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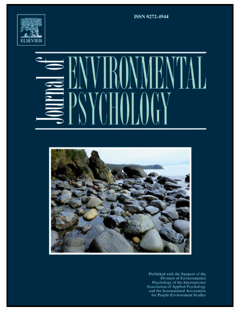

Long-term exposure to greenspace and anxiety from preschool and primary school children

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Running head: Greenspace and anxiety in children

Long-term exposure to greenspace and anxiety from preschool and primary school children

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Abstract

Exposure to greenspace has been associated with mental health benefits in children; however, the available evidence for such an association with anxiety is still scarce. This longitudinal study aimed to evaluate that association on a community cohort of 539 children, from Barcelona province, followed from 3 to 11 years. Long-term exposure to greenspace was characterized at both residential address and school as (i) surrounding greenspace based on satellite-derived indexes (normalized difference vegetation index (NDVI) and Vegetation Continuous Field (VCF) across different buffers and (ii) distance to the nearest green space. We characterized anxiety using the *Child Behavior Checklist* and the *Spence Children's Anxiety Scale,* and cross-sectionally and longitudinally analyzed the associations between the greenspace exposure and the anxiety, using linear mixed models. Higher greenspace surrounding home and school were associated with lower levels of anxiety. Our findings suggest that increasing exposure to greenspace, specially at schools, could be included in preventive policies to promote mental health in children.

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Keywords: Emotional health, Green spaces, Nature, Parks, Psychology, Stress.

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1. *Introduction*

Mental health in children and adolescents has become one of the major public health concerns (WHO, 2015) and, as such, public policies have focused in promoting mental health in children (e.g., European Commission, 2020; Mental Health Support Teams (Public Health England (PHE), 2021); The Mental Health Strategy for Canada: A Youth Perspective (Mental Health Commission of Canada, 2016)). One of the reasons for the interest in this early stage of life is that it is sufficiently established that most mental health problems have their origin in these developmental periods (Angold, 2012; Mulraney et al., 2021). Knowing what happens at these stages is therefore decisive to be able to implement effective preventive interventions.

The developmental perspective of psychopathology presupposes that, during development, the cognitive, affective, social, and biological systems of the child and adolescent become more integrated, thus allowing various vulnerability or protection mechanisms to act synergistically. The objective, therefore, is to elucidate which developmental processes could underlie all areas of functioning and how the complex integration of the person's biological, psychological, and social systems occurs. In this context, it is necessary to explain both adaptive and maladaptive behaviors (Cicchetti & Cohen, 1995a, 1995b). Among the numerous environmental factors to which children and adolescents are exposed, and might have some influence on their development, greenspace has attracted attention in the past few years.

Recent systematic reviews (Jimenez et al., 2021; Li, Menotti, Ding, & Wells, 2021;) have reported protective associations between early-life exposure to greenspace across different settings (rural, semi-rural, urban) and the incidence of a wide range of mental health (Donovan, Michael, Gatziolis, Mannetje, & Douwes, 2019), psychiatric symptoms, emotional and conduct problems (Bezold et al., 2018; Feng & Astell-Burt,

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2017; Flouri, Midouhas, & Joshi, 2014) and cognitive function (Dadvand et al., 2018; Ulset, Vitaro, Brendgen, Bekkhus, & Borge, 2017).

There is also evidence for a relationship between childhood greenspace exposure and increased positive emotions (Zhang et al., 2020). Symptoms of depression seemed to be contingent upon neighborhood-level contextual factors such as population density and deprivation and studies suggested that early life exposure to greenspace may decrease levels of depression and depressive symptoms at adulthood (Bezold et al., 2018). Findings of a longitudinal study suggested positive associations between natural landscapes and better emotional status which predicted an increased self-reported happiness (Van Aart et al., 2018). Also, in a cross-sectional study in Barcelona the school children reports of lower total difficulties scores, emotional problems, and peer relationship problems were associated with more green-space playing time (Amoly et al., 2014). A recent systematic review (Vanaken & Danckaerts, 2018) based on a limited number of studies reported a beneficial association of exposure to greenspace with mental well-being in children and with depressive symptoms in adolescents and young adults. These benefits could be framed within the concept of restoration, a process of renewal, or reestablishment of adaptive capacities that are diminished by the continuous demands of the urban environment (Hartig, 2004).

Anxiety is one of the most prevalent mental health disorders in childhood (Essau, et al. 2018) that can be chronic, adversely affecting the development and wellbeing of the child. Therefore, the study of possible risk and protective factors of this condition is crucial. In adults, a substantial body of evidence supports a protective relationship between greenspace exposure and anxiety (Gascon et al., 2015). Recently, a couple of systematic reviews on greenspace's exposure benefits on children and adolescents also showed associations between greenspace exposure and stress, mood,

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depressive symptoms, emotional well-being, and psychological distress (Davis, et al., 2021; Yang et al., 2021). Anxiety is reported to be significantly reduced by the exposure to greenspace in a dose-response relationship, even if only visual stimulation without physical exposure is used, a corpus of knowledge that has embodied as the stress reduction theory (SRT; Ulrich, et al. 1991), one of the most influential theories that have proposed psychological mechanisms to explain nature exposure's restorative benefits. Being in green spaces could increase social cohesion and contacts, which have been associated with lower anxiety in adults (Vert et al, 2017). A recent systematic review (Sakhvidi, et al. 2022) reports that higher levels of exposure to greenspace might enhance prosocial behavior among children and adolescents. The availability of green spaces might increase the opportunity to engage in social interactions (Dadvand et al. 2019) and the opportunity for play. That gives the chance to practice and develop adequate social attitudes and behaviors. Green spaces have also been associated with increased physical activity, which, in turn, has been reported to have protective effect with anxiety and with the recovery from mental fatigue. This mechanism is a second tentative explanatory model that is framed as the Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989). ART states that spending time in natural spaces helps the overcoming of mental fatigue and stress and restores direct attention, both dismissed by modern urban lifestyle. Particularly, green exercise has been shown to induce reductions in anxiety (Mackay & Neill, 2010). Although exposure to greenspace could have a potential protective association with anxiety in children and adolescents through these mechanisms, to date, the available studies on such an association are very scarce and results are still inconsistent. A recent study by Hartley et al. (2021) found no direct relationship between greenspace exposure and overall symptoms of self-reported anxiety and depression in adolescents with a single measure at 12 years of age. In their

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scoping review, Reece et al. (2021) has pointed out the lack of studies measuring anxiety with clinical measures in children and adolescents as outcomes. The aim of this study was therefore to evaluate the association between the long-term exposure to greenspace, both at school and residential settings, and anxiety from preschool age to adolescence assessed longitudinally with clinical measures of anxiety.

2. *Material and Methods*

2.1 Study setting

This study was conducted in Barcelona province (636 km²), in the northeast Spanish coast, with a population of 5.6 million inhabitants (Instituto Nacional de Estadística, 2020). Barcelona is the capital of the Catalonia autonomous region and is the second most populated city in Spain. It has one of the highest population densities and air pollution levels in Europe. The area has a Mediterranean climate, with hot and dry summers and mild winters (average annual temperature is 21.2 °C during the day and 15.1 °C at night) and much of precipitation occurring during spring and autumn months (on average 78 rainy days a year). Currently, several nature-based interventions such as “Let’s protect schools” (“Protegim les escoles”, Ajuntament de Barcelona (2022a)) and “Climate Shelters in Schools” (“Refugis Climàtics”, Ajuntament de Barcelona (2022b)) are underway in Barcelona, targeting children and adolescents at schools.

