Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Contact with blue-green spaces during the COVID-19 pandemic lockdown beneficial for mental health

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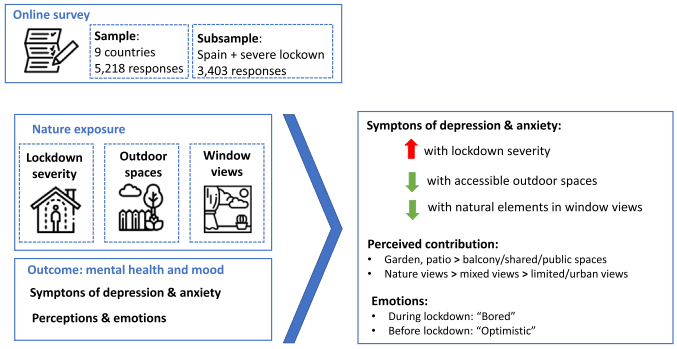
HIGHLIGHTS

- Lockdown severity is positively associated with poor mental health.
- Nature contact 'buffers' the negative effect of lockdown on mental health.
- People perceived that nature helped them to cope better with lockdown measures.
- Access to outdoor spaces and nature views associated with more positive emotions.

GRAPHICAL ABSTRACT



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ABSTRACT

There is growing evidence that ecosystem services and especially the exposure to the natural world (blue-green spaces) have potential benefits for mental health and well-being. The COVID-19 pandemic and the measures adopted to control it provide a natural experiment to investigate the links between nature exposure and mental health under extreme conditions. Using a survey distributed online, we tested the following hypotheses: 1) People will show greater symptoms of depression and anxiety under lockdown conditions that did not allow contact with outdoor nature spaces; 2) Where access to public outdoor nature spaces was strictly restricted, (2a) those with green/blue nature view or (2b) access to private outdoor spaces such as a garden or balcony will show fewer symptoms of depression and anxiety, and a more positive mood. Based on 5218 responses from 9 countries, we found that lockdown severity significantly affected mental health, while contact with nature helped people to cope with these impacts, especially for those under strict lockdown. People under strict lockdown in Spain (3403 responses), perceived that nature helped them to cope with lockdown measures; and emotions were more positive among individuals with accessible outdoor spaces and blue-green elements in their views. These findings can help decision-makers in developing potential future lockdown measures to mitigate the negative impacts, helping people to be more resilient and maintain better mental health, using the benefits that ecosystem services are providing us.

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1. Introduction

In December 2019, a new coronavirus (SARS-CoV-2) and associated disease (COVID-19) were identified in China, and quickly spread to the rest of the world as a pandemic (Wang et al., 2020). The rapid increase of infections and deaths jeopardized the capacity of global public health systems all over the world,[1] forcing governments to take exceptional measures to contain the pandemic.

These measures varied among countries but the most common included border and school closures, encouraging teleworking, social distancing, and restrictions on mobility, including 'lockdowns' (Benzell et al., 2020; Tobías, 2020). In Europe, the first country to enact a national lockdown was Italy (11th March), followed by, among others, Spain (15th March), France (17th March), Germany (22nd March), and the United Kingdom (23rd March). The stringency of the implemented measures varied among countries; from severe lockdowns, where people were not allowed to leave their homes except for essential activities (e.g. China, Italy or Spain), to the limitation of movements as recommendations rather than binding rules (e.g. Scandinavian countries).

The implementation of physical distancing and lockdowns are likely responsible for having saved millions of lives; with estimates of >3 million lives saved in 11 European countries alone (Flaxman et al., 2020). However, these interventions are likely to have led to many unintended consequences and the COVID-19 pandemic has provided a natural experiment. Thus, parallel to the fast-moving medical research to find effective treatments and a vaccine, studies on how the pandemic and the subsequent lockdown measures are impacting the environment (Helm, 2020; Le Quéré et al., 2020), the economy (Goodell, 2020) and people's mental health (Holmes et al., 2020; Ozamiz-Etxebarria et al., 2020; Pappa et al., 2020) have also been conducted.

Central to COVID-19 restrictions in most countries has been physical distancing and even "self-isolation" or "quarantine" from others. There is very strong evidence suggesting that isolation from others can damage mental health (Leigh-Hunt et al., 2017; Smith and Victor, 2019; Brooks et al., 2020). Thus, it is not surprising that symptoms of depression and anxiety (already some of the most common mental health disorders) (World Health Organization, 2017), increased in the early stages of lockdown (Balluerka Lasa et al., 2020; Fancourt et al., 2020). However, contact with nature can buffer or mitigate against the negative effects of social isolation on mental health (Cartwright et al., 2018; Yang et al., 2020), an effect that may have been especially important during lockdown (Samuelsson et al., 2020; Venter et al., 2020).

