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The role of social and built environments in predicting self-rated stress: A multilevel analysis in Philadelphia

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Abstract

Most studies of the predictors of stress focus on individual characteristics. Linking multiple contextual data sources to an individual-level health survey, we explore the associations of both built and social environment determinants with self-rated stress. At the individual level few social factors were significant predictors, though neighborhood trust and food insecurity have independent effects on stress. At the neighborhood level, the presence of hazardous waste sites and traffic volume were determinants of self-rated stress even after controlling for other individual characteristics. The latter two factors are of relevance to public health policy as they are potentially modifiable.

Keywords

self-rated stress; built environment; multilevel analysis; Philadelphia

Introduction

Biological stress was first defined in the 1930s (Selye, 1936). It originally referred to a syndrome occurring in laboratory rats and gradually evolved into a concept of understanding the interaction between individuals and their environment (Viner, 1999). Today, stress is implicated in a wide range of social and health outcomes, such as cardiovascular diseases (Black and Garbutt, 2002; Kristensen, 1996), cancers (Helgesson et al., 2003), deviant behaviours (Wills et al., 2002), depression (Maddock and Pariente, 2001), and biological reactions (Tausk et al., 2008).

The environment should play a crucial role in determining stress (Kasl, 1984). Several recent studies have concluded that the neighborhood etiological factors for mental health, stress and depression in particular, have been underexplored (Cutrona et al., 2006; Kim, 2008). Specifically, relatively little is known about the effects of the built environment (both resources and risks) in a neighborhood on mental health. The proliferation of geospatial data and techniques to analyze such data coupled with developments in multilevel modeling, however, has facilitated analysis of the relationships between neighborhood characteristics and health-related outcomes. The array of neighborhood characteristics available for analysis has allowed researchers to be creative vis-à-vis their inclusion of explanatory

factors. Researchers are no longer tied to decennial census variables but can draw on land use, crime, transportation and infrastructural databases. Our goal was to add to the stress research literature by integrating readily available geospatial information on the social and built environment with individual survey data and to conduct a multilevel analysis. To frame our analysis we first review the literature to explore potential ecological determinants of stress.

Stress in different residential locations: built environment

Since the 1960s, the literature has reported the connections between social status variables and mental health problems (Turner and Marino, 1994). These connections are seen in the variations in the experience of individuals of divergent socioeconomic characteristics (social causation) rather than as an outcome of selecting individuals into different social positions (social selection) based on their mental health status (Aneshensel, 1992; Turner et al., 1995). Explicitly then, individual-level characteristics, such as marriage (Ross, 1989; Shields, 2004; Turner and Lloyd, 1999; Turner and Marino, 1994; Turner et al., 1995), employment (Jin et al., 1995; Larocco et al., 1980; Pearlin et al., 1981; Tennant, 2001) and socioeconomic status (Shields, 2004; Turner and Marino, 1994; Turner et al., 1995), are fundamental individual-level determinants of stress.

In addition to individual features, environments should contribute to stress assessment (Kasl, 1984). Social stress research, however, has not focused on how the built environment contributes to stress (Ahlberg et al., 2003; Carlsson et al., 2006; Silverman et al., 1987; Thoits, 1995). Perceived threats to personal health can result in stress, cause psychological trauma, and harm mental health (Elliott et al., 1993; Taylor et al., 1997). For example, it has been found that neighborhood residents who realize that they have been exposed to toxic material tend to report more psychological distress symptoms than those who do not, such as stress disorders, fear, and loss of sleep (Edelstein, 2002). Clinically, the “hazardous waste syndrome” refers to the phenomenon where patients exposed to very low doses of a chemical exhibit physical symptoms associated with the chemical and subtle psychological disturbances (Ramsey, 1986). Residents living around hazardous waste sites are more likely to show this syndrome. Several studies in California, for example, did not find evidence indicating excessive rates in cancer or birth defects around the waste sites; however, the total number and the prevalence of many psychological problems, such as stress and anxiety, were higher in the areas near the sites (Neutra et al., 1991; Schiffman et al., 1995; Smith and Rigau, 1988). The presence of potential threats to residents’ well-being in a neighborhood does not necessarily result in adverse physical health outcomes, but may become a determinant of stress and mental health (Luginaah et al., 2002). Hazardous waste sites, thus, can be a source of stress (Elliott and Taylor, 1996; Eyles et al., 1993).

