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Greenness and neuropsychiatric symptoms in dementia

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ABSTRACT

Objectives: It is acknowledged that living in a green environment may help mental well-being and this may be especially true for vulnerable people. However, the relationship between greenness and neuropsychiatric symptoms in dementia has not been explored yet.
Methods: We collected clinical, neuropsychiatric, and residential data from subjects with dementia living in the province of Modena, Northern Italy. Neuropsychiatric symptoms were measured with the Neuropsychiatry Inventory, a questionnaire administered to the caregiver who assesses the presence and severity of neuropsychiatric symptoms, including delusions, hallucinations, agitation/aggression, dysphoria/depression, anxiety, euphoria/elation, apathy/indifference, disinhibition, irritability/lability, aberrant motor behaviors, sleep disturbances, and appetite/eating changes. Normalized Difference Vegetation Index (NDVI) was used as a proxy of greenness. Regression models were constructed to study the association between greenness and neuropsychiatric features.
Results: 155 patients with dementia were recruited. We found that greenness is variably associated with the risk of having neuropsychiatric symptoms. The risk of apathy was lower with lower levels of greenness (OR = 0.42, 95% CI 0.19–0.91 for NDVI below the median value). The risk of psychosis was higher with lower levels of greenness but with more imprecise values (OR = 1.77, 95% CI 0.84–3.73 for NDVI below the median value).
Conclusion: Our results suggest a possible association between greenness and neuropsychiatric symptoms in people with dementia. If replicated in larger samples, these findings will pave the road for identifying innovative greening strategies and interventions that can improve mental health in dementia.

1. Introduction

About half of the world population is currently living in cities. It is projected that by 2030 three out of five persons will be living in urban areas worldwide (Rydin et al., 2012). Living in urban areas can be beneficial for people's well-being as it facilitates the establishment of social networks and access to services, including health care services. However, some aspects of living in urban areas can be detrimental for people's health and well-being (e.g., air and noise pollution, availability of public and green spaces, segregation, and social injustice), and these aspects may potentially increase in the near future. Trees and green areas ("greenness") have been associated with better mental health conditions, in relation to both aesthetic benefits given by the closeness to green space as well as the use of such spaces for physical, cultural, and social recreation.

Exposure to green space has been suggested to lower depression, stress, and schizophrenia risk, to improve children's cognitive development, and to reduce neural activity linked to psychiatric disorders

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(see Houlden et al., 2018 for a review). Greenness may benefit health through various pathways: improved air quality, enhanced physical activity, and stress reduction (Nieuwenhuijsen et al., 2017). Support for such beneficial role on health has been provided by studies demonstrating that viewing or being in green space is associated with restorative physiological responses, including reduced blood pressure, heart rate, skin conductance and muscle tension (Chan et al., 2021; Roe et al., 2013; Frost et al., 2022). A recent World Health Organization (WHO) document offers a review of the existing evidence on the health effects of green space alongside a summary of health-relevant measures of green space availability, accessibility, and use (World Health Organization, 2016). It is indeed very conceivable that living in an environment with high amount of greenness may lead to health enhancing experiences and behaviors.

Several recent studies have shown a possible effect of greenness in the reduction of the incidence and prevalence of dementia (see Zagnoli et al., 2022 for an extensive review). Other studies have shown that higher neighborhood greenness is associated with greater structural and functional integrity of brain regions involved in cognitive and behavioral disturbances (Dadvand et al., 2018; Kuhn et al., 2017; Lederbogen et al., 2011; Min et al., 2021). However, whereas studies conducted in the general population have demonstrated that greenness has significant mental health benefits (Razani et al., 2018; Zhang et al., 2022), it remains unknown if it can specifically improve mental well-being also in people with dementia. Psychological distress and reduced mental well-being are indeed common symptoms of people with dementia, leading to the development of the so called *behavioral and psychological symptoms* or *neuropsychiatric symptoms* of dementia. While the presence of cognitive impairment is necessary and sufficient for a diagnosis of dementia, the presence of overlapping neuropsychiatric symptoms is frequent and can significantly impact the prognosis and management of dementia (American Psychiatric Association, 2013). These neuropsychiatric symptoms include delusions, hallucinations, agitation/aggression, dysphoria/depression, anxiety, euphoria/elation, apathy/indifference, disinhibition, irritability/lability, aberrant motor behaviors, sleep behavioral disturbances and appetite/eating disturbances (Cummings et al., 1996; Devanand et al., 1997).

