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The association between road traffic noise and depressed mood among different ethnic and socioeconomic groups. The HELIUS study

Julianna Berthe Leijssen[a,*], Marieke Brigitte Snijder[a,b], Erik Johan Timmermans[c], Ellen Generaal[d,e], Karien Stronks[a], Anton Eduard Kunst[a]

[a] Department of Public Health, Amsterdam UMC, University of Amsterdam, Amsterdam Public Health Research Institute, Meibergdreef 9, PO Box 22660, 1100 DD, Amsterdam, the Netherlands

[b] Department of Clinical Epidemiology, Biostatistics and Bioinformatics, Amsterdam UMC, University of Amsterdam, Amsterdam Public Health Research Institute, Meibergdreef 9, Amsterdam, the Netherlands

[c] Department of Epidemiology and Biostatistics, Amsterdam UMC, VU University Medical Center, Amsterdam Public Health Research Institute, de Boelelaan, 1117, Amsterdam, the Netherlands

[d] Department of Psychiatry, Amsterdam UMC, VU University Medical Center, Amsterdam Public Health Research Institute, de Boelelaan, 1117, Amsterdam, the Netherlands

[e] GGZ InGeest Specialized Mental Health Care, Research and Innovation, Oldenaller 1, Amsterdam, the Netherlands

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ABSTRACT

Background: Although there is growing evidence that depressed mood is affected by road traffic noise, previous results are not fully consistent. Furthermore, to our knowledge, no previous research has assessed ethnic and socioeconomic inequalities in the association of noise exposure with depressed mood.

Objective: To investigate the association between road traffic noise with depressed mood and to determine to what extent this association varies between ethnic and socioeconomic groups.

Method: We investigated cross-sectional data collected between 2011 and 2015 from 23,293 HELIUS participants (18–70 years) living in Amsterdam. Our study included five different ethnic groups (Dutch, Moroccan, Turkish, South-Asian Surinamese and African Surinamese origin). All respondents were linked by their residential postal code to geographic data on road traffic noise levels (24 h noise average in A-weighted decibels [dB(A)]). Noise was categorized into five categories (45–54 dB(A), 55–59 dB(A), 60–64 dB(A), 65–69 dB(A), ≥70 dB(A)) and high noise exposure was defined as noise levels ≥65 dB(A). Depressed mood was defined as a sum-score of ≥10 on the 9-item Patient Health Questionnaire (PHQ-9). Logistic regression was performed to assess the relationship between road traffic noise and depressed mood. Multilevel analyses were used to take into account the clustering of observations within neighbourhoods. Lastly, logistic regression analyses were applied to estimate relative risks for depressed mood per different ethnic and socioeconomic groups exposed to high noise exposure ≥65 dB(A) compared to < 65 dB(A). Analyses were adjusted for individual- and neighbourhood-level confounders.

Results: Exposure to ≥70 dB(A) compared to the reference group of 45–54 dB(A) showed a significant positive association with depressed mood (OR: 1.65, 95% CI 1.10, 2.48). Participants exposed to 60–64 dB(A) showed a significantly lower odds ratio of 0.82 (95% CI 0.70, 0.97) compared to the reference group. We observed no differences between ethnic groups in the association of high noise exposure ≥65 dB(A) with depressed mood. Regarding socioeconomic groups, results were different for the medium-low educated group and unemployed group only.

Conclusion: This study adds new evidence regarding a positive association between high road traffic noise exposure and depressed mood in residential settings. We found no evidence for systematic ethnic or socioeconomic inequalities regarding this association.

* Corresponding author.
E-mail addresses: j.b.leijssen@amc.uva.nl (J.B. Leijssen), m.b.snijder@amc.uva.nl (M.B. Snijder), ej.timmermans@vumc.nl (E.J. Timmermans), E.Generaal@ggzingeest.nl (E. Generaal), k.stronks@amc.uva.nl (K. Stronks), a.kunst@amc.uva.nl (A.E. Kunst).

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1. Introduction

Noise pollution is defined as a distressing noise which can harm humans emotionally, physically and physiologically (Kinsler et al., 2000). Environmental noise is a public health problem and has a great health impact on both individual and community level (World Health Organization, 2011). Previous studies have shown that noise pollution from road, rail, and air traffic is associated with various physical problems, such as type 2 diabetes, ischemic heart disease and hypertension (Dzhambov and Dimitrova, 2018; Heidemann et al., 2014; Vandasova et al., 2016).

Previous studies found an association between noise pollution and mental health problems, such as sleep disorders, noise annoyance and depression (Halonen et al., 2012; Seidler et al., 2017; Wothge et al., 2017). Adverse mental health outcomes due to traffic noise can be explained by its unwanted and annoying character (Basner et al., 2014). Road traffic noise is a constant sound which causes non-auditory effects, such as stress reactions. These stress reactions can arise when noise interferes with individuals' daily tasks, communication, concentration and sleep. When these reactions persist it might cause mental health problems, including depressive symptoms (Lupien et al., 2009).

Depression is a major global burden of disease and the leading cause of disability worldwide (Hyman, 2006). The prevalence increased by 18% between 2005 and 2015, with more than 300 million people worldwide now suffering from depression (World Health Organization, 2017). Depression is associated with an increased risk of mortality due to suicide, but also because of an elevated risk for cardiovascular disease and type 2 diabetes (Knol et al., 2006; Wulsin et al., 1999). In 2010, the economic burden of major depressive disorder was estimated at $210.5 billion, in the United States alone (Greenberg et al., 2015). The causes of depression are complex and include a combination of physical, psychobiological and environmental factors (Kendler et al., 2006). Reciprocal relationships between depression and physical health problems are known. For example, stress, insomnia and cardiovascular disease can increase the risk of depression and vice versa (Abramson et al., 2001; Chen et al., 2017; Chiriboga et al., 2002; Herrick and Sateia, 2016; Kendler et al., 1999; Thomas et al., 2004).

Although there is growing evidence that there is an association between traffic noise and depression, results from previous studies are not fully consistent (Orban et al., 2016; Seidler et al., 2017; Stansfeld et al., 1996). For example, a prospective study among men 50–64 years in Caerphilly, South Wales, found no association between noise exposure and the development of depressive symptoms (Stansfeld et al., 1996). A prospective study in Western Germany found a positive association between traffic noise and the development of depressive symptoms (Orban et al., 2016). Lastly, a recent cross-sectional study conducted around Frankfurt international airport found a positive relation between traffic noise exposure and the risk of a newly diagnosed depression as measured with health insurance fund data (Seidler et al., 2017).

Little is known about the influence of residents' social and economic characteristics on their vulnerability to noise exposure. The effect may differ strongly between residents, depending on the degree to which they are vulnerable to exposure to noise. Previous research indicates that this vulnerability (i.e. noise sensitivity) may depend on residents' psychological characteristics, such as personality traits, pre-existing stress and coping mechanisms (Belojevic et al., 2003; Maris et al., 2007). It may as well depend on the capability for noise abatement, such as having double-paned windows or being able to reside in less noisy compartments (Babisch et al., 2012). Rates of depressive symptoms are found to be higher in ethnic minority groups than in host populations (Bainey and Jugdutt, 2009; Missinne and Bracke, 2012; Stirbu et al., 2006), but the association of noise exposure with depressive symptoms within these different groups is still unclear. A study conducted in the United States of America showed higher environmental noise levels among socioeconomically disadvantaged groups (Casey et al., 2017). A second study, conducted in Germany showed that insomnia odds tended to be increased by 11 per cent per year in less educated participants under high exposure to noise (Riedel et al., 2012). Another study found the association between road traffic noise > 50 dB(A) and depressive symptoms to be positive in low-educated participants, but negative in high-educated participants (Orban et al., 2016).