Traffic, like hazardous waste sites, can be an important environmental factor related to stress. Since the 1990s, traffic has been identified as a salient source of stress (Hennessy and Wiesenthal, 1999; Novaco et al., 1990). Residents in a neighborhood with high traffic exposure are found to report high self-rated stress (Babisch et al., 2001; Gee and Takeuchi, 2004). Noise is one of the problems brought on by high traffic density and this can elevate an individuals’ stress. In addition, biologically, traffic noise will induce the release of the stress hormones (i.e. adrenaline), affecting both cognitive and emotional responses (Babisch et al., 2001). Moreover, high traffic volume brings congestion, which can increase both drivers’ stress and the perception of risk of injury to pedestrians (Song et al., 2007). Perceived traffic danger not only has been reported as the second leading barrier to walking and biking in the U.S. (CDC, 2002), but this also has become a widely cited neighborhood problem (Balfour and Kaplan, 2002).

Stress in different residential locations: social environment

Residential locations not only include built environment characteristics, but also social characteristics. We introduce three possible factors associated with stress: neighborhood crime, residential stability, and socioeconomic status. Stress symptoms are closely related to neighborhood safety. For example, residents of a high-crime neighborhood tend to exhibit more signs of mental illnesses than counterparts in areas of low-crime (Ross, 2000; Ross and Mirowsky, 2001). Indeed, residents of high crime neighborhoods are more likely to be affected, both directly (victimization and perception of threats) and indirectly (grief for loved ones and neighbors) in ways that may lead to high stress and hypertension (Taylor et al., 1997).

Residential stability has been found to alleviate stress. A stable neighborhood is good for residents' interaction, facilitates the development of social capital, and strengthens levels of civil engagement (Glaeser et al., 2002; James et al., 2001; Putnam, 2000). Collective efficacy will not only establish a sense of belonging, but also generate emotional support and facilitate access to resources. When exposed to stressors individuals living in a more stable neighborhood may be able to draw on sufficient support to cope with them (Berkman et al., 2000). Evidence for this was confirmed in a study examining the mediating role of residential stability between stress and health (Boardman, 2004). Residential stability might not directly contribute to physical health but a beneficial impact on stress may be evident.

Socioeconomic status (i.e., household income, education, and occupation) is the fundamental proxy describing the social environment where people live (Sampson et al., 1997). Residents of poor neighborhoods report more life stress events, i.e. hunger and declining health (Krivo and Peterson, 1996). Inadequate infrastructure and discriminatory practices are associated with low socioeconomic neighborhoods (Schulz et al., 2000) and these also can lead to stress (Dalgard and Tambs, 1997).

Prior social stress research has documented the impact of social position on stress. In contrast, this study broadens the array of predictors of stress by considering both the built and social environments. Utilizing geospatial data and the multilevel methods, we examine following related hypotheses. After controlling for individual socioeconomic and demographic features, (a) *the presence of potential threats to health (hazardous waste) will be positively associated with individual stress*; (b) *high neighborhood traffic will be positively related to individual stress*; (c) *neighborhood crimes will be positively associated with stress*; (d) *residents in a stable neighborhood will report low stress*; and (e) *individuals in a neighborhood of high SES will tend to perceive less stress even after controlling for personal characteristics*.

