household income, marital status (married, cohabitating, single/never married, widowed, divorced, separated), number of children in the household (0, 1, 2, 3+), and household region (North East, North West, Yorkshire and the Humber, East Midlands, West Midlands, East of England, London, South East, South West).

A potential concern was that the bus pass eligibility age overlapped with women's state pension age (Appendix Tables 2-3; Appendix Figure 2). Therefore, we also controlled for employment status (employed, unemployed, retired, out of labour force) and indicators of whether the respondent received a state pension or a private pension. In sensitivity analyses, we also (a) controlled for the natural log amount of state and private pensions received, (b) ran sub-group analyses by gender, and (c) restricted the sample to people who were out of the labour force and thus less likely to be eligible for pensions.

To further examine the robustness of our results, we implemented a linear fixed effect model, [28] which did not use the instrument, thus avoiding potential issues from overlap between bus pass eligibility age and women's state pension age. The fixed effect model exploited the longitudinal nature of the data and estimated whether changes in transport use were associated with changes in depressive symptoms within individuals. Fixed effect models use each individual as their own control

to effectively eliminate all time-invariant confounding. We incorporated a wide range of covariates to control for measured time-varying factors.

RESULTS

Across all waves, 8.9% of the sample used public transport a lot or nearly every day, 11.3% used it quite often or 2-3 times per week, 17.2% used it sometimes or 2-5 times per month, 29.7% used it rarely or less than once a month, and 32% never used public transportation (Appendix Table 4). Table 1 indicates that public transport users differed from non-users along several dimensions at baseline. For example, transport users were more likely to be female, retired, and to receive pensions, while they were less likely to have physical limitations and be socially isolated or depressed. Appendix Figure 3 shows that transport use varies with age, and in most years, transport use increases from age 50 to around age 70, after which it declines.

Insert Table 1

Figure 1 shows locally weighted regression smoothed curves of CES-D scores by age, separately for public transport users and non-users. The U-shaped curves show an average decrease in depressive symptoms around retirement age (60-65 years) followed by an increase in depressive symptoms thereafter for both users and non-users of public transport. Figure 2 suggests that transport users have lower average CES-D scores than non-transport users at every age. On average across all ages, transport users have a 0.31 lower CES-D score than non-transport users.

Insert Figure 1

Models estimating the association between transport use and depressive symptoms are summarised in Table 2. Column 1 of Table 2 presents the estimates from an OLS model and suggests that transport use is associated with less depressive symptoms (β: -0.122, 95% Confidence Interval [CI]: -0.161 to -0.083). Column 2 summarises results from the IV model. First-stage IV results suggest that eligibility for the free bus pass was associated with an 8% (95%CI: 6.4% to 9.6%) increase in public transportation use. A supplementary analysis using a logistic model indicates that eligibility for free bus travel was associated with increased odds of using public transportation (Odds Ratio: 1.51, 95% CI: 1.40 to 1.64) (Appendix Table 5). A supplementary model using ordinal categories of transport use also yields consistent results (Appendix Table 6). Results from the second

stage of the IV (Table 2) suggest that increased transport use—due to eligibility for the free bus pass—leads to a significant decline in CES-D depressive symptom scores (β: -0.952, 95% CI: -1.712 to -0.192). Results were of a smaller magnitude but significant and in the same direction in the fixed effect model (β: -0.059, 95% CI: -0.096 to -0.021) (Table 2, column 3).

Insert Table 2

Table 3 shows second stage results from IV models that estimate the associations between public transport use and loneliness, social isolation, and social engagement. Transport use was associated with a reduction in the UCLA loneliness score (β: -0.794, 95% CI: -1.528 to -0.061), and an increase in volunteering at least monthly (β: 0.237, 95% CI: 0.059 to 0.414). Transport use was also associated with increased face to face contact with children (β: 0.480, 95% CI: 0.208 to 0.752) and friends (β: 0.311, 95% CI: 0.109 to 0.513), but less contact with other family members (β: -0.320, 95% CI: -0.566 to -0.073). We did not find associations between transport use and social isolation or group membership.