By using data from the Healthy Life in an Urban Setting (HELIUS) study, we were able to investigate a large sample of nearly 24,000 participants from different ethnic groups, with a wide range of age and of various socioeconomic (SES) positions in Amsterdam, the Netherlands. The aim of our study was (1) to obtain further evidence on the association between noise exposure and depressed mood and (2) to investigate potential differences in the association of noise exposure with depressed mood between ethnic and socioeconomic groups.

2. Methods

2.1. Study sample and design

Baseline data of the HELIUS study were obtained between 2011 and 2015, as previously described (Snijder et al., 2017; Stronks et al., 2013). In brief, the HELIUS study included nearly 25,000 men and women residing in Amsterdam, of Dutch, Surinamese, Ghanaian, Turkish and Moroccan ethnic origin. Participants aged 18–70 years were randomly sampled, stratified by ethnicity, from the municipal population register of Amsterdam. Potential participants were sent an invitation letter (and a reminder after 2 weeks) by mail. We were able to contact 55% (n = 49,952) of those invited (55% among Dutch, 62% among Surinamese, 46% among Turks, 48% among Moroccans, 57% among Ghanaians), either by response card or after a home visit by an ethnically-matched interviewer (Snijder et al., 2017). Of those, about 50% (n = 24,789) agreed to participate (participation rate; 60% among Dutch, 51% among Surinamese, 41% among Turks, 43% among Moroccans, 61% among Ghanaians). After a positive response, participants received a confirmation letter of the appointment for the physical examination, including a digital or paper version of the questionnaire (depending on the preference of the subject). Participants who were unable to complete the questionnaire themselves were offered assistance from a trained ethnically-matched interviewer. All who filled in the questionnaire were selected for this study (n = 23,942). We excluded all participants with missing data regarding depressive symptoms (n = 247) and noise exposure (n = 38). In addition, we excluded participants with missing data on educational level (n = 159) and occupational status (n = 205), which provided a total of 23,293 participants. The HELIUS study has been approved by the Institutional Review Board of the Academic Medical Center, University of Amsterdam.

2.2. Assessment of depressed mood

In HELIUS, the 9-item Patient Health Questionnaire (PHQ-9) was used to measure depressive symptoms (Kroenke et al., 2010). Its cross-cultural validity has been demonstrated across the ethnic groups included in the HELIUS study (Galenkamp et al., 2017). The PHQ-9 determines the prevalence of depressive symptoms over the preceding two weeks. It consists of nine items, with a response scale varying from never (0) to nearly every day (3). Individual scores were summed to a total score ranging from 0 to 27 points. If one of the nine items was missing, the mean score of the other eight items was used to replace the missing item. If more than one item was missing, the variable was considered missing. Participants having a sum-score of 10 or higher were considered to have a 'depressed mood' (Kroenke et al., 2010).

2.3. Linked geographic data

Nationwide data on noise exposure and other neighbourhood characteristics were retrieved from national registration organisations, initiated by the Geoscience and Health Cohort Consortium and linked to individual-level cohort data using postal code information from HELIUS participants at the level of 6-digit postcodes (Snijder et al., 2017; Timmermans et al., 2018). A 6-digit postcode area is the smallest geographical unit available in the Netherlands with an average of 50 by 50 m in size and include 10–20 households. All other neighbourhood variables (income, liveability, green and blue space) were linked at the level of 4-digit postcodes, with an average area size of 2.5 km^2.

2.4. Assessment of noise exposure

The Netherlands Environmental Assessment Agency modelled daily average noise levels on road-traffic for the year 2011 in the Netherlands by using the Empara Noisetool with a resolution of 25 by 25 m. Noise is measured in Level day-evening-night (Lden) and is expressed in A-weighted decibels (dB(A)) rounded to two decimals. The measure Lden accounts for the fact that noise in the evening and at night is reported as more annoying than during the day (Wirth et al., 2004). The average noise levels during the day (07:00–19:00), the evening (19:00–23:00) and at night (23:00–07:00) were calculated first and the levels of noise in the evening and at night were increased by 5 and 10 dB(A) respectively. Subsequently, the daily mean noise was calculated as the average of the noise levels during the day, evening and night (The Netherlands Environmental Assessment Agency (PBL), 2008). The address-level road traffic noise data were aggregated to mean values of 6-digit postal code areas (Timmermans et al., 2018). Noise was categorized into five different categories (45–54 dB(A), 55–59 dB(A), 60–64 dB (A), 65–69 dB(A), ≥70 dB(A)). In addition, high noise exposure was defined as annual mean 24-hr noise levels ≥65 dB(A) according to the criteria of OECD (Organization for Economic Cooperation and Development, 1991).

2.5. Covariates

We collected data on potential confounders, which we defined as variables that may have influenced both participants' risk of depressive mood and their preference for specific places of residence. These include variables both at the individual-level (age, sex, SES, ethnicity, marital status, household composition, neuroticism, and stressful life events) and at the neighbourhood-level (neighbourhood-level SES, blue/green space, and liveability). Lifestyle factors, such as smoking, alcohol consumption and physical activity, were not included as covariates in this study, since it is more likely that they are influenced by depressed mood rather than the other way around (Walsh, 2013). Individual-level SES variables included educational level (Low: no schooling or elementary schooling only, Medium-low: lower vocational schooling or lower secondary schooling, Medium-high: intermediate vocational schooling or intermediate/higher secondary schooling, High: higher vocational schooling or university) and occupational status (Unemployed: no job and/or on social security, Disabled: participants with incapacity for work, Not in labour force: retired participants, students at school/university, and housemen/house women, Employed: fulltime or part-time job). Ethnicity included participants with Dutch, Moroccan, Turkish and Surinamese (South-Asian and African) origin and was defined according to the country of birth of the participants and their parents (Stronks et al., 2009). More specifically, a person was defined as of non-Dutch ethnic origin if he/she fulfilled one of two criteria: (1) he/she was born outside the Netherlands and has at least one parent born outside the Netherlands (first generation) or (2) he/she was born in the Netherlands but both parents were born outside the Netherlands (second generation). For the Dutch sample, we invited people who were born in the Netherlands and whose parents were born in the Netherlands. Of the Surinamese living in the Netherlands, approximately 80% are either of African or South-Asian origin. After data collection, self-reported ethnicity was used to further classify participants of Surinamese ethnic origin into 'African', 'South-Asian', 'Javanese' or 'other/unknown' Surinamese origin (such as Chinese, Brazilian, Portuguese, or mixed origins, not including an African origin) (Snijder et al., 2017; Stronks et al., 2009). Because the Ghanaian group (n = 2.357) had too low prevalence of high noise exposure ≥65 dB(A) and the Javanese Surinamese group (n = 247), the other/unknown Surinamese group (n = 274) and other/unknown ethnicity group (n = 47) were too small to perform stratified analyses, we combined them into one group of 'other' ethnic origin. The NEO Five-Factor inventory (NEO-FFI) and the NEMESIS-II questionnaires were used to measure neuroticism (continuous variable) and stressful life events (categorical variable), respectively (Trull and Sher, 1994). Marital status was categorized as married/registered partnership, living together, unmarried, divorced, widow/widower. Household composition was defined as living with children younger than 18 years old.