We hypothesized that greenness is associated with reduced risk of neuropsychiatric symptoms in patients with dementia. We tested this hypothesis in a clinical group of patients with dementia living in the province of Modena, which encompasses an area of about 2689 square kilometers and includes both rural and metropolitan areas.

2. Methods

For the purpose of this study, we recruited newly diagnosed dementia cases from Memory Clinics of the province of Modena as previously described (Adani et al., 2020; Chiari et al., 2021b) with the following inclusion criteria: a dementia diagnosis made according to current clinical criteria, dementia as the principal cause of disability, having a caregiver available for interview, being resident in the province of Modena, and availability of the Neuropsychiatry Inventory (NPI) (Cummings et al., 1996), a measure of behavioral symptoms in dementia, at the time of recruitment. The recruitment period lasted from October 2016 to February 2020. Exclusion criteria included coexisting diagnoses of pervasive developmental disorder or major psychiatric disorder, and cognitive impairment in the context of another neurological disorder in which disability was primarily related to noncognitive symptoms (e.g., multiple sclerosis, cerebrovascular disease with severe motor disability). Diagnoses were made according to the clinical diagnosis at the moment of recruitment in Alzheimer's Dementia (AD) (McKhann et al., 2011), vascular dementia (VaD) (Roman et al., 1993; Skrobot et al., 2018), possible or probable Dementia with Lewy Body (LBD) (McKeith et al., 2017), Frontotemporal Dementia (FTD, including behavioral variant, semantic variant of primary progressive aphasia, and non-fluent agrammatic variant of primary progressive aphasia) (Gorno-Tempini et al., 2011; Rascovsky et al., 2011), atypical parkinsonism (i.e. Progressive Sopranuclear Palsy (PSP) or Corticobasal Degeneration (CBD) (Litvan et al., 1996)). The study was approved by local Ethical Committee (approval no. 186/2016) and was conducted according to the Declaration of Helsinki. All patients signed a written informed consent.

For each patient, we collected demographic data, clinical information such as type of dementia diagnosis and duration of disease, level of cognitive impairment measured by the Mini Mental State Examination (MMSE) (Folstein et al., 1975), address of residence at the time of recruitment and NPI assessment, and functional ability assessed by the ADCSADL scale (Galasko et al., 1997).

According to Gascon et al., 2016, we used Normalized Difference Vegetation Index (NDVI) as a proxy of greenness. NDVI has been shown to be effective in capturing neighborhood greenness for epidemiologic purposes: it is a commonly used index of greenness because of its simplicity, good sensitivity in vegetation changes, and best dynamic range (Fong et al., 2018). Normalized Difference Vegetation Index (NDVI) is a measure of photosynthetic activity and is expressed as a function of near-infrared radiation and visible radiation: NDVI = Near Infrared Radiation − Visible Radiation/Near Infrared Radiation + Visible Radiation. NDVI is unitless with value ranging from −1 to +1 for a given pixel. Negative values indicate water features (rivers, coastal water, and clouds), values close to zero represent no vegetation, and positive values indicate the existence of green vegetation. A higher value is indicative of greener and denser surface vegetation. The NDVI data for this study have been taken from the Copernicus Global Land Service (CGLS) that is a component of the Land Monitoring Core Service (LMCS), within the European flagship program on Earth Observation. The data specifically comes from PROBA-V, which is a miniaturized ESA satellite tasked with a full-scale mission to map land cover and vegetation growth across the entire planet. This satellite provided 10 days composite data with a spatial resolution of 300 m. To exclude potential seasonal effect/bias on NDVI measures, in accordance with several studies reporting the use of the average annual NDVI value (Song et al., 2019; Sun et al., 2023) to estimate association with psychiatric symptoms, we decided to consider annual mean NDVI value of the year before (and including) NPI assessment. If there was a change in residence in the year before NPI assessment, the last address was considered. Copernicus datasets are raster data, in which each value of NDVI is linked to a specific coordinate. We converted each address into coordinates in WGS84 and saved them in a matrix in R. The R software has been used to extract, with a raster function, the NDVI values related with the coordinates of the patients' address. To calculate the NDVI annual mean values, 12 satellite images have been analyzed for a total of 53 images to cover all the patients. Fig. 1 show an example of a plotted dataset from Copernicus.

