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Does greenery experienced indoors and outdoors provide an escape and support mental health during the COVID-19 quarantine?

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\textbf{ABSTRACT}

\textit{Background:} The COVID-19 pandemic has profoundly changed people’s ability to recreate in public green spaces, which is likely to exacerbate the psychological impacts of the pandemic. In the current study, we seek to understand whether greenery can support mental health even with insufficient outdoor exposure in times of physical isolation from the outdoor environment.

\textit{Methods:} Between 17 May and 10 June, 2020, we conducted an online survey among 323 students (21.99 ± 3.10 years; 31\% male) in health-related programs from two universities in the city of Plovdiv, Bulgaria. Severities of depressive and anxiety symptoms over the past two weeks were measured with the Patient Health Questionnaire 9-item and the Generalized Anxiety Disorder 7-item scale. We employed two self-reported measures of greenery experienced indoors (number of houseplants in the home and proportion of exterior greenery visible from inside the home) and two measures of greenery experienced outdoors (presence/absence of a domestic garden and availability of neighborhood greenery). Restorative quality of the home (the “being away” dimension of the Perceived Restorativeness Scale; PRS) and the neighborhood (the “being away” and “fascination” dimensions of the PRS), engagement with outdoor greenery (frequency of different types of interaction) and perceived social support were treated as mediators. Associations between greenery and mental health were tested using generalized linear regression and logistic regression. Structural equation modelling (SEM) techniques were used to test the theoretically-indicated relations among the variables.

\textit{Results:} Clinically-meaningful symptoms of moderate depression and anxiety were reported by approximately 33\% and 20\% of the students, respectively. The relative abundance of greenery visible from the home or in the neighborhood was associated with reduced depressive/anxiety symptoms and lower depression/anxiety rates. Having more houseplants or a garden was also associated with some of these markers of mental health. As hypothesized, the mental health-supportive effects of indoor greenery were largely explained by increased feelings of being away while at home. Neighborhood greenery contributed to neighborhood restorative quality, which in turn facilitated social support and more frequent engagement with greenery, and that led to better mental health.

\textit{Conclusions:} Students who spent most of their time at home during the COVID-19 epidemic experienced better mental health when exposed to more greenery. Our findings support the idea that exposure to greenery may be a valuable resource during social isolation in the home. However, causal interpretation of these associations is not straightforward.

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1. Introduction

The COVID-19 pandemic has profoundly changed people’s ability to recreate outdoors. Most national governments issued stay-at-home orders (Gostin and Wiley, 2020; Petersen et al., 2020) for unprecedented lengths of time (Brooks et al., 2020) prohibiting visiting parks, community gardens, playgrounds, and other outdoor activity spaces (Shoari et al., 2020). Simultaneously, the fear and uncertainty instilled by the perceived health risk and economic ramifications of the pandemic have increased insomnia, anxiety, depression, and suicide rates (Zhu et al., 2020; Rajkumar, 2020; Huang and Zhao, 2020; Wang et al., 2020). On the one hand, coronavirus anxiety has been found to decrease as social isolation measures intensify (Lee and Neimeyer, 2020). On the other, however, limitations to outdoor recreation are likely to exacerbate these concerning psychological impacts of the pandemic, since exposure to greenery in public outdoor spaces benefits mental health (Gascon et al., 2015; Triguero-Mas et al., 2015; WHO, 2016; Callaghan et al., 2020) in multiple ways: by mitigating harmful exposures (e.g., air pollution and noise), by reserving depleted adaptive capacities (e.g., cognitive resources), and by promoting new adaptive resources (e.g., outdoor physical activity and social interaction) (Markeych et al., 2017). Most of these pathways toward good mental health are unavailable when people spend almost all of their time at home, however (cf. Hartig et al., 2007).

When outdoor interaction with greenery is impeded, three alternative forms of engagement are important for psychological restoration. First, looking out windows onto greenery promotes psychological health benefits. Over the course of a few hours or days, green window views have been shown in experimental research to provide micro-restorative episodes that promote healing (Ulrich, 1984; Kaplan, 2001; Jo et al., 2019; Hartig et al., 2014), psychological restoration (Lee et al., 2015a), and recovery from stressful events (Li and Sullivan, 2016). Over the course of several months, green window views have been shown to increase a person’s ability to complete difficult cognitive tasks, such as earning high grades/marks in a college writing course (Benfield et al., 2015). In cross-sectional analyses, window views of nature have also been associated with life satisfaction (Chang et al., 2020) and job satisfaction (Sop Shin, 2007). Such psychological benefits of green views are largely attributed to the extent to which they promote fascination and feelings of being away from everyday routines (Masoudinejad and Hartig, 2020). That is, the “being away” dimension reflects an absence of immediate threats to safety and a relative absence of perceived social and physical demands (e.g., crowding, noise or other obligations) in an environment. “Fascination” reflects how attention can also go effortlessly to interesting, pleasant aspects of the environment, thereby promoting faster and more complete decline in psychophysiological arousal (Kaplan and Kaplan, 1989; Kaplan, 1995).

