IS THERE AN ASSOCIATION BETWEEN URBAN GREENNESS AND AIR POLLUTION ANNOYANCE?

Donka Dimitrova[1], Angel Dzhambov[2]

[1]Department of Health Management and Healthcare Economics, Faculty of Public Health, Medical University of Plovdiv
[2]Department of Hygiene and Ecomedicine, Faculty of Public Health, Medical University of Plovdiv

ABSTRACT

BACKGROUND: Apart from its physical effects air pollution might exert psychological stress effect on health. Based on the limited evidence about the symbolic value of urban greenness in traffic perception and a small body of research indicating that greenness might abate the negative perception of noise pollution, we hypothesized that it could also reduce air pollution annoyance.

AIM: We aimed to test this hypothesis and determine whether greenness could buffer the annoyance reaction to air pollution.

MATERIALS AND METHODS: In a sample of 508 residents of Plovdiv, Bulgaria we investigated the interplay between objective and perceived air pollution exposure, annoyance, and several indicators of urban greenness, using path models.

RESULTS: Results showed that women living closer to a green space reported lower perceived air pollution exposure and through it – lower annoyance. This indirect path was driving the total effect and perceived air pollution acted as a full mediator. Among men there was no effect. With respect to perceived greenness, no effects on air pollution annoyance were found.

CONCLUSION: In conclusion, urban green spaces might act as a buffer for the psychological stress effect of air pollution. Nonetheless, at this formative stage of research the evidence is tentative.

Keywords: *air pollution, perceived air pollution, air pollution annoyance, stress, greenness, green space*

Address for correspondence:
Angel Dzhambov
Dept. Hygiene and Ecomedicine,
Faculty of Public Health,
Medical University of Plovdiv,
15A Vasil Aprilov Blvd.,
4002 Plovdiv, Bulgaria,
e-mail: angelleloti@gmail.com

Received: October 3, 2016
Accepted: December 23, 2016

INTRODUCTION

Ambient air pollution is a major environmental risk (1). It is associated with increased overall morbidity and mortality mostly due to cardiovascular and respiratory diseases (2). However, its indirect psychological effects have not been studied sufficiently and the evidence is still limited. Some have suggested that stress may be mediating these effects (3). According to Colligan, air pollution is "a general source of stress" which could affect people through

two psychological pathways – direct neurobehavioral effects of specific contaminants and an indirect arousal of the autonomic nervous system (4). Similar to noise annoyance, air pollution annoyance might be considered an indicator of these stress effects. Annoyance can be defined as a feeling of displeasure associated with any agent or condition believed to have an adverse effect (5). It gives account of the combined psychological and physiological stress caused by air pollution (6). The actual mechanisms underlying this annoyance reaction are not clear but it is contingent, on one hand, on the organoleptic properties of air pollutants, and, on the other, on the cognitive stress generated by the information and knowledge of people's personal exposure and its detrimental effects (7). While olfactory perception through the trigeminal system plays an important role in air pollution annoyance, health risk perception and health worry might be intervening factors. A study by Stenlund et al. proposed a model of the indirect effect of air pollution, according to which they were mediated through perceived air pollution, health risk perception, and annoyance (8). Later, Claeson et al. tested the same model but had to re-specify it, so that, in their final model, both air pollution and annoyance had only indirect effect on health symptoms through health risk perception (9). The evidence outlined above indicates that how we perceive air pollution is important element of its adverse effects. According to Oiamo "[h]ealth care strategies to manage or alleviate biomedical health outcomes of environmental exposure are well established, but little is known about the ecosocial health benefits of reducing exposures as a public health strategy" (10). Therefore, buffering these stress reactions should be investigated as a means of reducing the burden of disease associated with air pollution. However, research on air pollution annoyance and health is much scarcer in comparison to that on noise annoyance (11).

Green spaces are known to reduce air pollution in the urban environment by filtering particulate and gaseous pollutants, deposing them on plant surfaces, increasing their dispersion and altering the local temperature (12,13,14,15). There is, however, another alleged pathway, which has received little attention. Several studies have already shown that living in a greener environment and closer to green spaces are associated with lower levels of noise annoyance (16,17). It was suggested that the underlying pathways might be related to stress reduction and perceived control over the environment or even mitigating people's sensitivity to noise (17). However, almost nothing is known about the psycho-social benefits of interacting with urban greenness regarding air pollution perception. A survey carried out in London and based on phenomenological analysis of recorded interviews explored participants' attitudes, beliefs, knowledge, and subjective ratings of neighborhood air pollution (18). One of the findings was that the presence of trees and vegetation could balance the negative perception of traffic because participants believed trees to "have a physical function of actively cleaning the air and also of producing oxygen, which improved the air" (18). A symbolic and therapeutic value was attached to vegetation which "helped protect people from the experience of pollution and allowed them to feel that their neighbourhood was still healthy" (18). Field surveys have also shown that people rate the positive impact of green spaces on air quality as one of its important functions (19,20). Conversely, Shmool et al. looked at the correlations between perceived neighborhood air quality and area-level tree cover and found them to be modest and non-significant (21).