Insert Table 3

Sensitivity Analyses

Figure 2 and Appendix Tables 7 to 13 summarise results from sensitivity analyses. Estimates were similar to the main results in models using logged amounts of private and state pensions, applying sampling and non-response weights provided by ELSA, and including individuals with potentially misclassified eligibility statuses. Results were also consistent in models restricting the sample to the period 2006-2014, during which there was no change in our measure of transport use (Figure 2), and in models using different cut-offs for the binary transportation variable (Appendix Table 8). Results for women were similar to the main estimates and to the results for men (Figure 2). Estimates were also consistent when restricting the sample to people out of the labour force (Appendix Table 9), as well as in models that excluded all controls (Appendix Table 10) and used multiple imputation for missing values (Appendix Tables 11-13).

Insert Figure 2

For most years, we had no data on frequency of bus pass use. However, in 2012 and 2014, ELSA participants were asked whether they had the bus pass and how often they used it in the past

month. Most people who were eligible for the free bus fare reported having the bus pass (81% in 2012, 83% in 2014). In supplementary IV models, we examined the impact of frequency of bus pass use on depressive symptoms (Appendix Table 14). These results suggest a dose-response relationship whereby more frequent use of the bus pass was associated with lower depressive symptoms.

DISCUSSION

In this study, we show that increased public transportation use, as a result of the free bus pass, reduced depressive symptoms in older age. Our results suggest that benefits from increased transport use likely stem from reduced loneliness, increased participation in volunteering activities, and increased contact with children and friends. Our findings provide evidence that age-friendly transportation policies can improve mental health and encourage social engagement among older people.

Our findings expand upon previous studies showing that the free bus passes were associated with benefits to physical health, through increases in physical activity, decreases in adiposity,[11] and lower rates of obesity.[10] Our study suggests that the benefits also extend to mental health and social engagement. These results are consistent with findings from qualitative interviews suggesting that the bus passes improved quality of life and well-being,[12, 15] and increased participation in social activities.[15]

There are other mechanisms through which use of public transportation may improve mental health among older people. Increased use of public transportation may provide psychological benefits from exercise and time spent outdoors, both of which have been linked to mental health.[29, 30] Additionally, there is evidence that driving cessation is associated with increased depressive symptoms among older people.[31, 32] Free bus passes may offset some of these negative effects by offering older people the means to travel without a car.

An important finding from our study is that increased transportation use was associated with reduced loneliness. There is a lack of large-scale interventions targeting loneliness,[33] a measure of dissatisfaction with the quantity and quality of social relations[34] that is relatively common in later life.[33] Using a quasi-experimental approach, our study shows that a policy which increases access to public transport for older people may offer potential to reduce loneliness.

Despite the strengths of our study, there are several limitations. ELSA does not include urban/rural identifiers to examine effect heterogeneity across regions. Some local areas offer additional concessionary transport fares for older people, which are separate from the national bus fare scheme.[8] Although we could not study these local schemes, in sensitivity analyses, we found that results did not change when excluding participants from London, which has the most extensive set of concessionary fares (Appendix Table 15). Another limitation refers to potential violation of the second and third IV assumptions. For example, although we controlled for pension receipt, there may be some residual confounding, and we cannot fully rule out that some effect we observe in IV models may reflect the impact of pensions. Likewise, bus pass eligibility may have directly influenced depressive symptoms, for example, by making people feel valued by the government. Nevertheless, it is reassuring that our results were robust in fixed effect models that do not use bus pass eligibility as an instrument but rather exploit longitudinal changes in transport use. In addition, although less precisely estimated, gender-stratified results showed that estimates were similar for women and men, despite the fact that among the latter, state pension age is different from bus pass eligibility age. Overall, notwithstanding the limitations of each approach, these results provide some reassurance that there is a plausible relationship between public transport use and depressive symptoms.

