Data Access Statement: The data supporting the findings of this study are not publicly available due to restrictions imposed by the ethical approval granted for this research. Specifically, participants provided their full postcode, which constitutes personally identifiable information. As such, sharing the dataset would compromise participant confidentiality and violate the terms of ethical consent. Researchers interested in further information about the study may contact the corresponding author, subject to ethical review and data protection considerations.

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People and Nature

RESEARCH ARTICLE

Interdisciplinary and Transdisciplinary Research to Improve Treescapes for the Benefit of People and Nature

Green pathways to mental health: Relationships between treescapes and well-being and distress

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Abstract

1. We aimed to evaluate the mental health benefits and possible mechanisms of objective and subjective treescape exposures whilst also accounting for relationships with residential area greenspace in general. Independent variables were objective measures of residential neighbourhood tree cover density and woody linear features, and a subjective measure of perceived neighbourhood treescape richness. Outcome variables were four standard measures of positive mental health and two of psychological distress.
2. Questionnaire survey data ($N = 1376$) were merged with neighbourhood treescape and greenspace data on residential postcode. A structural equation model tested a set of theorised pathways from neighbourhood nature exposures to mental health outcomes, with indirect effects via nature connectedness, satisfaction with the local natural environment and nature visit exposure. A sensitivity analysis assessed whether observed effects were a mediated function of childhood exposure to nature.
3. Tree cover density and woody linear features were positively associated with perceived neighbourhood treescape richness. With the exception of a positive relationship between tree cover density and life satisfaction, the total effects of tree cover density and woody linear features were not significantly associated with positive mental health or psychological distress outcomes despite some significant specific indirect effects. In contrast, the total effects of perceived neighbourhood treescape richness were positively associated with positive mental health and negatively associated with psychological distress outcomes.
4. The total effects of neighbourhood greenspace were not significantly associated with positive mental health or psychological distress outcomes despite some significant specific indirect effects. In all cases, nature visit exposure was positively associated with positive mental health and negatively associated with psychological distress outcomes. Neighbourhood nature satisfaction was positively associated with all the positive mental health outcomes and negatively associated with

one of the two psychological distress outcomes. Nature connection was positively associated with all the positive mental health outcomes, but, contrary to expectations, was positively associated with both psychological distress outcomes.
5. *Policy implications*. Residents' perceptions of treescapes generally matter more for their mental health than objective measures of treescapes, so policy should promote meaningful engagement with treescapes to achieve the greatest benefits.

KEYWORDS
green space, mental health, nature exposure, trees, well-being

1 | INTRODUCTION

Trees are the most salient natural features of many landscapes. The importance of treescapes (understood as the combination of woodlands, isolated trees, linearly configured trees lining streets or along field boundaries, hedgerows, etc.) for a range of health, well-being and ecological outcomes is increasingly recognised (McGrath et al., 2024). However, the understanding of these links is still developing, with much earlier work focussing on nature and greenspaces in general. More information on the links between trees and well-being is needed to inform planning and management of treescapes (Wolf et al., 2020).

A wide range of observational studies has found that more residential area greenspace is related to both higher levels of well-being and lower levels of psychological distress. However, there have been few attempts to distinguish the role of green and natural areas in general (e.g. parks and gardens) from that of treescapes in particular in these relationships. The potential importance of trees to psychological health is suggested by work in controlled experiments (e.g. Jiang et al., 2016; Li & Sullivan, 2016) and by neurophysiological (Joung et al., 2015) and physiopsychological (An et al., 2004) research. The land cover measures of greenspace typically used in observational studies in this field (e.g. the Normalized Difference Vegetation Index, NDVI) do not efficiently distinguish tree cover from other vegetation, and our understanding of the impact of trees on human health has been limited (Salmond et al., 2016) or conflated (c.f. Nesbitt et al., 2017) by approaches which consider all vegetation (Astell-Burt & Feng, 2020). More generally, despite a wealth of evidence that greenspace exposure is related to increased well-being (Houlden et al., 2018) and reduced stress (Jones et al., 2021), it is recognised that future work should aim to distinguish types of 'green' in terms of these outcomes (Beute et al., 2023; Li et al., 2023).

Attempts to quantify the contribution of trees to mental health, as opposed to more generic nature, are limited, though several studies have related street tree prevalence to psychological outcomes. For example, Taylor et al. (2015) found a decrease of 1.18 antidepressant prescriptions per thousand population across London boroughs was associated with a unit increase in trees per km of street. Similarly, Marselle et al. (2020) found a lower rate of antidepressant prescriptions for people in Leibzig, Germany, who had a higher density of street trees within a 100 m residential buffer.

Accounting for all trees rather than just street trees, Akpinar et al. (2016) related neighbourhood tree cover (and not neighbourhood greenspace) to self-reports of well-being and psychological distress, and found Washington State respondents living in neighbourhoods with more trees reported fewer days of mental health complaint. An ecological study in Brussels by Chi et al. (2022) also examined overall neighbourhood exposure to trees and distinguished between tree crown volume and tree stem density; they found opposite relationships between these two operationalisations of exposure to trees and mood disorder prescription rates: whereas a 1 interquartile range (IQR) increase in crown volume was associated with 34% less medication, a 1 IQR increase in stem density was associated with 28% (women) and 32% (men) more medication. A study by Jiang et al. (2020) aimed to disaggregate the effects of trees from generic greenspace by distinguishing tree cover density from understory vegetation; they found higher neighbourhood concentrations of tree canopy were related to increased capacity to control stress, whereas understory vegetation had a negative relationship.

However, there is also increasing evidence from observational studies that the positive effects of neighbourhood nature on health may be mediated via other aspects of nature experience. For example, there is evidence of an indirect effect of neighbourhood greenspace on subjective well-being via nature visit exposure; Elliott et al. (2023) found that increased greenspace within 1 km of the residence was associated with increased visits to greenspace and that increased greenspace visit frequency was associated with increased well-being after accounting for neighbourhood greenspace. There is also evidence of an indirect effect of neighbourhood nature on subjective well-being via nature connectedness; Liu et al. (2022) found that increased parkland within 500 m of the residence (though not other operationalisations of neighbourhood nature exposure) was associated with increased nature connectedness and that increased nature connectedness was associated with increased well-being and decreased ill-being after accounting for neighbourhood parkland. An indirect effect of neighbourhood nature on psychological health via perceptions about environmental richness is also highly plausible given evidence that both actual observations and perceptions about environmental conditions affect self-reported subjective well-being (e.g. Cameron et al., 2020; Hepburn et al., 2021; Silva et al., 2012); Liu et al. (2019), for example demonstrated an indirect effect of higher NDVI within a 1 km buffer of the residence on well-being via

satisfaction with neighbourhood greenspace. The influence of treescapes specifically on psychological health, as opposed to greenspace in general, has not, to our knowledge, previously been considered from a pathways perspective.

1.1 | The current study

This study investigated the relationships between residential area treescapes and (a) positive mental health and (b) psychological distress. We aimed to quantify the impacts of treescape exposures whilst also accounting for the relationships with residential area greenspace in general. We further aimed to evaluate possible causal mechanisms underlying any observed relationships between neighbourhood exposures to treescapes and positive mental health and psychological distress.

We used four standard measures of positive mental health and two standard measures of psychological distress as dependent outcome variables in a structural equation model (SEM). These measures included the Personal Well-being Items (known as ONS-4) developed by the UK Measures of National Well-being programme of the Office for National Statistics (ONS, 2025). The SEM was used to test theorised pathways from (a) residential neighbourhood exposure to tree cover density; (b) residential neighbourhood exposure to woody linear features (i.e. hedgerows and linearly configured trees) and (c) perceived neighbourhood treescape richness. The model simultaneously tested the same theorised pathways to positive mental health and psychological distress from residential neighbourhood exposure to generic greenspace, of which treescapes are a minority component. In each case, direct effects and mediated effects via nature connectedness, neighbourhood natural environment satisfaction and nature visit exposure were quantified. Consistent with previous research, we hypothesised positive relationships between our nature exposure measures and the mediators, positive mental health outcomes and negative relationships with the psychological distress outcomes. We used sensitivity analyses to explore the extent to which findings were a mediated function of childhood exposure to nature.