2.2 *Participants and design*

This study was conducted in the context of an ongoing community-based cohort aiming at studying psychopathological risk factors from the age of 3-years old (Ezpeleta, de la Osa, & Domènech, 2014). The initial sample consisted of 2,283

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children recruited, through a double-phase approach, from 54 schools. Schools were randomly selected from the census of schools for 2009-10 (25.9% semi-public and 74.1% public). In the first phase of the recruitment, 1,341 families (58.7%) agreed to participate. There were no sex differences (p = .951) between those who agreed to participate and those who declined, but semi-public schools were significantly more likely to refuse to participate than public ones (44.4% vs. 35.7%; p < .001), and high socioeconomic status (SES) (Hollingshead, 1975) families participated more than low status families (p < .001).

Children showing intellectual disability or pervasive developmental disorders (e.g., autistic spectrum disorder), families with difficulties in communicating in Spanish or Catalan, children without a primary caregiver that could report about the child, or those who were moving to another city within a year were excluded (75 children). In the second phase of the sampling, children were screened for oppositional defiant disorder (ODD) (the principal disorder of interest in the original study). Parents filled the Strength and Difficulties Questionnaire (SDQ 3-4) (Goodman 2007) plus four symptoms of the Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV; American Psychiatric Association, 2000) that were not present in the SDQ questionnaire (deliberately bothering people, blaming others, being touchy, angry, and resentful). All the children with a positive screen result (N = 522) and a 30% of the children with negative screen result (N = 235) were invited to participate in the longitudinal study. Of those, 622 families (89.4 %, 417 from the screen positive group and 205 from the screen negative group) agreed to participate. There were no significant differences in sex (p = .815) neither in type of school (p = .850) between participants and drop-outs; nevertheless, participating children were of higher SES (p = .017). The annual assessment was done from age 3 (i.e., at recruitment) to age 11 (i.e., nine

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repeated assessments). Figure 1 outlines the sampling process and data collection during the 9-year follow-up, with indication of the sample size available at each follow-up.

The project was approved by the ethics review committee of the authors' institution (Ethics Committee on Animal and Human Research - CEEAH 1885). Parents or legal guardians of the children provided written informed consent before being enrolled into the study.

2.3 *Greenspace exposure assessments*

We characterized two different aspects of greenspace exposure including surrounding greenspace (as an indicator of general greenspace in living and education environments of children) and proximity to green spaces (as an indicator of access to green spaces (WHO/EURO, 2016)), at both participants' homes as well as schools, which are two important microenvironments for schoolchildren. During the nine years of follow-up there were a total of 101 school moving and 486 home moving. The greenspace exposure at home and school was measured annually based on the addresses obtained during the follow-up visit of that year, therefore, our measures of exposure took account of these changes in home and/or school addresses.

Surrounding greenspace

Our characterization of the surrounding greenspace was based on two satellite-derived indices of vegetation, namely Normalized Difference Vegetation Index (NDVI) and Vegetation Continuous Field (VCF).

NDVI has been one of the most widely used vegetation indices in studies of the health effects of greenspace exposure. It is calculated based on the land surface reflectance of the red light (which is absorbed by vegetation for photosynthesis) and

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near-infrared light (which is deflected by vegetation to avoid overheating). NDVI values range from −1 to 1, with negative values indicating lack of vegetation and higher positive values indicating higher density of photosynthetically active vegetation (Tucker, 1979). VCF is an indicator of tree canopy cover and displays the percentage of land (in each image pixel) covered by the woody vegetation with a height greater than five meters (Sexton et al., 2013). The higher VCF values indicate the higher percentage of tree cover.

All these indicators were generated using Landsat 5 (images from 2011-04-11, and 2011-04-02) and Landsat 8 (images from 2015-04-13 and 2015-05-08), except for the VCF, where the images were from 2010 and 2015 respectively, downloaded from USGS Earth Explorer (https://earthexplorer.usgs.gov/). We characterized greenspace surrounding home and school of each participant, separately as the averages of NDVI and VCF within circular buffers of 50m, 100m, 300m, and 500m (Euclidean distance) representing immediate, intermediate, and neighborhood areas around the residence and school address in each follow-up (i.e., 9 follow-ups × 2 environments (home/school) × 4 buffers = 72 measures of greenspace for each indicator).

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To better illustrate the area of study and its greenspace density, Figure 2 shows maps for the municipalities were most of the participants lived with geocoded schools and NDVI indexes obtained at years 2011 and 2015.

Distance to the nearest green space

We applied distance to the closest green space as an indicator of access to green spaces (European Commission Expert Group on the Urban Environment, 2001). To identify green spaces in our study area we used Urban Atlas (2012), a Europe-wide map of land cover for the urban areas, generated as a part of the Copernicus Land Monitoring

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Service (European Union, 2020). We applied the following land cover classes to develop the map of green spaces across our study area: "Arable land (annual crops)", "Complex and mixed cultivation patterns", "Forests", "Green urban areas", "Herbaceous vegetation associations (natural grassland, moors...)", "Open spaces with little or no vegetation (beaches, dunes, bare rocks, glaciers)", "Orchards at the fringe of urban classes", "Pastures", and "Permanent crops (vineyards, fruit trees, olive groves)". We then calculated the Euclidean distance separately from home and school to their nearest green space. As such, higher values corresponded to less access (exposure) to greenspace.

2.4 *Psychological variables assessment*

We chose two of the most used instruments to characterize anxiety, which were included in a wider battery along the longitudinal assessment of the cohort participants: a scale of general psychopathology including an anxiety scale: the *Child Behavior Checklist* (CBCL; Achenbach & Rescorla, 2001) and the *Spence Children's Anxiety Scale for parents* (SCAS-P; Spence, 1988) as a specific anxiety instrument.

The *CBCL* is a 113-item questionnaire completed by parents. It is widely used to evaluate behavioural and emotional problems, with each question being rated on a Likert-type scale from 0 (*it's not true*) to 2 (*it is very or often true*). The CBCL DSM-5-oriented scale for anxiety problems (Achenbach, 2013), consisting of nine items that resembles and describes the anxiety symptoms that conform the anxiety disorder categories proposed by the DSM, 5th edition (DSM-5; American Psychiatric Association, 2013), was used in our analysis. The questionnaire was answered by parents annually from children's ages 3 to 11 years, resulting in 9 repeated measures of

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anxiety. Ordinal alpha values for internal consistency reliability ranged between .81 and .90 for the nine follow-ups in the sample of the study.

The *Spence Children's Anxiety Scale-P* assesses the severity of anxiety symptoms following the anxiety disorder categories proposed by the DSM, 4th edition (DSM-IV; American Psychiatric Association, 1994). The parent version contains 38 items (0: *never* to 3: *always*) that were answered when children were 9-year-old. The generalized anxiety scale score (6 items, ordinal alpha = .77) was considered in our current study.

2.5 *Statistical Analysis*

Main analyses

Given the multistep sampling procedure used, all the analyses were weighted by the inverse probability of selection in the second phase of sampling (Lorh, 2019). We applied two analytical approaches:

(i) *The cross-sectional analysis* of the association of the greenspace exposure that occurred at the 9-year-old follow-up and the generalized anxiety characterized using the SCAS-P that was also measured at age 9. For exposures measured at home linear mixed models with the school as random effect were used. This random effect was not included in models for exposure measured at school because all children going to the same school had the same greenspace values.