We note that results from the IV model were larger than those from fixed effect and OLS models. A potential explanation is that the IV estimate captures the local average treatment effect [LATE], which is the effect of increased transport use on people who changed their behaviour as a result of the bus pass policy (the compliers).[17] By contrast, fixed effect estimates may be closer to the average treatment effect, and therefore of much smaller magnitude than the LATE.

This study suggests that an age-friendly public transportation policy, the free bus pass, positively impacted the mental health of older adults. Concerns have been raised about the high costs of the free bus scheme, which amount to approximately one billion pounds per year.[35] These concerns, however, overlook potential savings from reduced depressive symptoms, as the annual cost of diagnosed depression in England has been estimated at 7.5 billion pounds.[36] Increased transport use was also associated with increased social engagement, particularly volunteering. This suggests that the free bus pass may also bring wider societal benefits.[11, 37] Failure to consider these

unanticipated mental health and social benefits of the free bus pass policy may lead to an overestimation of the cost and underappreciation of the value of the policy.

Acknowledgements: We thank the MINDMAP Consortium.

Contributions: ER conceptualized and designed the study, carried out the analyses, and drafted the manuscript. MA conceptualized and designed the study, critically reviewed the results of analyses, and reviewed and revised the manuscript. EC and FvL critically reviewed the results of analyses and reviewed and revised the manuscript. ER is guarantor.

Competing Interests: None Declared.

Funding: This study was supported by the European Commission Horizon 2020 Programme under grant agreement n° 667661 (Promoting mental wellbeing in the ageing population - MINDMAP). The study does not necessarily reflect the Commission's views and in no way anticipates the Commission's future policy in this area. The funding source did not have a role in the design and conduct of the study, the collection, management, analysis, and interpretation of the data, or the preparation, review, approval, or decision to submit the manuscript.

Ethical Approval: This study is a secondary data analysis of the English Longitudinal Study of Ageing [ELSA]. No additional ethics approval was required. Ethical approval for ELSA was obtained from the London Multi-Centre Research Ethics Committee in England. International Review Board (IRB) number for the ethics approval of the ELSA study is IRB 00002308. Reference number for the last Medical Research Ethics Committee (MREC) approval for ELSA is MREC/04/006.

References

1. Ferrari AJ, Charlson FJ, Norman RE, et al. Burden of depressive disorders by country, sex, age, and year: findings from the global burden of disease study 2010. *PLoS Med* 2013;10(11):e1001547. doi: 10.1371/journal.pmed.1001547

2. Cacioppo JT, Hawkley LC, Thisted RA. Perceived Social Isolation Makes Me Sad: 5-Year Cross-Lagged Analyses of Loneliness and Depressive Symptomatology in the Chicago Health, Aging, and Social Relations Study. *Psychol Aging* 2010;25(2):453-63. doi: 10.1037/a0017216

3. Cacioppo JT, Hughes ME, Waite LJ, et al. Loneliness as a specific risk factor for depressive symptoms: cross-sectional and longitudinal analyses. *Psychol Aging* 2006;21(1):140-51. doi: 10.1037/0882-7974.21.1.140 [published Online First: 2006/04/06]

4. Glass TA, De Leon CF, Bassuk SS, et al. Social engagement and depressive symptoms in late life: longitudinal findings. *J Aging Health* 2006;18(4):604-28. doi: 10.1177/0898264306291017

5. World Health Organization. Global age-friendly cities: A guide: World Health Organization 2007. Available from: http://www.who.int/ageing/publications/Global_age_friendly_cities_Guide_English.pdf

6. Levasseur M, Genereux M, Bruneau JF, et al. Importance of proximity to resources, social support, transportation and neighborhood security for mobility and social participation in older adults: results from a scoping study. *BMC Public Health* 2015;15(1):503. doi: 10.1186/s12889-015-1824-0

7. Vaughan M, LaValley MP, AlHeresh R, et al. Which features of the environment impact community participation of older adults? A systematic review and meta-analysis. *Journal of Aging and Health* 2016;28(6):957-78. doi: 10.1177/0898264315614008

8. Butcher L. House of Commons Briefing Paper SN01499: Concessionary bus fares. 2015. Available from: http://researchbriefings.parliament.uk/ResearchBriefing/Summary/SN01499#fullrepo

9. Department for Transport. National Travel Survey, 2009. London, UK. Available from: http://webarchive.nationalarchives.gov.uk/20100910193305/http://www.dft.gov.uk/pgr/statistics/datatablespublications/nts/.