The presence of behavioral and psychological symptoms was assessed with the Neuropsychiatry Inventory (NPI), the most frequently used scale to measure neuropsychiatric symptoms in dementia (Cummings et al., 1996). This semi-structured questionnaire is administered to the caregiver and assesses the presence and severity of 12 symptoms, including delusions, hallucinations, agitation/aggression, dysphoria/depression, anxiety, euphoria/elation, apathy/indifference, disinhibition, irritability/lability, aberrant motor behaviors, sleep behavioral disturbances and appetite/eating disturbances. The NPI is typically used to assess changes in the patient's behaviour that have appeared in a defined period of time: for the purpose of the study, we considered changes occurred in the last months before recruitment. Each domain can generate a maximum of 12 points, and thus, the total possible score equals 144 points with higher scores indicating a more severe neuropsychiatric burden. For the purpose of this study, patients were classified in 2 groups according to the presence (total NPI score ≥1) or not (total NPI score = 0) of any neuropsychiatric symptoms. In addition, patients were also classified according to presence (NPI domain ≥1) or absence (NPI domain = 0) of any symptoms in the following 4 domains

Fig. 1. Example of a plotted dataset from Copernicus. The map in false color shows the Normalized Difference Vegetation Index (NDVI). The marked area indicates Modena province, Northern Italy.

of behavioral disturbances as classified by (Aalten et al., 2007): the *Hyperactivity* domain (based on the sum of agitation, disinhibition, irritability, euphoria, and aberrant motor behavior), the *Psychosis* domain (based on the sum of delusions, hallucinations and sleep behavior disturbances), the *Affective* domain (based on the sum of anxiety and depression), and the *Apathy* domain (based on the sum of apathy and appetite/eating abnormalities). The clustering of the symptoms (instead of the focus on individual symptoms) is useful because most of the neuropsychiatric symptoms tend to co-occur in clinical practice, and hence, this approach can provide more meaningful interpretations; the clustering of symptoms also helps to avoid the issue of multicollinearity among correlated neuropsychiatric symptoms. Due to lack of single NPI domain values for three patients, clustering of neuropsychiatric symptoms was performed for 152 patients. We used a presence/absence dichotomous classification because our goal was to define the risk of neuropsychiatric symptoms based on NDVI values and not the severity of neuropsychiatric symptoms (Geda et al., 2014; Peters et al., 2013). We used a logistic regression model to calculate odds ratios (ORs) and 95% confidence intervals (95% CI) to estimate the risk of presence and absence of neuropsychiatric symptoms according to different exposure to greenness. The OR was computed considering classification based on below and above the median value, classification based on tertiles, and for continuous 1-unit increase of greenness. MMSE values and ADCSADL at the time of NPI administration, and dementia diagnosis were included for adjusted OR; age at the time of NPI administration was not included in the final adjusted analysis because of high collinearity with both MMSE and ADCSADL values (nevertheless an exploratory analysis with age also included as covariate did not show substantial different results; data not shown). We also explored the relation between greenness and neuropsychiatric symptoms risk (for overall NPI scale and subdomains of psychosis and apathy) using a restricted cubic spline regression model with three knots at fixed percentiles (10th, 50th, and 90th) adjusting for MMSE, ADCSADL, and dementia diagnosis. For all estimates, we assessed statistical imprecision through calculation of 95% confidence interval (CI). We used SPSS (Version 24.0, IBM Corp., IBM SPSS Statistics for Windows, Armonk, NY, 2023) and Stata 18.0 (Stata Corp., College Station, TX, 2023) for data analysis.