2 | METHODS

2.1 | Sample

We used a convenience sample of adults residing in postcode sectors included within The National Forest; The Mersey Forest and Brecon Beacons National Park, partner study sites for the Connected Treescapes project which have or are developing tree and woodland development strategies that include the aim of promoting well-being through exposure to trees. This convenience sampling was administratively convenient (in aligning the study to other aspects of the Connected Treescapes project) and enabled us to have stakeholder involvement in our findings. Of note, the great majority of participants did not reside within the boundaries of the three sites, but in urban areas adjacent to them and in postcode sectors that extend into them. It is possible, however, that this proximity to recent woodland development makes our sample atypical; the National Forest, for example saw forest cover increase from about 6% in 1991 to about 19% in 2013, with 8 million trees planted (DEFRA, 2013). The data collection was via an online questionnaire administered by a commercial survey company in August 2022. Our estimation sample comprised 1376 individuals who disclosed full residential neighbourhood information and had complete predictor variable data, drawn from 1823 questionnaire respondents who had given informed consent. The study received ethical approval from the University of York Department of Environment and Geography Ethical Review Committee (Ref: DEGERC/RES/05082022/1).

2.2 | Positive mental health and psychological distress outcome variables

The four positive mental health outcomes were Well-being, Life Satisfaction, Eudemonia and Happiness. Well-being was measured with the multi-item WEMWBS instrument (Tennant et al., 2007), where the scale scores range 0–56; Cronbach's alpha in our main analysis estimation sample was 0.93. Life Satisfaction was measured with the single item Office for National Statistics (ONS) question 'Overall, how satisfied are you with your life nowadays?' (ONS1, measured from 0 = 'not at all' to 10 = 'completely'). Eudemonia was measured with the single item ONS question 'Overall, to what extent do you feel that the things you do in your life are worthwhile?' (ONS2, measured from 0 = 'not at all' to 10 = 'completely'). Happiness was measured with the single item ONS question 'Overall, how happy did you feel yesterday?' (ONS3, measured from 0 = 'not at all' to 10 = 'completely').

The two psychological distress outcomes were Depression, Anxiety and Stress (abbreviated to DAS), and Anxiety. DAS was measured with the 10-item short-form Depression, Anxiety and Stress Scale (Halford & Frost, 2021), where scale scores ranged from 0 to 30; Cronbach's alpha in our main analysis estimation sample was 0.91. Anxiety was measured with the single item ONS question, 'Overall, how anxious did you feel yesterday?' (ONS4, measured from 0 = 'not at all' to 10 = 'completely').

2.3 | Local treescape variables of interest

Two objective measures of neighbourhood treescape were used. Tree cover density (TCD), the percentage crown cover (mean of 10 m^2 spatial units) within a 1 km buffer around the residential postcode centroid, was derived from the Copernicus Tree Cover Density 2018 dataset (10 m raster; Copernicus, 2018). Woody linear features (WLF), the modelled total length of hedges and lines of trees within a 1 km buffer around the residential postcode centroid, was derived from the UKCEH Woody Linear Features dataset (UKCEH, n.d.). We

also included a subjective measure of perceived neighbourhood treescape richness (PNTR) in the SEM, which was a latent variable indicated by 4 Likert scale items asking about agreement with the statements, 'There are a large number of trees within a five-minute walk of my home'; 'There are a large number of hedgerows within a five-minute walk of my home'; 'There are a wide variety of kinds of trees (e.g. oak, ash, hawthorn) within a five-minute walk of my home' and 'There are a large variety of tree sizes within a five-minute walk of my home' (each measured from 1 = 'Completely disagree', to 7 = 'Completely agree').

A confirmatory factor analysis was performed to assess the one-dimensionality of the 4 perceived neighbourhood treescape richness measurement items, using a Maximum Likelihood estimator with bootstrap CIs (1000 draws). The first iteration of the measurement model showed poor fit (χ^2 df(2) = 94.03, $p < 0.001$). A term for the covariance of residuals between the items on perceived neighbourhood abundance of trees and of hedges was added to the model, which made sense conceptually since the 'trees versus hedgerow' distinction may not always be clear to all respondents. This second iteration showed good fit (χ^2 df(1) = 0.69, $p = 0.407$). Requirements for reliability and convergent validity were met (composite reliability = 0.892; average variance extracted = 0.684). Each item loaded positively onto the underlying concept, and all loadings were significant (detail in Table 1). The measurement model thus supported the one-dimensionality of the perceived neighbourhood treescape richness factor indicators, and this latent variable was used in the structural part of the SEM.

2.4 | Wider nature experience variables

Greenspace (GS), operationalised as the percentage of land within a 1 km buffer around the residential postcode centroid, which was not urban or suburban built-up land, was derived from the UKCEH Land Cover Map for 2020 at 10 m^2 resolution (UKCEH, 2021). The operationalisation divided the green land cover classes (Broadleaf woodland; Coniferous woodland; Arable; Improved grassland; Semi-natural grassland; Mountain, heath and bog; Saltwater; Freshwater and Coastal) by the total classified land including the built-up land to derive the proportion of 'natural' land cover; thus, the greenspace measure here includes some 'blue space'. Of note, the broadleaf and coniferous woodland categories combined made up a mean of 19.76% of the total land classified as neighbourhood greenspace in our sample (SD = 14.85); thus, woodland is a minority component in the greenspace land cover metric.

Nature connectedness (NC) was measured with the short-form Nature Relatedness scale (NR6), which has good psychometric properties and correlates with positive affect (Nisbet & Zelenski, 2013). NR6 has 6 items (responses measured from 1 = 'Completely disagree' to 7 = 'Completely agree'); in our main analysis estimation sample, NR6 had Cronbach's alpha of 0.86.

Neighbourhood nature satisfaction (NNS) was a single-item subjective measure of the quality of the local natural environment, 'I am extremely satisfied with the natural environment within a five-minute walk of my home' (responses measured from 1 = 'Completely disagree' to 7 = 'Completely agree'). Research into local greenspace satisfaction in the UK using dominance analysis of a wide range of significant predictors showed that close to half the variance in the perception of local greenspace as good compared to green and natural spaces generally was accounted for by, cumulatively, its perceived value for mental health and well-being, physical exercise, watching nature, children's play and socialising (Alcock et al., 2025).

Nature visit exposure (NVE) was an ordered categorical measure (low, medium–low, medium–high, high) derived from multi-category responses to two questions: 'In the past 12 months, how often on average have you spent free time outside in green and natural spaces?' and, if applicable, 'On average, how long have these occasions typically lasted?' An indicative exposure level was derived by assigning representative specific values to the responses and multiplying frequency (times per year) by duration (in minutes), and these values were collapsed to the low–high (quartile) categories (to simplify the analysis and improve interpretability). The frequency question had response categories (and assigned representative specific values): 'Never' (0); 'Less often than once every 2-3 months' (3); 'Once every 2-3 months' (5); 'Once or twice a month' (18); 'Once a week' (52); 'Twice a week' (104); 'More than twice a week, but not every day'(208); 'Every day' (365), and the duration question had the response categories, 'Up to 30 minutes' (20); 'Over 30 minutes and up to an hour' (45); 'Over 1 hour and up to 2 hours' (90); 'Over 2 hours and up to 3 hours' (150); 'Over 3 hours and up to 5 hours' (240); 'Over 5 hours' (420).

Childhood nature exposure (CNE) was a single-item self-rated measure of the extent of childhood nature contact, 'In my childhood I had a lot of contact with trees and nature' (responses measured from 1 = 'Completely disagree' to 7 = 'Completely agree').

2.5 | Socio-demographic control variables

Socio-demographic factors were measured with categorical measures of gender, age, social grade (Ipsos MediaCT, 2009), marital

TABLE 1 Perceived neighbourhood treescape richness (PNTR): Confirmatory factor analysis.

PNTR items	Standardised loading	(95% CI)	R^2
Large number of trees	0.757	(0.734, 0.780)	0.574
Large number of hedgerows	0.648	(0.618, 0.679)	0.420
Wide variety of kinds of trees	0.898	(0.883, 0.914)	0.807
Wide variety of tree sizes	0.910	(0.895, 0.926)	0.829

status, children in the household, employment status, neighbourhood deprivation and sample study area.

2.6 | Preliminary analyses

We examined descriptive statistics for our estimation sample on all variables used in the study. Correlation coefficients amongst our main variables were then calculated to identify general patterns of association in the data. We then ran regression models of each of our mental health outcomes against each of the objective measures of neighbourhood natural environment exposure (tree cover density, woody linear features and greenspace) as single independent variables of interest with adjustment for covariate control variables.