10. Webb E, Netuveli G, Millett C. Free bus passes, use of public transport and obesity among older people in England. *J Epidemiol Community Health* 2012;66(2):176-80. doi: 10.1136/jech.2011.133165

11. Webb E, Laverty A, Mindell J, et al. Free Bus Travel and Physical Activity, Gait Speed, and Adiposity in the English Longitudinal Study of Ageing. *Am J Public Health* 2016;106(1):136-42. doi: 10.2105/ajph.2015.302907

12. Green J, Jones A, Roberts H. More than A to B: the role of free bus travel for the mobility and wellbeing of older citizens in London. *Ageing & Society* 2014;34(3):472-94. doi: 10.1017/S0144686x12001110

13. Jones A, Goodman A, Roberts H, et al. Entitlement to concessionary public transport and wellbeing: a qualitative study of young people and older citizens in London, UK. *Soc Sci Med* 2013;91:202-9. doi: 10.1016/j.socscimed.2012.11.040

14. Mackett R. Impact of Concessionary Bus Travel on the Well-Being of Older and Disabled People. *Transportation Research Record* 2013(2352):114-19. doi: 10.3141/2352-13

15. Andrews G, Parkhurst G, Susilo YO, et al. The grey escape: investigating older people's use of the free bus pass. *Transportation Planning and Technology* 2012;35(1):3-15. doi: 10.1080/03081060.2012.635413

16. Steptoe A, Breeze E, Banks J, et al. Cohort profile: the English longitudinal study of ageing. *Int J Epidemiol* 2013;42(6):1640-8. doi: 10.1093/ije/dys168

17. Angrist JD, Imbens GW, Rubin DB. Identification of causal effects using instrumental variables. *J Am Statistical Association* 1996;91(434):444-55.

18. Martens EP, Pestman WR, de Boer A, et al. Instrumental variables: application and limitations. *Epidemiology* 2006;17(3):260-7. doi: 10.1097/01.ede.0000215160.88317.cb

19. Hernan MA, Robins JM. Instruments for causal inference: an epidemiologist's dream? *Epidemiology* 2006;17(4):360-72. doi: 10.1097/01.ede.0000222409.00878.37

20. Wooldridge JM. Introductory econometrics: A modern approach: Nelson Education 2015.

21. StataCorp L. STATA 14 [Computer software]. *College Station, TX: StataCorp LP* 2015.

22. Baum CF, Schaffer ME, Stillman S.ivreg2: Stata module for extended instrumental variables/2SLS, GMM and AC/HAC, LIML and k-class regression [program]. 2010 version, 2010. Available at: http://ideas.repec.org/c/boc/bocode/s425401.html.

23. Stock JH, Yogo M. Testing for weak instruments in linear IV regression: National Bureau of Economic Research Cambridge, Mass., USA, 2002.

24. Radloff LS. The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement* 1977;1(3):385-401.

25. Melchior LA, Huba GJ, Brown VB, et al. A Short Depression Index for Women. *Educational and Psychological Measurement* 1993;53(4):1117-25. doi: Doi 10.1177/0013164493053004024

26. Russell D, Peplau LA, Ferguson ML. Developing a measure of loneliness. *J Pers Assess* 1978;42(3):290-4. doi: 10.1207/s15327752jpa4203_11

27. Shankar A, McMunn A, Banks J, et al. Loneliness, social isolation, and behavioral and biological health indicators in older adults. *Health Psychol* 2011;30(4):377-85. doi: 10.1037/a0022826

28. Allison P. Fixed Effects Regression Models. Thousand Oaks, California: SAGE, 2009.

29. Strawbridge WJ, Deleger S, Roberts RE, et al. Physical activity reduces the risk of subsequent depression for older adults. *Am J Epidemiol* 2002;156(4):328-34.

