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Perceived neighbourhood characteristics and depressive symptoms: Potential mediators and the moderating role of employment status

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ABSTRACT

Multiple neighbourhood characteristics have been linked to depressive symptoms. However, few studies have simultaneously considered multiple mechanisms that explain this relationship, and how they might interact. Further, most studies regard exposure to the residential environment as constant, and therefore disregard variation in exposure by individual factors. This study investigates whether and to what extent stress and physical activity mediate the association between neighbourhood characteristics and depression, and also to what extent employment status moderates this relationship.

A population-representative survey of n = 11,505 people in the Netherlands was conducted. Depressive symptoms were measured using the Patient Health Questionnaire (PHQ-9). Neighbourhood characteristics were perceived green and blue space, pleasantness, environmental disturbance, social cohesion and safety. Employment status was combined with place of work to establish two groups: those who were non-working or who worked from home ('at home'), and those who worked somewhere outside of the home ('working'). Multi-group structural equation modelling was employed to understand the theorised relationships for both groups. Perceived environmental disturbance, social cohesion and safety were significantly indirectly related to depressive symptoms via stress, with larger effect sizes in the 'at home' group. Pleasantness was also significantly indirectly related to depressive symptoms via stress, in the 'at home' group only. There was no evidence for physical activity as a mediator.

Our findings suggest that neighbourhood social characteristics may have a greater influence on depressive symptoms than physical characteristics. Stress appears to be a key mediator of this relationship. In addition, the neighbourhood appears to exert a greater influence on those who spend more time in their neighbourhood. Interventions to promote mental health should focus on the social environment, and in particular pay attention to those who are spatially confined in poorer quality neighbourhoods.

1. Introduction

Depression is a major contributor to the global disease burden (Malhi and Mann, 2018), and there is growing recognition that it may be influenced by both physical and social environmental characteristics (Blair et al., 2014; Gong et al., 2016; Rautio et al., 2018). The residential neighbourhood has received particular attention, as a space that is central to a person's daily life (Groenewegen et al., 2018; Vallée et al., 2010). Both perceived and objective neighbourhood characteristics have been found to buffer against or exacerbate poor mental health, even after adjustment for individual factors (Generaal et al., 2019a; Gidlow et al., 2010; Helbich et al., 2019; Zhang et al., 2019).

Two proposed pathways linking neighbourhoods and health have received particular attention: stress and health-related behaviours such as physical activity (Diez Roux, 2016; Diez Roux and Mair, 2010). Some aspects of the neighbourhood are understood to be stress-inducing (Henderson et al., 2016), such as physical disorder and poor perceived safety, while other aspects are stress-reducing, such as the availability of green space (de Vries et al., 2013; Triguero-Mas et al., 2017). There is consistent evidence for a relationship between physical activity and neighbourhood physical characteristics (Smith et al., 2017). Quantitative evidence for a relationship between the social environment and

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physical activity is limited (Chaudhury et al., 2016), however, qualitative evidence suggests a consistent relationship (Salvo et al., 2018).

Most studies that examine the relationship between neighbourhood characteristics and health assume that a person is permanently fixed at their residential address (Chaix et al., 2013; Mair et al., 2010; Rainham et al., 2010). However, it is known that people are typically exposed to multiple environments in their daily life, such as work or leisure environments (Hurvitz and Moudon, 2012; Perchoux et al., 2013; Shareck et al., 2014). Previous research has suggested that associations between neighbourhood characteristics and health can vary according to individual factors such as employment status, household income, car access, and gender (Ivory et al., 2015), as well as activity space extent (Vallée et al, 2010, 2011). This indicates that individual factors may lead to different levels of 'exposure' to the neighbourhood, and in turn this modifies the relationship. Ivory et al. (2015) summarize a number of ways through which this might occur: variation in the amount of time spent in the environment; having a greater reliance on or preference for the environment; and having a greater intensity of a relationship with the environment. In this study we approach 'exposure' to the neighbourhood using the first definition and use employment status (in combination with workplace) as a proxy measure of time spent in the neighbourhood.

The present study uses a population-representative survey in the Netherlands to investigate whether and to what extent stress and physical activity mediate the relationship between neighbourhood characteristics and depressive symptoms. We also explore employment status as a moderator of the relationship.

2. Background

2.1. Neighbourhood characteristics and depression

In a recent pooled analysis of eight cohort studies (n = 32,487), higher urbanisation level, lower socioeconomic status, more social security beneficiaries, a higher number of immigrants, higher levels of air pollution, less green space and less social safety were associated with higher prevalence of depression in the Netherlands (Generaal et al., 2019a). These findings converge with previous research on the relative effects of perceived neighbourhood characteristics on mental health in the Netherlands and elsewhere (Gidlow et al., 2010; Helbich et al., 2019; Zhang et al., 2019). The studies are in agreement that the social environment (for example, perceived safety, social cohesion, and social support) appears to be more important for mental health than the physical environment, however, characteristics such as perceived walkability, traffic congestion, noise, and green space were also recognised as important. Physical and social neighbourhood characteristics can also be reinforcing. For example, a more green neighbourhood provides more opportunity for people to meet their neighbours and encourage social cohesion, while a more socially cohesive neighbourhood may have greater capacity to advocate for more green spaces in their area. Altogether, and in line with the socio-ecological model, the evidence points to a complex interplay of multiple physical and social neighbourhood characteristics, as well as individual attributes, either promoting or adversely affecting mental health (Stokols, 1992).

2.2. Mediating pathways

Following the framework of Diez Roux and Mair (2010), we consider the mediating roles of stress and health behaviours. Specifically, we consider physical activity as a mediating health behaviour, as growing research increasingly supports its role in the relationship between neighbourhood characteristics and mental health (Dzhambov et al., 2017; Kowitt et al., 2020; McEachan et al., 2015; Van Dyck et al., 2015).