We then tested single mediator models involving the mediators in our theorised model (see below). We tested, separately, mediation between the objective measures of neighbourhood natural environment exposure (tree cover density, woody linear features and greenspace) and the positive mental health and psychological distress outcomes via each of the theorised mediators (i.e. via perceived neighbourhood treescape richness, in the case of tree cover density and woody linear features, and, in all cases, via nature connectedness, neighbourhood nature satisfaction and nature visit exposure). For each combination of independent exposure variable (X), theorised mediator (M) and mental health outcome (Y) we evaluated, with adjustment for socio-demographic factors:

(i) the effect of X on M (whether $a \neq 0$ in the equation $M = a \times X + e_1$)
(ii) the effect of M on Y regressed on M and X (whether $b \neq 0$ in the equation $Y = c \times X + b \times M + e_2$)

taking mediation to exist if both conditions were met (Baron & Kenny, 1986).

2.7 | Theoretical model

We then specified a structural equation model (SEM) to test a set of theorised pathways from treescape exposures to mental health outcomes. We hypothesised direct effects from neighbourhood nature on mental health and indirect effects via wider experiences of nature, and in a sensitivity analysis, we further hypothesised direct and indirect effects from childhood nature exposures. To give an overview, this is summarised in a simplified form in Figure 1 (the details of the SEMs in our main and sensitivity analyses, as described below, are later summarised in Figures 2 and 3 below).

The independent variables of interest in our SEM comprised the two objective treescape measures, residential neighbourhood exposure to tree cover density (TCD) and residential neighbourhood exposure to woody linear features (WLF), and the subjective measure of perceived neighbourhood treescape richness (PNTR). The rationale for including the subjective measure was that (a) someone's experience of their neighbourhood treescape may be influenced by, for example the salience of treescape features immediately around their home and along their favoured neighbourhood walking routes, in addition to or, as opposed to, at the mean of the residential buffer area around their home and (b) more generally, how people perceive their neighbourhood treescape may differ from how it is objectively operationalised by the metrics of treescape feature abundance (e.g. a single much-loved tree might dominate a positive perception) and also may differ from objective metrics in its relevance to mental health outcomes. The range of personal relationships which people have with trees and which may influence their perception of the richness of their neighbourhood treescape is highlighted by qualitative studies (e.g. Ambrose-Oji et al., 2021; Iversen et al., 2022). However, we do expect that objective facts about neighbourhood trees and the perception of neighbourhood treescape richness will be connected, and our SEM theorised that perceived neighbourhood treescape richness would be positively influenced by

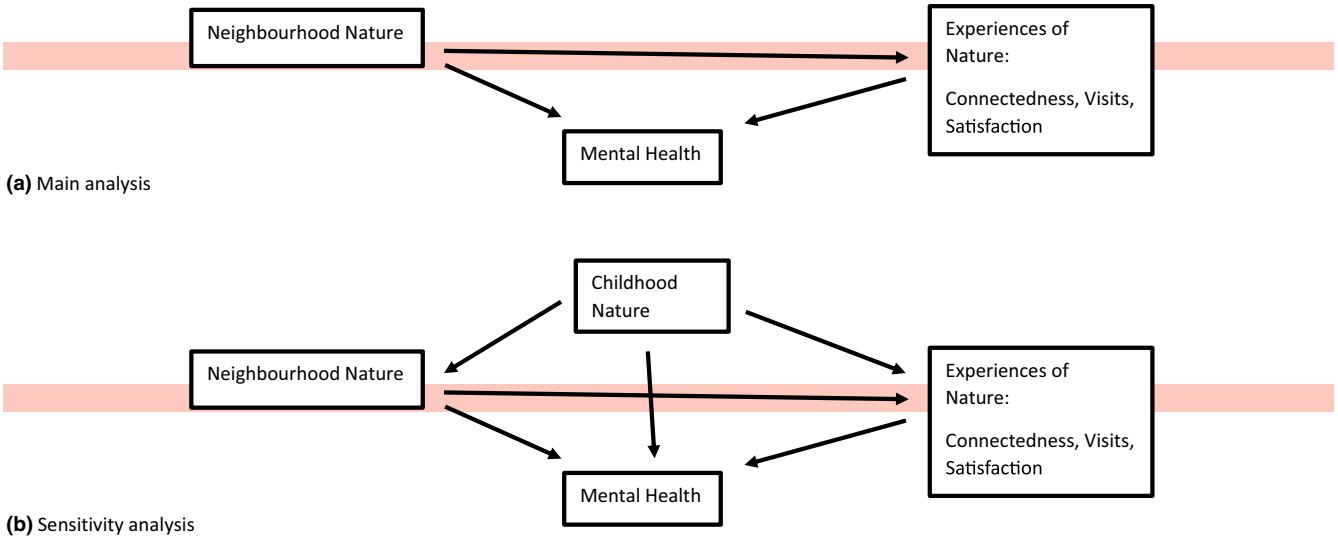

FIGURE 1 Summarised (simplified) form of the pathways accounted for in (a) the main analysis and (b) the sensitivity analysis.

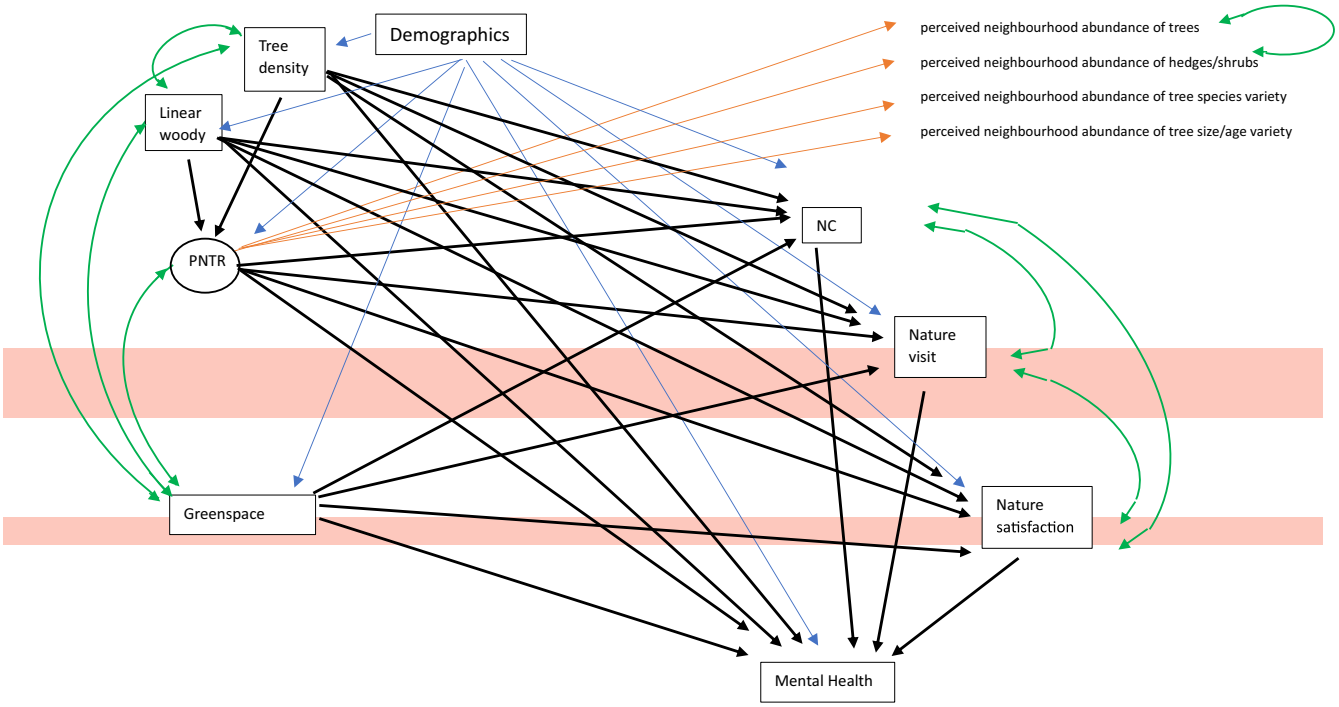

FIGURE 2 Schematic diagram of the theorised pathways in the main analysis SEM. NC, nature connectedness; PNTR, perceived neighbourhood treescape richness.