30. Bowler DE, Buyung-Ali LM, Knight TM, et al. A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health* 2010;10(1):456. doi: 10.1186/1471-2458-10-456

31. Marottoli RA, Mendes de Leon CF, Glass TA, et al. Driving cessation and increased depressive symptoms: prospective evidence from the New Haven EPESE. Established Populations for Epidemiologic Studies of the Elderly. *J Am Geriatr Soc* 1997;45(2):202-6.

32. Ragland DR, Satariano WA, MacLeod KE. Driving cessation and increased depressive symptoms. *J Gerontol A Biol Sci Med Sci* 2005;60(3):399-403.

33. Gardiner C, Geldenhuys G, Gott M. Interventions to reduce social isolation and loneliness among older people: an integrative review. *Health Soc Care Community* 2016 doi: 10.1111/hsc.12367 [published Online First: 2016/07/15]

34. Peplau LA, Perlman D. Perspectives on loneliness. *Loneliness: A sourcebook of current theory, research and therapy* 1982:1-20.

35. Department for Transport. Reimbursement of bus operators for concessionary travel by older and disabled people and reimbursement per journey by metropolitan area status: England, annual from 2010/11. 2016. Available from: https://www.gov.uk/government/statistical-data-sets/bus08-concessionary-travel

36. McCrone P, Dhanasiri S, Patel A, et al. Paying the price: The cost of mental health care in England to 2026. King's Fund 2008. Available from: https://www.kingsfund.org.uk/sites/default/files/Paying-the-Price-the-cost-of-mental-health-care-England-2026-McCrone-Dhanasiri-Patel-Knapp-Lawton-Smith-Kings-Fund-May-2008_0.pdf

37. Mackett R. Improving accessibility for older people - Investing in a valuable asset. *Journal of Transport & Health* 2015;2(1):5-13. doi: 10.1016/j.jth.2014.10.004

TABLES

Table 1: Baseline Characteristics of Public Transport Users and Non-Users. Values are numbers (percentages) unless otherwise stated.

	Users (n = 12554)	Non-Users (n = 5610)	χ^2 P-value	Total (n = 18164)
CES-D Score (Mean)	1.50	1.75		1.57
Depression[1]			<0.001	
Not Depressed	9440 (77.4)	3868 (72.7)		13308 (76.0)
Depressed	2754 (22.6)	1449 (27.3)		4203 (24.0)
Loneliness[2]			0.694	
Not Lonely	7318 (80.5)	3027 (80.2)		10345 (80.4)
Lonely	1774 (19.5)	748 (19.8)		2522 (19.6)
Social Isolation[3]			<0.001	
Not Isolated	5016 (68.7)	1945 (64.1)		6961 (67.3)
Isolated	2284 (31.3)	1091 (35.9)		3375 (32.7)
Group/Club Membership			<0.001	
Not a group member	2982 (27.8)	1749 (38.9)		4731 (31.0)
Group member	7757 (72.2)	2752 (61.1)		10509 (69.0)
Volunteering, monthly			<0.001	
Less than Monthly	9783 (79.0)	4743 (87.4)		14526 (81.6)
At Least Monthly	2594 (21.0)	683 (12.6)		3277 (18.4)
Face to Face Contact with Children			<0.001	
Less than monthly	3414 (34.0)	1287 (30.0)		4701 (32.8)
More than monthly	6638 (66.0)	2999 (70.0)		9637 (67.2)
Face to Face Contact with Family			0.121	
Less than monthly	5286 (49.7)	2173 (48.3)		7459 (49.3)
More than monthly	5352 (50.3)	2325 (51.7)		7677 (50.7)
Face to Face Contact with Friends			<0.001	
Less than monthly	2044 (19.0)	1213 (26.8)		3257 (21.3)
More than monthly	8690 (81.0)	3313 (73.2)		12002 (78.7)
Age			<0.001	
<60	6379 (50.8)	2945 (52.5)		9324 (51.3)
60-74	4602 (36.7)	1797 (32.0)		6399 (35.2)
75+	1573 (12.5)	868 (15.5)		2440 (13.4)
Gender			<0.001	
Male	5243 (41.8)	2989 (53.3)		8232 (45.3)
Female	7311 (58.2)	2621 (46.7)		9932 (54.7)
ADL's			<0.001	
None	10753 (85.7)	4250 (75.8)		15003 (82.6)
At least 1	1798 (14.3)	1360 (24.2)		3158 (17.4)
IADL's			<0.001	
None	10692 (85.2)	4167 (74.3)		14859 (81.8)
At least 1	1859 (14.8)	1443 (25.7)		3158 (17.4)
Access to Car			<0.001	