3. Results

The characteristics of study participants are shown in Table 1. A total of 155 eligible patients were included in the present study, 88 females and 66 males. Mean age was 71.25 (±8.50) years across the whole group. Mean education was 8.57 (±4.10) years. Mean disease duration was 69.45 (±38.08) months. Mean MMSE score was 16.44 (±8.50). Median NDVI value was 0.55, range from 0.36 to 0.84. Diagnosis of AD was made in 90 patients; 27 patients were diagnosed as FTD, 9 as VaD, 14 as LBD and 7 other atypical parkinsonism, and 8 as other dementias (e.g., amyloid angiopathy, normal pressure hydrocephalus). Neuropsychiatric symptoms were present in 93.5% of patients, irrespective of their frequency and/or gravity (total NPI). Neuropsychiatric symptoms of the *Hyperactivity* domain were present in 72.3% of patients, of the *Psychosis* domain in 36.1% of patients, of the *Affective* domain in 56.8% of patients, and of the *Apathy* domain in 66.5% of patients. Fig. 2 shows the distribution of total NPI values for each patient by increasing NDVI levels using a spline regression analysis (overall scale, continuous values).

Table 1
Clinical and demographical characteristics of patient.

	Total N = 155
Sex (male, N, %)	66 (42.9%)
Age (years, mean, SD)	71.25 (±8.50)
Education (years, mean, SD)	8.57 (±4.10)
MMSE (mean, SD)	16.44 (±8.50)
Disease duration (months, mean, SD)	69.45 (±38.08)
ADCSADL (median, range)	42 (0–77)
NDVI (median, range)	0.55 (0.36–0.84)
Diagnosis (N, %)	
AD	90 (58.1%)
FTD	27 (17.4%)
VaD	9 (5.8%)
LBD	14 (9.0%)
Atypical parkinsonism	7 (4.5%)
other	8 (5.2%)
NPI value, median (range)	14 (0–57)
NPI total (%)	93.5%
Hyperactivity domain	72.3%
Psychosis domain	36.1%
Affective domain	56.8%
Apathy domain	66.5%

Table 2 and Table 3 report unadjusted and adjusted neuropsychiatric symptoms OR (and 95% CI) respectively, according to greenness values measured by NDVI. When considering any neuropsychiatric symptoms (total NPI), we found small and variable risk for neuropsychiatric symptoms with different level of greenness. More precisely, for one-unit increase of NDVI value we found a decreased (but very imprecise) probability of having any neuropsychiatric symptoms. Considering