A second opportunity to engage with greenery at home is through indoor vegetation. Potted plants can reduce stress, physical discomfort, anxiety, and depressive symptoms (Chang and Cheng 2005; Fjeld, 2000; Hall and Knuth, 2019; Han and Ruan, 2019) as well as increase attention (Raanaas et al., 2011; Hall and Knuth, 2019; Kim et al., 2018, 2020), mood (Han and Ruan, 2019), and cognitive performance (Adamson and Thatcher, 2019; Hall and Knuth, 2019). In one study, the mere presence of plants in the classroom also contributed to higher perceived restoration and positive affect of students (Han and Ruan, 2019). Another study found that students transplanting an indoor plant experienced reduced anxiety, and depressive symptoms (Cervinka et al., 2016). Specifically, gardening (i.e., engagement with a garden) has been shown to reduce anxiety and depressive symptoms and myriad other components of mental health (Soga et al., 2017; Howarth et al., 2020).

To the best of our knowledge, these three opportunities to engage with greenery have rarely been compared, much less directly (cf. Akpinar et al., 2016; Korpela et al., 2017; Dzhambov et al., 2018a). Evaluating the psychological benefits of each opportunity and their underlying pathways toward supporting mental health is a critical step toward buffering the burden of the COVID-19 pandemic. Thereafter, such an understanding could inform biophilic design in settings where outdoor mobility is necessarily limited (i.e., clinical settings, workplaces, schools, and military/space-missions) (Nadkarni et al., 2017; Yeo et al., 2020).

Most previous studies on indoor greenery were related to workplaces, especially office spaces or classrooms (Raanaas et al., 2011; Han and Ruan, 2019). In addition, studies conducted in experimental settings have yielded mixed findings (Bringslimark et al. 2007, 2009). It is not clear how these findings translate to a situation where the daily loops of an individual are confined to the home environment for a prolonged period. One recent international study investigated the impact of green-blue environments on mental health during the COVID-19 lockdown and found that people perceived that nature helped them to cope with lockdown measures (Pouso et al., 2020). We can also draw parallels to other nature-deprived environments like prisons, where nature videos reduced stress and irritability of inmates in solitary confinement (Nadkarni et al., 2017), and green views were associated with perceived restoration (Moran, 2019). Intervention studies in hospitals with horticulture arrangements showed not only shorter postoperative stays, lower intake of analgesics, lower pain intensity and improved vital signs (heart rate, blood pressure) but also more positive emotions and feelings and other health improvements (Annerstedt and Währborg, 2011; Kamioka et al., 2014; Khan et al., 2016; Sui et al., 2020).

In the current study, we seek to understand whether greenery can support mental health even with insufficient outdoor exposure in times of physical isolation from the outdoor environment. The study was conducted in Bulgaria around the time that country was under a state of emergency declaration caused by the COVID-19 pandemic. The stay-at-home order was issued on March 13, 2020. The emergency declaration and formal ban on visiting green spaces was lifted on 14 May (https://en.wikipedia.org/wiki/COVID-19_pandemic_in_Bulgaria) but public perceptions of the coronavirus remained largely unchanged. Therefore, although unrestricted by law, engagement with urban greenery in this timeslot was expected to remain limited. It is in the few weeks after 14 May that we chose to survey a sample of students to investigate associations between different types of greenery at home and mental health. We hypothesized the following: (H1) greenery experienced indoors (houseplants and window view/s of greenery) would have protective effects on depression and anxiety principally by encouraging feelings of “being away,” (H2) greenery experienced indoors would have stronger protective effects than outdoor greenery (a garden and other residential greenery), and (H3) any protective effects of outdoor greenery would be principally by encouraging feelings of “being away” and “fascination” leading to actual engagement (i.e., working the garden, or visiting the outdoor residential greenery) given the mood benefits and likely downstream consequences on mental health of actually going outdoors into natural settings relative to viewing them remotely (Browning et al., 2020) and facilitating social support. The intertwined nature of these hypotheses is depicted in the study’s conceptual framework (Fig. 1).
Fig. 1. Conceptual framework showing hypothesized pathways between greenery experienced in or around the home and depressive and anxiety symptoms during home confinement. Note: Line widths represent hypothesized pathway strength, with thicker lines denoting potentially stronger associations.

2. Material and methods

2.1. Study design and sampling

Between 17 May and 10 June, 2020, we conducted an online survey among students from two universities in the city of Plovdiv, Bulgaria. Plovdiv is situated on the banks of the Maritza River. It has a well-defined core with concentric surroundings and stronger integration towards the south and west. The predominant types of residences are multi-family units and apartment buildings. Public green spaces in Plovdiv cover 381.5 ha comprising 75.3% of all green spaces in the city. The central district of Plovdiv, where the two university campuses are located, has 14.3 m² of green space per capita. The backbone of this green infrastructure are several prominent green vegetated hills and the park “Tzar Simeon Garden”, which offer recreational areas in walking distance to the university campuses. However, these green elements are mosaic and poorly integrated in the urban fabric owing to a lack of green corridors between them (Bulplan, 2015).

Students in medicine, dentistry and biology were approached by their lecturers with an invitation to participate in a survey on living conditions and mental health. Students could also forward the link to their peers. We targeted students in health-related programs because the psychological wear and tear of the student occupation more than likely contributes to students’ mental health (Huang et al., 2020). To be included, students had to be aged from 18 to 35 years and, to ensure that they were familiar with their neighborhood environment, had to have lived in their current home for at least six months.

The students received a link to an anonymized questionnaire in Microsoft Forms (https://forms.office.com/). The survey was administered in the Bulgarian language and included questions about socio-demographic factors, mental health, and the neighborhood and home environments. The average completion time was 13 min. Responses could be submitted only once from a unique IP address.