Data and Methods

Data

The Philadelphia Health Management Corporation's (PHMC) 2006 Southeastern Pennsylvania Household Health Survey is the source of the individual-level data. This survey includes comprehensive data on individual health behaviors and health care experience (PHMC, 2006). We analyze data on the 4,095 respondents in Philadelphia County. Though census tracts are often used to define neighborhoods, multiple contiguous census tracts sharing common characteristics (high positive spatial autocorrelation in attributes of interest) can be combined (Clapp and Wang, 2006). We aggregated census tracts in Philadelphia County into 158 neighborhoods. Two aggregation rules were followed. First, the census tracts can only be combined with contiguous tracts. These tracts must all be hierarchically embedded within one of the 45 defined PHMC neighborhoods in Philadelphia

county. Second, the boundary of a resultant neighborhood must not cross either a built environment barrier (e.g. freeways, railroads) or a physical environment barrier (e.g. rivers). The aggregation of contiguous tracts was based on the use of local indicators of spatial autocorrelation (LISA). The LISA maps indicate local clustering. A positive LISA value indicates spatial clustering of similar values (either high or low values) and a negative value represents spatial clustering of dissimilar values (Anselin, 1995, 1996). We examined LISA maps and statistics of several salient socioeconomic characteristics of census tracts (e.g., race/ethnicity and poverty) and combined tracts with similar LISA values. For example, we aggregated adjacent tracts if they had similar poverty rates or racial/ethnic components. The underlying philosophy of this approach is to maximize the homogeneity within our neighborhood units. Similar aggregation methods have been discussed elsewhere (Duque et al., 2007; Openshaw and Rao, 1995). The new neighborhood areas are thus aggregates of census tracts and conform to both natural and large scale built environment features (i.e. rivers, railroads, and freeways).

Analytic Strategy

To test the hypotheses listed above, we implement a series of hierarchical models using the statistical package HLM 6 (Scientific Software Inc., 2008). We first conduct a null model without explanatory variables to confirm that stress does indeed vary by neighborhood. This basic model contains no predictors (see Equation 1). γ_{00} is the grand mean of the stress measure. u_{0j} adjusts the grand mean for the j th neighborhood. For instance, if the average perceived stress of a neighborhood is greater than the grand mean, u_{0j} should be positive. Likewise, if the average stress is equal to the grand mean, u_{0j} should be zero. r_{ij} hence is the offset to the grand mean for the i th respondent in the j th neighborhood.

$$\begin{aligned} Y_{ij} &= \beta_{0j} + r_{ij} && \text{Individual Level} \\ \beta_{0j} &= \gamma_{00} + u_{0j} && \text{Neighborhood Level} \\ Y_{ij} &= \gamma_{00} + u_{0j} + r_{ij} \end{aligned} \quad (1)$$

,where Y_{ij} is the reported stress of the i th individual in the j th neighborhood and r_{ij} is the random effect for this respondent; γ_{00} is the unadjusted average stress level in the data and u_{0j} is the random effect for the j th neighborhood. Equation 1 is equivalent to a ANOVA model where the within- and between-neighborhood variances are separate. In HLM, the variance of dependent variable is defined as $Var(Y_{ij}) = Var(u_{0j} + r_{ij})$, which can be rewritten as $Var(Y_{ij}) = \tau_{00} + \sigma^2$, where τ_{00} is designated to capture the between-neighborhood variability and σ^2 represents the within-neighborhood variability. That is, this equation provides information about the variability of the stress at both individual and neighborhood levels.

Our modeling strategy is a conventional hierarchical modeling approach (Raudenbush and Bryk, 2002). The first step is to explore if the average stress at the neighborhood level varies across neighborhoods. A fully unconditional model (as discussed previously) is developed. Should the variance at the neighborhood level be statistically significant, it indicates that the average stress differs by neighborhoods. However, the significant variance at the neighborhood level may result from sampling. The differences between individuals may possibly lead to significant variance at the neighborhood level. To eliminate this competing explanation (for why neighborhood matters), it is important to include/control for the individual characteristics related to the outcome variable in the model. If the variance at the neighborhood level is still significant after accounting for individual factors, this provides evidence that factors at the neighborhood level play a role in understanding the variation across neighborhoods. Following from this the final step is to include the possible predictors

at the neighborhood level into models. This conventional approach can be found elsewhere (Matthews and Yang, forthcoming).