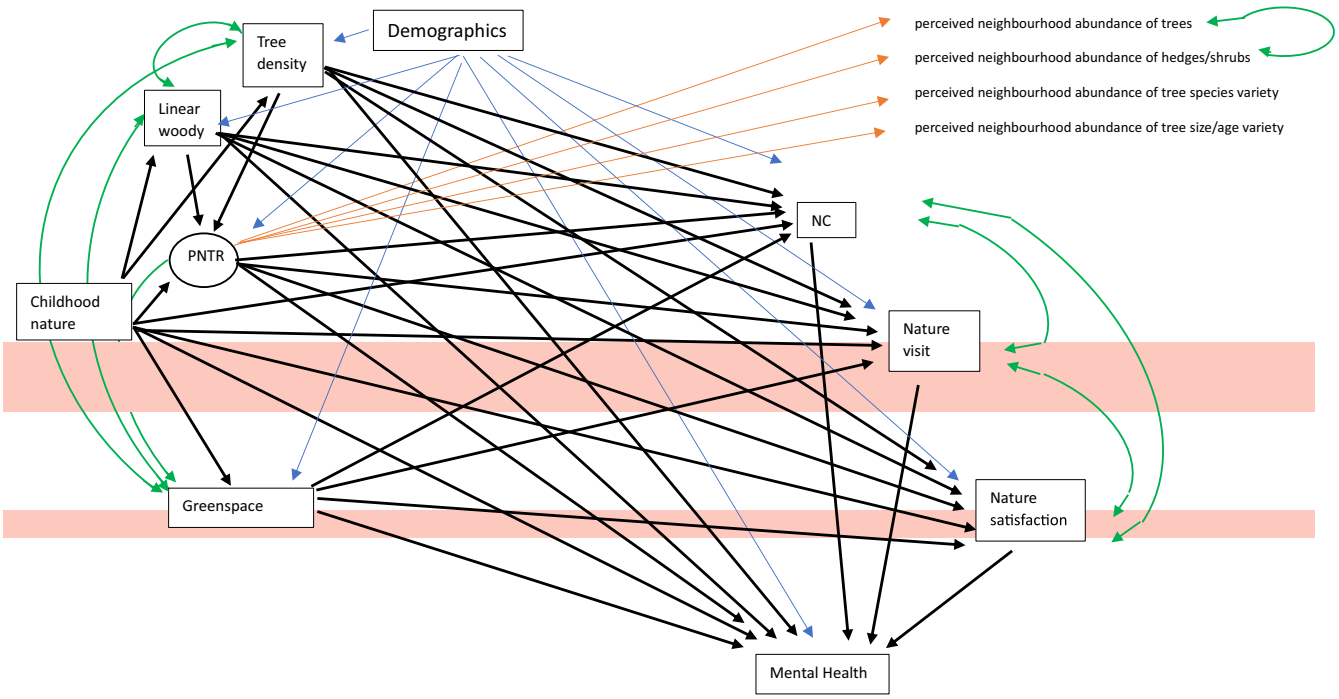

FIGURE 3 Schematic diagram of the theorised pathways in the sensitivity analysis SEM. NC, nature connectedness; PNTR, perceived neighbourhood treescape richness.

both tree cover density and woody linear features and may mediate their effects on mental health outcomes.

Our model also considered residential neighbourhood exposure to greenspace (GS), to avoid conflation of the effects of treescapes in particular with those of greenspace in general.

Informed by previous findings, our SEM theorised causal relationships between other aspects of people's experience of nature and their mental health outcomes besides neighbourhood exposure to greenspace and to objective and perceived treescapes. Our model accounted for people's nature connectedness (NC), their

neighbourhood nature satisfaction (NNS) and their nature visit exposure (NVE), and we theorised that these may mediate effects of tree cover density, woody linear features, perceived neighbourhood treescape richness and greenspace. That is to say, our model theorised that 'more' and better-rated neighbourhood nature might promote nature connectedness, increase satisfaction with the local natural environment and encourage nature visits and that there may be indirect effects of our three treescape variables of interest on mental health, as well as of greenspace, via these pathways.

All regressions in our SEM adjusted for socio-demographic factors. The theoretical model is represented schematically in Figure 2, where positive relationships are theorised across all pathways in the case of positive mental health outcomes, and negative relationships are theorised across all pathways in the case of psychological distress outcomes. Residual covariance was modelled between tree cover density and woody linear features; tree cover density and greenspace; woody linear features and greenspace and perceived neighbourhood treescape richness and greenspace. Residual covariance was also modelled between the mediator variables, nature connectedness and neighbourhood nature satisfaction; nature connectedness and nature visit exposure; and neighbourhood nature satisfaction and nature visit exposure. The inclusion of these residual covariance terms amounts to the assumption that there are variables absent from the model, which are predictive of both variables in each pair; their exclusion would have amounted to the (less plausible) assumption that there are not such variables.

The model equations for positive mental health and psychological distress outcome variables account for:

1. the direct effects of neighbourhood exposure to tree cover density (TCD), neighbourhood exposure to woody linear features (WLF), neighbourhood exposure to green space (GS), perceived neighbourhood treescape richness (PNTR), nature connectedness (NC), neighbourhood nature satisfaction (NNS) and nature visit exposure (NVE);
2. the mediated effects of tree cover density and woody linear features, each via perceived neighbourhood treescape richness (TCD→PNTR and WLF→PNTR), serially via perceived neighbourhood treescape richness and each of nature connectedness, neighbourhood nature satisfaction and nature visit exposure (TCD→PNTR→NC, TCD→PNTR→NNS and TCD→PNTR→NVE and WLF→PNTR→NC, WLF→PNTR→NNS and WLF→PNTR→NVE), as well as singly via each of nature connectedness, neighbourhood nature satisfaction and nature visit exposure (TCD→NC, TCD→NNS and TCD→NVE and WLF→NC, WLF→NNS and WLF→NVE);
3. the mediated effects of greenspace via each of nature connectedness, neighbourhood nature satisfaction and nature visit exposure (GS→NC, GS→NNS and GS→NVE);
4. the mediated effects of perceived neighbourhood treescape richness via each of nature connectedness, neighbourhood nature satisfaction and nature visit exposure (PNTR→NC, PNTR→NNS and PNTR→NVE).

Our primary interest lay in the overall effects of the treescapes variables (TCD, WLF, PNTR) on the positive mental health and psychological distress outcomes (and their significance at $p<0.05$), as measured by their total effects (i.e. combined direct and all indirect effects), as well as the relative magnitude and significance of the different pathways theorised to lead to effects on mental health. Subsidiary areas of interest were:

a. the contributions of tree cover density and woody linear features to perceived neighbourhood treescape richness;
b. the relative contributions of greenspace, nature connectedness, neighbourhood nature satisfaction and nature visit exposure to the positive mental health and psychological distress outcomes, and how these compare with the contributions of the three treescape variables of interest.

One aim of the research is to contribute to informing policy aimed at improving mental health through treescapes—for example would it be better to protect and increase tree cover density in residential areas, or to protect and increase woody linear features such as hedgerows, and how would such protection and planting programmes compare with actions to improve perceptions of neighbourhood treescape richness? Further, how would changing objectively measured and perceived treescapes compare with increasing greenspace or nature visits, etc. One factor that might limit inferences to policy is the role of childhood exposure to nature.

Some of the observed effects of treescapes and other natural elements on mental health might be partly due to childhood exposure to nature. This might be the case to some greater or lesser degree since people living with 'more nature' as children may experience 'more nature' as adults because, for example people often live somewhere close to, or somewhere similar to where they were brought up and predisposition towards positive or negative perception of neighbourhood trees, emotional connectedness to nature and the habit of making nature visits might all be influenced by formative experience of nature in childhood. Moreover, there may be lifelong direct effects of childhood nature exposure on positive mental health and psychological distress. For these reasons, and as a sensitivity analysis, our SEM was re-specified to include childhood nature exposure (CNE) as a primary level predictor, theorised to have direct effects on our outcome variables and indirect effects via all of: tree cover density (TCD), neighbourhood exposure to woody linear features (WLF), neighbourhood exposure to green space (GS), perceived neighbourhood treescape richness (PNTR), nature connectedness (NC), neighbourhood nature satisfaction (NNS) and nature visit exposure (NVE). This sensitivity analysis model is represented schematically in Figure 3.

The model equations for mental health outcomes here further account for this additional direct effect as well as the single and serial mediated effects via tree cover density (CNE→TCD, CNE→TCD→PNTR, CNE→TCD→PNTR→NC, CNE→TCD→PNTR→NNS, CNE→TCD→PNTR→NVE, CNE→TCD→NC, CNE→TCD→NNS and CNE→TCD→NVE), via linear woody

features (CNE→WLF, CNE→WLF→PNTR, CNE→WLF→PNTR→NC, CNE→WLF→PNTR→NNS, CNE→WLF→PNTR→NVE, CNE→WLF→NC, CNE→WLF→NNS, CNE→WLF→NVE), via greenspace (CNE→GS, CNE→GS→NC, CNE→GS→NNS, CNE→GS→NVE), via perceived neighbourhood treescape richness (CNE→PNTR, CNE→PNTR→NC, CNE→PNTR→NNS, CNE→PNTR→NVE), via nature connectedness (CNE→NC), via neighbourhood nature satisfaction (CNE→NNS) and via nature visit exposure (CNE→NVE).