The design and conduct of the study followed the general principles outlined in the Declaration of Helsinki. After reading the information about the objectives of the study and instructions on filling-in the questionnaire, all respondents confirmed that they were at least 18 years old and provided informed consent in the survey form, thereby agreeing that their personal information would be processed and stored according to the General Data Protection Regulation in the European Union. The generic design of earlier studies in this series has been approved by the Ethics Committee at the institution of the principal investigator (Dzhambov et al., 2018a).

2.2. Mental health assessment

Severities of depressive and anxiety symptoms over the past two weeks were measured with two widely-used screening instruments. The Patient Health Questionnaire 9-item (PHQ-9) measures the frequency of symptoms of depression like anhedonia, hopelessness, sleep problems, fatigue, appetite changes, and thoughts of death (Kroenke et al., 2001). Its nine items are based on the diagnostic criteria of the Diagnostic and Statistical Manual of Mental Disorders – IV for major depressive disorder. Response options include 0 (not at all), 1 (several days), 2 (more than half of the days), or 3 (nearly every day). Scores (sum of the item responses) could range from 0 to 27. The items loaded onto one latent factor and the internal consistency in our sample was high (McDonald’s $\omega = 0.87$). Here, an omega ($\omega$) coefficient was employed to overcome the limitations (i.e., inflated values if strict assumptions are not met) associated with a Cronbach’s alpha coefficient (Dunn et al., 2014).

The Generalized Anxiety Disorder 7-item (GAD-7) scale was designed to assess how often the person is bothered by common symptoms of anxiety, such as feeling nervous, worrying too much, having trouble relaxing, becoming easily annoyed, and feeling afraid that something bad might happen (Spitzer et al., 2006). Response options ranged from 0 (not at all) to 3 (nearly every day). Scores (sum of the item responses) could range from 0 to 21. The seven items loaded onto one latent factor and the internal consistency in our sample was high (McDonald’s $\omega = 0.91$).

The PHQ-9 and GAD-7 scales were mainly modeled as linear outcomes, with higher summary scores indicating greater depression and anxiety, respectively. Still, we also present main effects for dichotomized the PHQ-9 and GAD-7 scores, where scores of 10 or above were considered with moderate depression (Manea et al., 2012) and generalized anxiety disorder (Plummer et al., 2016), respectively.
2.3. Greenery assessment

We employed four measures of greenery experienced indoors and outdoors. All measures were self-reported and informed by literature precedent (Markevych et al., 2017; Korpela et al., 2017). The two indoor measures included the number of houseplants (pots/containers) in the home and the proportion of visible exterior from inside the home, through windows or from a terrace/balcony, that contained greenery (trees, green spaces, etc.). Responses for the latter measure were given on an 11-point scale with two verbal anchors (0 = 100% built-up view, 10 = 100% green view). The two outdoor measures included the presence or absence of a domestic garden and the availability of neighborhood greenery, the latter of which was measured in the same way as the visible greenery from inside the home question (0 = 100% built-up neighborhood, 10 = 100% green neighborhood).

2.4. Putative mediator assessment

We specified four a priori mediators. Restorative quality of the home was hypothesized to mediate the effect of greenery experienced indoors on mental health, whereas restorative quality of the neighborhood environment, engagement with greenery and social support were hypothesized to mediate the effect of outdoor greenery on mental health.

From the several aspects of restorative quality of the home, we measured only the concept of “being away” based on findings from previous research on green views from the home (Masoudinejad and Hartig, 2020). To reduce questionnaire length and response burden, we used a single item (Lindal and Hartig, 2013, 2015) adapted from the Perceived Restorativeness Scale (PRS, Hartig et al., 1997a; 1997b). The questionnaire instructions were adapted to refer to the home environment (i.e., “At home, the time spent gives me a break from my day-to-day routine and I can get away from the things that usually demand my attention”). Responses were again given on an 11-point scale with two anchors (0 = not at all, 10 = completely).

Both the “being away” and “fascination” dimensions of the PRS operationalized neighborhood restorative quality. We again used single items: “My neighborhood has places where the time spent gives me a break from my day-to-day routine and where I can get away from the things that usually demand my attention.” and “My neighborhood has places that are fascinating and where my attention is drawn to many interesting things.” (0 = not at all, 10 = completely (Lindal and Hartig 2013; 2015)).

We measured engagement with outdoor greenery using four items regarding the frequency of different types of interaction. These types of interaction included passing by/through greenspace on the way to somewhere, taking a walk near or in greenspace, doing sport in nature/greenspace, and gathering/interacting with other people in greenspace/park. Response options included 0 (never), 1 (several days), 2 (more than half of the days), 3 (every day), or 4 (several times a day) during the past two weeks. The four items loaded onto one factor, which demonstrated high internal consistency (McDonald’s ω = 0.83).

Social support was measured with three items, which we reduced from the original Duke-UNC Functional Social Support Questionnaire (Broadhead et al., 1988). Social support was considered a potential mediator after earlier studies (Maas et al., 2009; Fan et al., 2011). Social support items were measured on a 7-point agree-disagree scale and included: “I have people who care what happens to me”; “I have people I can talk to if I have a problem or need an advice”; and “There are people who will help me if I need it”. McDonald’s ω for this unidimensional scale was 0.88.

2.5. Covariate assessment

We selected a parsimonious set of variables that could confound or modify the associations between greenery and mental health based on previous research findings (Markevych et al., 2017). These variables included socio-demographic characteristics, home characteristics, and other factors.