The analytic strategy above can be translated into equation 2 as below:

$$Y_{ij} = \gamma_{00} + \sum \gamma_{0l} w_{lj} + \sum \beta_{kj} x_{ijk} + u_{0j} + r_{ij} \quad (2)$$

, where γ_{00} is the adjusted average stress level; γ_{0l} is the impact of neighborhood feature l ; w_{lj} is the feature l of the j th neighborhood; x_{ijk} is the characteristic k of the i th respondent in the j th neighborhood and β_{kj} indicates the impact of that characteristic. We tested whether the effect of a predictor, say γ_{0l} , is significant with a t ratio statistic. The null hypothesis is $\gamma_{0l}=0$, and the t ratio statistics is defined as $t = \hat{\gamma}_{0l} / (\hat{V}_{\gamma_{0l}})^{1/2}$, where $\hat{\gamma}_{0l}$ is the maximum likelihood estimate of γ_{0l} and $\hat{V}_{\gamma_{0l}}$ represents the estimated sampling variance of $\hat{\gamma}_{0l}$. The t statistic is asymptotically normally distributed. Based on the t statistic and the degree of freedom for the predictor, we can obtain the p-value and hence test the null hypothesis (Raudenbush and Bryk, 2002).

Measures

The dependent variable is self-rated stress. Assessing stress with a satisfactory objective perspective is extremely difficult, if not impossible, because whether an event leads to stress is subject to individual perception and interpretation of that event. That is, a similar event occurring at a different stage of life or to different people could result in different outcomes. Subjective measures, i.e. self-rated stress, are believed to better capture the combination of environmental demands and coping ability than a set of stressful events, reflecting the day-to-day stress (Lazarus, 1990). The respondents in the PHMC were asked to use a scale from 1 to 10 to assess how much day-to-day stress they experienced, where 1 meant “no stress” and 10 indicated “an extreme amount of stress.” Following Lazarus (1990), this subjective assessment is an appropriate measure to use in the absence of a complete inventory of stressful events.

Individual-level predictors in our models include demographic, SES, health, and social support variables. Four demographic variables are first considered. *Age* was entered as an ordinal variable on a scale from 1 to 5 (age 18–39, 40–49, 50–59, 60–74, and 75 or above). *Gender* was a dummy variable with males coded 1 and females 0. *Race* was coded 1 if respondents self-identified as African-Americans and 0 otherwise; African Americans are the largest race/ethnic group in the city of Philadelphia. *Marital status* was trichotomized into married/cohabited, widowed/separated/divorced (previously married), and single (reference group). In addition, three covariates related to socioeconomic status were included. *Employment status* was dichotomized into full time employed and others (reference group). *Education* was a dummy variable coded 1 if respondents completed high school, 0 otherwise. *Poverty* was captured by a dummy variable and coded 1 if the family income was below the federal poverty level, 0 otherwise. In addition to the variables aforementioned, *food insecurity* can have an adverse impact on stress in adults due to heightened concerns over basic resources (Hamelin et al., 1999). A recent study on 18 U.S. cities concluded that the prevalence of mental problems (i.e. depression) was more common among the mothers and children who were food insecure (Whitaker et al., 2006). Food insecurity was coded as 1 if the respondents have cut the size of meals or skipped meals because of the lack of budget for food, otherwise 0.

Individual *health* was also considered in the analysis. It was operationalized as a composite score based on physical health conditions and self-rated health. Respondents were asked if they had any of the following problems: asthma; heart problems; diabetes; arthritis; high

blood pressure; or high cholesterol. We summed and standardized the number of “no” responses in order to build a measure of positive health indicator. Participants were also asked to evaluate their overall health from “excellent” to “poor.” This indicator was consistent with the physical health (Cronbach’s $\alpha = 0.653$). The final health score was generated by standardizing the self-rated health score and averaging the physical condition measure within individuals (where higher scores indicate better health).

We use two variables as the proxy of social support received by individuals. *Religiosity*, was measured by the frequency of attending religious services. Those who participate weekly were coded as 1, in contrast to others coded 0. *Neighborhood trust* was measured based on whether respondents agreed that “most people in the neighborhood can be trusted,” ranking from 1 to 4 (strongly disagree, disagree, agree, strongly agree). We standardized the ranking with higher scores indicating higher levels of neighborhood trust.