There is a growing literature in different fields (e.g. ecosystem services, public health) indicating that exposure to blue-green spaces (e.g. urban parks, woodlands, rivers and the coast), has a range of potential benefits for mental health and well-being (Irvine et al., 2013; Gascon et al., 2015, 2017; Thomsen et al., 2018; Bratman et al., 2019; Borja et al., 2020), also referred to as cultural ecosystems services (Costanza et al., 2017). The mechanisms that link nature exposure to health benefits have been organized in three domains: (i) mitigation, e.g. reducing exposure to air pollution; (ii) restoration, e.g. recovery from stress; and (iii) instoration, e.g. promotion of physical activity (Markevych et al., 2017; White et al., 2020). Exposure to nature can come in three ways: *direct* contact, e.g. deliberately visiting a park for recreation; *indirect* contact, e.g. window views of natural spaces; and *incidental* contact e.g. passing through a park when commuting to work (Keniger et al., 2013). To date the strongest evidence in support of mental health benefits has been for direct contact in natural settings, with benefits to general (White et al., 2017; Kruize et al., 2020) and clinical (Roe and Aspinall, 2011; Berman et al., 2012) populations. A UK study with over 20,000 people estimated that people may need to spend at least two hours/week outdoors in blue-green spaces to derive significant wellbeing benefits (White et al., 2019). But indirect contact, by for example having a window view of nature, and especially blue spaces (water bodies), has also been found to be positively associated with better mental health, even once socio-economic factors have been taken into account (Nutsford et al., 2016; Dempsey et al., 2018; Garrett et al., 2019).

Importantly for the COVID-19 crisis, research suggests that maintaining contact with nature during stressful life events, such as relationship breakdown or job loss, can "buffer" individuals against stress; with those living in greener areas reporting fewer mental and physical symptoms of poor-health during, and shortly after, the stressful event (van den Berg et al., 2010). It is also important that while 'home' is generally considered a restorative environment in psychological literature (Hartig, 2012), during the COVID-19 crisis, school' closures and the increase of telework might have compromised its restorative potential (Hartig et al., 2007). Under these special circumstances, being able to maintain contact with nature from home might have had a relevant positive effect in mental health (Collado et al., 2017), compensating the loss of the restorative effect of the home, to some extent.

However, maintaining contact with nature is not, on its own, a guarantee of a buffer against poor-health. Mental and physical conditions, socio-demographic factors, or even personal circumstances (e.g. family responsibilities), can moderate the positive effect that nature exposure has on mental health. Among others, there is emerging evidence that individual's psychological resilience can help to cope and adapt to adverse circumstances (Heinen et al., 2017; Kocalevent et al., 2017). Also, that sociodemographic factors (e.g. age and gender) can act as moderators of green spaces exposure and mental health (Bos et al., 2016; Vanaken and Danckaerts, 2018), although findings are not consistent over studies (van den Berg et al., 2015). During the first wave of COVID-19, the country of residence could have also acted as a moderator of the effect of nature exposure on mental health. Thus, in countries severely hit by the pandemic, with weaker health systems, or countries were the public perception was more critic with political and public management of the crisis, individuals might be more likely to show symptoms of poor mental health.

While Europe[2] is immersed in the second wave of COVID-19 (Cacciapaglia et al., 2020; Leung et al., 2020; Xu and Li, 2020) and under the probable spread of new emerging diseases in the near future, we need to understand the specific factors that positively contributed to mental health during lockdown, so measures/strategies can be better designed.

The aim of the current study was to test whether, during the first wave of the COVID-19 outbreak, people who maintained direct and/or indirect contact with outdoor spaces coped better with lockdown measures in terms of fewer symptoms of poor mental health (i.e. depression and anxiety) and better maintenance of positive mood.

We tested the following two hypotheses: 1) People will show greater symptoms of depression and anxiety under lockdown conditions that did not allow contact with outdoor nature spaces; 2) Where access to public outdoor nature spaces was strictly restricted, (2a) those with green/blue nature view or (2b) access to private outdoor spaces such as a garden or balcony will show fewer symptoms of depression and anxiety, and a more positive mood.

2. Materials and methods

2.1. Survey structure and distribution

An online self-report survey was distributed between April–May 2020, to people around the world and under different lockdown scenarios. The online survey comprised 54 questions divided into 12 sections (Appendix A). The objective was to collect responses from as many countries as possible to capture the highest diversity of lockdown

[1] https://www.ecdc.europa.eu/sites/default/files/documents/COVID-19-guidance-health-systems-contingency-planning.pdf

[2] https://www.euronews.com/2020/10/26/is-europe-having-a-covid-19-second-wave-country-by-country-breakdown

conditions; therefore, the survey was designed in English and translated to Spanish. The survey was distributed using Google Forms, between 17th April and 8th May 2020, starting when most European countries had spent at least one month under lockdown (Flaxman et al., 2020) and finishing when some countries started to ease lockdown measures[3,4].

The design of the final survey followed the data protection advice for social studies of the Norwegian Centre for Research Data (NSD) and complied with its ethical requirements.