Neighbourhood-level SES consisted of the average income per income recipient in a particular neighbourhood (Statistics Netherlands (CBS), 2015). Liveability was measured using a liveability total score that was based on 49 indicators related to six dimensions: population composition, social cohesion, public space, safety, level of resources and housing. The total liveability score ranges from 1 (extremely negative) to 7 (extremely positive) (The Netherlands Ministry of the Interior and Kingdom Relations, 2008). Finally, adjustments were made for blue space (inland water, sea and lakes) and green space (urban parks, agricultural areas, forest and nature) area, measured as the percentage of blue/green area per neighbourhood. We included the latter two variables in the analyses to adjust for specific environmental characteristics that might influence both mental wellbeing and residential preferences of the participants (de Vries et al., 2016; Gidlof-Gunnarsson and Ohrstrom, 2007).

2.6. Statistical analysis

We applied logistic regression analyses to assess the relationship between road traffic noise exposure and depressed mood. We first adjusted for age and sex (Model A). Additional adjustments were made on individual-level, including educational level, occupational status, ethnic origin, marital status, household composition, neuroticism and stressful life events (Model B). Finally, additional adjustments were made on neighbourhood-level, including socioeconomic status, blue/green space and liveability (Model C). We used multilevel techniques to take into account the clustering of observations within the same neighbourhood by adding the neighbourhood code as random intercept to the multilevel models. This neighbourhood code consisted of 10 districts (large districts: on average 1.8 km^2) and 60 neighbourhoods (small districts: on average 0.4 km^2). We stratified the analyses by socioeconomic and ethnic groups and used logistic regression analyses to calculate the odds ratio for depressed mood per group, for those exposed to ≥65 dB(A) compared to those exposed to < 65 dB(A). To test for the statistical significance of ethnic differences in the association, we repeated the logistic regression analyses while adding interaction terms of noise levels with ethnicity to our model. In a similar way we tested for differences in the association by educational level and by occupational status in separate models.

Multilevel analyses were conducted with R Statistical Software. All other analyses were performed with SPSS statistic 24.0 (IBM Corp, Armonk, New York, United States of America).

3. Results

3.1. Socio-demographic characteristics

Results regarding individual and neighbourhood characteristics of the study sample are shown in Table 1a. A total of 23,293 residents of Amsterdam were included in this study, with a mean age of 44 years. 14.8% of the study sample reported depressed mood (men = 11.7% and

Table 1a
Individual and neighbourhood characteristics of the total study population, and prevalence of depressed mood (PHQ-9 sum-score ≥ 10) and mean PHQ-9 sum-score (range: 0–27).

Characteristic	Total n	Prevalence of depressed mood, %	Prevalence of depressive symptoms, mean (SD)
Total	23293	14.8	4.72 (5.20)
Sex			
Men	9920	11.7	4.05 (4.98)
Women	13373	17.1	5.22 (5.30)
Age			
18–29	4425	15.2	5.12 (4.87)
30–39	4215	14.4	4.91 (5.08)
40–49	5676	16.1	4.88 (5.46)
50–59	6018	15.7	4.65 (5.40)
≥60	2959	10.1	3.70 (5.20)
Ethnic group			
Dutch	4594	7.2	3.58 (3.74)
Moroccan	4200	20.6	5.79 (5.71)
Turkish	3939	23.1	6.31 (5.99)
South-Asian Surinamese	3293	18.6	5.37 (5.84)
African Surinamese	4342	10.5	3.85 (4.54)
Other*	2925	9.2	3.40 (4.34)
Education			
Low	4047	21.9	5.75 (6.01)
Medium-low	6195	15.9	4.80 (5.50)
Medium-high	6970	15.0	4.83 (5.12)
High	6081	8.6	3.82 (4.14)
Occupation			
Unemployed	3348	25.1	6.38 (6.28)
Disabled	1793	36.6	8.41 (7.02)
Not in labour force	4147	14.2	4.69 (4.98)
Employed	14005	9.7	3.86 (4.33)

* Other include: the Ghanaian group (n = 2.357), the Javanese Surinamese group (n = 247), the other/unknown Surinamese group (n = 274) and other/unknown ethnicity group (n = 47).

Table 1b
Area-level characteristics with Spearman's Rank Correlation Coefficient for neighbourhood characteristics and depressed mood and traffic noise.

Characteristic	Mean	SD	Correlation with traffic noise (Spearman's ρ)	Correlation with depressed mood (Spearman's ρ)
Neighbourhood SES	28.7	6.7	**.15**	**-.04**
Neighbourhood Liveability	3.8	0.8	**.28**	**-.02**
Neighbourhood space				
Blue space	10.7	9.6	-.00	-.01
Green space	18.6	12.5	**-.28**	-.00

Correlation between neighbourhood characteristics, traffic noise and depressed mood. Estimates with p value < 0.01 are highlighted in bold.

women = 17.1%). The prevalence of depressed mood was lowest in the higher than 60 years age group (10.1%). The prevalence of depressed mood varied from 8.6% in high-educated to 21.9% in low-educated. Participants incapable of working showed highest depressed mood rates (36.6%), while those employed reported the lowest (9.7%). Turkish, Moroccan and South-Asian Surinamese origin groups showed much higher prevalence of depressed mood as compared to the Dutch origin group (Table 1a). Neighbourhood income and liveability were both negatively correlated to depressed mood, whereas blue and green space showed no correlation (Table 1b).

3.2. Noise exposure among different ethnic and socioeconomic groups

Table 2 shows the road traffic noise levels at the residents' homes for the whole study sample and for different ethnic and socioeconomic groups. Most participants (46.6%) were exposed to traffic noise in the range of 55–59 dB(A), while only 1.2% of the study population was exposed to ≥70 dB(A). In general, the Dutch population was exposed to higher noise levels more often than other ethnic groups, while the South-Asian Surinamese group showed least exposure to higher noise levels. The high-educated group was on average exposed to higher noise levels than the other education groups. No statistical evidence was found for differences in noise exposure between different occupational status groups.

3.3. Traffic noise levels in relation to depressed mood

Prevalence rate of depressed mood per noise level category is presented in Table 3. The prevalence of depressed mood was 14.8% at lowest noise level (45–54 dB(A)), compared to 20.6% at the highest noise levels ≥70 dB(A). The results of the multilevel logistic regression analyses showed an odds ratio of 1.65 (95% CI 1.10, 2.48) for depressed mood in participants exposed to the highest noise level compared to the lowest noise level group after full adjustment (Model C). Furthermore, participants exposed to 65–69 dB(A) showed an non-significantly higher odds ratio of 1.07 (95% CI 0.85, 1.36) compared to the reference group (Model C). Participants exposed to 60–64 dB(A) showed a significantly lower odds ratio of 0.82 (95% CI 0.70, 0.97) compared to the reference group (Model C). In general, odds ratios decreased by adjusting for individual-level covariates (Model B), and remained stable by adjusting for neighbourhood-level covariates (Model C).