Based on the above, we hypothesized that the interaction with urban greenness would be associated with lower air pollution annoyance through lower perceived exposure to air pollution. We aimed to test this hypothesis and to determine whether greenness could buffer the annoyance reaction to air pollution.

MATERIAL AND METHODS

Study Area and Design

This study is based on a secondary analysis of a dataset from a cross-sectional survey carried out in the city of Plovdiv, Bulgaria (July – November, 2014). Plovdiv is the second-largest city in the country. It is characterized by a densely populated central area, several industrial zones, and a "wide network of busy streets and train tracks, big parks and other green yards" (22). Air pollution in the city is also high and often exceeds national standards (23).

Questionnaire data were collected via two procedures – snowball sampling and field interviews. Two hundred and forty nine questionnaires were distributed via snowball sampling and 213 were com-

pleted (85.5%); 1906 citizens were approached during the field sampling and of those only 368 agreed to participate (19.3%). Main reason for non-participation was the lack of time and/or fear of revealing personal information. A total of 508 cases were included in the analyses. Given the parameters of the tested mediation models in the present study, this sample size was considered sufficient (24; 25).

Because of its non-invasive measurements, observational nature, and adult population this secondary study did not undergo ethics approval by an Institutional Review Board (the primary study, for which data were collected, was approved). All participants were assured of anonymity and participation was voluntary. Answering the interview or completing the questionnaire implied informed consent. Further details on data collection and study design have been reported elsewhere (17).

Assessment of Objective and Perceived Exposure

The objective indicators for air pollution in the neighborhood that we used were average annual all-source fine particulate matter ($PM_{2.5}$) (a pollutant derived from fossil-fuel combustion) and average annual all-source benzo(α)pyrene (BaP) (a polycyclic aromatic hydrocarbon formed in the process of incomplete combustion of organic material). Data on these indicators were extracted from an official municipality source reporting air pollution maps (26). Pollutant dispersion modelling was done for 2011 with SELMA^{GIS} 9.28 (Lohmeyer GmbH & Co. KG). Owing to the low spatial resolution of the maps and the distribution of cases across the exposure categories, we dichotomized these variables in the analyses as follows: $PM_{2.5}$ (<25.0 μg/m^3 versus >25.0 μg/m^3) and BaP (<6.0 ng/m^3 versus >6.0 ng/m^3). Because of the spatial resolution, exposure levels were assigned to the participants even if only their residential neighborhood was reported.

Self-reported traffic exposure was used as a proxy for traffic counts and air pollution (27). The question asked: "How would you describe the road that your home is located at and its traffic? Please, rate the traffic intensity based on comparisons with other streets of Plovdiv." with possible responses: "very rare/no traffic", "moderately busy street", "considerably busy street", "heavy traffic", "extremely busy street/extreme traffic").

L_{den} – defined as "average" noise levels during daytime, evening, and night-time, applying a 5-dB penalty to noise in the evening and a 10-dB penalty to noise during the night – was chosen for road traffic noise indicator. Combined L_{den} data from all traffic sources were elicited from the official strategic noise maps (10 × 10 m grid, 4 m height) of Plovdiv created in 2009 in compliance with the Environmental Noise Directive 2002/49/EC. Noise levels were assessed at the coordinates of the residential address, unless the participant had indicated the orientation of the apartment. L_{den} was modelled with LimA v. 5 (Brüel & Kjær, Nærum, Denmark).

Perceived air pollution exposure in the neighborhood was derived from an 11-point visual analogue scale: "According to you, how severe is the air pollution in your neighborhood?" ("0, not at all" to "10, extremely").

The question on air pollution annoyance asked: "To what extent are you disturbed, annoyed or irritated by the air pollution in your neighborhood?" (11-point visual analogue scale: "0, not at all" to "10, very much").

Greenness indicators

The following indicators of greenness and interaction with it were used (17):

- After geocoding participants' addresses, we measured the Euclidean distance to the nearest green space, meeting several predefined minimum quality criteria for having a social function
- Perceived greenness of the neighborhood was elicited from the question: "According to you, how green (street trees, gardens, parks, etc.) is your neighborhood?" (10-point visual analogue scale ranging from "1, none at all" to "10, 100%")
- Time spent in green spaces per week (in hours)
- Having a garden at home ("no"/"yes")

Other factors

- Socio-demographics: age, gender, ethnicity, highest educational attainment, marital status, occupation, self-rated socioeconomic status
- Pack-years of smoking