As noted above we have used several neighborhood level predictors. We utilized tract-level crime data for 2004 from the Philadelphia Police Department to define neighborhood safety. Data on three crime types were summed for each neighborhood and converted into rates per 1,000 population: Part I violent crimes, property crimes, and missing persons. We used principal component analysis (PCA) to create a neighborhood crime score. The factor loadings for the three crime types were .94, .93, and .53, respectively, with 67.71 percent of the total variance explained. We followed Sampson and colleagues (Sampson et al., 1997) to create the social condition variables used in this study. We first extracted six indicators of socioeconomic status at the neighborhood level. Then we applied PCA to detect if these indicators can be further reduced into a single concept. The factor loadings on socioeconomic status were: percent of female-headed household (.83), unemployment rate (.92), poverty (.94), percent of people receiving public assistance (.94), median household income (−.91), and percent of people with at least a bachelor’s degree (−.88). This socioeconomic status factor explained 81.35 percent of the total variance. Higher scores should be interpreted as a lower socioeconomic status within the neighborhood.

The third social environment variable was residential stability. The percent of house ownership and the percent of residents living in the same address at least five years were calculated from 2000 census tract-level data. We aggregated the raw data for each neighborhood and standardize these two variables. Because these two characteristics are highly correlated (0.68 ($p < 0.01$)), we averaged the standardized scores to yield a single indicator of residential stability.

A strength of our study was an explicit spatial perspective and use of GIS to create objective measures of neighborhood built environment characteristics. Daily vehicle miles traveled (DVMT) – our measure of traffic volume – was constructed using Pennsylvania Department of Transportation (2008) geospatial data on traffic volume (based on the amount of vehicle traffic that traveled sections of road). Each segment of road had a DVMT calculated by multiplying the length of road (in miles) by average daily traffic estimate. The neighborhood boundaries were overlaid with the traffic network in a GIS and then we averaged the DVMT of each road segment within a neighborhood, generating the traffic volume measure for each neighborhood. To avoid small estimates, we standardized the DVMT and use z-scores.

With respect to the hazardous exposure, two variables were obtained from the Environmental Protection Agency (EPA, 2008) and the Pennsylvania Department of Environmental Protection (PDEP, 2006) – the number of toxic release inventory (TRI) sites and the presence of a residual waste operation (RWO) site. The TRI site was a facility that manages chemicals released from industries such as manufacturing, mining, electric utilities, and commercial hazardous waste treatment (EPA, 2008). The RWO was a primary facility

handling the materials and products that cannot be reused, recycled, or composted and require disposal technologies such as landfill and incineration (PDEP, 2006). These facilities were geocoded by EPA and PDEP, respectively, and we overlaid these with neighborhood boundaries. The count of TRI sites within a neighborhood was used in our analyses. In contrast to TRI, RWO was relatively rare in Philadelphia, we coded the neighborhoods with RWO sites as 1, 0 if without.

Results

Table 1 shows the descriptive statistics of the variables used in this study. The average reported stress was 5.3. (close to the mid-point of 5.5 on the scale). While almost 13 percent of the respondents reported no stress at all, a similar proportion (12.1%) of people characterized their life as extremely stressful (results not shown). Stress was a common experience for the residents in Philadelphia County. Approximately 40 percent of the PHMC respondents were black. Two out of three participants were either married or previously married. Fifty-three percent of respondents were full time employees and more than 40 percent had completed at least secondary education. The poverty rate among the adults was 17 percent and more than 40 percent of the respondents attended weekly religious activities.

Table 2 reports those models that included only individual-level characteristics. We used the variance inflation factor (VIF) to determine whether multicollinearity was a problem. A VIF greater than 10 would indicate problems. All the VIFs in Table 2 are smaller than the stricter cut-off value, 4 (Menard, 2002), and thus our results should not be biased by multicollinearity.

The null model indicates that stress differs by neighborhood (variance component = 0.0689 and significant at .01). Four nested models were implemented where different sets of individual characteristics are included. For the purpose of brevity, we focused on Model IV. While the literature suggests that stress level should vary by demographic factors, our analysis of self-rated stress provides little support. Our results confirm the age effect. To further confirm the general lack of support for demographic factors we compared the mean stress level by demographic variables and the t-test results indicate that self-rated stress does not vary by gender, race, and marital status (results not shown).