Yes car	10284 (81.9)	5166 (92.1)		15450 (85.1)
No car	2268 (18.1)	442 (7.9)		2710 (14.9)
Employment Status			<0.001	
Employed	5506 (43.9)	2532 (45.1)		8038 (44.3)
Unemployed	178 (1.4)	71 (1.3)		249 (1.4)
Retired	4994 (39.8)	1956 (34.9)		6950 (38.3)
Out of Labour Force	1876 (14.9)	1051 (18.7)		2927 (16.1)
Marital Status			<0.001	
Married/Civil Partnership	8351 (66.5)	4015 (71.6)		12366 (68.1)
Cohabitating	772 (6.1)	361 (6.4)		1133 (6.2)
Single, never married	697 (5.6)	227 (4.0)		924 (5.1)
Widowed	1521 (12.1)	604 (10.8)		2125 (11.7)
Divorced	987 (7.9)	325 (5.8)		1312 (7.2)
Separated	226 (1.8)	78 (1.4)		304 (1.7)
No. Kids in Household			0.544	
0 kids	11069 (88.2)	4964 (88.5)		16033 (88.3)
1 kid	972 (7.7)	404 (7.2)		1376 (7.6)
2 kids	379 (3.0)	176 (3.1)		555 (3.1)
3+ kids	134 (1.1)	66 (1.2)		200 (1.1)
Region			<0.001	
North East	828 (6.6)	334 (6.0)		1162 (6.4)
North West	1621 (12.9)	767 (13.7)		2388 (13.2)
Yorkshire and the Humber	1323 (10.5)	612 (10.9)		1935 (10.7)
East Midlands	1125 (9.0)	663 (11.8)		1788 (9.8)
West Midlands	1249 (10.0)	729 (13.0)		1978 (10.9)
East of England	1470 (11.7)	681 (12.1)		2151 (11.8)
London	1513 (12.1)	214 (3.8)		1727 (9.5)
South East	2139 (17.0)	866 (15.4)		3005 (16.6)
South West	1279 (10.2)	744 (13.3)		2023 (11.1)
Non-Pension Wealth (Mean)	268,774	242,244		259,529
Equivalised Income (Mean)	306	290		301
Private Pension			<0.001	
Receives Private Pension	3891 (31.0)	1564 (27.9)		5522 (29.9)
No Private Pension	8663 (69.0)	4046 (72.1)		12931 (70.1)
State Pension			<0.001	
Receives State Pension	5151 (41.3)	2088 (37.5)		7382 (40.3)
No State Pension	7308 (58.7)	3482 (62.5)		10934 (59.7)

[1]. Depression defined as ≥3-item cut-off for CES-D score
[2]. Loneliness defined as ≥6 cut-off for UCLA Loneliness Scale Score [26]
[3]. Social Isolation defined as ≥2 cut-off on Shankar et al [27] scale

Table 2: The impact of eligibility for free bus travel on the use of public transport (IV 2SLS first stage) and the impact of transportation use on depressive symptoms (IV 2SLS second stage)