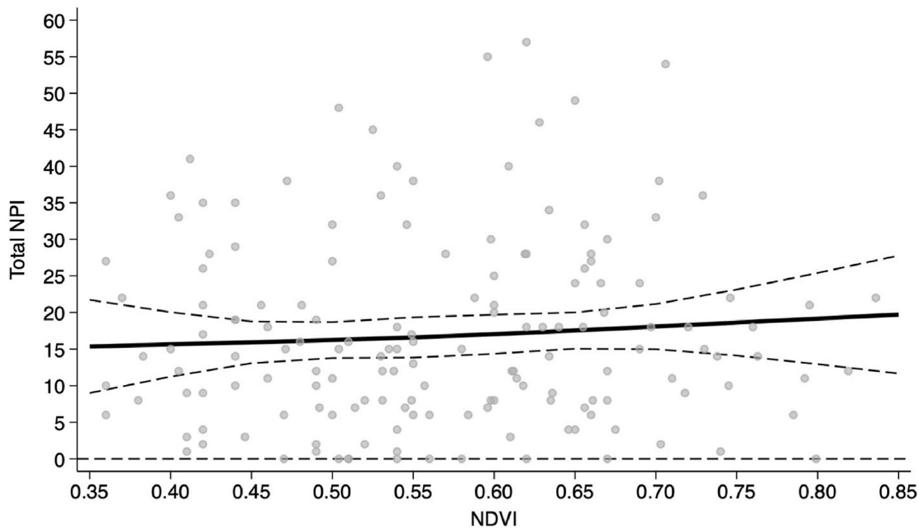

Fig. 2. Spline regression of the relation between greenness exposure evaluated through Normalized Difference Vegetation Index (NDVI) and total Neuropsychiatry Inventory (NPI) scores. Grey dots indicate subjects' individual values. The black solid line represents spline regression analysis with 95% confidence interval (dashed lines).

Table 2
Unadjusted Odds Ratio (OR) for neuropsychiatric symptoms based on median, continuous values and tertiles of greenness measured by Normalized Difference Vegetation Index (NDVI).

	NPI total ≥1 (N = 145)		NPI hyperactivity domain ≥1 (N = 112)		NPI psychosis domain ≥1 (N = 56)		NPI apathy domain ≥1 (N = 103)		NPI affective domain ≥1 (N = 88)	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
NDVI below the median	1.02	0.25–3.7	0.68	0.33–1.42	1.34	0.69–2.61	0.41	0.20–0.83	1.04	0.55–1.99
NDVI 1-unit increase	0.46	0.02–143,48	13.02	0.46–364.20	0.11	0.006–2.34	10.69	0.47–242.69	1.72	0.09–30.96
NDVI tertiles										
1st tertile (<0.51)	1.04	0.14–7.68	0.56	0.22–1.39	1.66	0.74–3.68	0.47	0.19–1.15	0.95	0.40–2.01
2nd tertile (0.52–0.62)	0.32	0.06–1.76	0.64	0.25–1.6	0.57	0.24–1.3	0.37	0.15–0.92	0.73	0.33–1.63
3rd tertile (reference) (>0.63)	1.00	–	1.00	–	1.00	–	1.00	–	1.00	–

Table 3
Adjusted Odds Ratio (OR) for neuropsychiatric symptoms based on median, continuous values and tertiles of greenness measured by Normalized Difference Vegetation Index (NDVI). MMSE, ADCSADL and dementia diagnosis were entered in the analyses for adjustment.

	NPI total ≥1 (N = 145)		NPI hyperactivity domain ≥1 (N = 112)		NPI psychosis domain ≥1 (N = 56)		NPI apathy domain ≥1 (N = 103)		NPI affective domain ≥1 (N = 88)	
	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI
NDVI below the median	1.08	0.27–4.37	0.74	0.33–1.64	1.77	0.84–3.73	0.42	0.19–0.91	1.09	0.55–2.13
NDVI 1-unit increase	0.66	0.001–400.43	17.36	0.45–670.10	0.07	0.003–2.10	14.08	0.44–445.82	1.24	0.06–25.44
NDVI tertiles										
1st tertile (<0.51)	0.65	0.07–5.77	0.51	0.18–1.41	1.57	0.65–3.81	0.36	0.13–0.99	1.00	0.43–2.33
2nd tertile (0.52–0.62)	0.21	0.36–1.34	0.50	0.18–1.37	0.46	0.18–1.21	0.27	0.10–0.73	0.76	0.33–1.74
3rd tertile (reference) (>0.63)	1.00	–	1.00	–	1.00	–	1.00	–	1.00	–