- Perceived health: "How would you rate your overall health status during the past year?" with the following response options: "very poor", "poor", "mostly poor", "mostly good", "good" and "very good".
- Noise sensitivity measured with the Noise Sensitivity Questionnaire Short Form (28). According to some authors (29,30,31), noise sensitivity is associated with environmental and odor sensitivities and shares some of their variability. Furthermore, noise sensitivity was found to correlate with air pollution annoyance (32).
- Duration of residence at the present address
- Number of the floor on which the participant lived/apartment floor

Data Analytic Strategy

Data were initially screened for missing rates, uni- and multivariate normality, and outliers. Welch's t-test and ANOVA were used to compare mean scores of air pollution annoyance and perceived severity of air pollution across other relevant factors, and Spearman correlations were used to correlate them with interval or ordinal variables.

We tested the hypothesis that a shorter distance to the nearest green space and higher perceived greenness of the neighborhood are associated with lower air pollution annoyance and that this total effect is significantly mediated through lower perceived air pollution exposure. Figure 1 presents the hypothesized model. The mediation analysis was conducted with PROCESS v. 2.13, an add-on for SPSS for statistical mediation, moderation, and conditional process analysis (33). PROCESS was used with the following specifications: model 4, bootstrap-generated bias corrected 95% confidence intervals (5000 samples, random seed) and heteroskedasticity-consistent standard errors. Indirect effects were considered statistically significant if the 95% CI did not overlap zero. Based on prior theory, the effects of distance to green space (per one interquartile range increase) and perceived greenness (per one interquartile range increase) were adjusted for age, gender, ethnicity (Bulgarian versus other), socioeconomic status (lower versus middle + upper), duration of residence at the address (per 1 year), $PM_{2.5}$ (< 25.0 μg/m^3 versus > 25.0 μg/m^3), BaP (< 6.0 ng/m^3 versus > 6.0 ng/m^3), L_{den} (per 5 dB increase), time spent in green spaces/week (per 1 hour), having a garden at home ("yes" versus "no"), and for each other. The model was initially run on the total sample (n = 508) and then separately for men (n = 185) and women (n = 323).

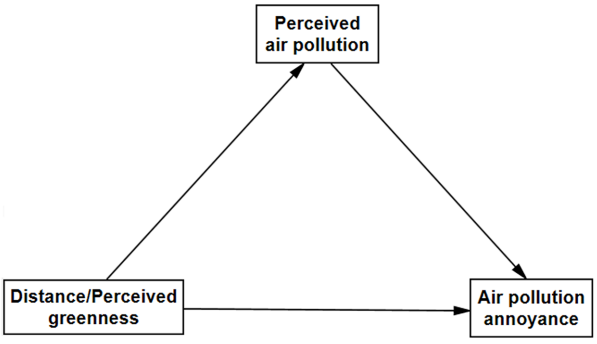

Figure 1. A priori hypothesized model of the associations between air pollution, its effects on annoyance and interaction with urban greenness

Due to underreporting of residential addresses, we had missing values on the variable "distance to green space". Therefore raw data were imputed using the expectation-maximization algorithm.

Results were considered statistically significant at the $p < 0.05$ level (two-tailed). Data analyses were conducted with SPSS v. 17.

RESULTS

Participants' average age was 36.45 years (SD = 15.39, range: 18 – 83 years) and 185 (36.06%) were male. The mean of air pollution annoyance was 5.80 (SD = 2.29) with 21.83% (n = 112) of participants being highly annoyed (score > 7). According to Table 1, air pollution annoyance was not significantly associated with age and gender, although middle-aged people and women reported higher annoyance. Widowed, divorced, and participants with lower socioeconomic status were significantly more annoyed. Higher noise sensitivity, self-reported traffic, and road traffic noise were also associated with higher annoyance. Although people exposed to higher levels of objectively estimated air pollution were more annoyed, those associations were non-significant. Perceived air pollution exposure was significantly and positively associated with air pollution annoyance. With respect to the green space indicators, living closer to a green space and in a greener neighborhood were associated with lower annoyance. Finally,

Table 1. Associations of air pollution annoyance and perceived severity of air pollution with other individual and environmental factors