Socio-demographic characteristics included age, gender, ethnicity, and income. Ethnicity was measured as a binary variable: Bulgarian or not. Income was measured with a single perceived income adequacy item: “Having in mind the total monthly income you can make use of, how easy is it for you to meet your expenses without depriving yourself?” Response options ranged from 0 = very difficult to 5 = very easy.

House-related characteristics and behaviors included four measures. Data on dwelling type (i.e., apartment, house, or hostel), crowding in the household (people-to-rooms ratio), duration of residence, and time spent at home per day were collected.

Several other factors related to health, nature, and geography were measured. Presence of non-communicable chronic physical illness (es) was assessed to control for its potential effects on interaction with outdoor greenery (Labib et al., 2020). Participant’s feeling that they are “connected” with nature (Tam, 2013) was measured with the Nature Connection Index (NCI, Richardson et al., 2019) to control for lower or higher levels of “connectedness” impacting the relationship between greenery and mental health (Bakir-Demir et al., 2019; Cleary et al., 2017). The NCI was translated to Bulgarian and included six items answered on a 7-point agree-disagree scale. The NCI was a unidimensional construct with McDonald’s ω of 0.92 in our sample.

We did not have information on the exact home address but did collect the settlement where the respondent currently lived. We classified these settlements as cities (>100 000 residents), towns (10 000 to 100 000) or villages (<10 000). Finally, we retrieved data on at which university the respondent studied.

2.6. Analysis

Missing values (<10%) on any given variable were missing completely at random and imputed using the expectation-maximization algorithm (Dempster et al., 1977). All variables in multivariate analysis models were included in the imputation. Inspection of histograms and D’Agostino–Pearson K^2 test revealed that distributions of PHQ-9 and GAD-7 were right skewed. Therefore, these were square-root transformed for analyses.

To probe for general patterns of associations within the data, we employed correlations (Pearson, point-biserial, and phi), Welch’s ANOVAs, Fisher’s exact tests, and Mood’s median tests. Associations between greenery and mental health were tested using generalized linear regression and logistic regression for the continuous and dichotomized PHQ-9 and GAD-7 scores, respectively. Models were adjusted for age, gender, ethnicity, income, dwelling type, settlement type, university, and connectedness to nature. Tolerance values > 0.2 (Menard, 1995) and Variance Inflation Factor values < 5.0 (Rogerson, 2001) indicated no multicollinearity.

Then, we employed structural equation modelling (SEM) to test our hypotheses and the theoretically-interrelated interplay between the variables (Fig. 1). Depression and anxiety were modeled as continuous summary scores, whereas neighborhood being away and fascination were assumed to load onto one latent factor (neighborhood restorative quality). We used a maximum likelihood estimator with bootstrap-generated (10 000 samples) confidence intervals and standard errors for all paths (Kelley, 2005; Haukoos and Lewis, 2005; Brown, 2006). Guided by theory and bivariate correlations in the dataset, we specified confounding paths between control variables and core variables in the model. Goodness of fit was evaluated using indices of acceptable model fit provided in Hu and Bentler (1999): a non-significant χ^2 (p > 0.05); a root mean square error of approximation (RMSEA) ≤ 0.06 with a 90% CI ≤ 0.06; a standardized root mean square residual (SRMR) ≤ 0.08; and a comparative fit index (CFI) ≥ 0.95. We also used the parsimonious normed-fit index (PNFI), which compensates for the increase in fit in more complex models (Muñukit et al., 1989). Standardized residuals and modification indices were inspected to identify localized points of ill fit.
in the initial solution (M0), after which the model was re-specified. This was done when the suggested model re-specification was justified by theory. Confounding paths with at least marginal statistical significance (p < 0.1) were retained in the final solution. An indirect effect (i.e., a product of coefficients for the constituent links) that significantly exceeded zero was evidence of mediation (Zhao et al., 2010; Hayes, 2013). While we use terminology accepted in mediation modeling to denote the overall (total effect), direct (direct effect), and indirect (indirect effect) relationships in the SEM, the word “effect” should not be taken to indicate claims of causality.

Multiplicative interaction terms were constructed to investigate possible effect modification of the total effect of greenery on mental health by each covariate. Gender, income, dwelling type, crowding in the household, duration of residence, time spent at home per day, connectedness to nature, and social support were tested as modifiers. Criterion for statistical consideration was relaxed to p < 0.1 (i.e., Type I error rate of 10%) to report relevant effect modification that might otherwise remain undetected (Selvin, 1996; Greenland and Rothman, 1998; Marshall, 2007.).

Then we tested competing models nested in the full SEM model (M1). We wanted to see whether having greenery experienced indoors and/or outdoors improved model fit. Hence, we tested a reduced model that fixed the regression pathways from Houseplants and Green View to Being away and Depression/Anxiety to zero (M2). Next, we tested another reduced model with the paths from Garden and Neighborhood Greenery to Restorative quality and Depression/Anxiety fixed to zero (M3). Since there was overlap between Garden and Dwelling type—that is, 98% of houses had a garden whereas 14% of apartments and 67% of hostels had one—another nested model had the pathways from Dwelling type to other variables fixed to zero (M4). In another nested model (M5), we fixed to zero the paths to and from the mediators Being away and Social support to see whether the serial mediation components contributed to the model.

