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RESEARCH ARTICLE

Environmental Noise Exposure and Mental Health: Evidence From a Population-Based Longitudinal Study

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Introduction: Exposure to environmental noise from within homes has been associated with poor mental health. Existing evidence rests on cross-sectional studies prone to residual confounding, reverse causation, and small sample sizes, failing to adequately consider the causal nature of this relationship. Furthermore, few studies have examined the sociodemographic distribution of noise exposure at a country level.

Methods: The study, conducted in 2021, examined the impact of environmental noise from road traffic, airplanes, trains, and industry on mental health and psychological distress as reported by 31,387 respondents using a 19-year longitudinal data set in Australia (2001–2019). To improve the capacity to make causal inference and reduce bias from measurement error, reverse causation, and unobserved confounders, analyses used instrumental variables, fixed-effects models, and an aggregated area-level measure of noise exposure. Utilizing the large-scale national data set, sociospatial distributions of noise exposure were described.

Results: Private and public rental tenants, lone parents, residents of socioeconomically disadvantaged areas, and those with long-term health conditions were more likely to report residential noise exposure. This exposure to noise was consistently associated with poorer mental health (self-reported noise: β= −0.58; 95% CI= −0.76, −0.39; area-level noise: β= −0.43; 95% CI= −0.61, −0.26), with the relationship strongest for traffic noise (β= −0.79; 95% CI= −1.07, −0.51). Notably, when noise exposure decreased over time, there was an increase in mental health (β= 0.43; 95% CI= 0.14, 0.72).

Conclusions: The study provides strong evidence of a negative mental health effect of perceived residential noise, and the results have implications for healthy home design and urban planning. These findings should be validated with further studies that measure noise intensity and housing quality.
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INTRODUCTION

Rapid population growth and urban development, coupled with a lack of adequate noise regulation, have exposed many people to environmental noise in their homes. Noise is an unwanted sound that disturbs speech communication, sleep, and mental tasks.[1,2] Sources of noise include transportation (road, rail, and air traffic), industry and construction, public work, and community.[1] Exposure to

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noise above 40–54 decibels, depending on the source and time of day, is associated with sleep disturbance, cardiovascular disease, cognition problems, and poor mental health and wellbeing.[3−7] Although a complex construct, noise exposure can negatively impact residents' health,[8] with the WHO recognizing residential noise as a potential health-harming housing condition.[9]

To develop appropriate urban- and housing-focused interventions, important gaps in the evidence base need to be addressed. First, minimal research has examined the sociodemographic disparities in noise exposure[10,11]; second, although there has been extensive research on occupational exposures to noise, few methodologically high-quality studies examined the impact of residential noise on mental health and psychological distress[12,13]; and third, there is a lack of studies that utilize robust causally focused methods to examine mental health impacts of noise exposure.[14] A better understanding of this relationship is critical to establishing how the quality and location of housing can impact people's quality of life and wellbeing.

Noise is complex to measure. Although objective noise exposure data (amplitude, frequency, duration) is crucial in quantifying the relationship between noise and health outcomes,[4] it is also important to highlight the value of people's subjective evaluations of noise.[15] This is particularly pertinent when examining the impact of noise on mental health and wellbeing, with perceived noise understood to influence psychological stress.[15,16] Previous studies suggest that the same level of sound may be subjectively identified as noise by some people and not others,[17,18] and recent studies have increasingly recognized the use of subjective perception of noise exposure to allow for more holistic understandings of noise evaluation and neighborhood environment.[15,19]

Evidence of a causal relationship between noise exposure in people's homes and their mental health remains mixed and inconclusive.[12,13,20] Meta-analyses concluded that most studies in this field were of low quality.[12,13] Overall, existing evidence of a negative mental health effect of noise in residential contexts rests on observational studies where residual confounding from socioeconomic factors remains unaccounted for. This knowledge gap needs to be addressed before recommending changes to policy and practice in relation to building standards and urban planning.

With a growing interest in the impacts of health-harming housing, there is a need for more robust casually focused research. This study aims to evaluate the inequalities in the distribution of perceived noise exposure in a residential context and causally test and quantify the negative impact of reported noise exposure on mental health and psychological distress in a population-based longitudinal cohort of Australians spanning the first 2 decades of this century.