(ii) *The longitudinal analyses* with annual greenspace measures as predictor and trajectories of anxiety obtained with Latent Class Growth Analysis (LCGA) applied to the nine repeated annual CBCL assessments as response. For LCGA, the Robust Maximum Likelihood (MLR) method of estimation and the expectation maximization algorithm for missing data with robust standard errors were used (Muthén & Muthén

2017). The imputation of the missing values explains why the sample size resulting from the sum of the classes is greater than the sample size available at last follow-up. The growth models considered intercept (I), slope (S; i.e., linear trend) and quadratic growth parameters over the nine annual assessments available. Time was rescaled to 0-9, so the intercept (i.e., the basal score) represented the first-year assessment (at age 3). Models with 1 to 4 latent classes of growth patterns were obtained. The best model was selected based on the best plausible clinical explanation and the following criteria: larger decrement in AIC and sample-size adjusted BIC (aBIC), greater power and more accurate classification by average posterior probabilities, entropy values equal to or greater than .70, and a minimum of 27 (5%) participants per class (Nylund, Asparouhov, & Muthén, 2007). Once the optimal number of classes was defined, mixed effect logistic regression models with the school as random effect, indicators of greenspace exposures at home (one at a time) as the main independent variable, and the class-membership as dependent variable (recoded so higher codes corresponded to higher anxiety levels) were conducted. For analyses of the greenspace exposure at school, we applied simple logistic regression models (i.e., school was not included as a random effect), given the fact that all children going to the same school had the same exposure level.

All regression models were adjusted for an *a priori* selected set of covariates including (i) sex, (ii) ethnicity (European, other), (iii) parental education (with vs. without university education) as an indicator of household SES, (iv) two indicators of neighbourhood SES: the percentage of illiterate (%) and the percentage of unemployment (%) at the census tract of the residential or school address, and (v) the number of stressful life events during the year preceding the psychological assessment. The association estimates were reported per each interquartile range (IQR) in each

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indicator of greenspace exposure based on all participants, to provide comparable results for different exposure indicators. The statistical analyses were carried out using MPlus8.4 and Stata 16.

Sensitivity and stratified analyses

We applied Modified Soil-Adjusted Vegetation Index (MSAVI) to assess home and school surrounding greenspace and we repeated our analyses using this alternative set of exposures. The MSAVI improves NDVI's estimation of greenspace by minimizing the soil background effect and hence obtaining a better vegetation sensitivity when there are areas with few vegetation cover or high proportions of bare soil (Qi et al., 1994). MSAVI values range from −1 to 1 with higher values indicating a higher density of vegetation (NASA earth observatory, 2000).

To explore the potential variation of our evaluated associations across strata of sex, family SES, neighbourhood SES and life events, we stratified our SCAS-P association analyses by at home and school surrounding greenspace (at 300 m buffer) and distance to the closest green space, by sex, by parental education (with or without university education), by home neighborhood unemployment rate, defined as low for values under the sample percentile 25 or high for values above the sample percentile 75 (the 50% of participants with central unemployment rate values were excluded from this analysis) and by having or not a stressful life event during the last year.

3. Results

The socio-demographic characteristics of the study sample are presented in Table 1. The sample included a 51.8% of girls, 64.9% of parents with university studies and 92.2% of White children. There were most families of medium-high/high SES.

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However, the percentages of unemployment and illiteracy were higher than expected, because they belonged to the neighbourhood of residence and school.

Table 2 shows the bivariate Pearson's correlations between greenspace measures obtained at home and school at age 9. Greenspace measures obtained with NDVI and VCF were highly associated both at residence (mean correlation = .80) and at school (mean correlation = .73). Association between NDVI – VCF and Distance to closest green space was medium-high (mean correlation = −.46). Finally, association between residence and school indicators was medium-high (mean correlation = .47 for NDVI-VCF and .50 for Distance to closest green space). Supplementary Figure S1 shows histograms for NDVI and VCF at 300 m buffer for homes and schools.

3.1 *Cross-sectional association of greenspace exposure and general anxiety scores*

Supplementary Figure S2 shows histograms for the two measures of anxiety at age 9. Table 3 presents the results of the cross-sectional analysis of the association of greenspace exposure on anxiety scores characterized by SCAS-P. All the associations were in the expected direction, with negative coefficients for the surrounding greenspace measures reflecting that higher exposure to greenspace at home or school was associated with lower anxiety scores. The association was positive for the distance to the closest green space, meaning that the longer distance to the closest green space (i.e., less access to green spaces) was associated with higher anxiety score. Statistically significant effects were observed for NDVI in all the buffers larger than 50 m around the participants' home. An increment of one IQR in NDVI measured within 100 and 500 m buffer was associated with a significant decrease of between 1.25 (95% confidence intervals (CIs): −2.38 to −0.11) and 1.86 (−3.26 to −0.46) points in the SCAS-P anxiety measure. We observed some suggestions for a linear trend in the

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association estimates across different buffer sizes with slightly stronger associations observed for larger buffer sizes. For the tree cover (VCF) surrounding home, although we observed protective associations, none were statistically significant.

Regarding the association between school surrounding greenspace and SCAS-P anxiety measure, significant associations for NDVI and VCF were found for buffers of 50 and 50 - 100 m respectively. The increase of one IQR in NVDI across a 50 m buffer was associated with a decrease of 2.47 (-4.13 to -0.81) in anxiety scores. Similar associations were observed for VCF with a decreased anxiety score of -1.74 (-2.70 to -0.79) for the 50 m buffer and -1.28 (-2.19 to -0.36) for the 100 m buffer.

3.2 *Longitudinal association of greenspace exposure and anxiety classes*

Table 4 shows the goodness-of-fit indices for the LCGA models from 1 to 4 classes including linear and quadratic trends. Based on the mentioned criteria, the 2-class model was selected. Onwards class 1 corresponded to children with low-medium anxiety and class 2 to children with medium-high anxiety. As can be seen in Figure 3 the two trajectories were quite stable over time.

Our findings regarding the effects of greenspace indicators on the two classes derived from LCGA are presented in Table 5. While the results for the greenspace exposure at residence were not significant, for the greenspace exposure at schools we observed statistically significant protective associations with anxiety for NDVI (buffers 50 and 100 m.), VCF (all buffers), and distance to the nearest green space. An increment of one IQR in NDVI measured at school was associated with a lower odd of belonging to the medium-high anxiety class for 50 (OR = 0.80, CI95%: 0.70 to 0.90) and 100m buffers (OR = 0.81, CI95%: 0.73 to 0.92).

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For VCF we observed statistically significant ORs associated to 1-IQR increment in exposure ranging between 0.89 (CI95%: 0.84 to 0.94) for 50 m buffer and 0.94 (CI95%: 0.89 to 1.00) for 500 m buffer, with some indications for potentially larger odds ratio (less protective effect) for larger buffer sizes. Finally, longer distance to the nearest green space was associated with a lower odd of belonging to the medium-high anxiety trajectory, with an OR of 0.88 (CI95%: 0.79 to 0.99) for 1-IQR increase in distance.

3.3 *Sensitivity and stratified analyses*

Supplementary Table S1 presents the results of the cross-sectional analyses using MSAVI to assess the association of home and school surrounding greenspace with the SCAS-P anxiety score. The direction and strength of the associations were similar to those observed for NDVI, with significant associations observed for three of the four buffer sizes. An increment of one IQR of MSAVI measured at residence within buffers of 100, 300, and 500 meters was associated with a decrease of 1.35 (CI95%: −2.50 to −0.21), 1.65 (CI95%: −2.87 to −0.44) and 1.93 (CI95%: −3.31 to −0.55) points in anxiety scores, respectively. Only the measure of school MSAVI across the 50m buffer was significantly associated with SCAS-P anxiety score, in line with the findings of our main analyses for NDVI and VCF.

Supplementary Table S2 shows the results of the longitudinal analyses using MSAVI to assess home and school surrounding greenspace associations with anxiety trajectories. Only greenspace exposure at school measured at 50m and 100m buffers was associated with a significant decrease in the odds of belonging to the medium-high anxiety trajectory, with an OR of 0.80 (CI95%: 0.70 to 0.92) and 0.83 (CI95%: 0.73 to 0.94) for 50m and 100m buffers, respectively.

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Supplementary Figure S3 presents the association between greenspace exposure at home/school and SCAS-P anxiety score stratified by sex. In general, all the associations both at home and school and both for boys and girls were suggestive of a protective effect of greenspace exposure against higher anxiety scores, with some suggestions for a potentially stronger associations for girls. Statistical significance was only achieved for home and school surrounding greenspace measured with NDVI for girls.