We were also concerned that participant’s mental health status could have affected their willingness to take care for indoor plants (i.e., reverse causality) (cf. Korpela et al., 2017). Therefore, we fitted two separate non-recursive models with a bidirectional relationship between Houseplants and Depression (M6) and Anxiety (M7), respectively. We followed analytic considerations raised by Wong and Law (1999), specifying reciprocal paths between the variables and a covariance link between their error variances. The stronger predictor was determined based on performance of competing models against the main model was evaluated on the basis of a chi-square difference test, Akaike information criterion (AIC) and Bayesian information criterion (BIC); the model with the best fit was considered better fitting (Kenny et al., 2006; Werner et al., 2010).

Data were processed with SPSS and Amos v. 23. A p-value of <0.05 was considered statistically significant except as noted above.
3. Results

3.1. Descriptive analyses

Out of the 328 respondents, we excluded five because they did not finish the questionnaire. This left us with an analysis sample of 323 unique respondents. Participant characteristics are shown in Table 1. The majority of participants were female, Bulgarian and in their late teens or early twenties. The majority were long-time dwellers in an apartment building or a detached house. Most resided in a city/town, with 137 spending the quarantine in Plovdiv. On average, they spent 20 h/day at home (See Supplemental Fig. S1 for the distribution of this variable). Approximately 33% of the participants reported symptom scores indicating moderate depression and 20% reported scores indicating moderate anxiety.

In terms of greenery, participants reported having 10 houseplants on average and half of participants reported having a garden. Participants rated both their view and their neighborhood as moderately green, on average. The restorative quality of the home and neighborhood was moderate. As expected during the COVID-19 pandemic, engagement with outdoor greenery was infrequent, especially in the form of sport or social interaction (See Supplemental Fig. S2).

Bivariate associations between the variables are given in Supplemental Table S1 and Table S2. Depressive and anxiety symptoms were more common in students who were older, female, an ethnic minority or lower-income as well as students who spent more time at home or experienced less social support. Greenery measures, except for the presence of a garden, as well as the feelings of being away and fascination and connectedness to nature were associated with better mental health. Greenery measures were also correlated with each other, the feelings of being away and fascination, settlement type, and dwelling type.

3.2. Total association between greenery, putative mediators and mental health

As a next step, we investigated the main associations between mental health and greenery, engagement with greenery, and the feeling of being away (Table 2). In linear models, greenery was generally associated with lower depressive and anxiety symptoms or clinically-meaningful levels of depression and anxiety. However, the estimates were marginally significant for Houseplants → Anxiety Symptoms and not significant for Houseplants → Anxiety. Neither were estimates significant for the presence of a garden predicting three of the four mental health outcomes. The feelings of being away and fascination, engagement with greenery and social support were inversely associated with both continuous and dichotomized depressive/anxiety symptoms.

3.3. Structural equation modeling

In the SEM, the initial model (M0) had a poor fit to the data: χ² (99) = 353.60, p < 0.001; CFI = 0.87; RMSEA = 0.07 (90% CI: 0.06, 0.08); SRMR = 0.08; PNFI = 0.55. As explained in the Methods, we followed an iterative process of removing non-significant confounding path and adding paths or covariance links indicated by high modification indices. Comparison between the initial and final model structures is shown in Supplemental Fig. S3.

The final model, which we will call the Main model (M1), had an acceptable fit to the data: χ² (135) = 204.93, p < 0.001; CFI = 0.96; RMSEA = 0.04 (90% CI: 0.03, 0.05); SRMR = 0.06; PNFI = 0.63. This model is shown in Fig. 2 (see Supplemental Table S3 for all direct effect estimates). Overall, M1 explained 30% of the variance in depressive symptoms and 24% in anxiety symptoms. As shown in Table 3, significant total effects were observed for Houseplants on Depressive symptoms and Neighborhood greenery on both Depressive and Anxiety symptoms. However, both greenery experienced indoors and outdoors were associated with depressive and anxiety symptoms indirectly. That is, having more houseplants and a greener view were associated with perceptions of being away, and in turn, with better mental health. At the same time, living in a greener neighborhood led to perceptions of higher restorative quality, which in turn led to greater social support, and in turn to better mental health. Another pathway from neighborhood greenery involved higher restorative quality, then more frequent engagement with outdoor greenery, and thus, less depressive symptoms. Having a garden was not associated with mental health either directly or indirectly.

3.4. Sensitivity analyses

Tests of potential effect modifiers revealed that these findings were mostly robust across levels of gender, income, crowding in the household, duration of residence, and social support (See Supplemental Tables S4 and S5). The few significant interactions suggested that the presence of a garden was associated with lower depressive symptoms for participants with higher levels of connectedness to nature. Also, houseplants were associated with lower anxiety symptoms only for respondents who spent more time at home. Green view was associated with lower anxiety in those living in an apartment and those with lower connectedness to nature.