The main sources of bias in observational studies are residual confounding, selection bias, and measurement error.[21] To reduce bias from these known sources of error, several analytical approaches are utilized. First, instrumental variable (IV) analysis is adopted. Commonly used in econometrics, it exploits an instrument, an external variable that is correlated with the causal variable of interest but uncorrelated with other determinants of the outcome,[22] to examine the relationship between noise and mental health free of reverse causation. Second, fixed effects (FEs) regression modeling is used to compare changes within people over time, thereby removing confounding from differences between people that do not vary over time. Third, an area-level noise measure aggregated from individual measures is employed to reduce individual-level measurement and selection bias. The combination of these approaches to modeling data from a longitudinal cohort will improve the estimation of the causal effect of noise exposure on mental health, advancing the current state of knowledge and maximizing the benefit of a large, national sample spanning nearly 20 years.

To quantify the mental health effect of noise exposure in residential environments, respondent reports of exposure to major sources of noise from road traffic, airplanes, trains, and industry and mental health are considered. Two IVs are used to reduce bias from reverse causation and measurement error: distance to a nearest train line or major road and population density at the local area level. These variables, commonly used in noise prediction models (i.e., they are correlated with noise exposure), are in testing independent of other determinants of mental health, conditional on covariates (i.e., in and of themselves, they are not correlated with mental health other than through their relationship with noise exposure).

METHODS

Study Sample

This study primarily uses the Household, Income and Labour Dynamics in Australia (HILDA) survey from 2001 to 2019. HILDA is a longitudinal study with a multistage clustered, stratified design that began with a nationally representative sample of 7,682 Australian households and 13,969 people and has gradually extended to include new household members from changes in the original household composition. The sampling unit is the household whose members are followed up annually. The data set is publicly available and deidentified, with the methodology and background detailed in Summerfield et al.[23]

Measures

Mental health is measured using 2 validated scales: (1) the 36-Item Short-Form Survey, measured annually in the HILDA data set using the mental health summary score, ranging from 0 to 100 (a higher score representing better mental health), and (2) the Kessler Psychological Distress Scale (K10), available in every second wave from 2007 to 2019 in the HILDA survey, on a 10−50 scale (a higher score reflecting higher psychological distress).

In 2001−2004 and every second year thereafter, respondents were asked: how common is noise from airplanes, trains or industry in your local neighbourhood? and how common is loud traffic noise in your local neighbourhood?. Their response was recorded as 1 (never happens), 2 (very rare), 3 (not common), 4 (fairly common), or 5 (very common). Subsequently, exposure to noise was constructed as a binary variable indicating whether the respondent reported experiencing either noise source fairly commonly or very commonly. Sensitivity analyses were conducted (1) investigating exposure to a single noise source and both noise sources and (2) using the ordinal measure of noise exposure.

A range of demographic, socioeconomic, health, and housing covariates were controlled for, including age, sex, country of birth, highest education attainment, equivalized household income, employment status, household structure, numbers of children in the household, area socioeconomic advantage/disadvantage in quintiles measured by Socio-Economic Index for Area, long-term health condition, housing tenure, and dwelling types (details are in Appendix, available online).

Statistical Analysis

To reduce bias from individual-level measurement and selection and allow only for within-Statistical Area Level 1 (SA1)−the smallest unit for census data containing about 400 persons in urban areas and 180 in rural areas[24]−variation in the noise level over time, an aggregated measure of noise exposure at the area level from individual reporting of noise was created by (1) averaging self-reported noise across the SA1 for each available year; (2) deriving a binary indicator at the SA1 equal to 1 if the mean noise exposure $\geq$0.5 (a commonly used threshold for binary classification[25]); and (3) imputing values in missing years of data collection with the value from the previous year or the value in the subsequent year if the previous value was unavailable, assuming no substantial changes in locations of major roads, train lines, and airline routes in adjacent years. The imputation allows for the K10 measures to be modeled in the same year as the aggregate noise measure (Appendix Table 1, available online). Sensitivity analyses were performed (1) using distance to main roads/train lines, population density, and other confounders to impute noise measures and (2) applying median as the classification threshold.