Supplementary Figure S4 presents the association between greenspace exposure at home/school and SCAS-P anxiety score stratified by parental education (at least one parent with university education versus both parents without university education). Significant lower anxiety scores were only found for children from parents without university studies when using NDVI both at home and school and when using VCF at school.

4. *Discussion*

To our knowledge, this is the first longitudinal study that has analyzed the association between greenspace exposure, both at home and school, and anxiety in community children. Our study benefited from nine repeated annual assessments of the anxiety as well as greenspace exposure in a well-established cohort with extensive availability of relevant covariate data. The instruments used to measure anxiety symptomatology were widely used and recognized and we had a comprehensive characterization of greenspace exposure, relying on several indicators and detailed residential and school history of the participants since they were 3 years old until nine years later. We observed that more greenspace surrounding both home and school was associated with a beneficial impact on anxiety, reflected as lower anxiety scores in

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SCAS-P. Regarding the trajectories of anxiety generated using CBCL scores from 3 to 11 years-old, we concluded that higher greenspace exposure at school reduces the risk of belonging to the medium-high anxiety trajectory. We also found some suggestions for a stronger association for children from families without university studies, and a higher benefit of greenspace exposure at residence and at school for girls when NDVI was used.

The association between anxiety trajectories and school's distance to closest greenspace was in the opposite direction than expected. These counterintuitive finding could be because our map for identifying green spaces did not have a high resolution. Only very large green spaces larger than 15 hectares appeared in the map, not the small green spaces that could be relevant for children, especially in Barcelona province, where it is common for children to meet in a park near the school after leaving the school.

Overall, previous reviews highlight the potential beneficial impact of green space in schoolyards on mental health of schoolchildren (Zhang, Mavoa, Zhao, Raphael, & Smith, 2020). Other studies including emotional symptomatology as outcome and home as setting of interest (Van Aart et al. 2018) presented results indicating better emotional status and total negative emotions using the Strengths and Difficulties Questionnaire, (Goodman, 1997) when exposure and outcome were analyzed cross-sectionally but not longitudinally. Opposite to this findings, in a cross-sectional study in Ontario schools, the authors did not find such a relationship (Srugo et al., 2019). These authors used a non-specific psychological distress scale, self-reported, and participants were between 11-20 years old. Aligned with those results, Hartley et al. (2021) found no direct relationship between greenspace and overall symptoms of anxiety either. Their study included older children than our sample and used self-reports.

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Our results partially replicate these findings as we found cross-sectional significant association between anxiety and both residential and school greenspace exposure, additionally we also obtained significant longitudinal associations in relation to school greenspace exposure. Our observed associations between greenspace exposure and anxiety might be explained through several pathways. First, the stress Reduction Theory (SRT) (Ulrich, 1984) describes how spending time in nature might activate the parasympathetic system reducing stress. Green spaces might help children and adolescents to alleviate stress by providing opportunities for physical, funny, and risky activities (Jimenez et al., 2021) that could increase autonomy and self-confidence, reduce the sense of parents' overprotection, and so reduce anxiety problems (Jones, Hall, & Kiel, 2021). In this context, an increase in the amount of the time children and adolescents spend outdoors and higher physical activity levels could underlie the association of greenspace exposure and anxiety (Tzoulas et al., 2007). Additionally, green spaces could reduce screen time, promote social contacts and sense of community (Amoly et al., 2014; van Nieuwenhuijzen, Vriens, Scheepmaker, Smit, & Porton, 2011), which, in turn, could reduce anxiety. This could be one reason for the null association between home exposure and the anxiety trajectories, as children spend much less time at home than at schools. At school, social interaction takes place during light hours of the day, especially in Mediterranean autumn or winter months, facilitating social cohesion, promoting confident and safe relationships, who rely on. The possibility to "train" social skills, in this critical period of development is important for the development and self-confidence. Green spaces mitigate air pollution, or high temperatures and give children the perception of freedom and nonexistence of routine and the difficulties and sustained attention that academic tasks require aligned with the ART thesis (Kaplan, 1989).

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We observed potentially stronger associations between greenspace surrounding schools and anxiety for children of lower educational level. This observation is in line with several previous studies on the health effects of the greenspace exposure, reporting a greater benefit for people from lower SES groups (Rigolon, Browning, McAnirlin & Yoon, 2021), who often have less desirable physical and mental health conditions and are less mobile, so they are more likely to benefit from greenspace in the vicinity of their homes and/or schools/workplaces. The beneficial effect of greenspace exposure for low SES families was not confirmed in the stratified analysis by neighborhood SES using unemployment rate. The halving of the sample size because of the definition of extreme groups could explain the absence of significant differences between low and high neighborhood SES groups. As regard to the stratified analysis by sex, we found that girls had a slightly higher benefit from greenspaces, which could be due to the higher prevalence of anxiety symptomatology in girls (NIMH, 2022). Finally, our results suggest that children with stressful life events during the year before the anxiety assessment did not show a higher benefit from greenspace exposure. These results are contrary to van der Berg, et al. (2010), who concluded that people with a high amount of green space in a 3-km radius were less sensitive to worsening its perceived mental health after experiencing a stressful life event. The fact that we analyzed children instead of adults' data and greenspace buffers much smaller than 3-km may explain the contradictory conclusions.

The findings of this study should be interpreted considering its limitations. We did not have data on the duration and frequency exposure to greenspace (e.g., use of green spaces) and the type of activity realized in green spaces. Moreover, we lacked information on the quality characteristics of green spaces such as safety as well as their ownership (public, semi-public, or private) that could determine the use of these spaces

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by children. Due to children's age, we could not conduct our psychological assessment using self-administered questionnaires. Therefore, our measures of the anxiety symptoms were based on parental information, which could have resulted in outcome misclassification. Moreover, given our community sample with low anxiety diagnose prevalence, we could not look at the incidence of anxiety disorder as a clinical outcome and instead we focused on anxiety symptomatology. Additionally, some of our findings might be of limited validity given the fact that the participant families tended to have a higher SES than the general population, which at the same time could influence the global estimations because the influence of familiar SES on the greenspace exposure – anxiety relationship has been stated in supplementary analysis. Neither did we have data on other potentially relevant covariates (e.g., health status and family environment), which also could have biased our results.

Similarly, we did not have data on potential mediators (e.g., stress reduction, physical activity, and social interaction) of our evaluated association, which remains as an open question for future studies.

We were not able to conduct a mediation analysis of the mediatory role of air pollution in our observed associations between greenspace and anxiety because the available air pollution models (i.e., ESCAPE (European Study of Cohorts for Air Pollution Effects) and ELAPSE (Effects of Low-level Air Pollution: A Study in Europe)) included components of greenspace as predictors. …Although our study region was in a coastal area, we did not evaluate the potential effect of blue spaces on anxiety because most of the participants were living away from the coast. Similarly, none of the schools were close to blue spaces.

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5. *Conclusions*

Our study of children followed over a 9-year period between preschool and preadolescence showed that higher surrounding greenspace at home and school was associated with less anxiety symptoms. We also found indications for a stronger association for children with lower SES. These findings, if confirmed by future studies, call for considering the inclusion of adequate levels of greenspace in the neighborhoods as well as schools to promote mental health in urban children. Further studies are required to replicate our findings in other settings with different climates and cultures, while investigating the underlying mechanisms and pathways of the association between green space and anxiety, (e.g., stress reduction, physical activity, and social interaction) evaluating sensitive periods in the early life, and collecting more detailed information on greenspace exposure such as objective measures of time spent in green spaces, quality of green spaces, and the type of activities realized in those spaces. There is also a need for (quasi-)experimental studies that can establish causal effects of green space exposure on anxiety in children. The control of the greenspace exposure by using other research designs would allow to establish or discard the recommendations derived from the present and similar studies.