	Model 1: Ordinary Least Squares β (95% CI)	Model 2: 2SLS Instrumental Variable β (95% CI)	Model 3: Linear Fixed Effect β (95% CI)
Impact of public transport use on depressive symptoms	-0.122 (-0.161,-0.083)***		-0.059(-0.096, -0.021)**
1st Stage: Impact of eligibility for free bus pass on public transport use		0.080 (0.064, 0.096)***	
2nd Stage: Impact of public transport use on depressive symptoms		-0.952 (-1.712, -0.192)*	

*p<0.05 **p<0.01 ***p<0.001

The outcome variable for Model 1, OLS, Model 2, second stage IV, and Model 3, Fixed Effect, is total CES-D Score (0 – 8)

Models 1 and 2, OLS and IV, control for age, wave, gender, any ADL limits, any IADL limits, car ownership, log net total non-pension wealth, log equivalised income, receiving a private pension, receiving a state pension, employment status, marital status, number of kids in the household, region

Model 3, Fixed Effect, controls for age, wave, any ADL limits, any IADL limits, car ownership, log net total non-pension wealth, log equivalised income, receiving a private pension, receiving a state pension, employment status, marital status, number of kids in the household, region

F-statistic for first stage IV: 131.47

Table 3: The impact of transportation use on loneliness, social isolation, and social engagement in 2SLS instrumental variable models

	Model 1: IV
Outcome	β (95% CI)
Loneliness[1]	-0.794 (-1.528, -0.061)*
Social Isolation[2]	-0.437 (-0.941,0.067)
Member of group/organisation/club	0.156 (-0.054,0.365)
Volunteers at least monthly	0.237 (0.059,0.414)**
Face to face contact with friends at least monthly	0.311 (0.109,0.513)**
Face to face contact with children at least monthly	0.480 (0.208,0.752)***
Face to face contact with family members at least monthly	-0.320 (-0.566,-0.073)*

*p<0.05 **p<0.01 ***p<0.001

The exposure variable for Model 1 is predicted transport use from the first stage IV

All models control for: age, wave, gender, any ADL limits, any IADL limits, car ownership, log net total non-pension wealth, log equivalised income, receiving a private pension, receiving a state pension, employment status, marital status, number of kids in the household, region

[1] Loneliness refers to the total score on the 3-item UCLA Loneliness Scale [26], Total Loneliness Scale Score ranging from 3 (not lonely) to 9 (very lonely)

[2] Social Isolation refers to the total score on the 5-item Shankar et al [27] Social Isolation scale, ranging from 0 (not isolated) to 5 (very isolated)

FIGURES:

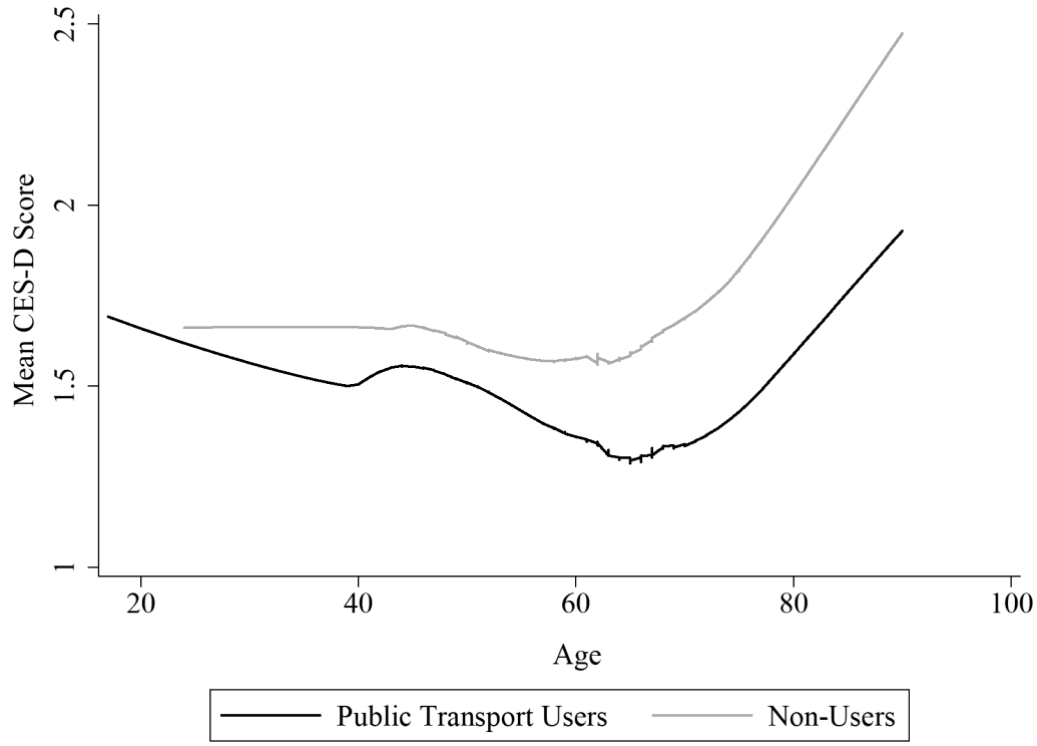

Figure 1: Locally weighted regression, Mean CES-D Score by Age for Public Transport Users and Non-Users

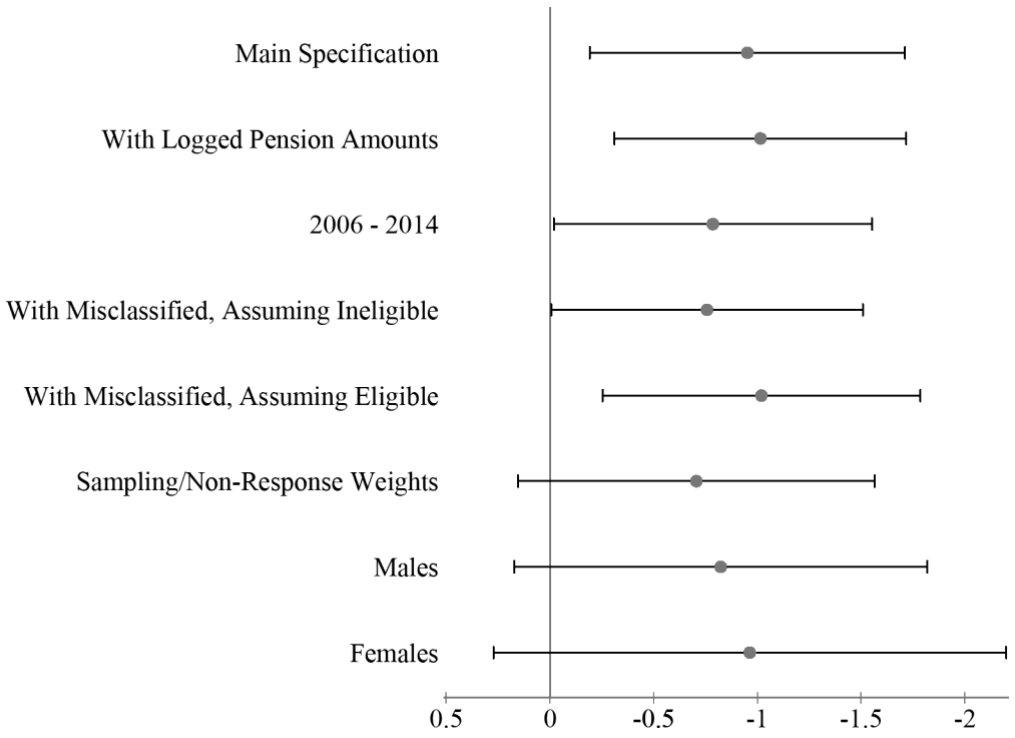

Figure 2: Beta coefficients and 95% confidence intervals from the second stage 2SLS IV main specification and sensitivity analyses