Factors	Air pollution annoyance		Perceived severity of air pollution	
	Mean (SD)	Correlation	Mean (SD)	Correlation
Age		.08		.05
18 – 25	5.52 (2.57)		5.55 (2.37)	
26 – 35	5.66 (2.30)		5.89 (2.14)	
36 – 45	6.03 (2.01)		5.64 (1.99)	
46 – 55	6.19 (2.02)		5.71 (2.25)	
56 – 65	6.06 (1.91)		6.18 (1.75)	
66 – 75	5.53 (1.85)		5.80 (1.61)	
76 – 85	6.20 (2.28)		5.00 (.71)	
Gender				
men	5.66 (2.22)		5.92 (2.02)	
women	5.88 (2.32)		5.60 (2.24)	
Ethnicity				
Bulgarian	5.84 (2.26)		5.75 (2.17)	
non-Bulgarian	5.61 (2.46)		5.61 (2.13)	
Marital status				
married/spouse	5.91 (2.22)*		5.85 (2.17)	
single	5.42 (2.36)*		5.49 (2.07)	
widowed	6.91 (2.55)*		5.36 (1.29)	
divorced	6.26 (2.24)*		5.78 (2.76)	
Occupation				
employed	5.90 (2.07)		5.83 (1.98)	
studying	5.60 (2.60)		5.56 (2.51)	
unemployed	6.00 (2.30)		5.94 (2.04)	
retired	5.93 (2.34)		5.39 (1.57)	
Education		.03		.04
basic	5.17 (2.23)		5.83 (2.56)	
upper secondary	5.76 (2.47)		5.65 (2.30)	
bachelor/master	5.80 (2.09)		5.71 (1.96)	
PhD/DSc	7.18 (1.78)		7.27 (2.45)	
Socio-economic status		-.11*		-.06
lower	6.30 (2.37)*		5.93 (2.09)	
middle	5.65 (2.24)*		5.68 (2.20)	
upper	5.33 (2.25)*		5.06 (2.01)	
Pack-years of smoking		.01		-.03
Noise sensitivity		.32**		.06
Perceived health		-.19**		-.12**
Apartment floor		-.02		-.04

Duration of residence		.04		.03
$PM_{2.5}$		.09		.13*
< 25.0 μg/m³	5.58 (2.56)		5.23 (2.34)*	
> 25.0 μg/m³	5.98 (2.23)		5.97 (2.14)*	
BaP		.05		.13*
< 6.0 ng/m³	5.71 (2.35)		5.45 (2.28)*	
> 6.0 ng/m³	6.02 (2.29)		6.05 (2.14)*	
L_{den}		.21**		.21**
Self-reported traffic		.18**		.26**
very rare/no traffic	5.01 (2.56)**		4.95 (2.08)**	
moderately busy street	5.73 (2.34)**		5.43 (2.23)**	
considerably busy street	5.90 (2.22)**		5.88 (1.94)**	
heavy traffic	6.11 (2.03)**		6.40 (1.97)**	
extremely busy street/extreme traffic	6.49 (1.75)**		6.51 (2.11)**	
Perceived severity of air pollution		.50**		1.00
Distance to green space		.17**		.18**
Time in green spaces		-.03		-.08
Perceived greenness		-.10*		-.04
Garden at home				
yes	5.89 (2.15)		5.97 (2.02)**	
no	5.63 (2.51)		5.31 (2.34)**	

Note. Complete-case analyses are presented.
$PM_{2.5}$ – fine particulate matter, BaP – benzo(α)pyrene, L_{den} – indicator for road traffic noise.
**coefficient is significant at $p < 0.05$, **coefficient is significant at $p < 0.01$; p-values are associated with Welch's t-test/ANOVA or Spearman correlation.*
Spearman correlations are reported for factors measured on continuous/ordinal scale.

there was a negative correlation between annoyance and perceived health.

Perceived air pollution exposure was not associated with any of the individual characteristics; conversely, it was significantly higher when objective air pollution, road traffic noise, and self-reported traffic were higher. It was lower for those living closer to a green space and having a garden at home and it was inversely associated with perceived health.

The median distance to a green space was 90.88 m (IQR = 171.83 m), 35% had a garden at home, the median rating of neighborhood greenness was 6.00 (IQR = 2.25), and participants who were visiting neighborhood green spaces spent there a median of 1.75 h/week (IQR = 2.50). Living closer to a green space was associated with higher perceived greenness of the neighborhood and with having a garden. Those spending more time in green spaces also rated their neighborhood as "greener" and had a garden at home. Further associations between these greenness indicators and demographics are reported elsewhere (17).

Based on prior theory and the observed associations in the dataset, we set up a data-based mediation model to test the a priori model. The total effect of distance to green space on air pollution annoyance was .28 (95% CI: .06, .50). It was comprised of a non-significant direct effect (B = .08, 95% CI: -.12, .27) and a significant indirect effect through perceived air pollution exposure (B = .20, 95% CI: .11, .33). Figure 2 presents the path coefficients depending on gender. Among men, neither of the paths was

statistically significant, whereas among women, both the total and indirect effects were significant. The non-significant direct and significant indirect paths suggest that among women the effect of distance to green space was fully mediated through perceived air pollution exposure.