Neighbourhood physical characteristics have been shown to be associated with physical activity, which has clear mental health benefits (Penedo and Dahn, 2005). This includes attributes such as walkability (Nichani et al., 2019), street connectivity (Pearce and Maddison, 2011), and green space (Maas et al., 2008; Richardson et al., 2013). Social characteristics can also play a role: where there is poor perceived safety, steps may be taken to limit outdoor physical activity (Lorenc et al., 2012).

In addition, people living in poorer quality neighbourhoods may be exposed to more stressors which impact on their mental health, such as neighbourhood disorder, noise, and air pollution (Fan et al., 2020; Kim, 2008). Not only are these stressors experienced directly, but research shows that they also indirectly limit opportunity for restoration from stress (von Lindern et al., 2016). At the same time, poor quality neighbourhoods may also offer fewer resources that evidence shows offer restoration from stress, such as social cohesion and green and blue spaces (de Vries et al., 2013; Hartig et al., 2014; Triguero-Mas et al., 2017; Wang et al., 2019).

Previous studies of potential mediators between neighbourhood characteristics and depression have typically considered a single mediator, or a single environment (e.g. built, natural, social) (Triguero-Mas et al., 2017; Van Dyck et al., 2015; Zijlema et al., 2016). However, it is likely that these mediators do not act in isolation but are interrelated (Diez Roux and Mair, 2010; Markevych et al., 2017). Increased stress might lead to a lack of exercise, while engaging in physical activity can buffer the adverse effects of stress. Failure to recognise this may lead to incorrect conclusions regarding the relative contribution of each pathway (Dzhambov et al., 2020). In this study, we include a range of perceived neighbourhood characteristics and consider multiple mediators simultaneously.

2.3. Moderating variable

A key limitation of the current research on neighbourhood characteristics and health is that it is assumed people are fixed to their residential address (Ruijsbroek et al., 2017; Zijlema et al., 2016). However, it is known that people typically encounter multiple other environments in their daily life, such as work and leisure environments. This can result in exposure to an environment that is markedly different to the one that is assumed (Holliday et al., 2017; Vich et al., 2019).

It is reasonable to expect that the degree to which a person is constrained to their neighbourhood influences the strength of the association between neighbourhood characteristics and health outcomes. This was found in a previous study whereby those with a negative perception of their neighbourhood were significantly more likely to report depression if they had a limited activity space, compared to those whose activity space extended beyond their neighbourhood (Vallée et al., 2011). Another study found that relationships between the neighbourhood built environment and physical activity were stronger for those with a lower household income and restricted car access (Ivory et al., 2015). Weaker relationships were also found for women and those not working full time (Ivory et al., 2015). This suggests that certain population groups may be more vulnerable to the influence of neighbourhood characteristics due to greater exposure.

In this study, we combine data on employment status and place of work to produce a proxy measure of exposure to the residential environment. We approach exposure as time spent in an environment, and work is a 'fixed activity' that is central to daily life and typically spatially and temporally constrained (Perchoux et al., 2013). We also integrate with this data on workplace to delineate those who work from home and those who work elsewhere. In our sample, 94.9% of those in work stated that they travelled to another fixed address or to different locations besides their home for work, representing regular travel beyond their residential environment.

2.4. Conceptual model

We developed a conceptual model (Fig. 1) to show the direct and indirect relationships between physical and social neighbourhood

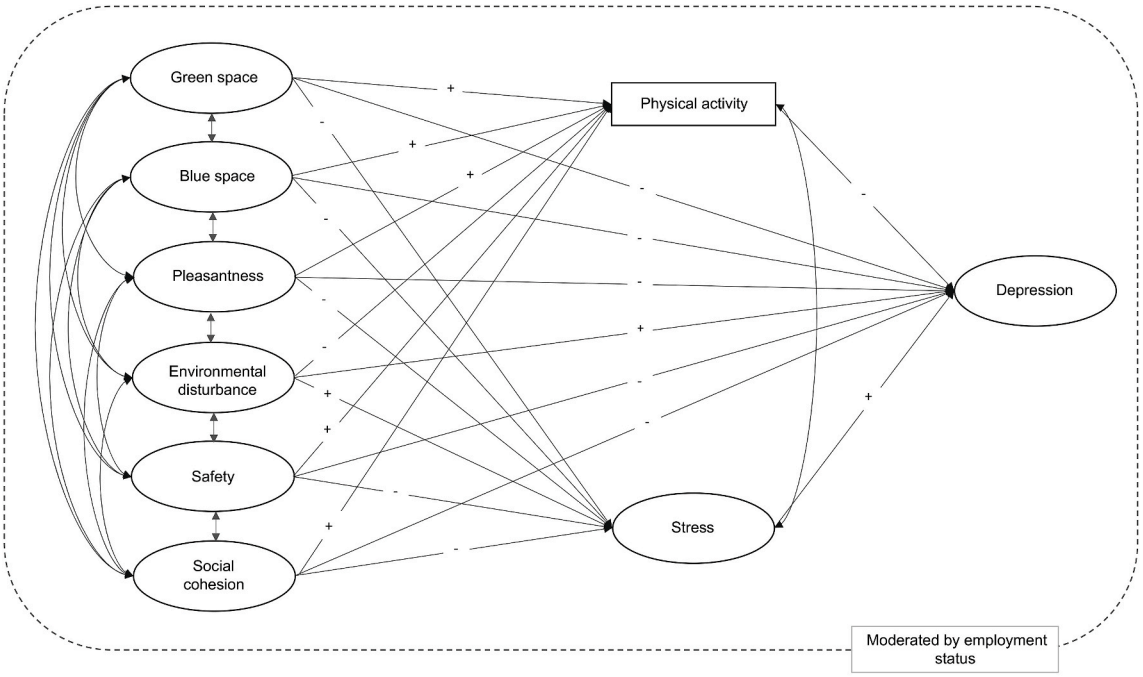

Fig. 1. Conceptual model linking perceived neighbourhood characteristics and depression, with stress and physical activity as mediators. *Note.* Plus signs (+) indicate a positive relationship, minus signs (−) indicate a negative relationship. Model is moderated by employment status (at home/working).