The survey was distributed using a snow-ball sampling technique: the link to the survey was distributed among authors´ professional and personal contacts using email and social media (e.g. WhatsApp, LinkedIn, Facebook, Instagram, Twitter), and recipients were encouraged to re-forward the link within their contacts and social networks. The link to survey was also shared by authors' institutional social media in Spain, Norway and the UK. Once the survey was closed, answers were downloaded and deleted from the platform.

2.2. Exposure assessment: contact with outdoor nature

During COVID-19 lockdowns, exposure to outdoor nature was of two broad types: 'general accessibility' and 'individual accessibility'.

'General accessibility' differed by country or region, and can be classified into three main levels in terms of allowance of contact with nature: in Level 1, people were not allowed to leave their homes except for activities such as essential jobs, buying food and medicines, emergencies or walking the dog (e.g. China, Italy or Spain); Level 2, severe lockdown but with certain time for outdoor exercise (e.g. France, United Kingdom); and Level 3, the limitation of movements was a recommendation rather than a binding rule (e.g. Scandinavian countries). To classify responses according to the three levels of lockdown, in the first question of the survey respondents had to indicate the level of lockdown in which they were when answering the survey. An alternative approach to define the "lockdown level" of respondents might have been to find out what the technical rules were in the respondents' approximate home location. However, given that we did not have the exact address, alongside the widespread uncertainty about the rules in some locations and regular changes,[5] and the fact that what probably matters more for mental health is what people thought the rules were, these self-reported lockdown assessments were deemed important in their own right.

'Individual accessibility' was operationalised using two home characteristics: (i) window views of natural features (e.g. woods, coast), used as indicator of indirect contact with nature, and (ii) outdoor space availability (e.g. garden), used as indicator of direct contact with nature. To explore individual accessibility, the survey included questions on views from residence (Appendix A, question 11) and on accessible outdoor spaces (Appendix A, questions 15 and 17). Responses to the questions were codified in two ways, adapting to the hypothesis to be tested. For testing hypothesis 1 (i.e. people show greater symptoms of depression and anxiety under lockdown level that did not allow contact with outdoor nature spaces), both were transformed in binomial variables as follows: whether respondents had nature views from residence (yes/no) and access to outdoor spaces (yes/no). To test hypothesis 2 (i.e. where access to public outdoor nature spaces was strictly restricted, those with green/blue nature view or access to private outdoor spaces will show fewer symptoms of depression and anxiety), responses were transformed into two categorical variables, according to: the type of views that respondents could see from their lockdown residence, considering the level of natural component (i.e., few views or urban views, mixed views and natural views); and the type of accessible outdoor spaces (i.e. none, balcony, garden/patio, and shared or public areas).

2.3. Outcome assessment: effects on mental health and mood

To analyse mental health issues, the 4-item Patient Health Questionnaire (PHQ-4) screening scale was used (Kroenke et al., 2009) (Appendix A, question 40). The PHQ-4 scale is a self-administered survey, commonly used in primary care and in remote health surveys to detect people at risk of suffering depression and anxiety (Kroenke et al., 2009, 2010; García-Campayo et al., 2012). It is composed of two ultra-brief screening scales with two questions each: Generalized Anxiety Disorder scale (GAD-2) for screening anxiety disorders (Kroenke et al., 2007); and the PHQ-2 for screening depression disorders (Kroenke et al., 2003). Respondents chose between four possible response options (from "not at all" (0) to "nearly every day" (3)). Scores for the GAD-2 and PHQ-2 range from 0 to 6, and for PHQ-4, from 0 to 12. Following established protocols, the PHQ-2 and GAD-2 scales were turned into binary variables applying a cut-off value of ≥3, reflecting being at higher risk of depression and anxiety (Kroenke et al., 2003, 2007). The PHQ-4 scale results, which serves as marker of psychological distress, were transformed as *None-to-minimal* (values ≤2), *Mild* (3–5), *Moderate* (6–8) and *Severe* (9–12) (Kroenke et al., 2009).

Lockdown measures may have affected a much broader range of emotions than are characterized by the PHQ-4. To capture these richer emotional changes, respondents self-assessed their emotions pre- and during lockdown, using a figure designed based on Plutchik's wheel of emotions (Plutchik, 1980) (Appendix A, questions 38 and 39). The figure comprised a total of 41 emotions classified into seven core emotions (i.e., happy, sad, disgusted, angry, fearful, bad, surprised). Respondents had to select the emotions that best described their current general mood and their character under normal and before coronavirus outbreak (they were asked to select between one and three emotions for each question).

Respondents also indicated to what extent they perceived that contact with outdoor nature might have helped them to cope better with the lockdown situation. Perceptions were captured by answering two questions; one related to views from home (Appendix A, question 12) and the second, related to access to outdoor spaces (Appendix A, question 20), on response scales from 1 'not at all' to 5 'very much'.