Declaration of interests: none

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References

Achenbach, T. M., & Rescorla, L. A. (2001). *Manual for the ASEBA school-age forms & Profiles*. University of Vermont, Research Center for Children, Youth & Families.

Achenbach, T.M. (2013). DSM Guide for the ASEBA. Burlington, VT: University of Vermont, Research Center for Children, Youth, & Families.

Ajuntament de Barcelona. (2022a). https://ajuntament.barcelona.cat/ecologiaurbana/en/what-we-do-and-why/urban-planning-for-neighbourhoods/protect-schools

Ajuntament de Barcelona. (2022b). https://www.barcelona.cat/barcelona-pel-clima/en/climate-shelters-schools

American Psychiatric Association. (1994). *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.).

American Psychiatric Association. (2000). *DSM-IV-TR Diagnostic and Statistical Manual of Mental Disorders Text Revised.4th Ed.* Washington, DC: APA.

American Psychiatric Association, (2013). *Diagnostic and Statistical Manual of Mental Disorders 5th Ed.* DSM5. Washington, DC: APA.

Amoly, E., Payam, D., Forns, J., López-Vicente, M., Basagaña, X., Julvez, J., … Sunyer, J. (2014). Research | Children ’ s Health Green and Blue Spaces and Behavioral Development in Barcelona Schoolchildren : The BREATHE Project. *Children's Health*, *122*(12), 1351–1358.

Angold, A., Erkanli, A., Copeland, W., Goodman, R., Fisher, P. W., & Costello, E. J. (2012). Psychiatric diagnostic interviews for children and adolescents: a comparative study. *Journal of the American Academy of Child & Adolescent Psychiatry*, *51*(5), 506-517.

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Bezold, C. P., Banay, R. F., Coull, B. A., Hart, J. E., James, P., Kubzansky, L. D., … Laden, F. (2018). The relationship between surrounding greeness in childhood and adolescence and depressive symptoms in adolescence and early adulthood. *Annals of Epidemiology*, *28*(4), 213–219. https://doi.org/10.1016/j.annepidem.2018.01.009

Cicchetti, D. y Cohen, D. J. (Eds.). (1995a). *Developmental psychopathology. Vol. 1: Theory and methods*. New York: Wiley.

Cicchetti, D. y Cohen, D. J. (Eds.). (1995b). *Developmental psychopathology. Vol. 2: Risk, disorder and adaptation*. New York: Wiley.

Dadvand, P., Pujol, J., Maciá, D., Martínez-Vilavella, G., Blanco-Hinojo, L., Mortamais, M., … Sunyer, J. (2018). The association between lifelong greenspace exposure and 3-dimensional brain magnetic resonance imaging in Barcelona schoolchildren. *Environmental Health Perspectives*, *126*(2), 1–8. https://doi.org/10.1289/EHP1876

Dadvand, P.; Hariri, S.; Abbasi, B.; Heshmat, R.; Qorbani, M.; Motlagh, M.E.; Basagaña, X. & Kelishadi,R. (2019). Use of green spaces, self-satisfaction and social contacts in adolescents: A population-based CASPIAN-V study. *Environmental Research,168*, 171-177. https://doi.org/10.1016/j.envres.2018.09.033.

Davis, Z., Guhn, M., Jarvis, I., Jerrett, M., Nesbitt, L., Oberlander, T., Sbihi, H., Su, J., & van den Bosch, M. (2021). The association between natural environments and childhood mental health and development: A systematic review and assessment of different exposure measurements. International Journal of Hygiene and Environmental Health. 235:113767. doi: 10.1016/j.ijheh.2021.113767. Epub 2021 May 11. PMID: 33989957.

Donovan, G. H., Michael, Y. L., Gatziolis, D., Mannetje, A. t., & Douwes, J. (2019).

Journal Pre-proof

Association between exposure to the natural environment, rurality, and attention-deficit hyperactivity disorder in children in New Zealand: a linkage study. *The Lancet Planetary Health*, *3*(5), e226–e234. https://doi.org/10.1016/S2542-5196(19)30070-1

Ezpeleta, L., de la Osa, N., & Domènech, J. M. (2014). *Prevalence of DSM-IV disorders, comorbidity and impairment in 3-year-old Spanish preschoolers. Social Psychiatry and Psychiatric Epidemiology, 49(1), 145-155.* Doi: 10.1007/s00127-013-0683-1.

Feng, X., & Astell-Burt, T. (2017). Residential Green Space Quantity and Quality and Child Well-being: A Longitudinal Study. *American Journal of Preventive Medicine*, *53*(5), 616–624. https://doi.org/10.1016/j.amepre.2017.06.035

Flouri, E., Midouhas, E., & Joshi, H. (2014). The role of urban neighbourhood green space in children's emotional and behavioural resilience. *Journal of Environmental Psychology*, *40*, 179–186. https://doi.org/10.1016/j.jenvp.2014.06.007

Gascon, M., Mas, M. T., Martínez, D., Dadvand, P., Forns, J., Plasència, A., & Nieuwenhuijsen, M. J. (2015). Mental health benefits of long-term exposure to residential green and blue spaces: A systematic review. *International Journal of Environmental Research and Public Health*, *12*(4), 4354–4379. https://doi.org/10.3390/ijerph120404354

Goodman, R. (1997). The Strengths and Difficulties Questionnaire: American Psychiatric Association. (2000). *DSM-IV Diagnostic and statistical manual of mental disorders* (4th Text Revised ed.). American Psychiatric Press.A Research Note. *Journal of Child Psychology and Psychiatry*, *38,* 581-586 https://doi.org/10.1111/j.1469-7610.1997.tb01545.x

Hartley, K., Perazzo, J., Brokamp, C., Gillespie, G.L., Cecil, K.M., LeMasters, G.

Journal Pre-proof

Yolton, K. & Ryan, O, (2021). Residential surrounding greeness and self-reported symptoms of anxiety and depression in adolescents, *Environmental Research, 194,* 110628, (https://www.sciencedirect.com/science/article/pii/S0013935120315255)

Jimenez, M. P., Deville, N. V., Elliott, E. G., Schiff, J. E., Wilt, G. E., Hart, J. E., & James, P. (2021). Associations between nature exposure and health: A review of the evidence. *International Journal of Environmental Research and Public Health*, *18*(9). https://doi.org/10.3390/ijerph18094790

Jones, L.B., Hall, B.A. & Kiel, E.J. (2021). Systematic review of the link between maternal anxiety and overprotection. *Journal of Affective Disorders,295,* 541-551 https://doi.org/10.1016/j.jad.2021.08.065.

Lawton, E., Brymer, E., Clough, P., & Denovan, A. (2017). The relationship between the physical activity environment, nature relatedness, anxiety, and the psychological well-being benefits of regular exercisers. *Frontiers in Psychology*, *8*(JUN). https://doi.org/10.3389/fpsyg.2017.01058

Li, D., Menotti, T., Ding, Y., & Wells, N. M. (2021). Life course nature exposure and mental health outcomes: A systematic review and future directions. *International Journal of Environmental Research and Public Health*, *18*(10). https://doi.org/10.3390/ijerph18105146

Mackay, G. J., & Neill, J. T. (2010). The effect of “green exercise” on state anxiety and the role of exercise duration, intensity, and greeness: A quasi-experimental study. *Psychology of Sport and Exercise*, *11*(3), 238–245. https://doi.org/10.1016/j.psychsport.2010.01.002

Mulraney, M., Coghill, D., Bishop, C., Mehmed, Y., Sciberras, E., Sawyer, M., Efron, D., & Hiscock, H. (2021). A systematic review of the persistence of childhood

Journal Pre-proof

mental health problems into adulthood. *Neuroscience and biobehavioral reviews*, *129*, 182–205. https://doi.org/10.1016/j.neubiorev.2021.07.030

National Institute on Mental Health (2022). Last retreive April 2022. https://www.nimh.nih.gov/health/statistics/any-anxiety-disorder .