In addition, IV methods are used to address the bias from unobserved confounders (time invariant or time varying), reverse causality, and measurement error and obviate the need for extensive controls as in RCTs.[22] Mixed-effects structural equations models were estimated using noise exposure at the individual level or area level, indicating whether the respondent or the local area on average fairly commonly or very commonly experienced noise. Leveraging national Australian Bureau of Statistics Census data and Open Street Map data, 2 variables predictive of noise exposure in people's local area were created as more objective measures of noise exposure than individual self-reports using Esri's ArcGIS 10.8 software: (1) distance to nearest train lines or major roads and (2) population density at the SA1. Several diagnostics tests on relevance and validity were conducted (details are in Appendix Model specification, available online).

To improve causal inference by reducing reporting bias and residual confounding from unobserved time-invariant confounders, FE regressions were also employed.[26] This modeling approach explores the relationship between exposure and outcome within people over time and removes the effect of time-invariant characteristics of residents that may impact or bias the causal effect of noise exposure on mental health.

Finally, to obviate the potential within-individual time-invariant reporting bias, the impact of changes in reported noise exposure on changes in mental health was also estimated. The changes in noise exposure are measured by a categorical variable indicating no change in noise exposure, a change from no/rare to high levels of exposure, or a change from high to no/rare levels of exposure.

RESULTS

Table 1 shows the descriptive statistics for the observed full sample (N=31,387; observations=260,991) and subsamples with self-reported elevated and low levels of noise, respectively. Most respondents lived as part of a couple (71.0%), were owner occupiers (70.0%), and were living in separate or semidetached houses (88.8%). People who reported commonly experiencing noise also reported worse mental health[27] (36-Item Short-Form Survey mental health= 71.7 vs 74.4).

From an equity perspective, householders in the rental sector (either as private tenants or in social housing), lone-parent or single-person householders, lower-income households, people living in socioeconomically disadvantaged areas, and people with long-term health conditions were more likely to report being exposed to noisy residential environments (Table 1). Noise levels differed by dwelling types with flats/units/apartments being located near greater noise.

Using the individual-level noise exposure measure, across all models, exposure to noise had a negative impact on mental health (IV approach: β= −0.58 [95% CI: −0.76, −0.39]; FE approach: β= −0.38 [95% CI: −0.54, −0.22]) compared with no or rare exposure to noise (Table 2). The negative individual-level cross-equation correlation (cor[$\theta_i \mu_i$]= -0.17) reveals that a disproportionate number of people who report experiencing frequent noise were observed among those with poorer mental health. Sensitivity analyses using ordinal noise exposures indicate consistent results, with the ordinal scale showing monotonically negative impacts of

Table 1. Summary Statistics

Covariates	Full sample N=260,991	Self-report high noise *n*=56,476	Self-report low noise *n*=204,515
Sex, % (*n*)			
Female	53.1 (138,591)	54.0 (30,497)	52.9 (108,445)
Male	46.9 (122,409)	46.0 (25,979)	47.1 (96,555)
Age, mean (SD)	44.8 (18.6)	42.8 (18.0)	45.3 (18.7)
Country of birth, % (*n*)			
Australia	78.9 (205,929)	78.8 (44,499)	78.9 (160,956)
Main English speaking	9.8 (25,578)	9.9 (5,591)	9.7 (19,788)
Other	11.4 (29,754)	11.3 (6,381)	11.4 (23,256)
Household structure, % (*n*)			
Couple without children	30.3 (79,083)	28.8 (16,265)	30.7 (62,935)
Couple with children	40.7 (106,227)	39.0 (22,026)	41.1 (84,255)
Lone parent	8.9 (23,229)	10.2 (5,761)	8.5 (17,425)
Lone person	15.4 (40,194)	16.4 (9,262)	15.2 (31,160)
Other	4.7 (12,267)	5.6 (3,163)	4.5 (9,225)
Number of children in the household, mean (SD)	0.6 (1.0)	0.6 (1.0)	0.6 (1.0)
Equivalized household income, mean (SD)	998.9 (573.4)	938.0 (540.9)	1,015.7 (581.0)
Education, % (*n*)			
Graduate/postgraduate	23.4 (61,074)	20.8 (11,747)	24.1 (49,405)
High school/advanced certificate	44.9 (117,189)	45.1 (25,471)	44.9 (92,045)
Year 11 or below	31.7 (82,737)	34.1 (19,258)	31.0 (63,550)
Employment, % (*n*)			
Employed	63.5 (165,735)	63.0 (35,580)	63.6 (130,380)
Unemployed	3.7 (9,657)	4.5 (2,541)	3.5 (7,175)
Not in labor force	32.8 (85,608)	32.5 (18,355)	32.9 (67,445)
Area SES, % (*n*)			
SEIFA lowest quintile	19.5 (50,895)	23.6 (13,328)	18.4 (37,720)
SEIFA second quintile	19.8 (51,678)	21.4 (12,086)	19.3 (39,565)
SEIFA third quintile	19.7 (51,417)	18.5 (10,448)	20.1 (41,205)
SEIFA fourth quintile	20.2 (52,722)	18.3 (10,335)	20.7 (42,435)
SEIFA highest quintile	20.8 (54,288)	18.2 (10,279)	21.5 (44,075)
Long-term health condition, % (*n*)	27.6 (72,036)	28.1 (15,870)	27.5 (56,375)
Housing tenure type, % (*n*)			
Owner	70.0 (182,700)	62.9 (35,523)	72.0 (147,600)
Private renter	22.7 (59,247)	28.2 (15,926)	21.2 (43,460)
Social renter	3.4 (8,874)	4.8 (2,711)	3.0 (6,150)
Other	3.9 (10,179)	4.1 (2,316)	3.8 (7,790)
Dwelling type, % (*n*)			
Flat/unit/apartment/other	11.2 (29,232)	14.6 (8,245)	10.3 (21,115)
House	88.8 (231,768)	85.4 (48,231)	89.7 (183,885)
SF-36 mental health, mean (SD)	73.8 (17.4)	71.7 (17.9)	74.4 (17.2)
Distance to trainlines/major roads, m, mean (SD)	322.5 (768.1)	247.5 (788.7)	340.0 (762.2)
Population density/km^2 at SA1 level, mean (SD)	2,179.4 (3,075.7)	2,557.0 (3,830.8)	2,100.1 (2,885.9)