Approximately 1% or less (small district ICC: 0.002 and large district ICC: < 0.001) of depressed mood rates in the population are explained by district-level effects.

3.4. Stratification by ethnicity and socioeconomic status

For specific ethnic and socioeconomic groups, we assessed the association between depressed mood and exposure to noise levels exceeding ≥65 dB(A). The total study population showed a statistical significant positive association (OR: 1.25, 95% CI 1.03, 1.52) (Table 4). Positive associations were observed for all ethnic minority groups, contrary to a slightly negative association for participants of Dutch origin (OR: 0.91, 95% CI 0.55, 1.50) (Table 4). However, none of these associations were statistically significant. We found a negative but non-significant association in high-educated participants (OR: 0.93, 95% CI 0.60, 1.45), compared to a statistical significant positive association for the medium-low educated group (OR: 1.59, 95% CI 1.07, 2.35). Lastly, we e found a statistical significant association for the unemployed (OR: 1.63, 95% CI 1.05, 2.54). We should however note that these variations should be interpreted with caution as 95% confidence intervals overlap. Additional analyses based on interaction terms showed that the variations between ethnic or socioeconomic groups cannot be demonstrated with statistical significance after full adjustments (Tables A1).

4. Discussion

4.1. Summary of results

Although there is growing evidence that depressed mood is affected by traffic noise, previous results are not fully consistent. In this study, exposure to noise levels ≥70 dB(A) was associated with higher prevalence of depressed mood, compared with the lowest noise levels (45–54 dB(A)). Participants exposed to medium-level noise (60–64 dB (A)) showed a significantly lower odds of depressed mood as compared to the lowest noise group. Except for statistical significant positive results in the medium-low educated group and the unemployed occupational group, we observed no substantial or significant differences between subgroups in the association of high noise exposure with depressed mood.

Table 2
Road traffic noise exposure in 2011 in the total study sample (n = 23,293) and by ethnic and socioeconomic groups.

Traffic noise exposure (%)	45–54 dB(A)	55–59 dB(A)	60–64 dB(A)	65–69 dB(A)	≥70 dB(A)
Total	30.9	46.6	16.4	4.7	1.2
Ethnicity					
Dutch	25.6	42.6	21.7	7.3	2.7
Moroccan	25.1	48.7	19.2	5.8	1.2
Turkish	28.4	47.6	17.3	5.3	1.4
South-Asian Surinamese	37.5	45.7	13.3	3.0	0.5
African Surinamese	34.5	46.8	14.8	3.5	0.4
Other	38.5	50.1	9.1	2.0	0.4
Education					
Low	30.1	48.0	16.3	4.6	0.9
Medium-low	33.7	48.3	13.4	3.7	0.8
Medium-high	31.2	47.5	16.0	4.4	0.9
High	28.4	43.4	20.1	6.1	2.1
Occupation					
Unemployed	29.3	49.4	16.0	4.3	1.0
Disabled	30.2	50.9	13.7	4.1	1.2
Not in labour force	28.7	47.3	17.6	5.1	1.3
Employed	32.1	45.4	16.5	4.8	1.2

Percentages represent prevalences within ethnic and socioeconomic groups.

Table 3
The association of different levels of noise exposure from road traffic with depressed mood (PHQ-9 sum-score ≥10) in the total study sample (n = 23,293).

Exposure	Prevalence of depressed mood (%)	Model A[a] OR [95%-CI]	Model B[b] OR [95%-CI]	Model C[c] OR [95%-CI]
Multi- level[d]				
45–54 dB(A)	14.8	1.00	1.00	1.00
55–59 dB(A)	15.0	1.01 [0.92, 1.10]	0.94 [0.84, 1.04]	0.94 [0.84, 1.06]
60–64 dB(A)	13.4	**0.87 [0.77, 0.99]**	**0.82 [0.71, 0.94]**	**0.82 [0.70, 0.97]**
65–69 dB(A)	15.7	1.08 [0.89, 1.30]	1.02 [0.82, 1.28]	1.07 [0.85, 1.36]
≥70 dB(A)	20.6	**1.71 [1.25, 2.35]**	**1.63 [1.10, 2.41]**	**1.65 [1.10, 2.48]**
Measures of variation				
Small district Variance (SD)		0.040 (0.199)	0.008 (0.090)	0.008 (0.092)
Large district Variance (SD)		0.040 (0.200)	0.000 (0.000)	0.000 (0.000)
Small district ICC[e]		0.002	0.002	0.002
Large district ICC[e]		0.000	0.000	0.000

[a] Adjusted for age and sex.
[b] Model A plus additional adjustments for individual characteristics (ethnic origin, educational level, occupational status, marital status, household composition, neuroticism and stressful life events).
[c] Model B plus additional adjustments for neighbourhood characteristics (socioeconomic status, blue/green space and liveability).
[d] Large districts (n = 10) and small districts (n = 60).
[e] Intraclass Correlation Coefficient. Estimates with p value < 0.05 are highlighted in bold.

4.2. Evaluation of study limitations

By using data from the Healthy Life in an Urban Setting (HELIUS) study, we were able to investigate a large sample of nearly 23,293 participants from six different ethnic groups, with a wide range of age and large socioeconomic variation. With our data we were able to adjust for several individual and neighbourhood characteristics, including marital status, household composition, neuroticism, stressful life events and blue/green space, which may have reduced the impact of confounding bias in our results.

Nonetheless, this study has some limitations. First, this study used cross-sectional data, whereby the temporal association between traffic noise exposure and depressed mood could not be ascertained. Second, we used noise exposure assessment regarding noise from road traffic only. Aircraft, railway or other environmental noise sources were not included in our analyses. Nonetheless, road traffic noise is the most widespread source of environmental noise pollution in European cities, including Amsterdam (European Environment Agency, 2017; Municipality of Amsterdam, 2016). Furthermore, the results of our multilevel analyses showed that neighbourhood characteristics, thus including all other noise sources, explain only 1% of the variation in depressed mood rates. Even though air traffic to the Schiphol airport, which is the main international airport of the Netherlands and located near Amsterdam, might affect mental health of residents in some city districts, the small amount of unexplained geographic variation in our study implies that this is unlikely to have biased our results. Third, we did not have all information about factors that may have influenced respondents' sensitivity to noise exposure. This includes information on hearing abilities of participants, their exposure to occupational noise or the time they spent at their residence. Neither did we have information about relevant housing conditions, such as insulation of the house, thickness of the windows or location of the bedroom within the residence.

4.3. Interpretation of results

Our findings demonstrate that exposure to higher noise levels is more common among Dutch origin participants and high-educated participants, compared to other ethnic and socioeconomic groups. These results are in contrast with several previous studies, which showed higher noise level exposure in ethnic minority and lower socioeconomic groups (Braubach and Fairburn, 2010; Casey et al., 2017;

Table 4
The prevalence of depressed mood by high (≥65 dB) or low (< 65 dB) noise exposure, and the association (odds ratio, OR) of high noise exposure with depressed mood for different ethnic and socioeconomic groups.