Nylund, K.L., Asparouhov, T. & Muthén, B.O. (2007) Deciding on the Number of Classes in Latent Class Analysis and Growth Mixture Modeling: A Monte Carlo Simulation Study. *Structural Equation Modeling, 14*, 535-569. http://dx.doi.org/10.1080/10705510701575396

Parker, G., Yiming, C., Tan, S., & Rutter, M. (2001). The development of a brief screening measure of emotional distress in children. *Journal of Child Psychology and Psychiatry*, *42*(2), 221–225. Retrieved from 10.1017/S0021963001006692

Rigolon A, Browning MHEM, McAnirlin O, Yoon HV. Green Space and Health Equity: A Systematic Review on the Potential of Green Space to Reduce Health Disparities (2021). International Journal of Environmental Research and Public Health, 18, 5, 2563. doi: 10.3390/ijerph18052563.

Sakhvidi, M.J.Z.; Knobel, P.; Bauwelinck, M.; de Keijzer, C.; Boll, L.M.; Spano, G.; Ubalde-Lopez, M.; Sanesi, G.; Mehrparvar, A.H.; Jacquemin, B. & Dadvand,P.(2022). Greenspace exposure and children behavior: A systematic review. *Science of The Total Environment,* 824. https://doi.org/10.1016/j.scitotenv.2022.153608.

Srugo, S. A., de Groh, M., Jiang, Y., Morrison, H. I., Hamilton, H. A., & Villeneuve, P. J. (2019). Assessing the impact of school-based greeness on mental health among adolescent students in Ontario, Canada. *International Journal of Environmental Research and Public Health, 16*(22). https://doi.org/10.3390/ijerph16224364

Ulrich, R.S., Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A. & Zelson, M.(1991).

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Sexton, J.O., Song, X.P., Feng, M., Noojipady, P., Anand, A., Huang, C. Kim, D.-H., Collins, K.M., Channan, S., DiMiceli, C. & Townshend, J.R. (2013) Global, 30-m resolution continuous fields of tree cover: Landsat-based rescaling of MODIS vegetation continuous fields with lidar-based estimates of error. *International Journal of Digital Earth*, 6:5, 427-448, DOI: 10.1080/17538947.2013.786146

Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology, 11,* 3, 201-230.https://doi.org/10.1016/S0272-4944(05)80184-7.

Tucker, C.J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment*, 8, 2, 127-150. https://doi.org/10.1016/0034-4257(79)90013-0.

Ulset, V., Vitaro, F., Brendgen, M., Bekkhus, M., & Borge, A. I. H. (2017). Time spent outdoors during preschool: Links with children's cognitive and behavioral development. *Journal of Environmental Psychology*, *52*, 69–80. https://doi.org/10.1016/j.jenvp.2017.05.007

Van Aart, C. J. C., Michels, N., Sioen, I., De Decker, A., Bijnens, E. M., Janssen, B. G., … Nawrot, T. S. (2018). Residential landscape as a predictor of psychosocial stress in the life course from childhood to adolescence. *Environment International*, *120*(August), 456–463. https://doi.org/10.1016/j.envint.2018.08.028

van Nieuwenhuijzen, M., Vriens, A., Scheepmaker, M., Smit, M., & Porton, E. (2011). The development of a diagnostic instrument to measure social information processing in children with mild to borderline intellectual disabilities. *Research in Developmental Disabilities*, *32*(1), 358–370. https://doi.org/10.1016/j.ridd.2010.10.012

Vanaken, G. J., & Danckaerts, M. (2018). Impact of green space exposure on children's

Journal Pre-proof

and adolescents' mental health: A systematic review. *International Journal of Environmental Research and Public Health*, *15*(12). https://doi.org/10.3390/ijerph15122668

World Health Organization/EURO (2016). *Urban green spaces and health* 2016-3352-43111-60341

Yang, B.Tianyu Zhao, Li-Xin Hu, Matthew H.E.M. Browning, Joachim Heinrich, Shyamali C. Dharmage, Bin Jalaludin, Luke D. Knibbs, Xiao-Xuan Liu, Ya-Na Luo, Peter James, Shanshan Li, Wen-Zhong Huang, Gongbo Chen, Xiao-Wen Zeng, Li-Wen Hu, Yunjiang Yu, Guang-Hui Dong,(2021). Greenspace and human health: An umbrella review. *The Innovation,2*, 4, 100164 https://doi.org/10.1016/j.xinn.2021.100164.

Zhang, Y., Mavoa, S., Zhao, J., Raphael, D., & Smith, M. (2020). The association between green space and adolescents mental well-being: A systematic review. *International Journal of Environmental Research and Public Health*, *17*(18), 1–26. https://doi.org/10.3390/ijerph17186640

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Table 1. Descriptive of the study participants (*N* = 539)

	Home*	School
Sex[a]: *N* (%) Female	279 (51.8)	
Parent with high studies[a]; *N* (%) Yes	350 (64.9)	
SES[a] ; *N* (%)		
High/Medium-High	364 (67.5)	
Medium/Medium-Low/Low	175 (32.5)	
Ethnicity[a] ; *N* (%) Caucasian	497 (92.2)	
Number of stressful life-events[b]	1 (2)	
Unemployement[b] (%)	19.5 (11.0)	17.96 (16.1)
Illiterate[b] (%)	7.1 (7.4)	5.2 (5.0)
Anxiety outcomes		
CBCL Anx[b]	2.0 (2.3)	
SCAS-P Gen.Anx[c]	2.0 (3.0)	

a. Categorical variable assessed at age 3.
b. Continuous variable assessed at 9 time points that is described by the median (and IQR) of the mean of the variable at each year.
c. Continuous variable assessed only at age 9 that is described by its median (and IQR).
*. The variables that are independent on the location are only described here.
SES: Socioeconomic status; CBCL Anx: Anxiety score from Child Behavior Checklist; SCAS-P Gen.Anx: Generalized anxiety score from Spence questionnaire reported by parents.

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Table 2. Bivariate Pearson's correlations between greenspace measures at age 9.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Greenspace at Residence	1.NDVI 50m	1																
	2.NDVI 100m	0.93	1															
	3.NDVI 300m	0.82	0.91	1														
	4.NDVI 500m	0.78	0.86	0.98	1													
	5.VCF 50m	0.85	0.80	0.70	0.65	1												
	6.VCF 100m	0.79	0.85	0.78	0.73	0.90	1											
	7.VCF 300m	0.66	0.76	0.83	0.81	0.66	0.85	1										
	8.VCF 500m	0.64	0.74	0.84	0.85	0.63	0.80	0.98	1									
	9.Distance GS	-0.40	-0.43	-0.51	-0.49	-0.30	-0.32	-0.33	-0.33	1								
Greenspace at School	10.NDVI 50m	0.30	0.31	0.39	0.38	0.20	0.23	0.32	0.33	-0.32	1							
	11.NDVI 100m	0.43	0.47	0.57	0.59	0.29	0.35	0.43	0.46	-0.31	0.80	1						
	12.NDVI 300m	0.55	0.59	0.71	0.73	0.40	0.44	0.52	0.56	-0.37	0.62	0.88	1					
	13.NDVI 500m	0.55	0.59	0.70	0.74	0.41	0.43	0.49	0.54	-0.37	0.57	0.85	0.98	1				
	14.VCF 50m	0.25	0.26	0.32	0.30	0.16	0.21	0.35	0.34	-0.23	0.81	0.62	0.43	0.38	1			
	15.VCF 100m	0.38	0.42	0.51	0.51	0.25	0.32	0.49	0.51	-0.24	0.75	0.84	0.70	0.64	0.84	1		
	16.VCF 300m	0.53	0.59	0.69	0.70	0.40	0.48	0.62	0.66	-0.29	0.56	0.79	0.91	0.87	0.50	0.77	1	
	17.VCF 500m	0.55	0.60	0.70	0.72	0.42	0.47	0.59	0.64	-0.29	0.56	0.78	0.93	0.92	0.46	0.70	0.97	1
	18.DCG	-0.41	-0.42	-0.51	-0.51	-0.28	-0.28	-0.32	-0.35	0.50	-0.51	-0.60	-0.66	-0.66	-0.35	-0.45	-0.53	-0.56

NDVI: Normalized Difference Vegetation Index; VCF: Vegetation Continuous Field (% of tree covering); DCG: Distance to closest green space (m)

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Table 3. Descriptive and effect of greenspace exposure at home and at school on generalized anxiety assessed from Spence questionnaire at age 9.