characteristics and depressive symptoms. The physical and social characteristics themselves are non-directionally related. We first hypothesized that stress and physical activity act as mediators between neighbourhood characteristics and depressive symptoms, and these mediators are reinforcing. Our second hypothesis was that the effects of neighbourhood characteristics on depressive symptoms would be stronger for the 'at home' group (i.e. non-working, or work at home), than the 'working' group (those who are employed and work elsewhere).

3. Methods

3.1. Survey

This study made use of survey data collected for the purposes of the NEEDS project (Helbich, 2019). The survey was conducted between September and December 2018 in conjunction with Statistics Netherlands. The eligibility criteria for participation were: a) registered in the Dutch National Personal Records Database, b) aged 18–65 years (i.e., born after September 11, 1952 and before September 12, 2000), and c) living in a private household (i.e., people in institutions and care homes were excluded). The initial random sample of 45,000 people was drawn from the eligible population. Each selected respondent received an invitation letter and was invited to fill in an online questionnaire. The survey included questions on demographics, socioeconomic status, physical and mental health, and perceived neighbourhood physical and social characteristics. Incentives (one iPad per 2000 respondents) were used to encourage participation. A total of n = 11,505 persons completed the survey, representing an overall response rate of 25.6%.

3.2. Data

3.2.1. Outcome

Symptoms of depression were measured using the nine-item Patient Health Questionnaire (PHQ-9) (Kroenke et al., 2001). Meta-analyses have reported good diagnostic performance, good sensitivity, and good specificity for this module of the Patient Health Questionnaire (Gilbody et al., 2007). Respondents are asked how often they have been bothered by problems such as, for example, "Little interest or pleasure in doing things", and "Feeling down, depressed, or hopeless". Response options range from 0 "Not at all" to 3 "Nearly every day" over the past two weeks. A higher score therefore indicates more depressive symptoms. Cronbach's alpha (internal consistency) was 0.88.

3.2.2. Perceived neighbourhood characteristics

Perception of neighbourhood pleasantness was assessed using the four-item 'pleasantness' module from the Instruments for Assessing Levels of Physical Activity and Fitness (ALPHA) questionnaire (Spittaels et al., 2009). Individual items included: "My local neighbourhood is a pleasant environment for walking or cycling", and "In my neighbourhood there are badly maintained, unoccupied or ugly buildings". Participants were asked to rate their agreement with the first statement on a scale from 1 "Strongly agree" to 4 "Strongly disagree" and give an indication of presence for the final three from 1 "None" to 4 "Plenty". Positive items were recoded so that a higher score indicated a more pleasant perception of the neighbourhood. Cronbach's alpha was 0.62. A low Cronbach's alpha can be attributed to the fact that the aim of the pleasantness items was to sample possible indicators that are not often intercorrelated (Spittaels et al., 2009), therefore a high alpha cannot be expected.

Participants were asked their perceptions of distance to several types of green space (park, play area, sports field, forest) and blue space (river/stream/canal, lake/pond, beach). Possible responses were: "Less than 300 m", "≥300 m to 1 km", "≥1–5 km" and "≥5 km or more". A higher score indicates greater distance to the nearest green or blue space. Cronbach's alpha was 0.64 for perceived distance to green space and 0.61 for blue space. Similarly to the pleasantness items, we do not expect that the distance to different types of green and blue spaces to be highly correlated (Schipperijn et al., 2010).

Environmental disturbance was comprised of three items concerning perceived traffic congestion and noise pollution in and around the home. Respondents indicated the level of traffic congestion in their neighbourhood in the last 6 months from 1 "Very busy or congested" to 4 "Very quiet". Respondents were also asked about noise pollution inside and outside of their home from 1 "Not noticeable at all" to 4 "Very noticeable". Traffic was reverse coded; Cronbach's alpha was 0.61. Because noise outside the home also referred to, for example, air traffic, construction work, factories, and restaurants, we did not expect this to correlate highly with traffic congestion.

Perception of safety in the neighbourhood was assessed using the safety module of the ALPHA questionnaire (Spittaels et al., 2009), which consisted of six statements, including: 'Walking in my neighbourhood is unsafe because of the traffic', and 'It is unsafe in my neighbourhood during the day due to the level of crime'. Participants were asked to rate their agreement from 1 "Strongly agree" to 4 "Strongly disagree". A higher score therefore indicates greater perception of safety. Cronbach's alpha was 0.82.

Social cohesion was measured using the Sampson social cohesion scale (Sampson et al., 1997). Participants were asked to rate their agreement on a scale ranging from 1 "Strongly disagree" to 5 "Strongly agree", with the statements such as: 'People around here are willing to help their neighbours', 'People in this neighbourhood can be trusted'. Negative items were reverse coded so that a higher score indicates greater perceived social cohesion in the neighbourhood. Cronbach's alpha was 0.83.

3.2.3. Mediating variables

Level of physical activity was operationalised with a single item by asking "Over the past 7 days, on how many days were you physically active for a total of at least 30 min per day" (range: 0–7).