In all cases, model fit was assessed using the test and indices of acceptable fit recommended by Hu and Bentler (1999): non-significant χ^2 ($p > 0.05$); root mean square error of approximation (RMSEA) ≤ 0.06; standardised root mean square residual (SRMSR) ≤ 0.08; comparative fit index (CFI) ≥ 0.95.

3 | RESULTS

3.1 | Descriptive and preliminary analyses

Descriptive data on all variables used in the study is given in Table 2. Correlation coefficients amongst our main variables are given in Table 3. Results of regressions of our mental health outcome variables against the objective measures of neighbourhood nature as single independent variables of interest (adjusted for covariate controls) are given in Table 4.

Results of our preliminary tests of single mediators are presented in Table S1; the models evidenced complementary mediation in some cases. Mediation, evidenced by our criteria, was observed for the effects of tree cover density and woody linear features via perceived neighbourhood treescape richness and via neighbourhood nature satisfaction on all outcomes, and for the effects of greenspace via neighbourhood nature satisfaction on all outcomes. Tree cover density, woody linear features and greenspace all did not positively affect nature connectedness at $p < 0.05$, and nature connectedness had non-significant or significant positive relationships in the models of psychological distress outcomes. Tree cover density was not significantly related to nature visit exposure, whereas the criteria for mediation of woody linear features and greenspace via nature visit exposure were met in most models (though nature visit exposure was only marginally associated with Anxiety when adjusted for these exposures).

3.2 | SEM results

3.2.1 | Regression of perceived neighbourhood treescape richness on tree cover density and woody linear features

As theorised, higher tree cover density and greater abundance of woody linear features within 1 km of the residence were positively associated with higher perceived neighbourhood treescape richness within a 5-min walk of home. Standardised coefficients for TCD and WLF (95% CI) were, respectively, 0.139 (0.096, 0.183) and 0.135 (0.081, 0.189). (These relationships were only negligibly different in the sensitivity model where childhood nature exposure was accounted for).

3.2.2 | Regression of positive mental health on neighbourhood treescapes and nature exposures

Main analysis results for the four outcome measures of positive mental health are summarised in Table 5. The three objective metrics of land cover within 1 km residential buffers, which quantify tree cover density, woody linear features and greenspace, all had no significant direct effect on any of the outcomes. In the case of tree cover density, when the total mediated effects via nature connectedness, neighbourhood nature satisfaction and nature visit exposure were also accounted for, there was a significant positive relationship with the life satisfaction outcome measure, with a 1 SD increase in tree cover associated with an increase in life satisfaction of about 7% of 1 SD. Tree cover density did not have significant total effects on the other positive mental health outcomes. The total effects of woody linear features and greenspace were also not significantly associated with any of the four positive mental health outcomes. In contrast, perceived neighbourhood treescape richness had no significant direct effects on the positive mental health outcomes but did have significant total effects on all four outcomes when mediated effects were accounted for. Nature connectedness, neighbourhood nature satisfaction and nature visit exposure also had significant positive relationships with all four outcomes. There was a high degree of consistency in the magnitude of effects of each perceived neighbourhood treescape richness, nature connectedness, neighbourhood nature satisfaction and nature visit exposure on the positive mental health outcomes. The effects of a 1 SD increase in perceived neighbourhood treescape richness were between 12% (Well-being) and 15% (Happiness) of 1 SD. The effects of a 1 SD increase in nature connectedness were between 7% (Life Satisfaction) and 13% (Eudemonia) of 1 SD. The effects of a 1 SD increase in neighbourhood nature satisfaction were between 15% (Happiness) and 20% (Well-being) of 1 SD. The effects of a 1 SD increase in nature visit exposure were between 11% (Eudemonia) and 15% (Life Satisfaction) of 1 SD.

Full results for the positive mental health outcomes are in Table S2 (Well-being), Table S3 (Life Satisfaction), Table S4 (Eudemonia) and Table S5 (Happiness). Although the total effect of tree cover density was significant only in the case of the Life Satisfaction outcome, the total indirect effects were positive and significant in the case of all four positive mental health outcomes, and there was consistency across the four outcomes in the specific pathways evidencing these positive relationships. In each case, there were small but significant positive specific mediated effects via neighbourhood nature satisfaction, serially via perceived neighbourhood treescape richness and neighbourhood nature satisfaction, and serially via perceived neighbourhood treescape richness and nature visit exposure.

TABLE 2 Descriptive statistics on the variables used in the study.

		Main analysis sample ($N = 1376$)		Sensitivity analysis sample ($N = 1361$)	
		M (SD)	%	*M* (SD)	%
Positive mental health and psychological resilience variables					
Well-being		33.42 (9.64)		33.47 (9.60)	
Life satisfaction		6.70 (2.29)		6.71 (2.29)	
Eudemonia		6.76 (2.28)		6.77 (2.27)	
Happiness		6.67 (2.41)		6.67 (2.41)	
DAS		23.11 (6.32)		23.11 (6.32)	
Anxiety		6.36 (2.94)		6.37 (2.94)	
Nature variables					
Neighbourhood tree cover density (rescaled)		3.61 (2.30)		3.60 (2.28)	
Neighbourhood woody linear features (rescaled)		2.99 (1.79)		2.99 (1.79)	
Neighbourhood greenspace (i.e. not built-up land, rescaled)		4.66 (2.27)		4.66 (2.27)	
Perceived abundance of nearby trees		10.01 (1.90)		10.01 (1.90)	
Perceived abundance of nearby hedges		9.84 (2.18)		9.84 (2.19)	
Perceived nearby tree species variety		9.12 (2.49)		9.12 (2.49)	
Perceived nearby tree size variety		9.43 (2.37)		9.44 (2.36)	
Nature connectedness		3.72 (0.87)		3.72 (0.86)	
Neighbourhood nature satisfaction		5.42 (1.46)		5.43 (1.45)	
Nature visit exposure	Low		28.6		28.6
	Medium–Low		29.5		29.5
	Medium–High		23.3		23.4
	High		18.7		18.6
Childhood nature exposure				5.23 (1.55)	
Socio-demographic covariates					
Gender	Male		44.1		43.9
	Female		55.9		56.1
Age	18–24		1.2		1.3
	25–34		10.4		10.3
	35–44		14.7		14.7
	45–54		16.6		16.8
	55+		57.1		56.9
Social grade	A/B/C1		78.1		78.3
	C2/D/E		21.9		21.8
Marital status	Living with spouse/partner		73.3		73.3
	Not living with spouse/partner		26.7		26.7
Children ≤16 years old	Living in household		23.5		23.7
	Not living in household		76.5		76.3
Employed	Full−/part-time		51.5		51.6
	Not employed		48.6		48.4
Neighbourhood deprivation	Less (IMD2019 deciles 1–7)		50.1		50.0
	More (IMD2019 deciles 8–10)		49.9		50.0
Area	Brecon Beacons National Park		0.9		0.9
	Mersey Forest		65.7		65.9
	National Forest		33.4		33.2

TABLE 3 Bivariate (Pearson, polyserial and polychoric) correlations between the main variables in the study[a].

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 Well-being	1	**0.72***	**0.69***	**0.69***	**−0.68***	**−0.55***	**0.13***	0.04	**0.08***	**0.10***	**0.17***	**0.18***	**0.27***	**0.23***
2 Life satisfaction		1	**0.77***	**0.81***	**−0.59***	**−0.50***	**0.09***	**0.07***	**0.09***	**0.09***	**0.18***	**0.14***	**0.27***	**0.24***
3 Eudemonia			1	**0.71***	**−0.54***	**−0.40***	**0.11***	0.05	**0.09***	**0.09***	**0.18***	**0.18***	**0.25***	**0.21***
4 Happiness				1	**−0.58***	**−0.55***	**0.10***	0.05	**0.07***	**0.08***	**0.18***	**0.15***	**0.24***	**0.22***
5 DAS					1	**0.65***	−0.03	−0.03	**−0.09***	**−0.11***	**−0.18***	−0.00	**−0.14***	**−0.14***
6 Anxiety						1	−0.04	−0.03	**−0.08***	**−0.09***	**−0.12***	0.05	**−0.16***	**−0.10***
7 CNE							1	−0.01	0.02	**0.07***	**0.06***	**0.42***	**0.11***	**0.18***
8 TCD								1	**0.08***	**0.18***	**0.14***	**0.06***	**0.19***	0.04
9 WLF									1	**0.68***	**0.18***	0.02	**0.20***	**0.11***
10 GS										1	**0.25***	**0.08***	**0.33***	**0.13***
11 PNTR											1	0.05	**0.49***	**0.20***
12 NC												1	0.04	**0.33***
13 NNS													1	**0.22***
14 NVE														1

Abbreviations: CNE, childhood nature exposure; DAS, Depression, Anxiety and Stress; GS, greenspace; NC, nature connectedness; NNS, neighbourhood nature satisfaction; NVE, nature visit exposure; PNTR, perceived neighbourhood treescape richness; TCD, tree cover density; WLF, woody linear features.