	Residence (*N* = 378)		School (*N* = 380)	
	Greenspace	Association	Greenspace	Association
	Median (IQR)	*B*[1] (CI 95%)	*Median (IQR)*	*B*[1] (CI 95%)
NDVI				
50 m buffer	0.159 (0.096)	-1.05 (-2.24;0.15)	0.192 (0.108)	-2.47 (-4.13;-0.81)*
100 m buffer	0.165 (0.095)	-1.25 (-2.38;-0.11)*	0.174 (0.149)	-1.55 (-3.30;0.20)
300 m buffer	0.178 (0.108)	-1.50 (-2.70;-0.31)*	0.219 (0.176)	-1.08 (-2.55;0.39)
500 m buffer	0.185 (0.126)	-1.86 (-3.26;-0.46)*	0.220 (0.179)	-1.03 (-2.54;0.48)
VCF				
50 m buffer	2.444 (2.319)	-0.37 (-1.04;0.31)	2.667 (2.111)	-1.74 (-2.70;-0.79)*
100 m buffer	2.559 (2.063)	-0.29 (-0.79;0.21)	2.469 (2.629)	-1.28 (-2.19;-0.36)*
300 m buffer	2.844 (2.132)	-0.35 (-0.74;0.04)	3.327 (3.094)	-0.41 (-0.98;0.16)
500 m buffer	3.002 (2.275)	-0.38 (-0.78;0.02)	3.571 (3.863)	-0.50 (-1.29;0.29)
Distance to closest green space (m)	189.0 (248.4)	0.53 (-0.83;1.88)	191.3 (280.4)	0.50 (-1.02;2.02)

NDVI: Normalized Difference Vegetation Index; VCF: Vegetation Continuous Field (% of tree covering).
[1] Regression coefficient for one interquartile range increase in each continuous indicator of exposure to greenspace. Models were adjusted by sex, ethnicity, parent with university studies, percentage of unemployment, percentage of illiterate, and total number of stressful events. CI: Confidence interval. IQR: Interquartile range
* $p < .05$

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Table 4. Fitting indices for one to four class in latent class growth analysis models

N. classes	AIC	aBIC	Class: *N* (weighted)	Class: probability*	Entropy
1	29528.724	29541.091	1: 495	-	-
2	28202.532	28219.021	1: 146 2: 349	1: .943 2: .983	.901
3	27804.366	27824.977	1: 27 2: 150 3: 318	1: .938 2: .935 3: .978	.916
4	27694.202	27718.935	1: 276 2: 69 3: 137 4: 13	1: .945 2: .904 3: .869 4: .985	.863

AIC: Akaike Information Criteria; aBIC: Sample-Size Adjusted Bayesian Information Criteria.
*On-diagonal values for posterior probability of class membership.

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Table 5. Effect of greenspace exposure at home and at school on trajectories of the Child Behavior Checklist-anxiety (Low/Medium – Medium/High)

	Residence (*N* = 475)	School (*N* = 485)
	OR[1] (CI 95%)	OR[1] (CI 95%)
NDVI		
50 m buffer	0.88 (0.66;1.17)	0.81 (0.73;0.91)*
100 m buffer	0.96 (0.75;1.24)	0.80 (0.70;0.90)*
300 m buffer	1.08 (0.82;1.42)	0.90 (0.80;1.00)
500 m buffer	1.17 (0.80;1.73)	0.91 (0.81;1.02)
VCF		
50 m buffer	1.08 (0.85;1.38)	0.89 (0.84;0.94)*
100 m buffer	1.09 (0.89;1.33)	0.90 (0.84;0.95)*
300 m buffer	1.05 (0.90;1.22)	0.94 (0.91;0.98)*
500 m buffer	1.08 (0.93;1.25)	0.94 (0.89;1.00)*
Distance to closest green space (m)	0.84 (0.60;1.18)	0.88 (0.79;0.99)*

NDVI: Normalized Difference Vegetation Index; VCF: Vegetation Continuous Field (% of tree covering)
[1] OR odds ratio of high vs low trajectory for one interquartile range increase in each continuous indicator of exposure to greenspace. Models were adjusted by sex, ethnicity, parent with university studies, percentage of unemployment, percentage of illiterate, and total number of stressful events. CI: Confidence interval.
* $p < .05$