Note: The panel data are unbalanced with noise measures observed on average 13.3 times per participant. The SF-36 mental health score is part of a quality-of-life assessment and has been recommended for screening mood, affective, and some anxiety disorders, whereas the K10 was designed specifically as a measure of nonspecific psychological distress on the anxiety–depression spectrum.[27] Internal consistency realizability of mental health measures was high, with Cronbach's alpha of 0.84 for SF-36 mental health and 0.93 for K10.

K10, Kessler Psychological Distress Scale; SA1, Statistical Area Level 1; SEIFA, Socioeconomic Indexes for Areas; SF-36, 36-Item Short Form Survey.

Table 2. Effects of Self-Reported Noise on Mental Health

Estimates (95% CI)	Basic regression (1)	Instrumental variables approach (2005–2007, 2010–2012, 2015–2017) (2)	Fixed effects approach (2001–2004, 2006, 2008, 2010, 2012, 2014, 2016, 2018) (3)
Base: low noise exposure at the individual level			
High noise exposure at the individual level	**−0.631***** (−0.783, −0.479)	**−0.575***** (−0.759, −0.390)	**−0.379***** (−0.535, −0.224)
Time-invariant and time-varying covariates	√	√	√
Observations, *n*	260,991	260,991	255,968
Model 1 versus Model 2 (χ^2 statistic)		145.922	
Correlation (*utiεti*)	0	0.009	
Correlation (*θiμi*)	0	**−0.165*****	
Test endogeneity of noise (χ^2 statistic)		16.567	
Test IV relevance (F statistic)		34.990	
Test IV exogeneity (χ^2 statistic)		5.000	
Test IV overidentification (Hansen J statistic)		0.012	

Note: Boldface indicates statistical significance (**p*<0.1; ***p*<0.05; ****p*<0.01).
Noise exposure is self-reported, indicating whether the respondent fairly commonly or very commonly experienced noise. H_0 in the endogeneity test is the endogenous variable that can be treated as exogenous, and χ^2 statistics with high values indicate the need to treat the suspected endogenous variables endogenously. H_0 in the relevance test is the excluded instruments that are not relevant, and F statistics with high values indicate relevance. H_0 in the exogeneity test is the excluded instruments that are not exogenous, and χ^2 statistics with low values indicate the validity of the instrument. H_0 in the overidentification test is the instruments that are not overidentified, and Hansen J statistics with low value indicate the validity of the instruments. A comparison between models 1 and 2 (χ^2 statistic) rejects model 1.
IV, instrument variable.

noise exposure frequency on mental health (Appendix Table 2, available online).