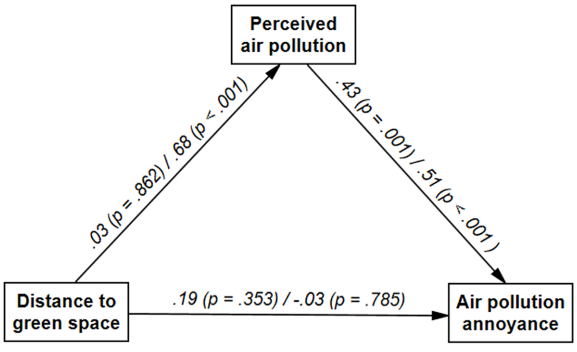

Fig. 2. Path model of the associations between the distance to green space, perceived air pollution exposure and air pollution annoyance among men and women

Note. Coefficients reported for 185 men/323 women. Model is adjusted for perceived greenness, age, gender, ethnicity, socioeconomic status, duration of residence at the address, $PM_{2.5}$, BaP, L_{den}, time spent in green spaces/week and having a garden at home.

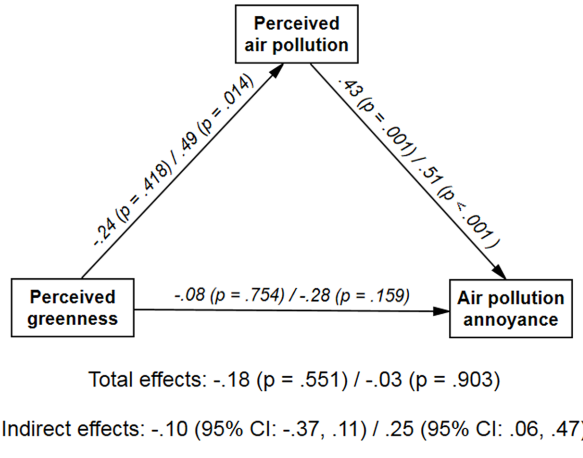

Fig. 3. Path model of the associations between the perceived greenness of the neighborhood, perceived air pollution exposure and air pollution annoyance among men and women

Note. Coefficients reported for 185 men/323 women. Model is adjusted for distance to green space, age, gender, ethnicity, socioeconomic status, duration of residence at the address, $PM_{2.5}$, BaP, L_{den}, time spent in green spaces/week and having a garden at home.

With respect to perceived greenness, neither the total (B = -.06, 95% CI: -.43, .30), nor the direct (B = -.20, 95% CI: -.51, .10), or the indirect effects (B = .14, 95% CI: -.0004, .31) were significant in the total sample. According to Figure 3, among women only the indirect effect was significant.

The total (B = -.61, 95% CI: -1.27, .04), direct (B = -.54, 95% CI: -1.17, .08), and indirect (B = -.07, 95% CI: -.36, .21) effects of $PM_{2.5}$ on air pollution annoyance were non-significant. For BaP, all three were significant – total: .94 (95% CI: .52, 1.37), direct: .45 (95% CI: .05, .85), and indirect: .49 (95% CI: .29, .75). For L_{den}, as well, – total: .47 (95% CI: .25, .69), direct: .31 (95% CI: .11, .51), and indirect: .17 (95% CI: .07, .28).

DISCUSSION

Initially we examined the distributions and univariate associations between the variables. Based on prior theory and the observed associations in the dataset, which were found to be theoretically feasible and meaningful, we tested a mediation path model adjusted for important confounders and stratified by gender. According to this model among women, living closer to a green space was associated with lower perceived air pollution exposure and through it – with lower annoyance. The indirect path was driving the total effect and perceived air pollution exposure acted as a full mediator. This mediation path is in line with the qualitative results of Day (18) – people living in greener environment may experience lower perceived air pollution because vegetation is held to have the ability to physically clean the air and reduce the level of harmful contaminants. Among men there was no effect. The gender differences we found could be explained by several psycho-social mechanisms. On one hand, women differ in their subjective risk assessment, they have higher proclivity to concern themselves (34), and are less likely to take risks (35). On the other, there are gender differences in the neuroendocrine and psychological response to stress (36). Moreover, green spaces affect the psycho-

logical and cortisol stress response of men and women in a different fashion (37), and, according to Richardson and Mitchell, men and women utilize different functions and experience green spaces differently (38). Thus women might be more susceptible to the psychological stress effects of air pollution and at the same time more likely to believe that green spaces could lower their exposure and, as a result, thus benefit more from them.

With respect to perceived greenness, no effect on air pollution annoyance was found. This might be explained by the fact that green space quality is important for people and, while it was considered when measuring the distance to the nearest green space, participants disregarded it in their assessment of perceived greenness (17). Moreover, greenness refers to various types of plants such as bushes and grass in addition to tress, and the effectiveness in air cleaning is vegetation type-dependent (14). It is also possible that the concept of a green space (that is, of spatially consolidated and socially organized vegetated public space) is the one associated with the notion of reducing air pollution, rather than the overall greenness of the neighborhood, which also includes street vegetation, backyard gardens, green patches, etc.