Supplemental Table S6 shows comparisons of model fit indices for six alternative structural models (M2-M7) as well as the Main model (M1). Model M2-5 displayed worse fit than M1 according to a significant increase in the chi-square and higher AIC and BIC indices. There was no improvement in model fit for the non-recursive models (M6 and M7) with the addition of bidirectional paths between Houseplants and Depressive/Anxiety symptoms. None of the reciprocal paths in those

| Greenery/mediators       | Depressive symptoms   | Anxiety symptoms   | Depression (PHQ-9 ≥ 10) | Anxiety (GAD-7 ≥ 10) |
|-------------------------|-----------------------|--------------------|------------------------|----------------------|
|                         | B (95% CI)            | p-value            | B (95% CI)             | p-value              | OR (95% CI)         | p-value | OR (95% CI)         | p-value |
| Houseplants             | −0.02 (−0.04, −0.01)  | <0.001             | −0.04 (−0.03, 0.00)    | 0.054                | 0.97 (0.94, 0.99)    | 0.007   | 1.00 (0.96, 1.03)   | 0.852   |
| Green view              | −0.06 (−0.11, −0.02)  | 0.002              | −0.05 (−0.10, −0.003)  | 0.038                | 0.88 (0.80, 0.98)    | 0.014   | 0.83 (0.74, 0.92)   | 0.001   |
| Garden                  | −0.27 (−0.61, 0.08)   | 0.122              | −0.47 (−0.89, 0.06)    | 0.025                | 0.44 (0.17, 1.13)    | 0.088   | 0.51 (0.18, 1.46)   | 0.208   |
| Neighborhood greenery   | −0.10 (−0.14, −0.05)  | <0.001             | −0.11 (−0.16, −0.05)   | <0.001               | 0.79 (0.70, 0.89)    | <0.001  | 0.80 (0.70, 0.91)   | 0.001   |
| Engagement              | −0.07 (−0.16, −0.04)  | <0.001             | −0.07 (−0.11, −0.04)   | <0.001               | 0.82 (0.76, 0.89)    | <0.001  | 0.87 (0.79, 0.95)   | 0.002   |
| Being away (home)       | −0.09 (−0.12, −0.06)  | <0.001             | −0.10 (−0.14, −0.06)   | <0.001               | 0.85 (0.79, 0.93)    | <0.001  | 0.83 (0.76, 0.91)   | <0.001  |
| Being away (neigh.)     | −0.09 (−0.12, −0.06)  | <0.001             | −0.09 (−0.13, −0.05)   | <0.001               | 0.83 (0.77, 0.91)    | <0.001  | 0.85 (0.77, 0.93)   | <0.001  |
| Fascination (neigh.)    | −0.08 (−0.12, −0.05)  | <0.001             | −0.08 (−0.13, −0.04)   | <0.001               | 0.80 (0.72, 0.88)    | <0.001  | 0.84 (0.75, 0.93)   | 0.001   |
| Social support          | −0.08 (−0.11, −0.05)  | <0.001             | −0.11 (−0.14, −0.07)   | <0.001               | 0.85 (0.79, 0.92)    | <0.001  | 0.83 (0.76, 0.89)   | <0.001  |

Note: GAD-7 = General Anxiety Disorder-7; PHQ-9 = Patient Health Questionnaire-9. Separate models are fitted for each of the greenery metrics/mediators. Models are adjusted for age, gender, ethnicity, income, dwelling type, settlement type, university, and connectedness to nature. Coefficients are unstandardized linear regression coefficients (B) or odds ratios (OR) with 95% confidence intervals (CI) and significance (p-values) reported and shown in bold text.

* Variable is square root-transformed.
models was significant (data not shown).

4. Discussion

4.1. General findings

In the present study, the mental health of homebound young adults during the COVID-19 pandemic was better if greenery was present. Specifically, the relative abundance of plants/greenery visible from windows/terraces/balconies or in the neighborhood was associated with reduced depressive/anxiety symptoms and lower rates of clinically-meaningful depression/anxiety levels. Having more houseplants or having a garden was also associated with some of these markers of mental health. As hypothesized, the mental health-supportive effects of greenery experienced indoors were largely explained by feelings of being away while at home, and the effects of outdoor greenery were largely explained by restorative quality and social support working together. However, despite the limited time spent outdoors, both indoor and outdoor experience of greenery seemed important.

Our findings are in line with literature precedent on the subject (Gascon et al., 2015; Jo et al., 2019; Han and Ruan, 2019; Hall and Knuth, 2019; Dzhambov et al., 2020; Callaghan et al., 2020; Pouso et al., 2020). Earlier studies in Plovdiv have shown that living in a greener neighborhood, closer to a green space, spending more time in greenery and having a green view were associated with better general mental health of students (Dzhambov et al., 2018a). We also corroborate mechanistic evidence that restorative quality, as measured here by feelings of being away and fascination, mediates the effect of greenery on mental well-being (e.g., Hipp et al., 2016; Dzhambov et al., 2018a; Dzhambov et al., 2019; Gulwadi et al., 2019). However, some studies found that while the presence of indoor plants led to greater restorative quality (perceived fascination), plants did not have superior restorative effects compared with inanimate objects (Evensen et al., 2015). It is assumed that natural environments enable restorative processes more readily than other environments owing to the relative absence of attentional demands and presence of engaging features which evoke “soft” fascination (Kaplan and Kaplan, 1989; Hartig, 2004). In turn, that can promote social interaction and feelings of social support (Dzhambov et al., 2018a). Earlier studies have also found that lack of social support partially mediated the association between green space and mental health indicators (Maas et al., 2009; Fan et al., 2011). Previously, restorative quality of the neighborhood has been in the spotlight of greenery-health research (Dzhambov et al., 2020). In our case, the unusual circumstances of the COVID-19 pandemic led to activities at home (i.e., attending university entirely online) that may not have been direct sources of stress but still reduced the restoration potential of the home environment. Notwithstanding, our results suggest that greenery contributed to higher perceived capacity of the home and neighborhood to confer psychological distance from mental routines and demands. In addition to restoring depleted capacities, outdoor natural settings are conducive to building new adaptive social resources needed to resist stress (Markevych et al., 2017).