Stress was measured using the Perceived Stress Scale (PSS) (Cohen et al., 1983). The instrument contains 10 items that ask about stress in the previous month. Example items include: "How often have you been upset because of something that happened unexpectedly?", and "How often have you felt that you were unable to control the important things in your life?". Items are answered on a 5-point scale from 0 "Never" to 4 "Very often". Positively stated items were reverse coded. A higher score indicates higher perceived stress. Cronbach's alpha was 0.87.

3.2.4. Moderating variable

We used employment status and place of work to split the sample into two groups, 'At home' and 'Working'. Employment status was obtained through enriching the survey data with register data, and the following responses were classed as 'at home': 'Jobseeker', 'Volunteer', 'Incapacitated', 'Student', 'Househusband/housewife', 'Retired' and 'None of these'. In addition, all those who were in paid work but indicated that they worked from home were included in this group. Persons in the 'working' group were those in paid work but who worked at a fixed location or different locations other than their home.

3.2.5. Control variables

We controlled for the following individual characteristics: age, sex, ethnic origin (Dutch, Western migration background, Non-Western migration background), marital status (married, separated/divorced, widow, never married), education level (low, medium, high), income quintile (1 = lowest quintile, 5 = highest quintile), and household type (single parent, couple without children, couple with children, other household type).

At an area level, we included address density as a proxy of urbanity, deprivation, and social fragmentation. These were computed by aggregating individual characteristics obtained from register data to the four-digit postal code area. Our respondents were from 2775 different postal code areas, from a total of 4072 in the Netherlands (CBS, 2018). On average, 6.46 respondents lived in one postal code area (range = 1–17). Address density was the number of addresses per hectare of the four-digit postal code area on January 1, 2018. Social fragmentation was based on the percentage of adult residents (>18 years) who are unmarried, live in a single-person household, and who moved to their residential address in the last year. Deprivation was based on the unemployment rate, the standardized median household income (reverse coded), and the share of households with a standardized income below the poverty line. Input variables were z-scored and summed, with higher scores indicating greater social fragmentation or deprivation. Input data for the indices were from 1st January 2016.

3.2.6. Statistical analysis

Descriptive characteristics of the sample were first calculated to understand the composition of the data. Because several of the continuous variables were non-normally distributed, Spearman's rank correlation coefficients were computed between all variables except the moderator, where the point biserial correlation coefficient was used.

Next, structural equation modelling (SEM) was employed to investigate the pathways outlined in Fig. 1. SEM allows for latent variable measurement models, multiple regression equations, and direct and indirect effects of various neighbourhood characteristics on depressive symptoms to be simultaneously estimated. The measurement model was estimated first, followed by the structural equation model, in line with the procedure introduced by Anderson and Gerbing (1988). In order to reduce the number of indicators for latent variables with more than three indicators initially, we employed a parceling technique. Parcels were formed by combining the item with the highest factor loading with the lowest factor loading, followed by the second highest and second lowest, and so forth (Little et al., 2013). We estimated a multi-group model (at home vs working) to examine the hypothesized moderating effect of employment status (in combination with workplace). Differences between groups were tested by defining a new parameter as the difference between corresponding parameters in the two models and testing the significance of this difference. Standard errors were adjusted for clustering by postcode area using a sandwich estimator.

To ensure generalizable results and prevent overfitting, we used a three-step modelling approach based on the machine learning workflow (Hastie et al., 2009). First, we constructed our model on a "training" sample, consisting of a randomly selected half (n = 1387) of postal code clusters. Our modelling decisions could then be adjusted based on this sample before using the second half of the data (a "testing" sample) to obtain an unbiased estimate of model fit using the final model. Lastly, we used the combined data to obtain estimates of model parameters. We thus report three sets of model fit indices (training, testing, and combined), of which the testing fit indices are an unbiased estimate of model fit. Model parameters using the combined data are reported. Goodness of fit is evaluated using root mean square error of approximation (RMSEA), a comparative fit index (CFI), the Tucker Lewis index (TLI) and the standardized root mean residual (SRMR). We consider RMSEA $\leq$0.08, CFI $\geq$0.90, TLI $\geq$0.90 and SRMR $\leq$0.08 to be indicative of good fit (Hu and Bentler, 1999).

Between-group comparisons of regressions and correlations require metric invariance. To establish measurement invariance between groups, we fitted a series of CFA models, imposing configural, metric and scalar constraints. Justifiability of these constraints was determined based on changes in model fit. In all cases, applying these constraints led to an improved RMSEA, and negligible changes (<0.01) to CFI and SRMR (Table S1).

We used Mplus 8.0 with robust full information maximum likelihood (FIML) estimation, and used tidySEM (Van Lissa, 2020) to tabulate and visualize the results in R (R Core Team, 2019). FIML makes use of all available information without imputing missing data and yields unbiased estimates under the assumption that data was missing at random (Schafer and Graham, 2002). FIML is also robust to moderately non-normal continuous data (Finney and DiStefano, 2006).

4. Results

4.1. Descriptive characteristics and bivariate associations

Participant characteristics are presented in Table 1. The average PHQ-9 score was 4.89 (standard deviation (SD) ± 4.96). Wilcoxon tests revealed significant differences in the outcome and mediating variables between groups: depressive symptoms, the number of physically active days, and perceived stress were significantly higher in the 'at home' group ($p < 0.001$) (Table S2). Overall, the gender split was roughly equal (47.4% men) and the mean age was 44.5 years. The 'working' group had higher proportions of married, highly educated, Dutch, and high-income participants. Meanwhile, the 'at home' group had significantly higher levels of deprivation ($p < 0.001$) and social fragmentation ($p = 0.001$) in comparison to the 'working' group.