NDVI median value as cutoff (NDVI = 0.55), we did not find relevant differences in risk for the two groups. When considering NDVI classified by increased level of exposure by using tertiles, we found that, considering higher tertile as reference category, lowest category of exposure was associated with similar risk of neuropsychiatric symptoms, whereas intermediate category was associated with lower risk of neuropsychiatric symptoms, suggesting a possible detrimental effect on neuropsychiatric symptoms by both highest and lowest greenness level; this "U-shaped" association was also demonstrated by results of spline regression analysis (Fig. 3A). When investigating neuropsychiatric symptoms clustered by domains, we observed that higher level of greenness was associated with greater risk of neuropsychiatric symptom in apathy domain specifically (for NDVI below the median value, OR = 0.42, 95% CI 0.19–0.91), whereas a similar but weaker association for hyperactivity emerged (for NDVI below the median value, OR = 0.74, 95% CI 0.33–1.64). The spline regression analysis for apathy domain well depicted the progressive increased risk with higher values of NDVI in the upper part of the exposure range (Fig. 3B). Instead, for psychosis domain, logistic regression analysis showed that higher level of greenness was associated with lower risk of psychosis symptoms but with more imprecise and weaker values (for NDVI below the median value, OR = 1.77, 95% CI 0.84–3.73) and spline regression confirmed an inverse association between NDVI values and risk of psychosis symptoms for lower NDVI values especially, with a reduced effect if NDVI increases (Fig. 3C). For affective domain, we found no substantial changes in symptoms risk with variation of greenness exposure (for NDVI below the median value, OR = 1.09, 95% CI 0.55–2.13).