[a]Pairwise correlations calculated for the estimation sample used in the main analysis (not that used in the sensitivity analysis).

*Bold indicates significant $p < 0.05$.

TABLE 4 Regressions of mental health outcomes against objective measures of neighbourhood nature as single independent variables of interest (standardised beta coefficients; adjusted for covariate control variables)[a].

	Well-being ($N = 1299$)	Life satisfaction ($N = 1366$)	Eudemonia ($N = 1354$)	Happiness ($N = 1366$)	DAS ($N = 1247$)	Anxiety ($N = 1361$)
TCD	$R^2 = 0.091$	$R^2 = 0.072$	$R^2 = 0.073$	$R^2 = 0.052$	$R^2 = 0.100$	$R^2 = 0.070$
	$F = 9.93$	$F = 8.04$	$F = 8.17$	$F = 5.64$	$F = 10.53$	$F = 7.77$
	0.039	0.074**	0.050†	0.045†	−0.030	−0.023
WLF	$R^2 = 0.093$	$R^2 = 0.071$	$R^2 = 0.077$	$R^2 = 0.052$	$R^2 = 0.102$	$R^2 = 0.073$
	$F = 10.09$	$F = 7.89$	$F = 8.55$	$F = 5.72$	$F = 10.77$	$F = 8.15$
	0.059*	0.070*	0.082**	0.056†	−0.060*	−0.066*
GS	$R^2 = 0.094$	$R^2 = 0.073$	$R^2 = 0.077$	$R^2 = 0.054$	$R^2 = 0.106$	$R^2 = 0.074$
	$F = 10.30$	$F = 8.12$	$F = 8.63$	$F = 5.91$	$F = 11.24$	$F = 8.29$
	0.072*	0.083**	0.085**	0.070*	−0.089**	−0.075**

Abbreviations: DAS, Depression, Anxiety and Stress; GS, greenspace; TCD, tree cover density; WLF, woody linear features.

[a]The estimation samples comprised observations included in the main analysis (not limited to observations included in the sensitivity analysis).

†$p < 0.01$.

*$p < 0.05$.

**$p < 0.01$.

Both the total effects and the total indirect effects of woody linear features were non-significant in the models of all four positive mental health outcomes. However, two specific mediated effects with small positive relationships were observed consistently across the outcomes: serially via perceived neighbourhood treescape richness and neighbourhood nature satisfaction, and serially via perceived neighbourhood treescape richness and nature visit exposure.

The non-significant positive total effects of greenspace across the four outcomes consistently broke down into non-significant negative direct effects and significant positive total indirect effects. The specific mediated pathway via neighbourhood nature satisfaction was consistently positive, and the pathway via nature connectedness was positive and significant only in the case of Eudemonia.

There were consistent positive total indirect effects of perceived neighbourhood treescape richness across the four outcomes, which combined with positive but non-significant direct effects to yield consistent positive total effects. There was also consistency across the four outcomes in the specific mediated pathways evidencing significant positive effects: via neighbourhood nature satisfaction and via nature visit exposure.

The sensitivity of the results described to the addition of childhood nature exposure as a primary level exposure with potential mediation through later life nature exposures and through nature sentiments showed in the case of Well-being that the significance of all the total effects was unchanged and estimates were little attenuated. In the case of Eudemonia, the significant total effects of perceived neighbourhood treescape richness, nature connectedness, neighbourhood nature satisfaction and nature visit exposure were still observed and only slightly attenuated, though woody linear features also had a significant total effect here, with a 1 SD increase being associated with an increase of 8% of 1 SD. In the case of Life Satisfaction and Happiness, the effects of nature connectedness were attenuated such that positive estimates were no longer significant, whilst the significance of other total effects was unchanged. Childhood nature exposure itself had consistent non-significant direct effects across the four positive mental health outcomes and consistent significant positive total effects, with a 1 SD increase being associated with 9%–11% of 1 SD increases.

3.2.3 | Regression of psychological distress on neighbourhood treescapes and nature exposures

Main analysis results for the two outcome measures of psychological resilience are summarised in Table 6. The three objective metrics of land cover within 1 km residential buffers, which quantify tree cover density, woody linear features and greenspace, all had no significant direct effects or total effects on either of the outcomes. In contrast, perceived neighbourhood treescape richness had a significant negative direct effect and total effect on Depression, Anxiety and Stress (DAS), where the total effect associated with a 1 SD increase was a decrease of 11% of 1 SD. Perceived neighbourhood treescape richness had a non-significant direct effect and a significant negative total effect on Anxiety, where the total effect associated with a 1 SD increase was a decrease of 7% of 1 SD. Contrary to our expectation, nature connectedness had a significant positive relationship with both DAS, where a 1 SD increase was associated with an increase of 6% of 1 SD, and with Anxiety, where a 1 SD increase was associated with an increase of 9% of 1 SD. Neighbourhood nature satisfaction had no significant association with DAS but had a significant negative effect on Anxiety, where a 1 SD increase was associated with a decrease of 11% of 1 SD. Nature visit exposure had a significant negative relationship with both DAS, where a 1 SD increase was associated with a decrease of 9% of 1 SD, and with Anxiety, where a 1 SD increase was associated with a decrease of 7% of 1 SD.

Full results for the psychological distress outcomes are in Table S6 (DAS) and Table S7 (Anxiety). In the model of DAS, the total indirect

TABLE 5 Summarised SEM results for positive mental health outcomes (standardised coefficients).

	Well-being		Life satisfaction		Eudemonia		Happiness	
	Direct effects	Total effects	Direct effects	Total effects	Direct effects	Total effects	Direct effects	Total effects
TCD	−0.001 (−0.050, 0.049)	0.033 (−0.017, 0.082)	0.036 (−0.014, 0.086)	**0.067** (0.017, 0.117)	0.009 (−0.044, 0.061)	0.043 (−0.009, 0.096)	0.006 (−0.046, 0.058)	0.039 (−0.014, 0.092)
WLF	0.039 (−0.035, 0.113)	0.043 (−0.034, 0.120)	0.047 (−0.026, 0.119)	0.055 (−0.019, 0.130)	0.067 (−0.008, 0.141)	0.072 (−0.005, 0.149)	0.035 (−0.041, 0.110)	0.046 (−0.032, 0.123)
GS	−0.038 (−0.115, 0.039)	0.019 (−0.060, 0.098)	−0.034 (−0.102, 0.035)	0.018 (−0.053, 0.088)	−0.041 (−0.114, 0.032)	0.013 (−0.061, 0.086)	−0.034 (−0.106, 0.038)	0.012 (−0.061, 0.086)
PNTR	0.012 (−0.063, 0.087)	**0.123** (0.057, 0.189)	0.023 (−0.051, 0.097)	**0.130** (0.065, 0.196)	0.035 (−0.034, 0.105)	**0.135** (0.071, 0.199)	0.061 (−0.015, 0.137)	**0.152** (0.084, 0.219)
NC	**0.109** (0.042, 0.177)		**0.073** (0.009, 0.137)		**0.130** (0.069, 0.191)		**0.090** (0.026, 0.153)	
NNS	**0.195** (0.132, 0.259)		**0.176** (0.113, 0.239)		**0.172** (0.101, 0.243)		**0.147** (0.079, 0.216)	
NVE	**0.113** (0.050, 0.175)		**0.152** (0.092, 0.213)		**0.107** (0.045, 0.168)		**0.130** (0.068, 0.193)	

Note: Bold indicates significance.