Table 2 shows the distribution of the perceived neighbourhood characteristics. Most participants had green space within 1 km of their home, while blue spaces were perceived to be further away. Participants perceived their neighbourhood as pleasant (mean (M) = 13.44, SD = 2.04, range = 4–16). Most people perceived traffic congestion in their neighbourhood as quiet, and for most, noise was not noticeable or only a little noticeable. Participants perceived their neighbourhood as safe (M = 19.83, SD = 2.99, range: 6–24) and socially cohesive (M = 19.29, SD = 3.30, range: 5–25).

Table 1
Participant characteristics.

Variable	Category	Total sample (n = 11,505)	
		n (%)	Mean (SD)
PHQ-9		11086 (96.4)	4.89 (4.96)
	Missing	419 (3.6)	
Number of active days		10932 (95.0)	4.11 (2.21)
	Missing	573 (5.0)	
PSS score		11300 (98.2)	12.94 (6.77)
	Missing	205 (1.8)	
Control variables			
Gender	Male	5449 (47.4)	
Age group	18–24	1301 (11.3)	
	25–35	2143 (18.6)	
	36–45	1979 (17.2)	
	46–55	2817 (24.5)	
	56–65	3265 (28.4)	
Marital status	Married	5960 (51.8)	
	Separated	1012 (8.8)	
	Widow	165 (1.4)	
	Never married	4368 (38.0)	
Household type	Couple with children	3533 (30.7)	
	Couple without children	5256 (45.7)	
	Single parent	719 (6.2)	
	Other	1997 (17.4)	
Education level	Low	2350 (20.6)	
	Middle	4119 (36.1)	
	High	4953 (43.4)	
	Missing	83 (0.7)	
Ethnicity	Dutch	9792 (85.1)	
	Western migrant	965 (8.4)	
	Non-Western migrant	748 (6.5)	
Income quintile	Q1 (lowest)	1177 (10.4)	
	Q2	1240 (11.0)	
	Q3	2171 (19.2)	
	Q4	2944 (26.1)	
	Q5 (highest)	3764 (33.3)	
	Missing	209 (1.8)	
Addresses per hectare		11505 (100)	16.8 (22.0)
Deprivation		11503 (99.98)	0.4 (2.2)
	Missing	2 (0.02)	
Social fragmentation		11503 (99.98)	0.627 (2.474)
	Missing	2 (0.02)	

Note. May not add up to 100% due to rounding. Q = quintile.

Table 2
Perceived neighbourhood characteristics.

Variable	Category	N (%)
Distance to nearest park	Less than 300 m	4550 (39.55)
	300 m to 1 km	4133 (35.92)
	1 km–5 km	1920 (16.69)
	5 km or more	562 (4.88)
	Missing	340 (2.96)
Distance to nearest play area	Less than 300 m	6763 (58.78)
	300 m to 1 km	2939 (25.55)
	1 km–5 km	901 (7.83)
	5 km or more	170 (1.48)
	Missing	732 (6.36)
Distance to nearest sports field	Less than 300 m	2570 (22.34)
	300 m to 1 km	4590 (39.90)
	1 km–5 km	3338 (29.01)
	5 km or more	378 (3.29)
	Missing	629 (5.47)
Distance to nearest forest	Less than 300 m	1014 (8.81)
	300 m to 1 km	2345 (20.38)
	1 km–5 km	4734 (41.15)
	5 km or more	3180 (27.64)
	Missing	232 (2.02)
Distance to nearest river	Less than 300 m	1515 (13.17)
	300 m to 1 km	2498 (21.71)
	1 km–5 km	3975 (34.55)
	5 km or more	2917 (25.35)
	Missing	600 (5.22)
Distance to nearest lake	Less than 300 m	1411 (12.26)
	300 m to 1 km	2422 (21.05)
	1 km–5 km	3899 (33.89)
	5 km or more	3109 (27.02)
	Missing	664 (5.77)
Distance to nearest beach	Less than 300 m	112 (0.97)
	300 m to 1 km	360 (3.13)
	1 km–5 km	1155 (10.04)
	5 km or more	9326 (81.06)
	Missing	552 (4.80)
Pleasantness		11141 (96.8)
	Missing	364 (3.2)
Traffic congestion	Very busy	400 (3.5)
	Fairly busy	3521 (30.9)
	Fairly quiet	4937 (43.3)
	Very quiet	2550 (22.4)
	Missing	97 (0.8)
Noise inside the home	Not noticeable at all	6254 (54.8)
	A little noticeable	4197 (36.8)
	Reasonably noticeable	694 (6.1)
	Very noticeable	272 (2.4)
	Missing	88 (0.8)
Noise outside the home	Not noticeable at all	4604 (40.5)
	A little noticeable	5521 (48.5)
	Reasonably noticeable	952 (8.4)
	Very noticeable	302 (2.7)
	Missing	126 (1.1)
Perceived safety		10902 (94.8)
	Missing	603 (5.2)
Social cohesion		10491 (91.2)
	Missing	1014 (8.8)

Bivariate correlations between the main variables were computed. The associations indicate that greater depression severity was associated with increased stress, reduced physical activity, reduced access to blue space, reduced perceived pleasantness, increased environmental disturbance, reduced safety and social cohesion, and the 'at home' group (Table S3).

4.2. Model testing

Using the training sample, we started with a basic measurement model, and then added regression coefficients and covariances until we arrived at our final SEM. Our final modelling decisions were then applied to the testing sample and the samples combined. The syntax for this analysis is available at https://osf.io/cqwje/. This contains details

of each modelling decision made, including: accounting for nested data using clustered standard errors; including control variables; using a binary moderator instead of a continuous one; and adding a cross-loading of traffic on environmental disturbance, and a covariance between two PHQ-9 items based on modification indices.