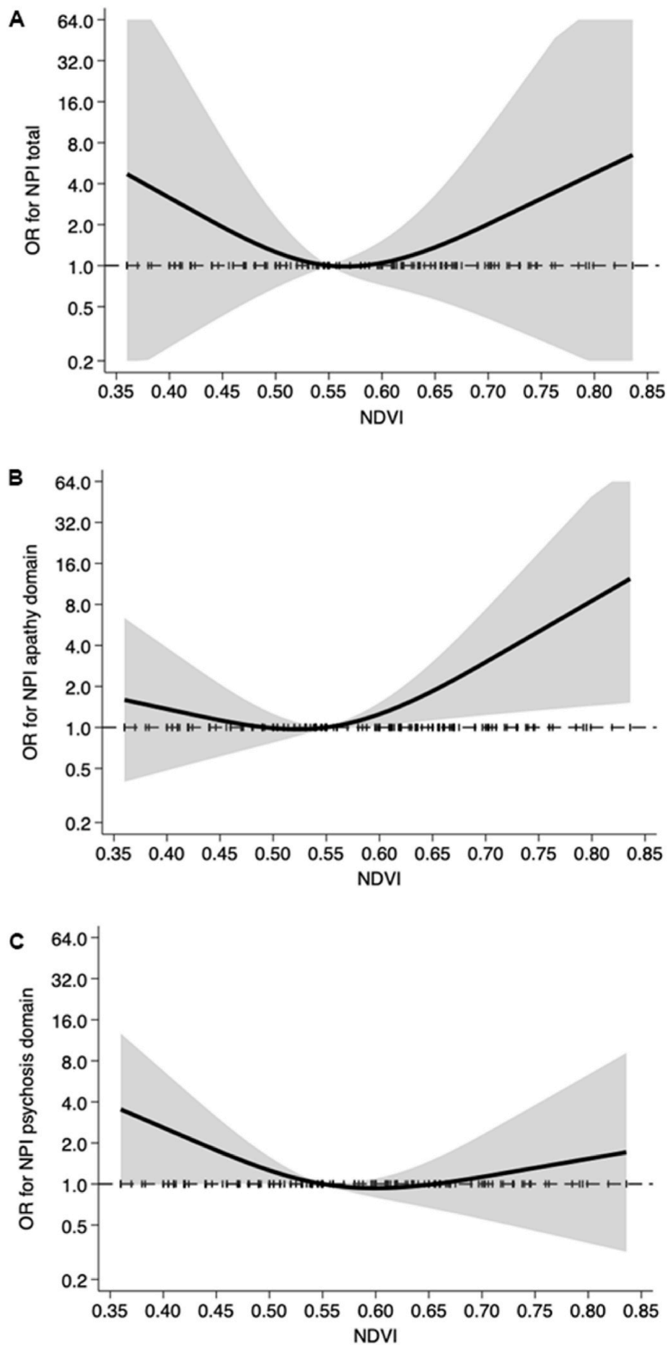

Fig. 3. Spline regression of the relation between greenness exposure evaluated through Normalized Difference Vegetation Index (NDVI) and odds ratio (OR) of presence of neuropsychiatric symtoms as assessed through Neuropsychiatry Inventory (NPI) (A, overall scale and subdomains of B, apathy and C, psychosis). Black vertical bars indicate subjects' individual values. The black line represents spline regression analysis with 95% confidence interval (grey shaded area).

4. Discussion

We explored the association between greenness and the presence of neuropsychiatric symptoms in a population of patients with dementia living in the province of Modena, Northern Italy. We found that greenness is variably associated with the risk of having neuropsychiatric symptoms, independently from dementia severity, type, and functional status.

There has been increasing interest in how exposure to natural vegetation, or greenness, may benefit human health. Contact with nature has been shown to have positive effects on the body's physiological response to green space exposure with beneficial effects on both cardiovascular and muscular systems (Roe et al., 2013). Experimental studies provided evidence that being in a green space improves mood and reduce anxiety immediately following the intervention (Bray et al., 2022). In a prospective study of individuals with diabetes, NDVI was associated with a lower risk of depression (Gariepy et al., 2015). In another study of pregnant women in Bradford, United Kingdom, those who resided in the 3rd or higher quintiles of greenness were 18–23% less likely to report depressive symptoms (McEachan et al., 2016). All these effects might be mediated by different effects of greenness on mental health: harm reduction (mitigating exposures to heat, noise, and air pollution), mental and physiologic stress relieve, and promotion of healthful activities such as exercise and socializing (Fong et al., 2018).

In our study we tested the hypothesis that greenness might be positively associated to mental well-being also in cognitively impaired people, i.e., those who have received a clinical diagnosis of dementia. We focused on the study of the so-called neuropsychiatric symptoms of dementia, the most common manifestation of psychological distress and reduced mental well-being in people with cognitive impairment. These symptoms are well known to be associated with increased loss of functioning, reduced quality of life, increased caregiver burden and increased dementia care costs (Chiari et al., 2021a; Chiari et al., 2022).

In our study, we found a high prevalence of neuropsychiatric symptoms. This was expected as we considered people with dementia of moderate degree of severity (mean MMSE was 16.44). But most importantly we found that the effect of greenness has variable and different effect in relation to different domains of neuropsychiatric symptoms. This result is novel because, to the best of our knowledge, no other studies have investigated the association of neuropsychiatric symptoms as measure of mental wellbeing and greenness in dementia. More precisely, we found that considering the risk of any neuropsychiatric symptoms, a lower risk, though weak and imprecise, was found for intermediate NDVI values, suggesting that a possible detrimental effect on neuropsychiatric symptoms might be related to both highest and lowest greenness level, whereas a "protective" effect might be related to intermediate greenness values. A "U-shaped" association was also demonstrated in studies investigating risk of dementia (Zagnoli et al., 2022) and may be related to possible interplay of greenness-associated factors, both beneficial (reduced air pollution and noise and increased physical activity) and adverse (greater social isolation, decreased interaction with neighbors, increased loneliness, and distance from medical and social services). Despite still imprecise, a small inverse association between lowest greenness exposure and risk of psychosis symptoms also emerged, and this is in line with previous studies conducted in patients with psychiatric diseases or in the general population showing significant associations between psychosis and low greenness exposure (Ebisch, 2020; Engemann et al., 2019). On the contrary, higher risk for apathy was associated with higher level of greenness. We can speculate that higher level of greenness might be associated with greater social isolation, therefore increasing the risk of apathy in patients. Even if not so intuitive, also hyperactivity and agitation symptoms might be correlated with higher level of greenness if we consider that most agitated behaviors seem to increase when patients are physically restrained, inactive, or alone (Cohen-Mansfield and Werner, 1995); in addition, it was demonstrated that, with apathy present, it is more likely for a patient to also manifest behaviors that are difficult to manage, such as impulsivity, socially embarrassing behaviors, or irritability, lability, and resistance to care (Chow et al., 2009).