2.4. Sociodemographic variables

In order to account for possible sociodemographic confounds (e.g. people with higher incomes may be more likely to have green views or a garden, and generally better mental health), we also recorded age, gender, marital status, maximum education level achieved, employment status before and during COVID-19, annual gross income, pet ownership and country of residence. To get a better understanding of the home conditions during lockdown, respondents were also asked whether they spent the lockdown alone, with only other adults, with children, and/or with people with special care needs. A question on the size of the house was also included. In order to control for basic levels of coping and resilience, we also asked participants to complete the 4-item Brief Resilience Coping Scale (BRCS) (Sinclair and Wallston, 2004; Kocalevent et al., 2017).

2.5. Data analysis

All statistical analyses were performed in R (version 3.6.2.) using RStudio (RStudio Team, 2019), significance was set at $p < 0.05$.

To determine the internal consistency of PHQ-2 and GAD-2, the Pearson correlation coefficient was calculated.

The first hypothesis (i.e. whether people showed different levels of symptoms of depression and anxiety depending on the level of lockdown

[3] https://www.bbc.com/news/explainers-52575313

[4] https://www.euronews.com/2020/03/19/coronavirus-which-countries-are-under-lockdown-and-who-s-next

[5] BBC (2020). Confused about lockdown? https://www.bbc.com/news/av/uk-wales-52625422

and the possibility of contact with nature) was tested with the whole usable sample (5218 observations). The second hypothesis (i.e. whether in places where access to public outdoor nature spaces was restricted, people with access to private outdoor spaces or with green/blue nature view will show fewer symptoms of depression and anxiety, and a more positive mood) was tested using a subsample from Spain (3403 obs.) (Fig. 1). The level of lockdown in Spain was one of the most severe in Europe, and the high number of responses received from this country allowed us to test the second hypothesis, splitting responses according to types of views and types of accessible outdoors spaces.

To elucidate whether levels of lockdown (hypothesis 1), types of accessible outdoor spaces (hypothesis 2a) and types of views (hypothesis 2b) influenced mental health, Kruskal-Wallis Test followed by Dunn's Test for multiple comparisons was used for PHQ-4 (ordinal variable with >2 categories) and the Chi-squared test with pairwise comparison as post hoc test for PHQ-2 and GAD-2 (ordinal variable with 2 categories). The *p*-values of post hoc tests were adjusted with Bonferroni corrections. To determine the relative odds of individuals with meaningful symptoms of depression and anxiety (i.e. above the cut-off value of ≥3), logistic Generalized Linear Models (GLMs) were built.

To test hypothesis 1, GLMs were built with PHQ-2 and GAD-2 results as a function of lockdown level, access to outdoor spaces and natural elements in the views from home. The views from residence and accessibility to outdoor spaces were introduced as binary variables in the model (yes, no), considering if the view included any natural element or not and if respondents had access to any outdoor spaces.

To analyse if the effect of contact with nature on mental health varied depending on the type of views and type of accessible outdoor spaces (i.e. hypothesis 2), the subsample of respondents in Spain under Level 1 of lockdown was used. These logistic GLMs used PHQ-2 and GAD-2 results as dependent variables and two independent variables: 1) the type of accessible outdoor spaces and 2) the type of views that respondents could see from their lockdown residence.

All the models were subsequently adjusted with 12 variables including sociodemographic characteristics, and home conditions: country of residence (Germany = reference), age (18–25 years = reference), gender (female = reference), maximum education level achieved (primary or secondary = reference), whether employment situation changed after coronavirus outbreak (no = reference), income (transformed to categorical variable by estimating the ratio Income / per capita Gross Domestic Product [GDP], and with income/GDP < 2 = reference), BRCS (numeric), whether respondents owned a pet that needed walking outside (no = reference), residence size (ratio of rooms per people in lockdown) and characteristics of the company during lockdown, such as whether respondent was alone (no = reference), with kids (no = reference), and with people with special care needs (no = reference). The variables were tested for multicollinearity estimating the Variance Inflation Factor (VIF) and assuming a threshold value of <3 (Zuur et al., 2010). The logistic GLMs were built using the *stats* package (R Core Team, 2019), while odds ratios (ORs) and 95% confidence intervals (CIs) were estimated with the *questionr* package (Barnier et al., 2020), and the fit of the models as the Cox and Snell Pseudo R^2 estimate using the *DescTools* package (Signorell et al., 2020).