Air pollution annoyance was not associated with exposure to fine particulate matter but rather with BaP and road traffic noise. The perceived level of pollution was a significant partial mediator of these effects, as previously hypothesized (9). Although we did not have a variable representing health risk perception, it could be a mediator antecedent to perceived air pollution in the causal chain between the distance to green space and annoyance. In short, we hypothesize that urban greenness might reduce the perceived level of air pollution by making people feel safer and a higher level of control over their environment, which in turn could reduce the perceived level of exposure and, as a result, mitigate their annoyance.

Strengths and Limitations

To our knowledge, this is the first study to investigate the quantitative relationship between urban greenness, perception of air pollution, and annoyance. Its strengths are its novelty, combination of objective and perceived exposure indicators, and employment of indicators representing different dimensions of interaction with urban greenness.

However, it has some limitations. First, owing to the cross-sectional design, the direction of the paths in the model does not imply causal relationships between the variables. For example, highly annoyed people might have proclivity to report higher exposure to air pollution. The partial representativeness of the sample and imperfect data collection procedure hinder generalization of the results. Nevertheless, at this formative stage of research this is acceptable. For this reason, we did not use a complex structural equation modelling because we wanted to adhere to a simplistic and parsimonious solution.

Secondly, the validity of the measures we used might be questioned. The objective air pollution data about $PM_{2.5}$ and BaP were based on dispersion models and referred to 2011, and noise data referred to 2009; exposure levels at the time of enrollment might have changed. Conversely, self-reported traffic was also a proxy for road traffic noise, but it was not included in the path model because, unlike $PM_{2.5}$ and BaP, it is a proxy only for traffic-related air pollution, whereas the question on annoyance referred to both linear and stationary sources. Moreover, self-reported traffic is biased by individual discrimination between the exposure categories (27). Road traffic noise, on the other hand, was included as a confounder because there is a complex interplay between traffic noise, exhaust and annoyances (32,39,6) and studies have shown that noise and air pollution might act synergically and both be associated with odor annoyance (40,10).

Our annoyance question did not specify the condition of keeping the participants' windows open like previous studies (11) but this might not be a limitation, since the latter restricts the measure to annoyance by outdoor air pollution when indoors (41). It also referred to general annoyance from air pollution, rather than odor annoyance. This means that the annoyance reaction was determined by both the organoleptic characteristics of the air pollutants (color, odor, etc.) and participants' knowledge of their own exposure and the harms of it, which acted as a cognitive stressor (7). We did not have a measure of odor sensitivity and we chose not to use noise sensitivity as a proxy for it, although it might be justi-

fied by some authors (29,30,31); others, however, cautioned against it (42,43). As for the validity of perceived air pollution exposure, it was not associated with demographics but rather with self-reported traffic, objective air pollution, and noise, which indicates criterion validity. The limitations of the greenness indicators have been discussed in detail elsewhere (17).

Future Research

In order to implement strategies for attenuation of the psychological stress effects of environmental pollution through urban greening and planning of green spaces we must first gain clear insight into the underpinning mechanisms, which are currently vaguely defined (17). More sophisticated and validated measures of objective air pollution and scales for perceived exposure, its stress effects, and odor sensitivity should be used; the constructs of perceived risk and control over the environment should be included in the models. Additional explanatory variables, representing interaction with green spaces and their social and symbolic functions for the local residents, need to be studied, using both qualitative and quantitative methods (18).

Alongside health risk perception, two other possible pathways merit further investigation. One is the general stress reduction, a hypothesis not supported by our study due to the lack of direct paths between the green space indicators and annoyance. On the other hand, traffic emissions may dominate the urban smellscape, masking floral and other subtle nature scents (44). It would be interesting to look at the interactions between olfactory perception of vegetation and traffic. Effect modification by individual differences such as gender is also of interest. Different air contaminants need to be included in the models, since their effects might vary depending on their characteristics (e.g., odor). Integrated models investigating the effects of greenness on both noise and air pollution perception will expand our perspective and capture a wider panorama of the epidemiological reality, because air pollution and traffic noise might act in synergy and have mutually confounded effects on both types of annoyance (40,10).

Public health programs should be contingent not only on biomedical but also on environmental interventions for mitigating environmental pollution. Pollution is an ecosocial phenomenon occurring within the urban context and influenced by the latter in terms of the actual level of exposure and how it is being evaluated by individuals. Thus in order to mitigate the health impact of air pollution, in addition to lowering its objective levels, its psychological stress effects should be targeted through increasing the amount and access to urban green spaces (18).

CONCLUSION

Women living closer to green spaces perceived their exposure to air pollution as lower and through this were less annoyed. Perceived air pollution acted as a full mediator. Among men no effect was found. Therefore we hypothesized that urban green spaces might act as a buffer for the psychological stress effects of air pollution. Nonetheless, we are still at a formative stage of research and the evidence requires caution.