This study has several limitations: first, we did not collect measures of accessibility and time spent in green spaces or measures of past/lifetime greenness exposure, but only current greenness as a "static" measure. Another limitation of our study is that we measured greenness only with the NDVI score, whereas it is well known from previous studies that other green space measures (for example land use or land cover) provide more comprehensive measures about the type of exposition and greenness use than the NDVI (Zagnoli et al., 2022). We used only NPI to assess neuropsychiatric symptoms as a measure of mental wellbeing, whereas several previous studies investigating association between greenness and mental health (for depression and anxiety in particular) have also considered self-judgment or questionnaires administered to the patients. Since the NPI is a caregiver-administered questionnaire, it might not fully catch self-perceived emotions that are thought to benefit most from greenness exposure trough mechanisms that increase mindfulness and interrupt rumination (Bratman et al., 2015) and this might explain the lack of evidence of an association between affective domain and greenness in our study. However, since patients with dementia are frequently unaware of their symptoms, including neuropsychiatric ones (Tondelli et al., 2021), using a caregiver-based questionnaires was mandatory in this specific population. We acknowledge that the limited sample size might affect the precision of the estimates. Nonetheless, to the best of our knowledge, no previous studies have addressed this specific topic. The existing literature has mainly focused on the relation between greenness and the actual risk of dementia without evaluating neuropsychiatric symptoms. Lastly, we did not collect data about ambient air, light, and noise pollution, which are known to be related and potentially associated both to dementia risk (Andersson et al., 2018; Mazzoleni et al., 2023; Urbano et al., 2023) and neuropsychiatric symptoms (Hao et al., 2022; Khosrorad et al., 2022). Future studies investigating the combined effect of greenness, noise, light, and air pollution on neuropsychiatric symptoms using multivariable modelling could be useful to deeply understand the effect of green spaces in dementia patients (Stanhope et al., 2021).

Despite the above limitations, the observation of a potential association between greenness and neuropsychiatric symptoms in dementia suggests a possible role of greenness exposure as an intervention to modulate and modify the presence of neuropsychiatric symptoms, opening a novel perspective towards the prevention and the managing of behavioral symptoms in dementia. However, given the methodological limitations of the study and the small sample size, the results of this study should be interpreted with caution. Further studies, both observational and interventional, are needed to better investigate these findings.

CRediT authorship contribution statement

Manuela Tondelli: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Annalisa Chiari:** Conceptualization, Data curation, Investigation, Methodology, Writing – review & editing. **Giulia Vinceti:** Conceptualization, Data curation, Investigation. **Chiara Galli:** Data curation. **Simone Salemme:** Data curation. **Tommaso Filippini:** Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Chiara Carbone:** Conceptualization, Data curation, Investigation. **Claudia Minafra:** Methodology. **Claudia De Luca:** Methodology. **Riccardo Prandi:** Methodology. **Simona Tondelli:** Conceptualization, Methodology. **Giovanna Zamboni:** Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing.

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.

Data availability

Data will be made available on request.

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