Two additional exploratory analysis were performed to explore: a) respondent's own perceptions with respect to how having outdoor views and access to outdoor spaces helped them to cope with lockdown measures; and b) the emotions respondents most commonly felt both before and during lockdown To test for significant differences in self-perceived contribution across types of accessible outdoor spaces and views, a one-way ANOVA was conducted, followed by post hoc Tukey's honestly significant difference (HSD) test. Two Ordinary Least Squares (OLS) regression models were built with the scores in the two Likert-scales as dependent variables, and 1) type of accessible outdoor area or 2) type of views as independent variable. Regressions were adjusted with the same 12 sociodemographic variables used in the above-mentioned GLMs. When analysing the perceived contribution of accessible outdoor spaces, individuals with no accessible outdoor spaces did

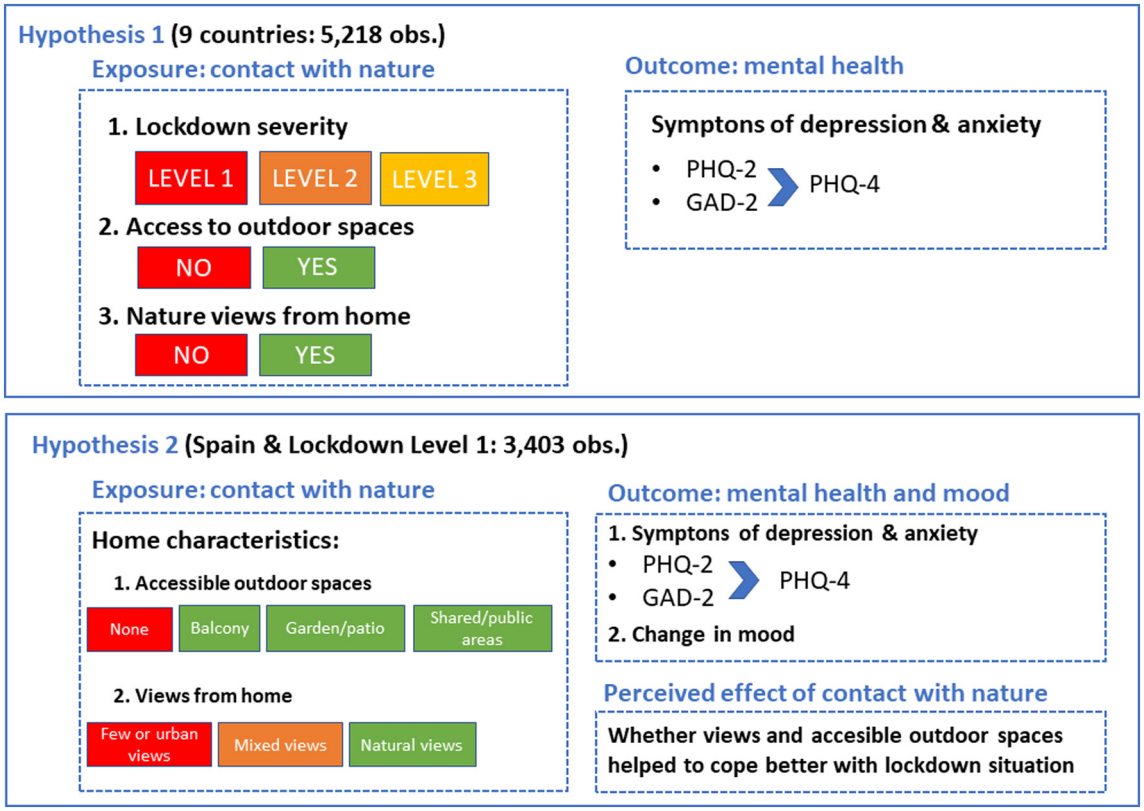

Fig. 1. Graphical representation of the data analysis performed.

not answer the question and were therefore excluded from the analyses.

Regarding changes in emotions, those mentioned as their most common feelings during lockdown were compared with those chosen under normal circumstances. Additional comparisons were performed to compare emotions of individuals with vs. without access to outdoor spaces and natural elements in home views. Emotions were ordered according to the frequency they were mentioned using the *tm* package in R (Feinerer et al., 2008; Feinerer and Hornik, 2019), and later grouped according to the seven core emotions (i.e. angry, bad, disgusted, fearful, happy, sad, surprised). To determine if frequency of core emotions changed after lockdown, and if differences exist depending on access to outdoor spaces and natural elements on views, the Chi-squared Test of Independence was used.

3. Results

A total of 6895 responses were received from the online survey, with 6080 valid responses, after the application of filters (Appendix B Fig. B.1). The valid responses came from 77 countries, with the highest representation corresponding to the European countries of Spain, United Kingdom and Germany (Appendix B Table B.1). Given that there was a low representation of some countries, and to reduce heterogeneity, only responses from countries with >100 responses/country were used. This corresponds to a total of 5218 responses from 9 countries: Spain, United Kingdom, Germany, France, United States, Portugal, Italy, New Zealand and Mexico. All 5218 participants were used to test the first Hypothesis. The subsample of respondents from Spain in severe lockdown (Level 1) ($n = 3403$) was used to test Hypothesis 2. This Spanish subsample was selected since in countries with strict lockdown measures, the effects on mental health of accessibility to outdoor spaces and nature views from home, is likely to be more important than for countries where access to nature and public outdoor spaces for recreational reasons was maintained (Levels 2 and 3). The socio-economic characteristics of the sample and subsample are summarized in Appendix B Table B.2.