	Total and exposed to ≥65 dB(A) (n)		Prevalence of depressed mood (%)		Depressed mood ≥65 dB(A)
	Total	≥65 dB(A)	≥65 dB(A)	< 65 dB(A)	OR[a]
Total	23.293	1.376	16.6	14.7	**1.25 [1.03, 1.52]**
Ethnicity					
Dutch	4594	463	6.7	7.2	0.91 [0.55, 1.50]
Moroccan	4200	293	25.3	20.2	1.34 [0.93, 1.95]
Turkish	3939	266	24.4	23.0	1.26 [0.87, 1.83]
South-Asian Surinamese	3293	114	27.2	18.3	1.47 [0.80, 2.71]
African Surinamese	4342	171	10.5	10.5	1.07 [0.57, 2.00]
Education					
Low	4047	223	26.9	21.6	1.20 [0.80, 1.79]
Medium-low	6195	282	20.2	15.7	**1.59 [1.07, 2.35]**
Medium-high	6970	372	19.4	14.8	1.29 [0.90, 1.83]
High	6081	499	8.0	8.6	0.93 [0.60, 1.45]
Occupation					
Unemployed	3348	179	35.8	24.5	**1.63 [1.05, 2.54]**
Disabled	1793	94	40.4	36.4	1.14 [0.65, 1.99]
Not in labour force	4147	266	18.4	13.9	1.35 [0.90, 2.04]
Employed	14005	837	9.3	9.7	1.07 [0.79, 1.44]

The group "other" is excluded because of too few people exposed to high levels of noise exposure.
Bold indicates P = < 0.05.
[a] Using logistic regression analyses adjusted for age, sex, ethnicity, socioeconomic status, marital status, household composition, neuroticism, stressful life events, neighbourhood socioeconomic status, blue/green space and liveability.

Kohlhuber et al., 2006; Orban et al., 2016). However, our results are in line with a study conducted in Paris, which showed that people living in advantaged neighbourhoods were more exposed to road traffic noise in their residential environment than their deprived counterparts (Havard et al., 2011). In Amsterdam, lower socioeconomic and ethnic minority groups mainly live in the suburbs with less road traffic (Savini et al., 2016). The most affluent areas, such as the city center and southern city part are primarily occupied by people with Dutch background and high socioeconomic status, and are known for their heavy road traffic (Savini et al., 2016). A previous study conducted in Amsterdam showed that residents with high economic status were able to satisfy their need for a relaxing residential environment by creating quiet places inside and around their houses (Booi & Van den Berg, 2012).

In this study we found a J-shaped pattern in the association between road traffic noise and depressed mood. We found a positive association for noise levels ≥65 dB(A), compared to the lowest noise exposure group. However, exposure to 55–59 dB(A) and 60–64 dB(A) was associated with lower risk of depressed mood compared to the lowest noise level group. Results from previous research show different patterns for the association between road traffic noise and depressed mood (Orban et al., 2016; Seidler et al., 2017). Seidler et al. (2017) found a linear trend for road traffic noise exposure, whereas Orban et al. (2016) showed a reversed U-shape, with higher depressive symptoms in the intermediate compared to the lowest and highest noise exposure group. It is uncertain why, in our particular case, the group with lowest noise exposure had a higher risk of depressive mood than those exposed to intermediate noise levels. Possibly, this may reflect a selection effect. If residents with strong needs for quietness, including those with mental health problems, are more likely to move to more quiet places, this could result in accumulation of people with depressed mood in quiet neighbourhoods (Cao, 2014). Another explanation might be related to the self-protection against noise pollution. In case of chronic exposure to high ambient noise, residents might undertake protective strategies, such as moving their bedroom in de back of the house, using better insulation for the house, and regularly moving to other areas for rest and recreation. (Stansfeld and Matheson, 2003). Such strategies might be applied particularly by high income groups living in the highly traffic areas of the center and the south. Our J-shaped patterns suggest that such self-protection might, however, no longer work when exposure reaches very high noise levels.

A prospective study found a strong association between residential road traffic noise > 50 dB(A) and high depressive symptoms in participants with a low educational level and a weak negative association in high-educated participants (Orban et al., 2016). In our study we observed the same trend in the association between high noise levels (≥65 dB(A)) and depressed mood in the medium-low and high-educated groups, respectively.

Our study also shows a stronger positive association between high noise exposure and depressed mood in unemployed participants as compared with employed participants. The fact that we found a higher risk in unemployed participants might be explained by their increases vulnerability to noise exposure due to pre-existing stress and less coping mechanisms (Belojevic et al., 2003; D'Arcy and Siddique, 1985). Moreover, unemployed participants are inclined to spent more time indoors (Scanlan et al., 2011) and previous study found that hours spent at home during the day was a potential effect modifier on the association between aircraft noise exposure and noise annoyance (Babisch et al., 2012), which might suggest the same applies to road traffic noise as measured in our study.

Furthermore, to our knowledge, this is the first study that has assessed the association of noise exposure from road traffic with depressed mood among different ethnic groups. Ethnic minority groups did not show significantly stronger associations for depressed mood comparing noise exposure ≥65 dB(A) with < 65 dB(A). However, we should note that most ethnic minority groups have a substantially higher prevalence of depressive mood, such that the same percentage impact of noise exposure would imply a larger increase in absolute risks. Thus, in absolute terms, noise exposure might affect a greater number of people in ethnic minority groups than in the native origin population.

5. Conclusion

To conclude, our study added new evidence for a positive association between depressed mood and high road traffic noise exposure in residential settings. We found no evidence that this association systematically differed according to socioeconomic status or ethnic minority status. Further studies are needed to replicate the latter finding. If confirmed by future studies, this association implies that noise pollution control can contribute to the prevention of depressed mood amongst all urban citizens.

Competing financial interests

None.

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Appendix

Table A1
The association between noise exposure ≥65 dB(A) and depressed mood, interacting by ethnicity.

Exposure	Model A[1] OR [95%-CI]	Model B[2] OR [95%-CI]	Model C[3] OR [95%-CI]
Dutch	1.00	1.00	1.00
Moroccan	3.23 [2.80, 3.73]	1.91 [1.59, 2.29]	1.83 [1.50, 2.23]
Turkish	3.92 [3.40, 4.52]	2.49 [2.07, 3.00]	2.40 [1.97, 2.94]
South-Asian Surinamese	2.91 [2.51, 3.37]	1.60 [1.34, 1.92]	1.53 [1.25, 1.88]
African Surinamese	1.47 [1.26, 1.71]	0.98 [0.81, 1.19]	0.96 [0.78, 1.18]
Other	1.25 [1.05, 1.49]	0.95 [0.76, 1.17]	0.96 [0.76, 1.22]
N ≥ 63 dB(A) *DU	1.00	1.00	1.00
N ≥ 63 dB(A) *MOR	1.41 [0.88, 2.26]	1.30 [0.75, 2.27]	1.35 [0.76, 2.40]
N ≥ 63 dB(A) *TUR	1.16 [0.72, 1.88]	1.48 [0.84, 2.59]	1.49 [0.83, 2.66]
N ≥ 63 dB(A) *SA-SUR	1.76 [1.00, 3.12]	1.70 [0.85, 3.41]	1.71 [0.83, 3.54]
N ≥ 63 dB(A) *AFR-SUR	1.07 [0.57, 2.01]	1.02 [0.50, 2.10]	1.14 [0.54, 2.38]
N ≥ 63 dB(A) *OTH	1.91 [0.87, 4.18]	**3.37 [1.39, 8.22]**	**3.31 [1.30, 8.42]**

[1] Adjusted for age and sex.
[2] Model A plus additional adjustments for individual characteristics (ethnic origin, educational level, occupational status, marital status, household composition, neuroticism and stressful life events).
[3] Model B plus additional adjustments for neighbourhood characteristics (socioeconomic status, blue/green space and liveability).