Abbreviations: GS, greenspace; NC, nature connectedness; NNS, neighbourhood nature satisfaction; NVE, nature visit exposure; PNTR, perceived neighbourhood treescape richness; TCD, tree cover density; WLF, woody linear features.

effects of tree cover density and greenspace were non-significant, but the total indirect effects of woody linear features were negative and significant. The specific serially mediated pathways from both tree cover density and woody linear features via perceived neighbourhood treescape richness and nature visit exposure had very small negative effects. In the model of Anxiety, non-significant total indirect effects of all three objective land cover metrics contributed to the non-significant total effects. Specific mediation pathways with small but significant negative effects were from greenspace via neighbourhood nature satisfaction, and serially from both tree cover density and woody linear features via perceived neighbourhood treescape richness and neighbourhood nature satisfaction.

In the model of DAS, the total indirect effects of perceived neighbourhood treescape richness were not significant, though the specific pathway via nature visit exposure evidenced a small negative effect. In the model of Anxiety, the total indirect effects of perceived neighbourhood treescape richness were significant and negative, with negative pathways via both neighbourhood nature satisfaction and nature visit exposure.

Sensitivity to the addition of childhood nature exposure as a primary level exposure showed that the significance of all the total effects on DAS remained unchanged. However, the sensitivity analysis showed that in the model of Anxiety, the negative estimated total effect of perceived neighbourhood treescape richness diminished and was no longer significant. In both models, the total effect of childhood nature exposure itself was not significant.

4 | DISCUSSION

Our preliminary analyses identified significant positive associations between residential area woody linear features (and also greenspace) and all our measures of positive mental health, and significant negative associations with both psychological distress outcomes; in contrast, positive correlations between tree cover density and the positive mental health outcomes were not significant, with the exception of Life Satisfaction (Table 3), and negative correlations between tree cover density and the psychological distress outcomes were also not significant. In regression models which adjusted for socio-demographic covariate controls, these relationships remained (Table 4), though the positive relationship between woody linear features and Happiness attenuated and became only marginally significant. These results on broad patterns of association, without accounting for other nature exposures, align with the findings of many previous studies that have found benefits of both greenspaces (Houlden et al., 2018) and treescapes (e.g. Akpinar et al., 2016). In their review of urban trees and health, Wolf et al. (2020) included 15 studies that examined effects on mental health, anxiety and mood and 25 studies that focused on the impacts on psychophysiological stress, and whilst the variation in measures, outcomes and activities makes it difficult to aggregate findings from the many unique insights reviewed, positive links between trees and various aspects of well-being were generally evidenced.

TABLE 6 Summarised SEM results for mental distress outcomes (standardised coefficients).

	DAS		Anxiety	
	Direct effects	**Total effects**	**Direct effects**	**Total effects**
TCD	−0.006 (−0.057, 0.044)	−0.020 (−0.071, 0.031)	−0.003 (−0.056, 0.049)	−0.015 (−0.066, 0.037)
WLF	−0.006 (−0.081, 0.068)	−0.025 (−0.100, 0.050)	−0.033 (−0.105, 0.039)	−0.044 (−0.117, 0.030)
GS	−0.043 (−0.118, 0.032)	−0.049 (−0.123, 0.026)	−0.013 (−0.086, 0.059)	−0.031 (−0.102, 0.041)
PNTR	**−0.083** (−0.159, −0.007)	**−0.111** (−0.181, −0.042)	−0.007 (−0.077, 0.063)	**−0.066** (−0.128, −0.003)
NC	**0.063** (0.001, 0.126)		**0.090** (0.029, 0.151)	
NNS	−0.033 (−0.098, 0.032)		**−0.105** (−0.168, −0.042)	
NVE	**−0.092** (−0.162, −0.023)		**−0.071** (−0.134, −0.007)	

Abbreviations: DAS, Depression, Anxiety and Stress; GS, greenspace; NC, nature connectedness; NNS, neighbourhood nature satisfaction; NVE, nature visit exposure; PNTR, perceived neighbourhood treescape richness; TCD, tree cover density; WLF, woody linear features.

However, in our main analysis, greenspace and two contrasting treescapes measures were isolated, with others controlled in order to disentangle and quantify their links with mental health. Impacts of treescapes were theorised to include indirect effects via perceptions of the treescape, and via wider experience of nature, in terms of contribution to satisfaction with the residential area natural environment, making visits to nature and feeling connected to nature. This approach aimed to address calls for research to consider which types of nature are most beneficial with regard to specific health outcomes (De Vries et al., 2021; Frumkin et al., 2017) and to clarify the relative importance of merely living near nature compared to more deliberate interactions with nature such as visiting (Markevych et al., 2017).

Accounting for this complexity, our analysis found that the total effects of the objective treescape variables, tree cover density and woody linear features, were non-significant in the models of all four operationalisations of positive mental health, with the sole exception of a positive total effect of tree cover density on Life Satisfaction. However, specific serial indirect effects of these treescape features were always positive and significant: via perceived neighbourhood treescape richness and neighbourhood nature satisfaction, and via perceived neighbourhood treescape richness and nature visit exposure. Tree cover density also had significant positive indirect effects via neighbourhood nature satisfaction in all cases. Similarly, we further found that the total effects of the objective treescape variables were non-significant in the models of both operationalisations of psychological distress, though specific serial indirect effects of these treescape features were always negative and significant: via perceived neighbourhood treescape richness and nature visit exposure in the case of DAS, and via perceived neighbourhood treescape richness and neighbourhood nature satisfaction in the case of Anxiety.

In contrast, our subjective measure of treescape richness had significant positive total effects on all the positive mental health outcomes and significant negative total effects on both psychological distress outcomes. These total effects were mainly due to indirect effects in all cases except in the model of DAS, where a significant negative direct effect comprised the bulk of the total effect. Significant specific positive indirect effects on positive mental health and negative effects on psychological distress were observed in all cases via nature visit exposure and in all cases except DAS via neighbourhood nature satisfaction.

Taken together, these results highlight the relevance of perceptions of neighbourhood treescapes for positive mental health and for psychological distress. Perceived treescapes had significant total effects in all cases and were the initial mediator in many significant serial pathways for effects of the objective treescape features, via influence on both neighbourhood nature satisfaction and nature visit exposure. Total effects of the objective treescape features were rarely significant (only for tree cover density on Life Satisfaction), and the only indirect effects that were significant which did not involve perceived neighbourhood treescape richness were for tree cover density on positive mental health outcomes via neighbourhood nature satisfaction.

The picture that emerged regarding the roles of objective treescape features and perceptions of treescape richness is 'mirrored' in the findings regarding the roles of the objective greenspace coverage measure and the perception of neighbourhood nature: neighbourhood nature satisfaction had positive effects in all cases on positive mental health and a negative effect on Anxiety (though not on DAS), whereas greenspace had no significant total effects. Greenspace had significant specific indirect effects via neighbourhood nature satisfaction in all cases except DAS and further via nature connectedness in the cases of Well-being and Eudemonia. The association between perceived biodiversity and mental well-being is established (e.g. Cameron et al., 2020). Interestingly, there is evidence to suggest that whilst perceptions of trees are most salient to people, bird diversity is a key factor in well-being. These interconnections between the perceived and perceiver complement wider theories of embodied cognition where our minds and the wider environment operate as a coupled system with humans being embedded in the natural world (Borghi & Cimatti, 2010; Clark, 1997), with researchers increasingly recognising the integration between biology, phenomenology and the sciences of mind (e.g. Thompson, 2010). With humans being biological beings that evolved to make sense of the natural world, there is sense in perceptions of natural environment

richness being important for well-being. Additionally, there is a rich multidisciplinary literature that attends to how the configuration and placement of trees are bound up with social as well as ecological meaning, with trees posing as significant agents and actants in the way people connect with nature, symbolising historical continuity, contributing to personal and collective identities, and providing physical and mental well-being through their presence and interaction (Garner, 2004).

The value of our approach is shown by the contrast between the bivariate relationships evidenced in our preliminary analyses, and those in our theoretically driven SEM. Woody linear features (such as hedgerows and tree-lined boundaries) and greenspace had strong bivariate relationships to the mental health outcomes, but after accounting for the aspects of wider nature experience that we considered, there were no longer significant relationships, though specific pathways via those aspects of wider nature experience were significant. Whilst our bivariate findings are consistent with much previous work which did not adjust for the effects of, or account for mediation via, neighbourhood nature satisfaction, nature visit exposure or nature connectedness, in showing passive exposure to neighbourhood greenspace coverage was associated with enhanced mental health (e.g. Astell-Burt et al., 2014), the lack of observed significant total effects of woody linear features and greenspace after accounting for these aspects of wider nature experience is also consistent with the limited previous research which has considered these aspects. For example, White et al. (2021) reported significant effects of residential area greenspace on mental health, which diminished and were null when parameters for nature visits and nature connectedness were added to their models. Subjective perceptions about treescape richness also had strong bivariate relationships to the mental health outcomes, and these relationships remained after accounting for the aspects of wider nature experience that we considered and were largely mediated via those wider nature experiences. The studies considered by Wolf et al. (2020) included those where tree exposures were measured both objectively and subjectively, although that was not a focus of the narrative review. Yet, the current results suggest that rather than identifying simple direct relationships between trees and well-being that can provide treescape planning and management with specific levers to pull, the overall story is like that of treescapes themselves, many and varied. Treescapes and greenspaces are good for people, but that benefit comes via many pathways.