Regarding reliability, Pearson correlation coefficient indicated a good correlation between the two items of the PHQ-2 ($r = 0.620$, df = 5216, $p < 0.001$) and GAD-2 ($r = 0.567$, df = 5216, $p < 0.001$) scales.

3.1. Effect of lockdown severity and contact with nature on people's mental health

Supporting our first hypothesis, people in Level 1 lockdown countries reported greater signs of poor mental health overall (Kruskal Wallis $H(2) = 37.494$; $p < 0.001$ and significant differences after post hoc test) (Table 1). Specifically, 23.9% of respondents in Level 1 reported 'Moderate' or 'Severe' symptoms of poor mental health vs. 18.4% in Level 2 and 19.2% in Level 3, respectively. Regarding the PHQ-2 and GAD-2, there was a higher percentage of individuals at risk of depression and anxiety in Level 1 than in Levels 2–3, but the differences were only significant between Level 1 and 2 for depression and between Level 1 and 3 for anxiety (Table 1).

From the 12 variables preselected for inclusion in the logistic GLMs, 'country of residence' was removed, after the results of the multicollinearity test (VIF > 3). Results from the logistic GLMs supported hypothesis 1, even after controlling for the remaining 11 socio-demographic variables as a) nature views from home and b) access to outdoor spaces, were associated with lower symptoms of depression and anxiety (Table 2). Regarding lockdown levels, and in accordance with results summarized in Table 1, individuals in Level 1 have a) higher odds for depression than individuals at Level 2, and b) higher odds for anxiety than individuals at Level 3 (Table 2).

Table 1
Distribution of responses by scores in the mental health scales and lockdown severity. Chi-squared test was used for PHQ-2 (Patient Health Questionnaire) and GAD-2 (Generalized Anxiety Disorder) values (ordinal variables with 2 levels), and Kruskal Wallis test for PHQ-4 values (ordinal variable with >2 levels). Different letters (A,B) indicate significant differences ($p < 0.05$ with Bonferroni correction) between groups, after the corresponding post hoc tests (pairwise comparison for PHQ-2 and GAD-2 and post hoc Dunn Test for PHQ-4).

	Lockdown levels						Statistical test	
	Level 1		Level 2		Level 3		X^2/H_2	p-Value
PHQ-2								
<3	2639	74.5%	917	79.9%	414	78.6%	16.294	<0.001
≥3	905	25.5%	230	20.1%	113	21.4%		
Post hoc test	A		B		AB			
GAD-2								
<3	2527	71.3%	832	72.5%	407	77.2%	8.119	0.017
≥3	1017	28.7%	315	27.5%	120	22.8%		
Post hoc test	A		AB		B			
PHQ-4								
Normal	1362	38.4%	508	44.3%	256	48.6%	37.494	<0.001
Mild	1336	37.7%	428	37.3%	170	32.2%		
Moderate	594	16.8%	132	11.5%	77	14.6%		
Severe	252	7.1%	79	6.9%	24	4.6%		
Post hoc test	A		B		B			

In terms of covariates, the more psychologically resilient the individual (i.e. according to BRCS scores), the lower the odds for depression and anxiety. Women, younger adults, and pet owners were more likely to show symptoms of depression and anxiety than men, older people and people who did not own a pet. Other variables specifically affected either depression or anxiety symptoms; e.g. people who changed their employment status during COVID-19 (regardless of the type of change) were more likely to show symptoms of depression than respondents whose employment status did not change, but the effect was not significant for anxiety. On the other hand, spending the lockdown with people with special care needs was linked to higher odds of anxiety, while the effect for depression was not significant.

Models with intermediate level of adjustment or the inclusion of interaction terms (i.e. lockdown levels vs. sociodemographic conditions) did not affect the main results (Appendix B, Table B.3). The consideration of all the valid responses (6080 observations from 77 countries) led to minor changes in some covariates but did not alter the pattern (Appendix B Table B.3). In the GLMs stratified by level of lockdown (Appendix B, Table B.3), people in Level 1 were significantly less likely to show symptoms of depression and anxiety as a function of accessibility to outdoor spaces and nature views, also after adjustment with sociodemographic variables. However, for the adjusted GLMs built with individuals in Levels 2–3, neither views nor access to outdoor spaces were positively associated with a reduction of depression or anxiety symptoms.