Table A2
The association between noise exposure ≥65 dB(A) and depressed mood, interacting by educational level.

Exposure	Model A[1] OR [95%-CI]	Model B[2] OR [95%-CI]	Model C[3] OR [95%-CI]
Low	1.00	1.00	1.00
Middle-low	0.69 [0.62, 0.76]	0.96 [0.83, 1.10]	0.96 [0.82, 1.11]
Middle-high	0.58 [0.52, 0.64]	1.04 [0.90, 1.20]	1.04 [0.89, 1.21]
High	0.32 [0.29, 0.37]	0.84 [0.71, 1.00]	0.82 [0.69, 0.99]
N ≥ 65 dB(A) *LOW	1.00	1.00	1.00
N ≥ 65 dB(A) *M-LOW	1.01 [0.66, 1.55]	1.22 [0.70, 2.11]	1.26 [0.72, 2.20]
N ≥ 65 dB(A) *M-HIGH	1.01 [0.68, 1.52]	1.12 [0.67, 1.89]	1.05 [0.61, 1.79]
N ≥ 65 dB(A) *HIGH	0.68 [0.43, 1.07]	0.78 [0.45, 1.36]	0.77 [0.43, 1.36]

Table A3
The association between noise exposure ≥65 dB(A) and depressed mood, interacting by occupational status.

Exposure	Model A[1] OR [95%-CI]	Model B[2] OR [95%-CI]	Model C[3] OR [95%-CI]
Unemployed	1.00	1.00	1.00
Disabled	1.89 [1.66, 2.15]	1.53 [1.29, 1.80]	1.56 [1.31, 1.86]
Not in labor force	0.45 [0.40, 0.51]	0.63 [0.54, 0.74]	0.64 [0.54, 0.76]
Employed	0.32 [0.29, 0.36]	0.65 [0.57, 0.74]	0.67 [0.58, 0.76]
N ≥ 65 dB(A) *UNEMP	1.00	1.00	1.00
N ≥ 65 dB(A) *INCAP	0.71 [0.42, 1.20]	0.81 [0.41, 1.61]	0.78 [0.39, 1.56]
N ≥ 65 dB(A) *NILF	0.84 [0.53, 1.32]	0.75 [0.42, 1.33]	0.83 [0.46, 1.49]

(*continued on next page*)

Table A3 (*continued*)

Exposure	Model A[1] OR [95%-CI]	Model B[2] OR [95%-CI]	Model C[3] OR [95%-CI]
N ≥ 65 dB(A) *EMP	**0.53 [0.36, 0.80]**	**0.58 [0.35, 0.94]**	0.62 [0.37, 1.03]

[1] Adjusted for age and sex.
[2] Model A plus additional adjustments for individual characteristics (ethnic origin, educational level, occupational status, marital status, household composition, neuroticism and stressful life events).
[3] Model B plus additional adjustments for neighbourhood characteristics (socioeconomic status, blue/green space and liveability).

Table A4
The association between noise exposure ≥65 dB(A) and depressed mood, interacting by age.

Exposure	Model A[1] OR [95%-CI]	Model B[2] OR [95%-CI]	Model C[3] OR [95%-CI]
18–29	1.00	1.00	1.00
30–39	0.93 [0.82, 1.05]	0.78 [0.67, 0.92]	0.77 [0.65, 0.92]
40–49	1.07 [0.96, 1.20]	0.78 [0.67, 0.91]	0.80 [0.68, 0.95]
50–59	1.03 [0.92, 1.15]	0.62 [0.53, 0.73]	0.63 [0.53, 0.75]
60–70	0.63 [0.54, 0.73]	0.40 [0.30, 0.45]	0.39 [0.32, 0.49]
N ≥ 65 dB(A)*18-29	1.00	1.00	1.00
N ≥ 65 dB(A)*30-39	1.21 [0.76, 1.93]	1.29 [0.73, 2.28]	1.46 [0.81, 2.62]
N ≥ 65 dB(A)*40-49	1.13 [0.72, 1.78]	1.11 [0.64, 1.93]	1.20 [0.67, 2.13]
N ≥ 65 dB(A)*50-59	1.47 [0.96, 2.25]	1.42 [0.84, 2.39]	1.54 [0.90, 2.65]
N ≥ 65 dB(A)*60-70	1.34 [0.77, 2.32]	1.23 [0.63, 2.41]	1.33 [0.67, 2.64]

[1] Adjusted for age and sex.
[2] Model A plus additional adjustments for individual characteristics (ethnic origin, educational level, occupational status, marital status, household composition, neuroticism and stressful life events).
[3] Model B plus additional adjustments for neighbourhood characteristics (socioeconomic status, blue/green space and liveability).

Table A5
The association between noise exposure ≥65 dB(A) and depressed mood, interacting by gender.

Exposure	Model A[1] OR [95%-CI]	Model B[2] OR [95%-CI]	Model C[3] OR [95%-CI]
Men	1.00	1.00	1.00
Women	1.57 [1.45, 1.70]	1.33 [1.20, 1.47]	1.38 [1.24, 1.53]
N ≥ 65 dB(A) *MEN	1.00	1.00	1.00
N ≥ 65 dB(A) *WOMEN	0.85 [0.63, 1.15]	0.71 [0.49, 1.04]	0.69 [0.47, 1.02]

[1] Adjusted for age and sex.
[2] Model A plus additional adjustments for individual characteristics (ethnic origin, educational level, occupational status, marital status, household composition, neuroticism and stressful life events).
[3] Model B plus additional adjustments for neighbourhood characteristics (socioeconomic status, blue/green space and liveability).

References

Abramson, J., Berger, A., Krumholz, H.M., Vaccarino, V., 2001. Depression and risk of heart failure among older persons with isolated systolic hypertension. Arch. Intern. Med. 161 (14), 1725–1730.

Babisch, W., Swart, W., Houthuijs, D., Selander, J., Bluhm, G., Pershagen, G., ... Hansell, A.L., 2012. Exposure modifiers of the relationships of transportation noise with high blood pressure and noise annoyance. J. Acoust. Soc. Am. 132 (6), 3788–3808. https://doi.org/10.1121/1.4764881.

Bainey, K.R., Jugdutt, B.I., 2009. Increased burden of coronary artery disease in South-Asians living in North America. Need for an aggressive management algorithm. Atherosclerosis 204 (1), 1–10. https://doi.org/10.1016/j.atherosclerosis.2008.09.023.

Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., Stansfeld, S., 2014. Auditory and non-auditory effects of noise on health. Lancet 383 (9925), 1325–1332. https://doi.org/10.1016/s0140-6736(13)61613-x.