Complexities of indirect effects aside, the positive relationships observed between nature connectedness, neighbourhood nature satisfaction and nature visit exposure to positive mental health align with previous research (e.g. Martin et al., 2020), as does the negative relationship between visiting nature and psychological distress (e.g. Shanahan et al., 2016). It is also worth noting that the magnitude of the effects of perceived neighbourhood treescape richness (total effects), nature connectedness, neighbourhood nature satisfaction and nature visit exposure on positive mental health was broadly consistent, both with one another for each outcome and across the four outcomes examined, although, in line with previous research (e.g. Martin et al., 2020), nature connectedness accounted for more variation in well-being and eudaimonia than in life satisfaction and happiness. Tree cover density also had a positive effect (total effects) on life satisfaction only, though this was smaller in magnitude; we interpret this with caution: it is possible that despite covariate controls for neighbourhood deprivation and for social grade, this represents residual confounding with other factors related to the desirability of 'leafier' residential neighbourhoods as reflected in higher property values (Sachs et al., 2023; Sander et al., 2010).

It should also be noted that nature connectedness had a significant positive relationship with both DAS and anxiety. This contrasts with findings from a multi-national study, which similarly accounted simultaneously for greenspace and nature visits (White et al., 2021). Given it is known that people seek out nature to help manage their emotions (Korpela et al., 2018; Tester-Jones et al., 2020), it could be that those suffering from depression and anxiety develop a closer relationship with nature, thus leading to the mixed results in the literature.

Turning to childhood nature exposure, this had consistent non-significant direct effects across the four positive mental health outcomes, but consistent significant positive total effects. This overall impact aligns with previous findings (Pensini et al., 2016; Preuß et al., 2019) which showed adults with higher levels of childhood exposure to natural environments had, when compared to adults with lower childhood exposure, significantly better mental health and well-being. Whilst Pensini et al. (2016) found childhood nature exposure effects were mediated via adult exposure, Preuß et al. (2019) found, in contrast to the current study, no mediating role of adulthood exposure to residential area greenspace or nature visits exposure, nor mediation via adult neighbourhood nature satisfaction (operationalised as the amount of neighbourhood nature, its quality, maintenance and safety). Our study also found no significant direct or total effects of childhood nature exposure on both the psychological distress outcomes we examined. This contrasts with previous findings that showed that children growing up with less residential area greenspace had a differentially higher risk in adulthood of symptoms of depression, anxiety and stress (Bezold et al., 2018; Engemann et al., 2019); Snell et al. (2016) found this protective effect of childhood nature exposure and that it was mediated via adult exposure. Whilst this aspect of our work contributes in passing to calls for further research to address life course nature exposure and mental health outcomes (Li et al., 2021), childhood nature exposure was considered in our study as a test of whether its addition to our pathway model substantially changed the findings on relationships between neighbourhood treescapes and greenspace and mental health: in general it did not, noting that the total effect of perceived neighbourhood treescape richness on Anxiety diminished and became only marginally significant.

Our finding of positive relationships between perceived neighbourhood treescape richness and the mental health measures examined, and its contrast with the general absence of overall positive relationships between the objective metrics of treescape features

and mental health, has implications for neighbourhood treescape management. This research implies that residents' perceptions that their treescape is 'rich', with many and varied trees and hedgerows, involve more than a simple numeration of trees and hedges and that these perceptions should be taken seriously in decision-making processes because they are significantly associated with well-being. The perception that a neighbourhood treescape is rich may, like the motivation to preserve local trees, involve personal relationships with trees in which aesthetic, heritage and cultural values play a role (Chan et al., 2016; Dwyer et al., 1991). Treescape management, and especially the street tree management policies of local authorities in compliance with the 1980 Highways Act, has become increasingly contentious in the UK (Dempsey, 2024; Heydon, 2020), where a common theme is community protest against the removal and replacement of neighbourhood trees. Our findings may be viewed as offering empirical support to those who argue for locally inclusive environmental governance in this context (Harrison, 2024; Sheppard et al., 2017).

4.1 | Limitations

Whilst the causal assumptions theorised in our SEM were not rejected by the test of whether they fitted the data, the study was based on cross-sectional data. The time precedence requirement (that a cause must precede an effect) was not always clearly met. This limits the potential of the work to contribute to the tentative plausibility of those causal assumptions and the insights offered by the quantitative causal conclusions derived from the data under those assumptions. For example, respondents' current residential exposures were posited as causes of their visits to nature over the previous year and of their current nature connectedness; whilst respondents are likely to have lived in their neighbourhoods for substantially longer than the preceding year, this was not investigated. Potential inaccuracy in the retrospective measure of childhood nature contact is also relevant here. Moreover, plausible alternative structures were not considered; for example, a reverse relationship may be theorised: that mental well-being increases nature exposure.

It should also be noted that the convenience sample used for this study is markedly different from a nationally representative sample. In particular, 55% of our sample were aged 55 and over, whereas in the UK this group accounted for 31% in 2021, which limits the generalisability of our findings. The age profile of our sample may be especially relevant if older people have greater exposure to treescapes or value them more, or if there is a different relationship between nature contacts and mental health in older people compared to younger people. Moffat et al. (2024) found more positive support for urban trees amongst older people than younger people across a range of operationalisations, though the variance explained by age was very small (generally less than 1.5%). The findings by Liu et al. (2024) of greater protective associations between residential area nature exposures with psychiatric disorders amongst those aged over 65 compared to younger individuals also underscore this limitation.

5 | CONCLUSIONS

A pathways perspective of the influence of perceived and real treescapes on mental health whilst including wider nature exposures provides a novel perspective. Whilst a large body of previous research has demonstrated that nature exposures are associated with better mental health, the analysis presented highlights the complexity of those relationships. The benefits of neighbourhood nature were mostly via experiences of nature, and perceived neighbourhood treescape richness had significant positive total effects where objective metrics of treescape features and greenspace mostly did not. Similarly, childhood exposure also plays a role. Treescapes cannot be viewed as isolated levers for well-being; rather, the benefits come through the interactions with, and perceptions of, trees. For treescape planning, a relational perspective is needed, with both residents' perceptions and the reality of tree and hedgerow cover and quality mattering for well-being. This suggests that residents should be actively and meaningfully engaged with treescapes and the wider natural world in order to achieve the greatest benefits for human well-being.

AUTHOR CONTRIBUTIONS

Ian Alcock, David Sheffield, Piran C. L. White, Peter A. Coventry and Miles Richardson conceived the ideas and designed the methodology; Merryn L. Hunt prepared and merged objective neighbourhood nature variables at postcode centroid buffers to our survey data; Ian Alcock analysed the data and led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are not publicly available due to restrictions imposed by the ethical approval granted for this research. Specifically, participants provided their full postcode,

which constitutes personally identifiable information. As such, sharing the dataset would compromise participant confidentiality and violate the terms of ethical consent. Researchers interested in further information about the study may contact the corresponding author, subject to ethical review and data protection considerations.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1. Tests of single mediators: linear and ordinal regressions of theorised mediators (perceived neighbourhood treescape richness; nature connectedness; neighbourhood nature satisfaction and nature visit exposure) against independent nature exposure variables (tree cover density; woody linear features and greenspace) and linear regressions of mental health outcomes (Well-being; Life Satisfaction; Eudemonia; Happiness; Depression, Anxiety and Stress (DAS); Anxiety) against theorised mediators and nature exposure variables. All regressions adjusted for socio-demographic covariates. Coefficients are fully standardised (X-standardised in ordinal regressions of nature visit exposure).

Table S2. SEM results for Well-being (standardised coefficients).

Table S3. SEM results for Life Satisfaction (standardised coefficients).

Table S4. SEM results for Eudemonia (standardised coefficients).

Table S5. SEM results for Happiness (standardised coefficients).

Table S6. SEM results for Depression, Anxiety and Stress (DAS) (standardised coefficients).

Table S7. SEM results for Anxiety (standardised coefficients).

Data S2. Full Survey.

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