3.2. Effect of contact with nature on the mental health of people under severe lockdown

To unpack these associations between nature views, access to outdoor spaces and symptoms of depression and anxiety under Level 1 lockdown, we further analyzed the Spanish sample alone. Specifically, as outlined in Section 2.2., types of views from home were classified according to three categories and types of accessible outdoor spaces according to four categories. Results (Table 3) suggested that type of view and type of accessible outdoor space were related to the likelihood of exhibiting symptoms of mental disorders (for PHQ-4 values vs. type of view or vs. type of outdoor space, Kruskal Wallis Tests $p < 0.001$; for PHQ-2 and GAD-2 values vs. type of view or vs. type of outdoor spaces, all chi-squared tests $p < 0.001$). Post hoc tests confirmed that people with no nature elements in their views (i.e. limited or urban views) had higher odds for clinically important symptoms of depression (PHQ-2 post hoc test $p < 0.05$) and higher PHQ-4 scores (Dunn's Test p

Table 2
Logistic Generalized Linear Models for depression and anxiety for the whole sample ($n = 5218$). OR < 1 indicates a decrease in the likelihood of showing depression or anxiety symptoms; OR > 1 equals to an increase in symptoms. OR = Odds ratio; CI = Confident Interval; GDP = Gross Domestic Product; PHQ-2 = Patient Health Questionnaire-2; GAD-2 = Generalized Anxiety Disorder-2. Statistically significant p-Values (p<0.05) are in bold.

	Depression (PHQ-2)				Anxiety (GAD-2)			
	OR	95% CI		p-Value	OR	95% CI		p-Value
		Low	High			Low	High	
Unadjusted models								
(Intercept)	0.50	0.44	0.57	**<0.001**	0.54	0.48	0.61	**<0.001**
Lockdown								
Level 2	0.82	0.69	0.97	**0.021**	1.03	0.88	1.20	0.741
Level 3	0.84	0.67	1.04	0.115	0.76	0.61	0.94	**0.013**
Outdoor views with natural elem.								
Yes	0.73	0.64	0.84	**<0.001**	0.80	0.70	0.90	**<0.001**
Access outdoors								
Yes	0.68	0.59	0.79	**<0.001**	0.75	0.65	0.86	**<0.001**
Pseudo R^2	*0.014*				*0.009*			
Adjusted models								
(Intercept)	26.15	16.11	42.67	**<0.001**	8.46	5.40	13.28	**<0.001**
Lockdown								
Level 2	0.84	0.70	1.02	0.076	1.10	0.93	1.30	0.275
Level 3	0.83	0.65	1.05	0.129	0.79	0.63	1.00	**0.049**
Outdoor views with natural elem.								
Yes	0.77	0.67	0.89	**<0.001**	0.82	0.72	0.93	**0.003**
Access outdoors								
Yes	0.72	0.61	0.84	**<0.001**	0.75	0.64	0.87	**<0.001**
House Space (Rooms/person)								
(numeric)	0.91	0.82	1.00	0.061	0.97	0.89	1.07	0.570
Gender								
Male	0.82	0.70	0.95	**0.010**	0.54	0.47	0.62	**<0.001**
Other	0.61	0.28	1.25	0.199	0.59	0.29	1.12	0.122
Age								
26–35	0.47	0.38	0.59	**<0.001**	0.58	0.47	0.72	**<0.001**
36–45	0.27	0.21	0.34	**<0.001**	0.55	0.44	0.69	**<0.001**
46–55	0.20	0.15	0.25	**<0.001**	0.40	0.32	0.50	**<0.001**
56–65	0.19	0.14	0.25	**<0.001**	0.35	0.27	0.46	**<0.001**
>65	0.15	0.10	0.23	**<0.001**	0.30	0.20	0.44	**<0.001**
Education level								
Proff. Educ./University degree	0.84	0.66	1.08	0.168	0.86	0.68	1.08	0.190
Higher (Master, PhD)	0.82	0.63	1.07	0.149	0.82	0.64	1.05	0.110
Income (rank)								
income/GDP per capita > 2	0.97	0.75	1.26	0.840	1.08	0.86	1.35	0.506
no data	1.05	0.90	1.21	0.546	1.09	0.95	1.25	0.230
Change in employment								
Yes	1.30	1.03	1.64	**0.028**	0.99	0.79	1.24	0.938
Brief Resilience Coping Scale								
(numeric)	0.83	0.81	0.85	**<0.001**	0.88	0.86	0.90	**<0.001**
Lockdown with kids								
Yes	0.91	0.76	1.08	0.286	1.03	0.88	1.21	0.684
Lockdown alone								
Yes	1.23	0.95	1.57	0.108	0.82	0.64	1.04	0.105
People with Special Care Needs								
Yes	1.13	0.89	1.42	0.310	1.26	1.02	1.55	**0.030**
Pet needs walking								
Yes	1.30	1.08	1.55	**0.004**	1.28	1.08	1.51	**0.003**
Pseudo R^2	*0.122*				*0.078*			

< 0.05) than individuals with mixed or natural views. Individuals with accessible outdoor spaces had higher odds of clinically important symptoms of depression (PHQ-2 post hoc test $p < 0.05$) and overall mental health (PHQ-4 post hoc Dunn's Test $p < 0.05$) than people with any of the three kinds of accessible outdoor spaces (balcony, garden/patio, shared or public spaces). Regarding anxiety (GAD-2), results suggest that people were more likely to be ≥3 threshold when they had limited or urban views and when they did not have accessible outdoor spaces. However, for GAD-2 values, the post hoc test results were not conclusive, neither for views (limited or urban views vs. natural views, $p < 0.05$), nor for outdoor spaces (none vs. shared or public spaces, $p < 0.05$).