Belojevic, G., Jakovljevic, B., Slepcevic, V., 2003. Noise and mental performance: personality attributes and noise sensitivity. Noise Health 6 (21), 77–89.

Booi, H., Van den Berg, F., 2012. Quiet areas and the need for quietness in Amsterdam. Int. J. Environ. Res. Publ. Health 9 (4), 1030–1050. https://doi.org/10.3390/ijerph9041030.

Braubach, M., Fairburn, J., 2010. Social inequities in environmental risks associated with housing and residential location–a review of evidence. Eur. J. Publ. Health 20 (1), 36–42. https://doi.org/10.1093/eurpub/ckp221.

Cao, J., 2014. Residential Self-selection in the Relationships between the Built Environment and Travel Behavior: Introduction to the Special Issue, vol. 7.

Casey, J.A., Morello-Frosch, R., Mennitt, D.J., Fristrup, K., Ogburn, E.L., James, P., 2017. Race/ethnicity, socioeconomic status, residential segregation, and spatial variation in noise exposure in the contiguous United States. Environ. Health Perspect. 125 (7), 077017. https://doi.org/10.1289/ehp898.

Chen, P.J., Huang, C.L., Weng, S.F., Wu, M.P., Ho, C.H., Wang, J.J., ... Hsu, Y.W., 2017. Relapse insomnia increases greater risk of anxiety and depression: evidence from a population-based 4-year cohort study. Sleep Med. 38, 122–129. https://doi.org/10.1016/j.sleep.2017.07.016.

Chiriboga, D.A., Black, S.A., Aranda, M., Markides, K., 2002. Stress and depressive symptoms among Mexican American elders. J. Gerontol. B Psychol. Sci. Soc. Sci. 57 (6), P559–P568.

D'Arcy, C., Siddique, C.M., 1985. Unemployment and health: an analysis of "Canada Health Survey" data. Int. J. Health Serv. 15 (4), 609–635. https://doi.org/10.2190/0q1g-rjg7-dpr9-v6xn.

de Vries, S., Ten Have, M., van Dorsselaer, S., van Wezep, M., Hermans, T., de Graaf, R., 2016. Local availability of green and blue space and prevalence of common mental disorders in The Netherlands. BJPsych Open 2 (6), 366–372. https://doi.org/10.1192/bjpo.bp.115.002469.

Dzhambov, A.M., Dimitrova, D.D., 2018. Residential road traffic noise as a risk factor for hypertension in adults: systematic review and meta-analysis of analytic studies published in the period 2011-2017. Environ. Pollut. 240, 306–318. https://doi.org/10.1016/j.envpol.2018.04.122.