ACKNOWLEDGEMENTS

Authors would like to thank all contributors who recruited other participants during the snowball sampling and all participants who made this study possible.

AUTHORS' CONTRIBUTIONS

Both authors contributed equally to this study. The order of authorship was determined by a coin toss.

CONFLICT OF INTEREST STATEMENT

This study received no external funding and the authors declare that they do not have any financial relationships which could be construed as potential conflict of interest.

REFERENCES

1. WHO. Fact sheet: Ambient (outdoor) air quality and health; 2014.
2. Mannucci PM, Harari S, Martinelli I, Franchini M. Effects on health of air pollution: a narrative review. Intern Emerg Med. 2015:10, 657-662.
3. Mehta AJ, Kubzansky LD, Coull BA, Kloog I, Koutrakis P, Sparrow D, Spiro A. 3rd, Vokonas P, Schwartz J. Associations between air pollution and perceived stress: the Veterans Administration Normative Aging Study. Environ Health 2015:14, 10.

4. Colligan MJ. The psychological effects of indoor air pollution. Bull N Y Acad Med. 1981:57, 1014-1026.

5. Lidén E, Nordin S, Högman L, Ulander A, Deniz F, Gunnarsson AG. Assessment of odor annoyance and its relationship to stimulus concentration and odor intensity. Chem. Senses. 1998:23, 113-117.

6. Fernández-Somoano A, Llop S, Aguilera I, Tamayo-Uria I, Martínez MD, Foraster M, Ballester F, Tardón A. Annoyance Caused by Noise and Air Pollution during Pregnancy: Associated Factors and Correlation with Outdoor NO2 and Benzene Estimations. Int J Environ Res Public Health. 2015:12, 7044-7058.

7. Klaeboe R, Amundsen AH, Fyhri A. Annoyance from vehicular air pollution: A comparison of European exposure-response relationships. Atmos Environ 2008:42(33), 7689-7694.

8. Stenlund T, Lidén E, Andersson K, Garvill J, Nordin S. Annoyance and health symptoms and their influencing factors: a population-based air pollution intervention study. Public Health. 2009:123, 339-345.

9. Claeson AS, Lidén E, Nordin M, Nordin S. The role of perceived pollution and health risk perception in annoyance and health symptoms: a population-based study of odorous air pollution. International Arch Occup Environ Health. 2013:86, 367-374.

10. Oiamo TH. Environmental Health Effects of Multiple Exposures: Systemic Risks and the Detroit River International Crossing Study. [PhD thesis]. London, Ontario, Canada: The University of Western Ontario; 2015

11. Jacquemin B, Sunyer J, Forsberg B, Götschi T, Bayer-Oglesby L, Ackermann-Liebrich U, de Marco R, Heinrich J, Jarvis D, Torén K, Künzli N. Annoyance due to air pollution in Europe. Int J Epidem. 2007:36, 809-820.

12. Janhäll S. Review on urban vegetation and particle air pollution – Deposition and dispersion. Atmos Environ. 2015:105, 130–137.

13. Nowak DJ, Crane DE, Stevens JC. Air pollution removal by urban trees and shrubs in the United States. Urban For Urban Gree. 2006:4, 115-123.

14. Givoni B. Impact of planted areas on urban environmental quality: a review. Atmospheric Environment. Part B. Urban Atmos. 1991:25, 289-299.

15. Akbari H. Shade trees reduce building energy use and CO2 emissions from power plants. Environ Pollut. 2002:116, S119-S126.

16. Dzhambov AM, Dimitrova DD. Urban green spaces' effectiveness as a psychological buffer for the negative health impact of noise pollution: A systematic review. Noise Health. 2014:16, 157-165.

17. Dzhambov AM, Dimitrova DD. Green spaces and environmental noise perception, Urban For Urban Gree. 2015:14, 1000-1008.

18. Day R. Place and the experience of air quality. Health Place. 2007:13, 249-260.

19. Madureira H, Nunes F, Oliveira JV, Cormier L, Madureira T. Urban residents' beliefs concerning green space benefits in four cities in France and Portugal. Urban For Urban Gree. 2015:14, 56–64.

20. Lo AYH, Jim CY. Citizen attitude and expectation towards green space provision in compact urban milieu. Land Use Policy. 2012:29, 577–586.

21. Shmool JL, Reid CE, Kubzansky LD, Spengler J, Clougherty JE. Intra-urban air pollution concentrations, perceived air quality, and greenspace across New York City. The International Society of Exposure Science – 25th Annual Meeting: Exposures in an Evolving Environment. Henderson, Nevada; 2015

22. Petrova S, Yurukova L, Velcheva I. Horse chestnut (Aesculus hippocastanum L.) as a biomonitor of air pollution in the town of Plovdiv (Bulgaria). J Biosci Biotechnol. 2012:1, 241-247.