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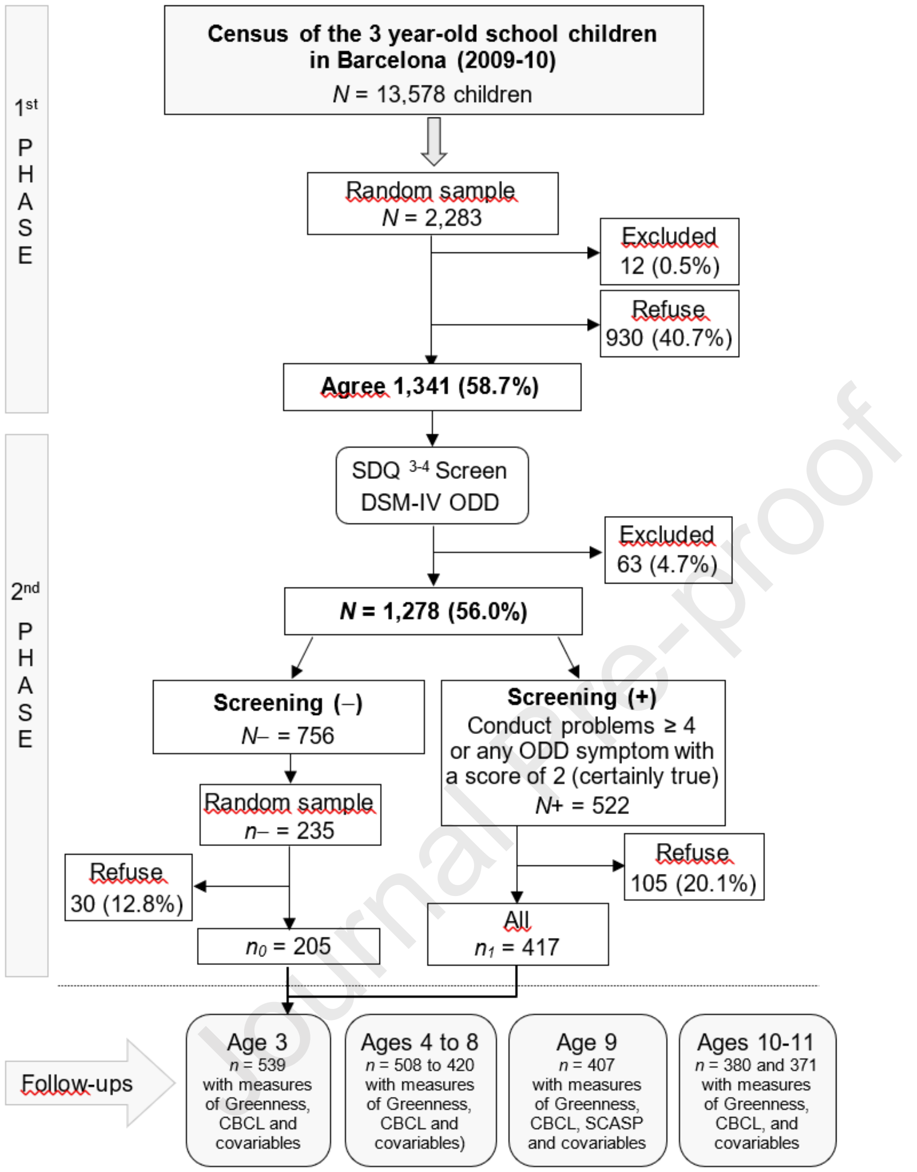
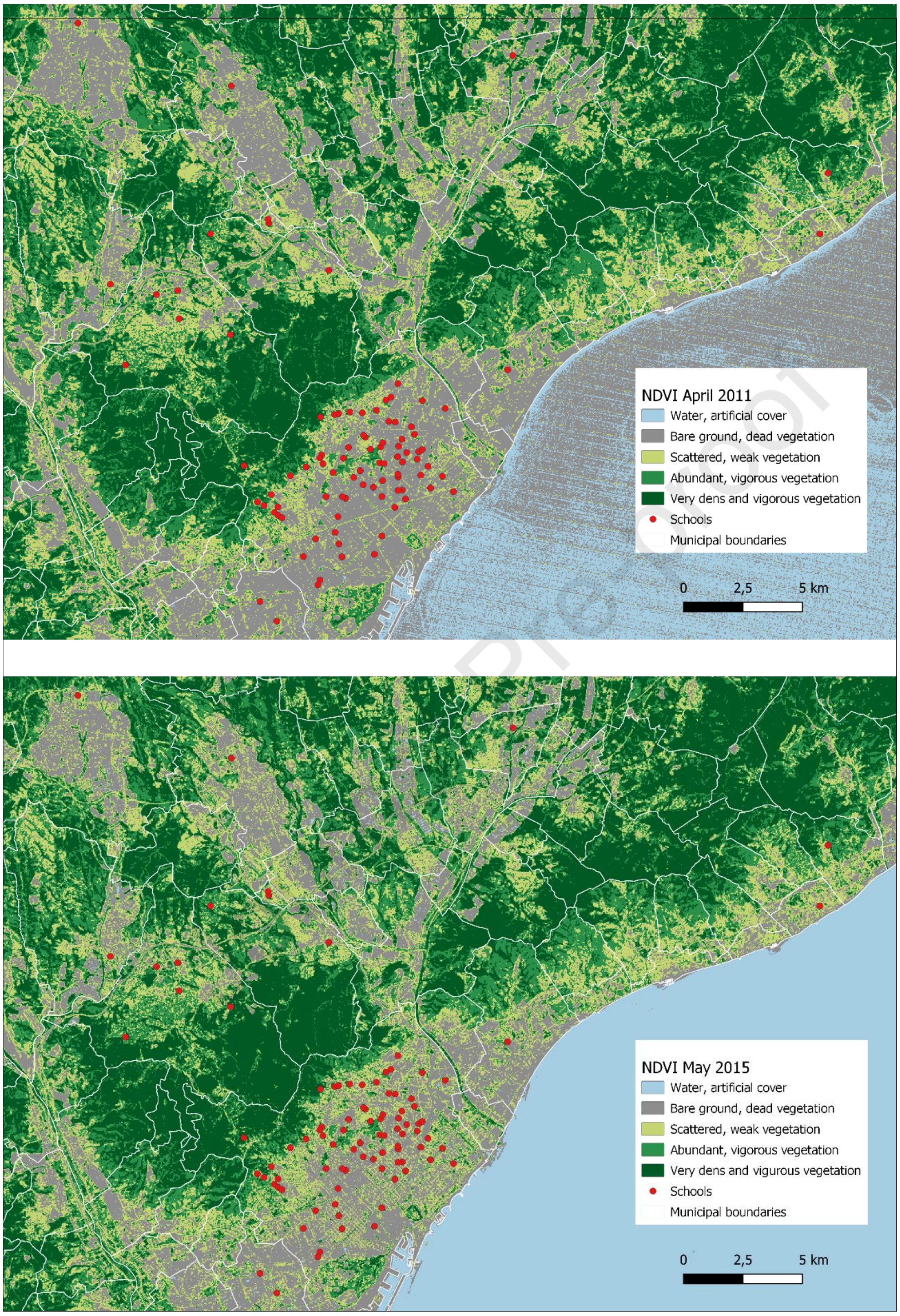
Figure 1. Two-Phase Sampling Design and Study Follow-ups



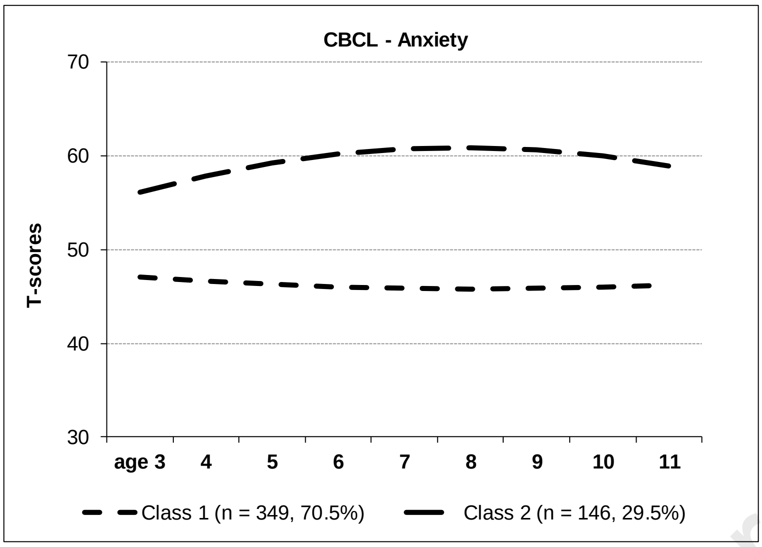
SDQ$^{3\text{-}4}$: Strengths and Difficulties Questionnaire for ages 3-4; DSM-IV: Diagnostic and Statistical Manual of Mental Disorders version IV; ODD: Oppositional Defiant Disorder; CBCL: Anxiety score from Child Behavior Checklist; SCASP: Generalized anxiety score from Spence questionnaire reported by parents; covariables were Socioeconomical status, Sex, Ethnicity, Number of stressful life-events, % of Unemployment and % of Illiterate

Figure 2. NDVI images, generated from Landsat 5 (2011) and Landsat 8 (2015), that characterize the greenspace surrounding the homes and schools



NDVI: Normalized Difference Vegetation Index

Figure 3. Trajectories of Child Behavior Checklist-anxiety for the 2 class-model selected



Note: The two lines show the growth or developmental trajectory on CBCL anxiety T-scores of each of the two classes/groups generated by Latent Class Growth Analysis. Both classes exhibited stable scores during the 9 follow-ups, with class 1 having low anxiety and class 2 high anxiety scores. CBCL: Child Behavior Checklist

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Highlights

- Growing up surrounded by greenness is associated with less anxiety symptoms.
- Children from low socioeconomic status could be highly benefit from greenness proximity.
- Levels of proximal greenspace should be considered to promote mental health.

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We are very grateful to the Editor and the Reviewers for their comprehensive review of our work and very insightful and constructive comments, which enabled us to improve our manuscript. We have provided point-by-point answers to all the comments.

We state no conflict of interest.

No IA has been used to answer the questions or writte the manuscript

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