Comparing alternative nested models, we found that both greenery experienced indoors and outdoors were important. In fact, removing the effects of either of the two form of experience of greenery worsened the model fit. Against this background, we propose that having more houseplants and living in a greener neighborhood might partially offset the constrained restoration opportunities resulting from the restrictive measures imposed as part of the COVID-19 lockdown. It follows that keeping parks and green infrastructure accessible may confer mental health benefits in times of social isolation (Slater et al., 2020) despite few documented cases of epidemiologic risk in outdoor greens spaces (Weed and Foad, 2020). Therefore, populations without ready access to safe outdoor greenspaces – such as marginalized low-socioeconomic or ethno-racial minorities in many parts of the Global North (Astell-Burt et al., 2014; Gerrish and Watkins, 2018; Rigolon et al., 2018) and even
some cities in the Global South (Rigolon et al., 2018) – may benefit most from initiatives to increase greenery experienced indoors. Further, these populations are at high risk of COVID-19 infection and mortality, given lifestyle and employment characteristics (Selden and Berdahl, 2020); thus, such promising interventions to reduce psychological impacts without increasing physical health concerns may be extremely valuable.

We are not aware of other studies concerning this specific context of greenery impacts on mental health for housebound university students. Closest to this situation is probably research on hospitalized patients and other institutionalized residents. This research indicates that staying in a hospital room with plants or having a view of green landscapes engenders relaxation, reduced anxiety and fatigue, and ultimately faster recovery after surgical interventions (Ulrich, 1984; Park and Mattson, 2009; Aslam et al., 2016). The same goes for prisoners visually exposed to nature sceneries. They report improved affective state and restoration without increasing physical health concerns may be extremely valuable.

Recent reports indicate increased interest in home gardening during the COVID-19 pandemic and positive effects on mood (Carvalho and Gois, 2020; Lades et al., 2020). Yet, in our study, the presence of a garden was only weakly associated with mental health (Farrier et al., 2019). However, the majority of the students in our study were in their late teens and early twenties—a period in one’s life when gardening is not a common leisure occupation especially in urban areas. Therefore, it could also be that the effect of having a domestic garden was reflected in the other greenery indicators or that the question students were asked was not specific enough to account for garden characteristics (e.g., green vs. paved area).

The present study has a number of strengths. We could take advantage of an unprecedented situation when people were largely confined to their homes and therefore primarily experiencing greenery indoors. This limited mobility considerably reduced exposure misclassification, which is a common issue when static exposure assessment is employed as was done here (Helbich, 2018, 2019). To partially overcome this bias, we considered multiple greenery indicators that reflected different aspects of exposure, including visual engagement in different settings and usage of green spaces for walks, sport and social interaction. Furthermore, we accounted for multiple contextual factors (i.e., income, housing type, and connectedness to nature), which could have confounded or modified the effects of greenery on mental health. We also investigated the role of both indoor and outdoor restorative experiences.

We found evidence of effect modification by rather few contextual factors. Houseplants were associated with lower anxiety only in students spending more time at home. Interestingly, green view related to lower depression and anxiety only in apartment dwellers. Since we did not have information on the apartment’s floor, we could not determine whether this was due to the broader viewshed from taller apartment buildings. It is also plausible that because students living in houses had considerably higher exposure to greenery (see Supplemental Table S2), the impact of green view was diluted, whereas in apartment dwellers, its relative importance became more obvious. Regarding effect modification by connectedness to nature, results were inconclusive. While domestic garden was associated with lower depression in students reporting high connectedness, green view was associated with lower anxiety in students reporting low connectedness. We suspect that this inconsistency could either be a statistical artefact or due to a more complex interaction between connectedness to nature and other contextual or behavioral factors, which we could not model.

Overall, our findings support the idea that exposure to greenery and ensuing restorative experiences both at home and outdoors may be valuable resources during physical isolation. A restorative environment may support adaptation by compensating the lack of coping resources, such as social connections (Cartwright et al., 2018), or by contributing to personal or dyad coping resources (i.e., physiological, social, emotional and attention restoration) (Berto, 2014; Von Lindern et al., 2017; Hartig, n.d.).

### Table 3

| Greenery/mediators | Depressive symptoms a | Anxiety symptoms a |
|--------------------|----------------------|--------------------|
|                    | β (95% CI) p-value    | B (95% CI) p-value |
| **Total effects**  |                      |                    |
| Houseplants        | -0.02 (-0.03, -0.01) | <0.001             |
| Green view         | -0.02 (-0.07, 0.02)  | 0.349              |
| Garden             | 0.09 (0.12, 0.30)    | 0.412              |
| Neighborhood greenery | -0.07 (-0.12, -0.01) | 0.16               |
| Engagement w/ greenery | -0.03 (-0.07, 0.001) | 0.057              |
| Being away (home)  | -0.07 (-0.11, -0.04) | <0.001             |
| Restorative quality (neighborhood) | -0.04 (-0.07, -0.02) | <0.001             |
| Social support     | -0.07 (-0.10, -0.04) | <0.001             |
| **Indirect effects** |                      |                    |
| Houseplants → Being away | -0.004 (-0.01, -0.002) | <0.001             |
| Green view → Being away | -0.02 (-0.04, -0.01) | <0.001             |
| Garden → Restorative quality → Engagement | -0.002 (-0.02, 0.01) | 0.593             |
| Garden → Restorative quality → Social support | -0.002 (-0.02, 0.01) | 0.709             |
| Neighborhood greenery → Restorative quality → Engagement w/ greenery | -0.01 (-0.03, 0.00) | 0.047             |
| Neighborhood greenery → Restorative quality → Social support | -0.02 (-0.03, -0.01) | <0.001             |