In Model IV neighborhood trust not only offsets the detrimental effect of poverty, but we find a beneficial effect on stress independent of other explanatory variables. Food insecurity was positively associated with self-rated stress. As suggested by Hamelin et al. (1999), food insecurity is associated with both acute and chronic stress. Since the respondents were asked to rate their stress on a day-to-day basis, the positive association between food insecurity and stress is not unexpected. Despite its negative correlation with stress, individual health was a marginally significant predictor. It seems, at the individual level, self-rated stress was affected by age, neighborhood trust and food insecurity. After controlling for all individual level variables, the variance component in Model IV is still significant, which leaves room to explore the role of neighborhood-level characteristics of the built and social environment in predicting self-rated stress.

Table 3 demonstrates the results of models including the neighborhood factors. Model V only considers socioeconomic status factors. Although it is believed that the residents from a neighborhood with low socioeconomic status tend to report high stress, the results here do not support this. Model VI adds neighborhood crime and residential stability. Residential stability was beneficial, but marginal, in its association with stress; similar to findings in previous studies (Berkman et al., 2000; Boardman, 2004). A neighborhood with low turnover rates and high homeownership is generally regarded as a stable neighborhood, one

that can influence individual behaviors and emotional responses and hence affect self-reported stress (Berkman et al., 2000). Neighborhood crimes were not related to stress. Despite the suggestion that lack of sense of safety could lead to undesirable mental health outcomes the difference in residents' stress level between high- and low-crime neighborhoods was not significant.

The built environment factors were incorporated in Model VII and VIII. Model VII includes two measures of hazardous waste exposure. The number of TRI sites within a neighborhood was positively correlated with individual stress, even after controlling for other covariates. This relationship echoes the hazardous waste syndrome and reflects that a visible potential threat to individual safety can exert an adverse effect on self-rated stress. Nonetheless, unlike TRI, the presence of RWO was not a predictor of stress. The marginally beneficial association of residential stability with stress was no longer significant when the hazardous waste factors in Model VII. Residential stability may have been confounded with hazardous waste. It has been reported that "wanting to move but cannot" is among the five most common sources of stress for both females and males in Canada (Shields, 2004). Assuming this finding holds in Philadelphia County, those who wanted to move out of the neighborhoods with hazardous waste sites but cannot might increase residential stability at the neighborhood level but residents report high individual stress. Explicitly, whether high residential stability is a result of voluntarily staying or the inability to move out may affect the relationship between stress and residential stability, especially for the respondents from neighborhoods in a high-risk and poor resourced built environment.

Traffic volume was added in Model VIII. Following theoretical expectations, busy traffic was associated with high stress. While the association between TRI and stress was reduced by the inclusion of traffic volume, it remained significant, indicating both built environment factors contributed to levels of stress independently. It is worth noting that social environment variables alone (Model VI) does not fully account for the variation of stress at the neighborhood level. The variance component becomes insignificant only after built environment predictors were included. Thus both social and built environments are important in understanding why people living in certain neighborhoods report higher stress than their counterparts living in elsewhere in Philadelphia.

Revisit Hypotheses

Beyond individual characteristics, we anticipated that environmental factors could explain individual self-rated stress. With respect to social environment, neither socioeconomic status nor neighborhood crime exhibit significant associations with stress. Residential stability had marginal influence but this may be confounded with the presence of hazardous waste sites. This issue requires more detailed data to explore the intertwined relationships among stress, residential stability, and the exposure to hazardous waste sites. Two built environment factors (traffic volume and TRI) derived from geospatial data confirm the anticipated associations with stress. In contrast to the social environment, the built environment is perhaps more easily perceived and/or seen. Individuals, thus, presumably respond to the built environment, one such response being to report higher stress. Our results support this and suggest that visible threats to individual safety (or health) might better explain why stress differs by neighborhood across Philadelphia.