Unstandardized and standardized factor loadings for the measurement model using the combined data are shown in Table S4. All factor loadings were substantial and statistically significant at the $p < 0.001$ level, indicating all the latent constructs were well represented by the observed indicators.

Table S5 shows model fit indices using the training data, testing data and combined data. The fit on the testing data is most important and should be interpreted as an estimate of the model fit on new data. The model fit was good according to all indices; and in fact, fit was marginally better for the testing data than for the training data, suggesting that model overfitting is not a concern.

4.3. Associations between neighbourhood characteristics, physical activity, stress and depression

Table 3 shows the standardized parameter estimates for the two structural models using the combined data; Fig. 2 illustrates these results. Covariances between neighbourhood characteristics and between the mediators are shown in Table S6; unstandardized estimates, including model comparison estimates, are available in Table S7. In terms of direct effects, a poorer perception of safety had a significant positive direct effect on severity of depression for the 'at home' group only. In the 'working' group model, environmental disturbance significantly increased and social cohesion significantly decreased depression severity, albeit with small effect sizes. However, there were no significant differences between groups in terms of direct effects (Table S6). Associations between pleasantness, green space, blue space, and depressive symptoms were marginal and not significant.

Stress and physical activity were theorised as mediators of the relationship between perceived neighbourhood characteristics and depressive symptoms. Perceived stress was significantly associated with depressive symptoms in both models, and with a significantly stronger relationship for the 'at home' group (Table S7). Physical activity was also significantly associated with a reduction in depressive symptoms for both groups, however, effect sizes were small and not significantly different between groups (Table S7). The strength of the correlation between the two mediators was stronger in the 'at home' group (Table S6).

Environmental disturbance, safety, and social cohesion were significantly indirectly related to depression severity in the expected directions, with larger effect sizes observed in the 'at home' group. Pleasantness also had an indirect effect on depression severity for the 'at home' group only. Specific indirect associations were identified via the stress pathway; physical activity was not a significant mediator in any of the theorised neighbourhood characteristic-depressive symptom relationships.

Table 3
Standardized total, direct and indirect effects between neighbourhood characteristics and depressive symptoms.

	Working group		At home group	
	β	95% CI	β	95% CI
Pleasantness				
Total effect	0.03	[-0.04, 0.10]	0.06	[-0.10, 0.23]
Direct effect	0.02	[-0.03, 0.08]	−0.08	[-0.22, 0.05]
Total indirect effect	0.01	[-0.04, 0.06]	0.14*	[0.02, 0.27]
→ stress	0.01	[-0.04, 0.06]	0.14*	[0.02, 0.27]
→ physical activity	−0.00	[-0.01, 0.00]	0.00	[-0.00, 0.01]
Green space				
Total effect	0.06	[-0.00, 0.11]	0.06	[-0.10, 0.22]
Direct effect	0.03	[-0.01, 0.07]	−0.01	[-0.16, 0.15]
Total indirect effect	0.03	[-0.02, 0.07]	0.07	[-0.07, 0.20]
→ stress	0.02	[-0.02, 0.06]	0.06	[-0.07, 0.19]
→ physical activity	0.00	[-0.00, 0.01]	0.01	[-0.00, 0.01]
Blue space				
Total effect	−0.05	[-0.11, 0.00]	−0.04	[-0.19, 0.11]
Direct effect	−0.02	[-0.06, 0.02]	−0.03	[-0.18, 0.12]
Total indirect effect	−0.03	[-0.07, 0.01]	−0.01	[-0.14, 0.11]
→ stress	−0.04	[-0.07, 0.00]	−0.01	[-0.14, 0.11]
→ physical activity	0.00	[-0.00, 0.01]	−0.00	[-0.00, 0.00]
Environmental disturbance				
Total effect	0.14***	[0.09, 0.19]	0.15***	[0.07, 0.23]
Direct effect	0.06**	[0.02, 0.10]	0.04	[-0.02, 0.10]
Total indirect effect	0.08***	[0.05, 0.12]	0.12***	[0.05, 0.18]
→ stress	0.08***	[0.05, 0.12]	0.12***	[0.05, 0.18]
→ physical activity	0.00	[-0.00, 0.00]	−0.00	[-0.00, 0.00]
Safety				
Total effect	−0.09**	[-0.15, −0.03]	−0.05	[-0.15, 0.05]
Direct effect	0.02	[-0.02, 0.07]	0.10*	[0.01, 0.19]
Total indirect effect	−0.12***	[-0.16, −0.07]	−0.15**	[-0.24, −0.06]
→ stress	−0.12***	[-0.16, −0.08]	−0.15***	[-0.24, −0.07]
→ physical activity	0.00*	[0.00, 0.01]	0.00	[-0.00, 0.01]
Social cohesion				
Total effect	−0.14***	[-0.20, −0.09]	−0.24***	[-0.33, −0.15]
Direct effect	−0.05*	[-0.09, −0.01]	−0.04	[-0.10, 0.03]
Total indirect effect	−0.10***	[-0.14, −0.05]	−0.20***	[-0.27, −0.13]
→ stress	−0.09***	[-0.14, −0.05]	−0.20***	[-0.27, −0.13]
→ physical activity	−0.00	[-0.01, 0.00]	−0.00	[-0.01, 0.00]

β = Standardized path coefficient; CI = Confidence interval; *p < 0.05, **p < 0.01, ***p < 0.00.