The results also reveal that people residing in private rental tenure (average marginal effect [AME]= 0.14 [95% CI: 0.09, 0.19]) or in a flat/unit/apartment (AME= 0.15 [95% CI: 0.12, 0.19]) were more likely to experience noise and that the probability of reporting noise exposure decreased as the area's SES increased (compared with lower quintile, second-quintile AME= −0.08 [95% CI: −0.11, −0.04], third-quintile AME= −0.13 [95% CI: −0.17, −0.09], fourth-quintile AME= −0.18 [95% CI: −0.22, −0.14], highest-quintile AME= −0.25 [95% CI: −0.29, −0.21]) (Appendix Figure 1, available online).

Models using the aggregated noise measure confirm the finding of a deleterious effect of exposure to noise on mental health (β= −0.43 [95% CI: −0.61, −0.26]) and psychological distress (β= 0.15 [95% CI: 0.05, 0.25]) (Table 3). Effect estimates are slightly smaller than those observed using individual-level measures. Sensitivity analyses using alternative threshold and imputation confirm the results.

Across different noise sources, the mental health effect of noise exposure is found to be driven by noise from loud traffic, with a 0.79-point (95% CI: −1.07, −0.51) decrease in mental health with reporting high exposure to noise from loud traffic only (21.83%; 24,100 of 110,374) compared with a 0.24-point (95% CI: −0.57, 0.09) decrease in mental health with reporting high exposure to noise from airplanes, trains, or industry only (14.09%; 14,149 of 100,423) (Table 4). Exposure to both sources of noise (16.76%; 17,369 of 103,643) was associated with the largest decrease in mental health (β= −1.90, 95% CI: −2.26, −1.54). The results are consistent using IV and FE approaches.

The results on the impacts of changes in noise exposure show that adjusting for sociodemographic characteristics and occurrence of confounding life events, mental health declined with increased noise exposure (change from reporting no/rare to common/very common exposure) in the order of −0.27 (95% CI: −0.57, 0.02) and improved with decreased noise exposure (a change from reporting common/very common to no/rare exposure) in order of 0.48 (95% CI: 0.19, 0.77) (Appendix Table 3, available online).

DISCUSSION

This study finds consistent evidence of a negative impact of noise from nearby traffic, airplanes, trains, and

Table 3. Effects of Area-Level Noise on Mental Health and Psychological Distress

Estimates (95% CI)	Instrumental variables approach (2005–2007, 2010–2012, 2015–2017)	Fixed effects approach (2001–2019)
(a) Mental health (2001–2019)		
Base: low noise exposure at SA1 level		
High noise exposure at SA1 level	**−0.433***** (−0.609, −0.257)	**−0.187**** (−0.338, −0.035)
Time-invariant and time-varying covariates	√	√
Observations, *n*	267,043	257,175
Correlation (*utiεti*)	**0.018****	
Correlation (*θiμi*)	**−0.077*****	
Test endogeneity of noise (χ^2 statistic)	14.694	
Test IV relevance (F statistic)	40.260	
Test IV exogeneity (χ^2 statistic)	5.000	
Test IV overidentification (Hansen J statistic)	0.005	
(b) Psychological distress (2007, 2009, 2011, 2013, 2015, 2017, 2019)		
Base: low noise exposure at SA1 level		
High noise exposure at SA1 level	**0.150**** (0.053, 0.247)	0.022 (−0.070, 0.114)
Time-invariant and time-varying covariates	√	√
Observations, *n*	166,388	100,504
Correlation (*utiεti*)	−0.018	
Correlation (*θiμi*)	**0.071*****	
Test endogeneity of noise (χ^2 statistic)	5.226	
Test IV relevance (F statistic)	36.306	
Test IV exogeneity (χ^2 statistic)	3.020	
Test IV overidentification (Hansen J statistic)	0.364	

Notes: Boldface indicates statistical significance (**p*<0.1; ***p*<0.05; ****p*<0.01).
Noise exposure is an aggregated measure at the SA1 level, indicating whether the local area on average fairly commonly or very commonly experienced noise. H_0 in the endogeneity test is the endogenous variable that can be treated as exogenous, and χ^2 statistics with high values indicate the need to treat the suspected endogenous variables endogenously. H_0 in the relevance test is the excluded instruments that are not relevant, and F statistics with high values indicate relevance. H_0 in the exogeneity test is the excluded instruments that are not exogenous, and χ^2 statistics with low values indicate the validity of the instrument. H_0 in the overidentification test is the instruments that are not overidentified, and Hansen J statistics with low value indicate the validity of the instruments. A higher score in mental health represents better mental health, and a higher score in psychological distress reflects higher psychological distress.
IV, instrument variable; SA1, Statistical Area Level 1.

industry on residents' mental health. It is among the first to substantiate the findings of observational studies with more robust analytical approaches and a large-scale longitudinal data set. An aggregated area-level measure, an IV approach, and a FE model, along with adjustment for time-invariant and time-varying covariates, were applied to reduce bias from residual confounding, selection bias, and measurement error.