Discussion and Conclusion

The most significant contribution of this study was to establish the association between self-rated stress and the perceived environmental threats, hazardous waste sites and traffic volume in particular. The relatively understudied built environment neighborhood-level

factors may play a role that is as important as the individual factors in determining self-rated stress. As Healthy People 2010 (DHHS, 2000) indicated, health is not only determined by individual features but also by the environmental characteristics to which people are exposed. Social stress research can be expanded in scope if neighborhood factors including measures of the built environment.

In cognitive theory stress is conceptualized as a dynamic person-environment transaction (Lazarus and Folkman, 1984). Primary appraisal occurs when a person evaluates whether the environment is relevant to personal wellbeing, and is followed by secondary appraisal, a process through which a person determines what can be done to benefit personal wellbeing. Coping strategies may be adopted when the person-environment transaction taxes resources or reduces a person's wellbeing (Folkman et al., 1986). When the coping strategies are ineffective, stress levels may rise. Our findings appear to mirror this process. For example, residents in a neighborhood containing a TRI may feel that their health is endangered by the presence of toxic wastes (primary appraisal). Several coping strategies can be taken including moving out of the neighborhood, accepting the situation, and seeking more information on the TRI (secondary appraisal). If a coping strategy is to move but the costs of moving are prohibitive, stress level would rise accordingly. Similarly, DVMT can be understood in the same way. Residents usually lack the ability to ameliorate the busy traffic that may pose a potential threat to wellbeing in their neighborhoods. A disequilibrium between environment demand and individual coping may lead to high stress.

Several policy implications may be drawn from the findings of this study. As the presence of hazardous waste sites might induce high stress, it is important to inform residents of both potential advantages and disadvantages such facilities might bring. Reducing residents' misgiving about TRI sites and disseminating useful information might reduce stress. In addition, to minimize the adverse impact of traffic on stress, encouraging the use of public transportation and developing a more pedestrian- and bike- friendly environment might decrease traffic volume and the stressors related to traffic. Neighborhood trust can be beneficial for coping with stress, and thus programs and policies that can enhance the collaboration and communication among residents may facilitate the development of more trust. Both individually-oriented policies and neighborhood-based health promotion in tandem may improve self-rated stress.

This study shares several limitations with earlier research. First, changing the definition of neighborhood may alter the findings aforementioned. The influence of different levels of geographic aggregation on stress should be noted (Soobader and LeClere, 1999). Second, this study assumes that respondents are only affected by the neighborhood where they live. That is, we only take the residential environment into account but other places where people spend significant amounts of their time (workplace), could also have implications for stress. While methodologically a cross-classified and multi-membership models can solve this problem (Raudenbush and Bryk, 2002), the data we used and many other existing datasets do not support this kind of analysis. Third, this study is a cross-sectional analysis using the 2006 PHMC individual level data. While several data sets from earlier time periods are integrated into the analysis, the causal associations between stress and environmental factors are not fully examined. Quasi experimental intervention research design that collects information on the changes in individual stress before and after changes in social and/or built environments would further clarify any causal pathways.

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Table 1

Descriptive statistics of the variables used in analysis

	Minimum	Maximum	Mean	S.D. (N) ^a
<u>Individual Level (N=4095)</u>				
Stress	1.0000	10.0000	5.2909	2.8705
Age Group	1.0000	5.0000	2.5909	1.3710
Gender	1.0000	0.0000	0.2963	1,213
Race (Black = 1, else 0)	0.0000	1.0000	0.4139	1,695
Marital Status				
Married	0.0000	1.0000	0.3942	1,614
Previously Married	0.0000	1.0000	0.2825	1,157
Employed	0.0000	1.0000	0.5329	2,182
Education (Over high school =1, else 0)	0.0000	1.0000	0.4499	1,842
Poverty (Poor = 1, else 0)	0.0000	1.0000	0.1740	713
Religiosity (weekly =1, else 0)	0.0000	1.0000	0.4129	1,691
Neighborhood Trust	-2.9792	1.7036	0.0004	0.9940
Food Insecurity	0.0000	1.0000	0.1365	559
Health	-2.7182	1.2496	0.0029	0.8604
<u>Neighborhood Level (N=158)</u>				
Socioeconomic Status	-1.7173	2.6668	0.0000	0.9968
Neighborhood Crimes	-0.8443	9.5688	0.0026	1.0026
Residential Stability	-3.5638	1.7274	0.0000	0.9170
TRI	0.0000	7.0000	0.4304	0.9264
RWO	0.0000	1.0000	0.1329	21
DVMT	-0.8754	4.1086	0.0000	1.0000

^aFor continuous variables, standard deviation (S.D) is reported and bolded. For dummy variables, the total number of observation in a category (N) is noted.