5. Discussion

5.1. Main findings

We examined the direct and indirect effects of multiple perceived neighbourhood characteristics on depressive symptoms in the Netherlands. We also considered employment status (in combination with workplace) as a moderator. Small direct effects between neighbourhood characteristics and depression were found, but these were not significantly different between groups. There was evidence of indirect effects of pleasantness, environmental disturbance, safety, and social cohesion on severity of depression through stress, with stronger effects for the 'at home' group. There was no evidence for physical activity as a potential mediator.

Our findings support previous research that has highlighted the importance of the neighbourhood social environment on mental health (Gidlow et al., 2010; Helbich et al., 2019; Zhang et al., 2019). We identified social cohesion and safety as important characteristics that related to depression severity, driven by stress. Increased perceived neighbourhood social cohesion has consistently been associated with reduced depression (Liu et al., 2019; Mair et al., 2008; Ruiz et al., 2019). It is assumed that a neighbourhood with high social cohesion offers more social support and a social network, which promotes mental health. Safety was also identified as a key neighbourhood social characteristic, with greater safety being associated with reduced depression severity via stress. This is in line with the findings of a recent pooled analysis of eight Dutch cohort studies that used objective data (Generaal et al., 2019b). In terms of neighbourhood physical characteristics, increased environmental disturbance was shown to significantly increase depression severity via stress. Environmental disturbance was comprised of perceived traffic congestion and noise inside and outside the home. Exposure to noise is a known environmental stressor that, if chronic, can result in a prolonged stress response which can lead to the development of depression and anxiety disorders (Clark and Paunovic, 2018; Lan et al., 2020). Lastly, pleasantness was shown to indirectly increase depressive symptoms via stress in the 'at home' group only, however, considering the confidence intervals, this was only marginally significant.

It was observed that the indirect effects were stronger in the 'at home' group. This suggests support for our second hypothesis, whereby the 'at home' group is differentially exposed to neighbourhood

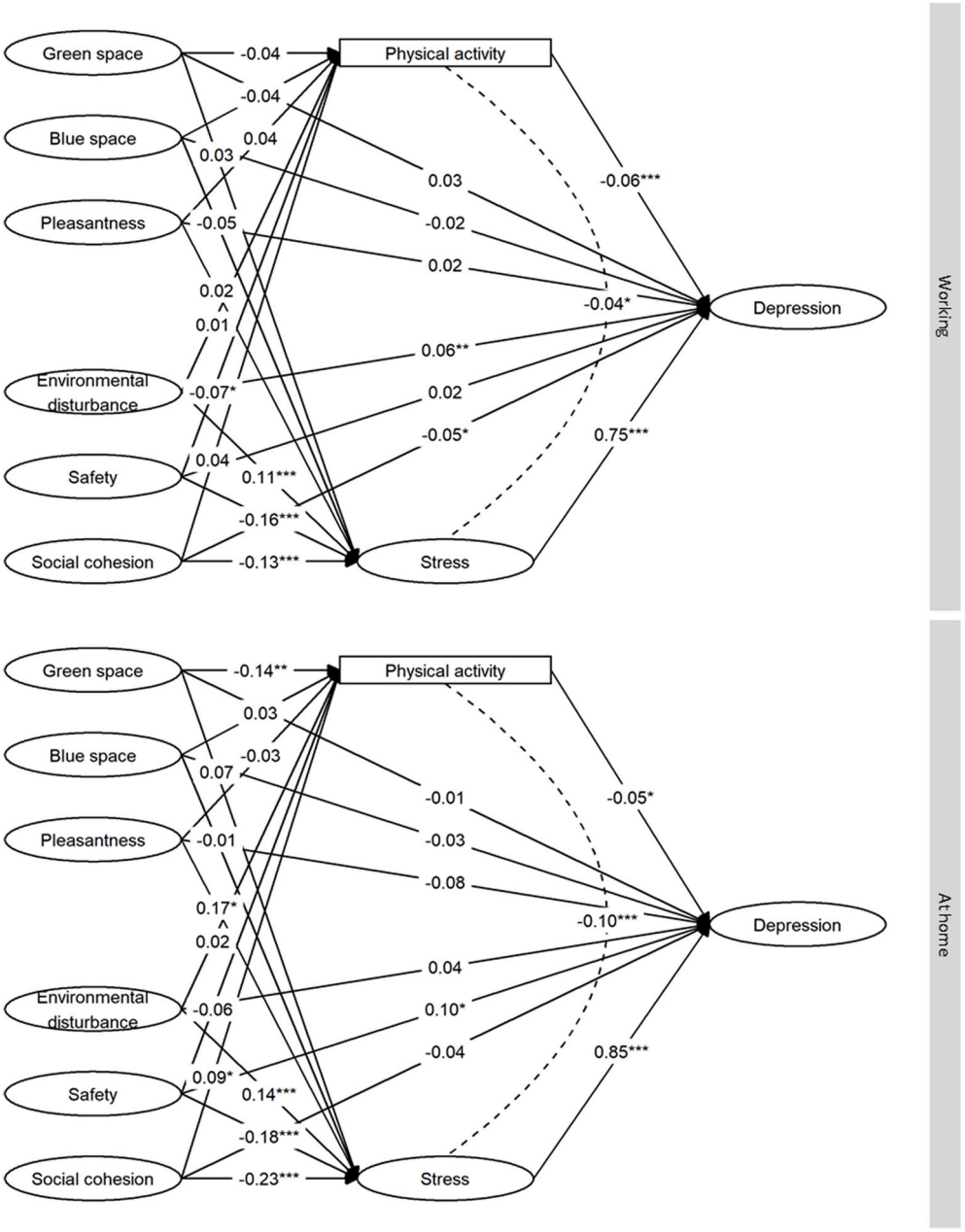

Fig. 2. Structural equation models. *Note*. The measurement model, control variables and covariances between neighbourhood characteristics are not shown to enhance readability. Dotted line indicates covariance.