The results are consistent with a growing body of studies linking residential environmental noise to negative mental health effects.[3,20,28] The study reveals that the negative mental health effect was driven by loud traffic noise, corroborating findings from recent studies using measured or perceived noise.[15–17] It is also observed that people experiencing frequent noise from both loud traffic and airplanes/trains/industry had particularly poor mental health. Importantly, moving away from frequent noise exposure was associated with improved mental health of respondents. This suggests that measures could be taken to reduce noise in homes for people who live in areas where there are major roads or other sources of noise.

Importantly, we identified significant equity issues with socioeconomically disadvantaged groups being more likely to be exposed to potentially health-harming noise. People in private rental or social housing, living in socioeconomically disadvantaged areas, and with long-term health conditions were more likely to be exposed to noisy residential environments. Uneven distribution of persistent noise exposure will therefore play a role in the maintenance or exacerbation of health inequalities in Australia and internationally.

Given that >70% of Australia's population lives in cities, with a high proportion of noise-emitting infrastructure in urban environments, the potential scale for health improvement is clear. Our study has significant

Table 4. Effects of Self-Reported Exposure to Different Noise Sources on Mental Health

Estimates (95% CI)	Instrumental variables approach (2005–2007, 2010–2012, 2015–2017)	Fixed effects approach (2001–2004, 2006, 2008, 2010, 2012, 2014, 2016, 2018)
(a) Noise from loud traffic only		
Base: low noise exposure at the individual level		
High noise exposure at the individual level	−**0.788***** (−1.068, −0.508)	−**0.316**** (−0.578, −0.055)
Time-invariant and time-varying covariates	√	√
Observations, *n*	110,374	110,267
Correlation (*utiεti*)	**0.039*** **	
Correlation (*θiμi*)	−**0.093*** **	
Test endogeneity of noise (χ^2 statistic)	6.581	
Test IV relevance (F statistic)	39.404	
Test IV exogeneity (χ^2 statistic)	5.000	
Test IV overidentification (Hansen J statistic)	0.181	
(b) Noise from airplanes, trains, or industry only		
Base: low noise exposure at the individual level		
High noise exposure at the individual level	−0.241 (−0.574, 0.091)	−0.108 (−0.420, 0.204)
Time-invariant and time-varying covariates	√	√
Observations, *n*	100,423	100,321
Correlation (*utiεti*)	−0.004	
Correlation (*θiμi*)	−**0.067*** **	
Test endogeneity of noise (χ^2 statistic)	3.897	
Test IV relevance (F statistic)	10.940	
Test IV exogeneity (χ^2 statistic)	5.000	
Test IV overidentification (Hansen J statistic)	1.993	
(c) Noise from airplanes, trains, or industry and loud traffic		
Base: low noise exposure at the individual level		
High noise exposure at the individual level	−**1.903***** (−2.263, −1.542)	−**1.314***** (−1.687, −0.940)
Time-invariant and time-varying covariates	√	√
Observations, *n*	103,643	
Correlation (*utiεti*)	0.024	
Correlation (*θiμi*)	−**0.123*** **	
Test endogeneity of noise (χ^2 statistic)	1.651	
Test IV relevance (Kleibergen-Paap Wald rk F statistic)	33.995	
Test IV exogeneity (χ^2 statistic)	5.000	
Test IV overidentification (Hansen J statistic)	0.605	

Notes: Boldface indicates statistical significance (*$p<0.1$; **$p<0.05$; ***$p<0.01$).
Noise exposure is self-reported, indicating whether the respondent fairly commonly or very commonly experienced noise. H_0 in the endogeneity test is the endogenous variable that can be treated as exogenous, and χ^2 statistics with high values indicate the need to treat the suspected endogenous variables endogenously. H_0 in the relevance test is the excluded instruments that are not relevant, and F statistics with high values indicate relevance. H_0 in the exogeneity test is the excluded instruments that are not exogenous, and χ^2 statistics with low values indicate the validity of the instrument. H_0 in the overidentification test is the instruments that are not overidentified, and Hansen J statistics with low value indicate the validity of the instruments.
IV, instrument variable.