Coefficients are unstandardized linear regression coefficients (β) with their 95% confidence intervals (CI).

a The variable is square root-transformed.
young residents (age M = 19.9, SD = 1.6) found 14.8% with depression (Xin et al., 2020) whereas we observed 34.7% with depression, which also exceeds the prevalence of depression in many earlier studies using the PHQ (Manea et al., 2012). Collectively, these studies demonstrate a unifying force of the pandemic on the mental health of residents globally—one which some environmental exposures might protect against.

Several limitations should also be noted. For one, our sample size was modest; therefore, our models could have lacked sufficient power to detect other potentially important pathways. This was implied by several marginally significant path estimates. Next, findings for our convenience sample of students cannot be generalized to all youth experiencing mental health challenges during the COVID-19 epidemic. Moreover, an actual response rate could not be calculated given that students were also allowed to forward the survey link to their peers.

The cross-sectional design prevents us from making causal claims about the associations observed. While we statistically investigated possible reverse causation in the SEM by comparing alternative structural models, we only focused on a subset of potentially bidirectional pathways. Thus, it is conceivable that participant’s mental health influenced perception of greenery because depressed individuals oftentimes pay little attention to their surroundings (Keller et al., 2019) and have deficits in memory for spatial context (Lamy et al., 2008). Likewise, affective state can determine engagement with greenery rather than be an outcome of it (Korpela et al., 2017). A more stringent approach would have been to use repeated measurements during and after the COVID-19 lockdown to see how the importance of different types of greenery would change over time. Further, more than half of students returned to their family home outside of Plovdiv which could have improved their mental health due to family support.

Because of privacy concerns and our desire to elicit honest answers to questions about behaviors inconsistent with the official stay-at-home orders (e.g., visiting green spaces), all data collected were anonymized. Because of that, residential addresses were unknown and we could not calculate georeferenced greenery indicators (i.e., normalized difference vegetation index, NDVI). While perceptual measures accurately capture first-person experiences of the individual’s surrounding environment, we acknowledge that having self-reported data for both exposure and outcome variables may have engendered same-source bias (Chum et al., 2019). In an attempt to not alarm the students, we deliberately refrained from asking coronavirus-related questions. Therefore, we could not directly test the stress-buffering effect of greenery.

Relatively, we collected no data on the specific green view features (e.g., coherence, complexity), which may be more important predictors of well-being than the overall amount of green in the view (van Esch et al., 2019; Lavdas and Schirpke, 2020). Likewise, we considered only the number of indoor plants rather than multisensory modalities, which regulate people’s preferences (Qin et al., 2014), their potential to induce relaxation (Choi et al., 2016), and other myriad effects that may relate to their mental health benefits, such as climate control and indoor air pollutants (Armijos Moya et al., 2018). We did not have data on exposure to blue spaces, which may confer similar health benefits (e.g., Pasamen et al., 2019; Pouso et al., 2020).

Further, we acknowledge that for different students the extent of greenness of their garden/yard could vary. Moreover, students who lived in hostels or apartment buildings had access to a shared garden in front of the building, that is gathering places that were not entirely private or used by a single family. Taken together, the unknown degree of greenness and perceived safety of the garden might explain why it did not show strong associations with mental health on its own.

While we observed potentially protective effects of greenery, the clinical importance of this finding is difficult to judge. We had to rely on screening tools rather than psychiatric diagnoses. When we used dichotomized definitions of the outcomes, one-unit increase in neighborhood greenery, on a scale from 0 to 10, surprisingly led to 20% lower odds of moderate depression and anxiety. However, the greenery variables did not contribute much to the proportion of variance explained in continuously-measured depressive and anxiety symptoms and their effect sizes were rather small. Unfortunately, we did not have sufficient statistical power to model depressive and anxiety symptoms as dichotomized outcomes in the SEM, which could have revealed a different picture if the mean and right ends of their distribution were differentially associated with greenery.

Finally, we had no information on other variables that may have confounded or moderated associations between greenery and mental health. In particular, being married (Crouse et al., 2017) and higher cumulative life stressors (i.e., adverse childhood experiences) (Olvera-Alvarez et al., 2020) may increase the protective effects of outdoor residential greenery on health. Students with pre-existing mental illness diagnoses or risk factors (i.e., social stressors) may also have shown stronger effects from greenery, since some evidence suggests restorative environments provides an equigenic effect whereby populations in greatest need benefit most (Mitchell et al., 2015).

5. Conclusions

Students who spent most of their time at home during the COVID-19 epidemic experienced better mental health when exposed to higher greenery. Experiencing greenery both indoors and outdoors was associated with lower depressive and anxiety symptoms. Houseplants and window view of exterior greenery led to higher perceived restorative quality of the home, and in turn to lower depressive/anxiety symptoms. Neighborhood greenery worked through perceptions of higher neighborhood restorative quality, which in turn facilitated social support and more frequent engagement with greenery. Our findings support the idea that exposure to greenery may be a valuable resource during social isolation in the home. However, causal interpretation of these associations is not straightforward.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envres.2020.110420.

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