characteristics, resulting in a stronger influence on stress and in turn on depressive symptoms. This is in line with the idea that greater exposure to the neighbourhood can result in greater vulnerability to its characteristics (Ivory et al., 2015; Vallée et al, 2010, 2011). Ivory et al. (2015) previously identified car access and household income as modifiers of the built environment-weekday physical activity association. In agreement with our results, there was evidence that 'not working full time' was an effect modifier, albeit with a reduced magnitude. We also identified that income quintile, as well as all but one of the control variables, were significantly different between the two groups. This suggests there may be differences in exposure according to these groupings too, however, the mechanisms behind this are unclear (Diez Roux and Mair, 2010). Nevertheless, the results underscore the need to consider variation between individuals in environment-health research, as it cannot be assumed that everyone experiences their residential environment equally (Perchoux et al., 2014).

Few relationships were observed concerning physical activity. A significant but small direct effect was found for physical activity on depressive symptoms, but this was not significantly different between groups. Green space and social cohesion were related to physical activity in the 'at home' group only. This is in line with previous reviews that have found a relationship between the neighbourhood and physical activity (Barnett et al., 2017; McCormack and Shiell, 2011). A weak relationship was observed between safety and physical activity in the 'working' group. There were no significant indirect effects of neighbourhood characteristics on depression via physical activity. Overall, our results may be explained by the operationalisation of physical activity: we did not distinguish between types, intensity or setting. A previous Dutch study found that 'green' physical activity (namely gardening, and walking and cycling for transport or leisure) was a weak mediator of the relationship between streetscape greenery and mental health, however, total physical activity was not a mediator (de Vries

et al., 2013).

5.2. Strengths and limitations

This paper has several key strengths. We made use of a large sample that was nationally representative for the Netherlands, meaning our results are robust. We applied SEM, a powerful method that allows the complex direct and indirect relationships between perceived neighbourhood characteristics and depressive symptoms to be considered. This method has so far seen limited use in health studies. We were also able to examine employment status (in combination with workplace) as a moderator. Lastly, a number of validated tools were used to assess neighbourhood characteristics, depression and stress (e.g. PHQ-9, PSS).

Alongside these strengths, several limitations are recognised. First, this study is cross-sectional, therefore we cannot draw conclusions regarding causality from these results. It is recommended that future research adopts a longitudinal approach whereby the development of mental health issues can be followed over time alongside the presence of various neighbourhood characteristics.

Second, in this study we examined perceptions of neighbourhood characteristics, therefore responses are subject to reporting bias (Mair et al., 2008). This could lead to a misclassification of the true exposure. For example, participants were asked to estimate the distance to various green and blue spaces from their home. Responses to these questions may deviate from the actual distance. Moreover, people with more depressive symptoms may be more likely to have a negative perception of their neighbourhood even if the neighbourhood is objectively of good quality. Vallée et al. (2011) suggest that reporting bias may be reduced by measuring neighbourhood characteristics independent of the sample, although this may not be concordant with the personal exposure of some individuals. Nevertheless, our findings align with studies of mental health that used objective measures of neighbourhood characteristics (Generaal et al., 2019a). Previous research has also indicated that mental health is affected more by the perceived environment than the objective environment (Zhang et al., 2019), therefore it is important to consider the perceptions that people hold.

Third, we combined employment status and workplace to produce a proxy measure for exposure to the residential environment. However, we recognise that this does not fully capture all the places in which time was spent and indeed exposure can be defined in multiple ways. Ivory et al. (2015) has discussed previously that exposure may not be viewed simply as a function of time spent in an environment but may also be the result of deeper engagement with or reliance on an environment. In this study, we approached exposure using the former definition, hypothesizing that the effects of the residential neighbourhood would be stronger for non-working people or people who work from home because they spend more time there. However, this does not capture the whole mobility pattern of a person - other environments are engaged with in the course of daily life (e.g. recreation and leisure environments), and those not in work can still potentially regularly travel beyond the neighbourhood. Previous findings suggest that for those not working, activity space is smaller and more centred on the residential environment (Perchoux et al., 2014), but a certain degree of exposure misclassification is still possible. In order to capture multiple locations and improve exposure estimation, detailed activity space questionnaires or Global Positioning Systems (GPS) technology may be used, therefore going beyond the foundational residential and work environment (Helbich, 2018; Kestens et al., 2018; Shareck et al., 2014). Moreover, to understand the potential implications of greater engagement with or reliance on an environment, future research might incorporate questions on attitudes towards environments or motivations for use.

Lastly, while our results were representative for the Netherlands, the findings may not be applicable to other settings. The Netherlands is a highly developed, urbanised and densely populated country; differences in perceptions of the neighbourhood and associations with mental health may be uncovered in other regions of the world.

6. Conclusion

The findings of this study demonstrate the relationships between multiple neighbourhood characteristics and depressive symptoms. Social cohesion and safety were associated with reduced depression severity, whereas environmental disturbance increases severity. Stress was identified as a mediator of these relationships, and effects were stronger for those who were non-working or worked at home. This underscores the need to consider variation in exposure by individual factors in environment-health research. Interventions to promote mental health should first focus on the social environment, and particular attention should be paid to those who are spatially confined in poorer quality neighbourhoods.

Author statement

Hannah Roberts: Conceptualisation, Methodology, Data Curation, Formal analysis, Visualisation, Writing – Original Draft; Caspar van Lissa: Methodology, Formal analysis, Visualisation, Writing – Review & Editing; Marco Helbich: Conceptualisation, Writing – Review & Editing, Project Administration, Funding Acquisition.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2020.113533.

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