Table 2

The impacts of individual-level factors on stress in Philadelphia County

Variables	VIF	Null Model	Model I	Model II	Model III	Model IV
Intercept	N.A.	5.2761***	6.6995***	6.6327***	6.5665***	6.1476***
Individual Level (N=4095)						
Age Group	1.0307		-0.5200***	-0.5168***	-0.5105***	-0.4693***
Gender (Male =1)	1.0394		-0.1294	-0.1093	-0.1005	-0.1017
Race (Black = 1, else 0)	1.0509		-0.0847	-0.0842	-0.1113	-0.1070
Marital Status						
Married	1.4270		-0.0330	-0.0117	0.0181	0.0818
Previously Married	1.4704		0.0098	0.0069	0.0498	0.0294
Employed	1.3441			-0.0378	-0.0237	0.0413
Education (Over high school =1, else 0)	1.1390			0.0687	0.0894	0.1674
Poverty (Poor = 1, else 0)	1.1357			0.2112*	0.1678	0.0345
Religiosity (weekly = 1, else 0)	1.0449			0.0522	0.0522	0.0753
Neighborhood Trust	1.0620				-0.1565***	-0.1210**
Food Insecurity	1.0294					0.1626***
Health	1.3187					-0.1127 ⁺
Variance Component μ_0	N.A.	0.0689**	0.0486**	0.0360*	0.0328*	0.0382*

⁺ p<.1;

* p<.05;

** p<.01;

*** p<.001

Table 3

The impacts of individual and neighborhood factors on stress in Philadelphia County

Variables	VIF	Model V	Model VI	Model VII	Model VIII
Intercept	N.A.	6.1469***	6.1493***	6.1015***	6.0592***
<u>Individual Level (N=4095)</u>					
Age Group	1.0406	-0.4693***	-0.4672***	-0.4648***	-0.4646***
Gender (Male =1)	1.0424	-0.1015	-0.0999	-0.0966	-0.0953
Race (Black = 1, else 0)	1.1380	-0.1051	-0.1264	-0.0927	-0.0436
<u>Marital Status</u>					
Married	1.4318	0.0812	0.0835	0.0817	0.0798
Previously Married	1.4763	0.0288	0.0279	0.0250	0.0301
Employed	1.3482	0.0408	0.0417	0.0403	0.0415
Education (Over high school =1, else 0)	1.1735	0.1659	0.1551	0.1613	0.1634
Poverty (Poor = 1, else 0)	1.1494	0.0355	0.0316	0.0302	0.0262
Religiosity (weekly =1, else 0)	1.0469	0.0759	0.0778	0.0809	0.0796
Neighborhood Trust	1.0751	-0.1216**	-0.1234**	-0.1244**	-0.1183**
Food Insecurity	1.0415	0.1627***	0.1633***	0.1630***	0.1627***
Health	1.3224	-0.1128 ⁺	-0.1110 ⁺	-0.1110 [*]	-0.1102 ⁺
<u>Neighborhood Level (N=158)</u>					
Socioeconomic Status	1.2556	-0.0052	-0.0097	-0.0358	0.0013
Neighborhood Crimes	1.1712		-0.0064	-0.0051	-0.0199
Residential Stability	1.0667		-0.0758 ⁺	-0.0812	-0.0408
TRI	1.2402			0.0677 [*]	0.0494 [*]
RWO	1.0931			-0.1312	-0.0651
DVMT	1.1861				0.0976**
Variance Component u_0	N.A.	0.0464 [*]	0.0444 [*]	0.0618	0.0657

⁺ p<.1;^{*} p<.05;^{**} p<.01;

100>d

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