European Environment Agency, 2017. Environmental Noise. Retrieved from. https://

www.eea.europa.eu/downloads/5404e35d8f064ccdad5830c80a3bb5fb/1513688644/environmental-noise.pdf, Accessed date: 2 May 2018.
Galenkamp, H., Stronks, K., Snijder, M.B., Derks, E.M., 2017. Measurement invariance testing of the PHQ-9 in a multi-ethnic population in Europe: the HELIUS study. BMC Psychiatr. 17 (1), 349. https://doi.org/10.1186/s12888-017-1506-9.
Gidlof-Gunnarsson, A., Ohrstrom, E., 2007. Noise and well-being in urban residential environments: the potential role of perceived availability to nearby green areas. Landsc. Urban Plann. 83 (2–3), 115–126. https://doi.org/10.1016/j.landurbplan.2007.03.003.
Greenberg, P.E., Fournier, A.A., Sisitsky, T., Pike, C.T., Kessler, R.C., 2015. The economic burden of adults with major depressive disorder in the United States (2005 and 2010). J. Clin. Psychiatr. 76 (2), 155–162. https://doi.org/10.4088/JCP.14m09298.
Halonen, J.I., Vahtera, J., Stansfeld, S., Yli-Tuomi, T., Salo, P., Pentti, J., ... Lanki, T., 2012. Associations between nighttime traffic noise and sleep: the Finnish public sector study. Environ. Health Perspect. 120 (10), 1391–1396. https://doi.org/10.1289/ehp.1205026.
Havard, S., Reich, B.J., Bean, K., Chaix, B., 2011. Social inequalities in residential exposure to road traffic noise: an environmental justice analysis based on the RECORD Cohort Study. Occup. Environ. Med. 68 (5), 366–374. https://doi.org/10.1136/oem.2010.060640.
Heidemann, C., Niemann, H., Paprott, R., Du, Y., Rathmann, W., Scheidt-Nave, C., 2014. Residential traffic and incidence of type 2 diabetes: the German health interview and examination surveys. Diabet. Med. 31 (10), 1269–1276. https://doi.org/10.1111/dme.12480.
Herrick, D., Sateia, M., 2016. Insomnia and depression: a reciprocal relationship. Psychiatr. Ann. 46, 164–172. https://doi.org/10.3928/00485713-20160121-01.
Hyman, S. e. a., 2006. Mental disorders. In: Jamison, Dean T. (Ed.), Disease Control Priorities in Developing Countries, second ed. Oxford University Press, New York.
Kendler, K.S., Gardner, C.O., Prescott, C.A., 2006. Toward a comprehensive developmental model for major depression in men. Am. J. Psychiatry 163 (1), 115–124. https://doi.org/10.1176/appi.ajp.163.1.115.
Kendler, K.S., Karkowski, L.M., Prescott, C.A., 1999. Causal relationship between stressful life events and the onset of major depression. Am. J. Psychiatry 156 (6), 837–841. https://doi.org/10.1176/ajp.156.6.837.
Kinsler, L.E., Frey, A.R., Coppens, A.B., Sanders, J.V., 2000. In: Fundamentals of Acoustics. John Wiley & Sons, New York City, pp. 359.
Knol, M.J., Twisk, J.W., Beekman, A.T., Heine, R.J., Snoek, F.J., Pouwer, F., 2006. Depression as a risk factor for the onset of type 2 diabetes mellitus. A meta-analysis. Diabetologia 49 (5), 837–845. https://doi.org/10.1007/s00125-006-0159-x.
Kohlhuber, M., Mielck, A., Weiland, S.K., Bolte, G., 2006. Social inequality in perceived environmental exposures in relation to housing conditions in Germany. Environ. Res. 101 (2), 246–255. https://doi.org/10.1016/j.envres.2005.09.008.
Kroenke, K., Spitzer, R.L., Williams, J.B., Lowe, B., 2010. The patient health questionnaire somatic, anxiety, and depressive symptom scales: a systematic review. Gen. Hosp. Psychiatr. 32 (4), 345–359. https://doi.org/10.1016/j.genhosppsych.2010.03.006.
Lupien, S.J., McEwen, B.S., Gunnar, M.R., Heim, C., 2009. Effects of stress throughout the lifespan on the brain, behaviour and cognition. Nat. Rev. Neurosci. 10 (6), 434–445. https://doi.org/10.1038/nrn2639.
Maris, E., Stallen, P.J., Vermunt, R., Steensma, H., 2007. Noise within the social context: annoyance reduction through fair procedures. J. Acoust. Soc. Am. 121 (4), 2000–2010.
Missinne, S., Bracke, P., 2012. Depressive symptoms among immigrants and ethnic minorities: a population based study in 23 European countries. Soc. Psychiatr. Psychiatr. Epidemiol. 47 (1), 97–109. https://doi.org/10.1007/s00127-010-0321-0.
Municipality of Amsterdam, 2016. Geluidbeleid Gemeente Amsterdam. Retrieved from. https://www.amsterdam.nl/bestuur-organisatie/organisatie/ruimte-economie/ruimte-duurzaamheid/geluidbeleid/#hd5f098f5-3e16-429b-a440-c2526fd7c536, Accessed date: 2 May 2018.
Orban, E., McDonald, K., Sutcliffe, R., Hoffmann, B., Fuks, K.B., Dragano, N., ... Moebus, S., 2016. Residential road traffic noise and high depressive symptoms after five years of follow-up: results from the Heinz Nixdorf recall study. Environ. Health Perspect. 124 (5), 578–585. https://doi.org/10.1289/ehp.1409400.
Organization for Economic Cooperation and Development, 1991. Fighting Noise in 1990s. OECD Publications, Paris, France, pp. 120.
Riedel, N., Fuks, K., Hoffmann, B., Weyers, S., Siegrist, J., Erbel, R., ... Dragano, N., 2012. Insomnia and urban neighbourhood contexts–are associations modified by individual social characteristics and change of residence? Results from a population-based study using residential histories. BMC Publ. Health 12, 810. https://doi.org/10.1186/1471-2458-12-810.
Savini, F., Boterman, W.R., van Gent, W.P.C., Majoor, S., 2016. Amsterdam in the 21st century: geography, housing, spatial development and politics. Cities 52 (Suppl. C), 103–113. https://doi.org/10.1016/j.cities.2015.11.017.
Scanlan, J.N., Bundy, A.C., Matthews, L.R., 2011. Promoting wellbeing in young unemployed adults: the importance of identifying meaningful patterns of time use. Aust. Occup. Ther. J. 58 (2), 111–119. https://doi.org/10.1111/j.1440-1630.2010.00879.x.
Seidler, A., Hegewald, J., Seidler, A.L., Schubert, M., Wagner, M., Droge, P., ... Zeeb, H., 2017. Association between aircraft, road and railway traffic noise and depression in a large case-control study based on secondary data. Environ. Res. 152, 263–271. https://doi.org/10.1016/j.envres.2016.10.017.
Snijder, M.B., Galenkamp, H., Prins, M., Derks, E.M., Peters, R.J.G., Zwinderman, A.H., Stronks, K., 2017. Cohort profile: the Healthy life in an urban setting (HELIUS) study in Amsterdam, The Netherlands. BMJ Open 7 (12). https://doi.org/10.1136/bmjopen-2017-017873. e017873.
Stansfeld, S., Gallacher, J., Babisch, W., Shipley, M., 1996. Road traffic noise and psychiatric disorder: prospective findings from the Caerphilly Study. Bmj 313 (7052), 266–267.
Stansfeld, S.A., Matheson, M.P., 2003. Noise pollution: non-auditory effects on health. Br. Med. Bull. 68, 243–257.
Statistics Netherlands (CBS), 2015. Toelichting Wijk- en Buurtkaart 2012, 2013 en 2014; Respectievelijk Versie 3, 2. en 1 [In Dutch]. Retrieved from. https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische%20data/wijk-en-buurtkaart-2012, Accessed date: 2 May 2018.
Stirbu, I., Kunst, A.E., Bos, V., Mackenbach, J.P., 2006. Differences in avoidable mortality between migrants and the native Dutch in The Netherlands. BMC Publ. Health 6, 78. https://doi.org/10.1186/1471-2458-6-78.
Stronks, K., Kulu-Glasgow, I., Agyemang, C., 2009. The utility of 'country of birth' for the classification of ethnic groups in health research: the Dutch experience. Ethn. Health 14 (3), 255–269. https://doi.org/10.1080/13557850802509206.
Stronks, K., Snijder, M.B., Peters, R.J.G., Prins, M., Schene, A.H., Zwinderman, A.H., 2013. Unravelling the impact of ethnicity on health in Europe: the HELIUS study. BMC Publ. Health 13, 402. https://doi.org/10.1186/1471-2458-13-402.
The Netherlands Environmental Assessment Agency (PBL), 2008. Road-, Rail- and Air-traffic Noise in the Netherlands in 2000-2008. 31 May 2018. Retrieved from. http://geoservice.pbl.nl/arcgis/rest/services/projecten/Geluidbelasting_weg_rail_en_luchtverkeer_in_Nederland_20002008/MapServer, Accessed date: 6 June 2018.
The Netherlands Ministry of the Interior and Kingdom Relations, 2008. Rapportage Instrumentontwikkeling. Retrieved from. https://www.rijksoverheid.nl/documenten/rapporten/2008/05/01/rapportage-instrumentontwikkeling, Accessed date: 2 May 2018.
Thomas, A.J., Kalaria, R.N., O'Brien, J.T., 2004. Depression and vascular disease: what is the relationship? J. Affect. Disord. 79 (1–3), 81–95. https://doi.org/10.1016/s0165-0327(02)00349-x.
Timmermans, E.J., Lakerveld, J., Beulens, J.W.J., Boomsma, D.I., Kramer, S.E., Oosterman, M., ... Huisman, M., 2018. Cohort profile: the geoscience and health cohort Consortium (GECCO) in The Netherlands. BMJ Open 8 (6). https://doi.org/10.1136/bmjopen-2018-021597. e021597.
Trull, T.J., Sher, K.J., 1994. Relationship between the five-factor model of personality and Axis I disorders in a nonclinical sample. J. Abnorm. Psychol. 103 (2), 350–360.
Vandasova, Z., Vencalek, O., Puklova, V., 2016. Specific and combined subjective responses to noise and their association with cardiovascular diseases. Noise Health 18 (85), 338–346. https://doi.org/10.4103/1463-1741.195800.
Walsh, J.L., 2013. Longitudinal Associations between Health Behaviors and Mental Health in Low-income Adults, vol. 3. pp. 104–113. https://doi.org/10.1007/s13142-012-0189-5. 1.
Wirth, K., Brink, M., Schierz, C., 2004. Aircraft Noise Annoyance at Different Times of Day.
World Health Organization, 2011. Burden of Disease from Environmental Noise: Quantification of Healthy Life Years Lost in Europe. Retrieved from. http://www.euro.who.int/_data/assets/pdf_file/0008/136466/e94888.pdf, Accessed date: 2 May 2018.
World Health Organization, 2017. Depression. Feb 2017. Retrieved from. http://www.who.int/mediacentre/factsheets/fs369/en/, Accessed date: 2 May 2018.
Wothge, J., Belke, C., Mohler, U., Guski, R., Schreckenberg, D., 2017. The combined effects of aircraft and road traffic noise and aircraft and railway noise on noise annoyance-an analysis in the context of the joint research initiative NORAH. Int. J. Environ. Res. Publ. Health 14 (8). https://doi.org/10.3390/ijerph14080871.
Wulsin, L.R., Vaillant, G.E., Wells, V.E., 1999. A systematic review of the mortality of depression. Psychosom. Med. 61 (1), 6–17.