23. Takuchev N, Vasileva I, Petrova S. Dispersion Modeling of the Air Pollution, Emitted by the Traffic in the Transport Tunnel under the Old Town of Plovdiv, Bulgaria. Ecol Balk 2014:6, 73-86.

24. Wolf EJ, Harrington KM, Clark SL, Miller MW. Sample size requirements for structural equation models an evaluation of power, bias, and solution propriety. Educ Psychol Meas. 2013:73, 913-934.

25. Fritz MS, Mackinnon DP. Required sample size to detect the mediated effect. Psychol Sci. 2007:18, 233–239.

26. Municipality of Plovdiv. Program for reaching the normative levels of fine particulate matter under 2.5 microns (PM2,5) and polycyclic aromatic hydrocarbons (PAH) in the atmospheric air on the territory of Municipality of Plovdiv. (in Bulgarian); 2011

27. Dzhambov AM. Validity of self-reported traffic intensity as a proxy for road traffic counts and noise. Noise Cont Eng J. 2015:63, 11-19.

28. Dzhambov AM, Dimitrova DD. Validating a short Bulgarian version of a psychometric instrument for multidimensional noise sensitivity assessment. Fol Med (Plovdiv). 2014:56, 116-125.

29. Stansfeld SA, Clark CR, Jenkins LM, Tarnopolsky A. Sensitivity to noise in a community sample: I. Measurement of psychiatric disorder and personality. Psychol Med. 1985:15, 243-254.

30. Andersson L, Johansson A, Millqvist E, Nordin S, Bende M. Prevalence and risk factors for chemical sensitivity and sensory hyperreactivity in teenagers. Int J Hyg Environ Health. 2008:211, 690-697.

31. Nordin S, Ljungberg JK, Claeson AS, Neely G. Stress and odor sensitivity in persons with noise sensitivity. Noise Health 2013:15, 173-177.

32. Dirks KN, Shepherd D, Welch D, McBride D. Annoyance to traffic noise and annoyance to air pollution: an orthogonal or co-varying relationship in noise-sensitive individuals? Internoise, Innsbruck, Austria; 2013

33. Hayes A. Introduction to mediation, moderation, and conditional process analysis: A regression-based approach. New York: Guilford Press; 2013

34. Gustafson PE. Gender differences in risk perception: theoretical and methodological perspectives. Risk Anal. 1998:18, 805-11.

35. Harris CR, Jenkins M. Gender Differences in Risk Assessment: Why do Women Take Fewer Risks than Men? Judgm Decis Mak. 2006:1, 48-63.

36. Verma R, Balhara YPS, Gupta CS. Gender differences in stress response: Role of developmental and biological determinants. Ind Psychiatry J. 2011:20, 4-10.

37. Roe JJ, Thompson CW, Aspinall PA, Brewer MJ, Duff EI, Miller D, Mitchell R, Clow A. Green space and stress: evidence from cortisol measures in deprived urban communities. Int J Environ Res Public Health. 2013:10, 4086-103.

38. Richardson EA, Mitchell R. Gender differences in relationships between urban green space and health in the United Kingdom. Soc Sci Med. 2010:71, 568-75.

39. Okokon EO, Turunen AW, Ung-Lanki S, Vartiainen AK, Tiittanen P, Lanki T. Road-traffic noise: annoyance, risk perception, and noise sensitivity in the Finnish adult population. Int J Environ Res Public Health. 2015:12, 5712-34.

40. Klaeboe R, Kolbenstvedt M, Clench-Aas J, Bartonova A. Oslo traffic study - part 1: An integrated approach to assess the combined effects of noise and air pollution on annoyance. Atmos Environ. 2000:34(27), 4727-4736.

41. Brody SD, Zahran S. Commentary: Linking particulate matter and sulphur concentrations to air pollution annoyance: problems of measurement, scale and control. Int J Epidemiol 2007: 36, 820-823.

42. Heinonen-Guzejev M, Koskenvuo M, Mussalo-Rauhamaa H, Vuorinen HS, Heikkilä K, Kaprio J. Noise sensitivity and multiple chemical sensitivity scales: properties in a population based epidemiological study. Noise Health. 2012:14, 215–223.

43. Shepherd D, Heinonen-Guzejev M, Heikkilä K, Dirks KN, Hautus MJ, Welch D, McBride D. The negative affect hypothesis of noise sensitivity. Int J Environ Res Public Health. 2015:12, 5284–5303.

44. Quercia D, Schifanella R, Aiello L, McLean K. Smelly Maps: The Digital Lives of Urban Smellscapes. In: AAAI Publications, Ninth International AAAI Conference on Web and Social Media, Oxford; 2015.