implications for policy makers and urban planners when considering zoning and development proposals to account for the mental health impacts of these decisions.[3] Given that environmental noise regulation is the responsibility of state and local authorities in Australia (with legislation varying across jurisdictions), there are opportunities for greater standardization of regulations, such as the consistent mechanisms associated with zoning and noise limits, or adopting existing guidance detailed in the WHO Environmental Noise Guidelines.[4] Improving building design regulation (through soundproofing and orientation) along with landscaping and barriers around transport infrastructure could further reduce these impacts.

These results contribute to the understanding of the health-harming impacts of residential environmental noise with a large-scale longitudinal national survey for more than 20 years and a causally focused approach to overcoming the high bias risk inherent in previous cross-sectional studies.[13,28,29] The study also has the strength of considering diverse sources of noise to identify the largest noise contributor to worsened mental health. In addition, both individual- and area-level noise exposure measures are included. The methods and results provide a reference for future studies in using self-reported noise and gauging the potential direction of bias. Using microdata over time, changes in mental health with shifts in noise exposure were estimated, which, to the best of our knowledge, has not been identified previously.

Limitations

The study has several limitations. First, lacking exact geocode locations of participants, traditional environmental static measures such as SA1 regions were used to derive the distance to the nearest main roads and train lines through polygon centroids. Other inputs such as traffic volume are often state based and difficult to consolidate. Second, the individual-level noise exposure is self-reported by the respondent rather than measured using a sound pressure level meter or a noise dosimeter. Although subjective perception measures of noise allow for more holistic understandings of neighborhood environment,[19] noise measures derived from finer exposure locations or assessed in decibels will increase the precision and validity of noise measurements. For the estimation of the impacts of changes in noise exposure, results can be subject to reverse causality possibly owing to time-dependent variables. Similarly, future research should utilize more precise noise measurements at the area level. Although being used to minimize bias from self-reporting and selection, the area-level noise measure aggregated from microdata will vary in its ability to describe each person's experience of noise in their home accurately. Third, analyses could further be enhanced with other validated measures of noise annoyance (e.g., International Committee on Biological Effects of Noise scale) and noise (e.g., sound pressure level).[4,30] In addition to noise exposure frequency considered in this study, noise exposure intensity and duration are also important dimensions that should be incorporated in exposure measures in future studies. Fourth, only major residential noise sources were considered, and occupational exposures were excluded. Different noise sources may, individually and in conjunction, impact residents' health and wellbeing. Fifth, the potential confounding of air pollution was not controlled for, although some noise sources such as aircraft noise are less likely to be covarying factors, and studies show that the negative impacts of noise remained after adjusting air pollution.[31] Housing conditions can also be a potential confounding factor and should be included in future studies where data are available. There is evidence that aspects of built environments, such as green spaces, can ameliorate environmental noise.[32] Future work should support the development of solutions to the problem of health-harming noise on the basis of planning and home design.

This study uses the best open-source data currently available at the national scale spanning 20 years in Australia with robust analytical approaches to provide causally focused evidence and redress knowledge gaps informing building standards and urban planning practices. Unlike the European Union's Environmental Noise Directive (2002/49/EC), there is no overarching policy within Australia that requires noise modeling or noise mapping, except for a single code in Queensland (QDC MP4.4). Future research could focus on the development of standardized national data to inform the burden of disease studies and land use planning.

CONCLUSIONS

This study provides evidence on the mental health effects of noise exposure. Although both measuring the quality and quantum of noise and establishing causal pathways to health are complex endeavors, our results suggest that this relationship generates inequitable health outcomes. Given that low socioeconomic populations are more likely to reside in inferior-quality areas, it is critical that noise-related health impacts are addressed with place-based interventions. Public policies and building standards should focus on both retrofitting areas with poor noise profiles and having consistent standards for urban planning and infrastructure design to reduce environmental noise. By adopting an integrated approach between land use planning and transport planning, such measures have the potential to improve the wellbeing of residents and address social health inequalities.

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SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2022.02.020.

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