Regression models confirmed the overall importance of the type of views and the type of outdoor spaces for the likelihood of showing

Table 3
Comparison of PHQ-4 (Patient Health Questionnaire), PHQ-2 and GAD-2 (Generalized Anxiety Disorder) values between types of views and types of accessible outdoor spaces. The subsample of people in Spain and in Level 1 (3403 obs.) was used. The statistical test performed were Chi-squared test for GAD-2 and PHQ-2 values and Kruskal Wallis test for PHQ-4 values. Different letters (A,B) indicate significant differences ($p < 0.05$) between groups (i.e. lockdown levels), after pairwise comparison for PHQ-2 and GAD-2 and after post hoc Dunn Test for PHQ-4. The post hoc tests' *p*-values were calculated with Bonferroni correction for multiple-comparisons.

	Accesible outdoor spaces										Views							
	None		Balcony		Garden/patio		Shared/Public		Statistical test		Limited or urban		Mixed		Natural		Statistical test	
	n	%	n	%	n	%	n	%	X^2/H_2	*p*-value	n	%	n	%	n	%	X^2/H_2	*p*-value
PHQ-2																		
<3	762	68.1%	1000	77.0%	516	77.6%	257	80.3%	37.401	<0.001	1379	71.0%	871	78.5%	285	80.7%	28.936	<0.001
≥3	357	31.9%	299	23.0%	149	22.4%	63	19.7%			562	29.0%	238	21.5%	68	19.3%		
Post hoc *test*	A		B		B		B				A		B		B			
GAD-2																		
<3	742	66.3%	954	73.4%	500	75.2%	227	70.9%	20.632	<0.001	1324	68.2%	838	75.6%	261	73.9%	20.038	<0.001
≥3	377	33.7%	345	26.6%	165	24.8%	93	29.1%			617	31.8%	271	24.4%	92	26.1%		
Post hoc *test*	A		B		B		AB				A		B		AB			
PHQ-4																		
Normal	360	32.2%	524	40.3%	281	42.3%	139	43.4%	41.757	<0.001	666	34.3%	490	44.2%	148	41.9%	39.056	<0.001
Mild	426	38.1%	487	37.5%	245	36.8%	122	38.1%			747	38.5%	391	35.3%	142	40.2%		
Moderate	223	19.9%	215	16.6%	94	14.1%	42	13.1%			364	18.8%	165	14.9%	45	12.7%		
Severe	110	9.8%	73	5.6%	45	6.8%	17	5.3%			164	8.4%	63	5.7%	18	5.1%		
Post hoc *test*	A		B		B		B				A		B		B			

symptoms of depression and anxiety (Appendix B Table B.4). However, in the adjusted models for depression, the effect of nature views shifted to $p > 0.05$, indicating that no clear positive effect was found in this type of view over the reference level "limited or urban views".

In connection with hypothesis 2, respondents under strict lockdown not only showed lower odds of symptoms of depression and anxiety depending on the type of outdoor view and accessible outdoor space, but also felt that those views and spaces had helped them to cope with lockdown restrictions (Appendix B, Table B.5). The self-reported contribution of view to mental health was significantly different depending on view type, with a significant decreasing association from natural views > mixed views > limited/urban views. With respect to accessible outdoor spaces, the self-reported contribution to mental health was more positive for people with access to a garden/patio ($M = 4.50 \pm 0.94$) than for people with access to a balcony ($M = 4.15 \pm 1.02$) or people with access to shared or public outdoor spaces ($M = 4.27 \pm 1.14$). Adjustment for socioeconomic variables did not change the main results, confirming that the self-reported contribution was dependent on the type of view and accessible outdoor space (Appendix B Table B.6).

According to the self-assessment of emotions, during lockdown, among the people in Spain in Level 1, the most frequently mentioned word was "bored" ($n = 559$), while "optimistic" was the most frequently mentioned to characterise the recalled emotional situation pre-lockdown ($n = 1177$) (Appendix B Table B.7). After the classification of emotions in a seven core type-emotions, results suggest that the emotional situation of people in Spain under lockdown Level 1 worsened after the adoption of lockdown measures (during lockdown vs. before lockdown, chi-square $p < 0.001$), with a decrease from 71% to 26.2% in the emotions classified inside the "happy" core-emotion (Fig. 2). During lockdown, individuals with natural elements in their views mentioned more positive emotions ("happy" accounts for 30.1%) than individuals with limited or urban views (23.3%). No significant differences were encountered between view types in the emotions reported to describe the emotional situation pre-lockdown (chi-squared $p > 0.05$). Regarding outdoor spaces, individuals with accessible outdoor spaces reported more positive emotions than individuals with no accessible outdoor spaces; however, the difference was significant both during and before lockdown, and therefore, differences in emotions cannot be directly linked to the lockdown situation.

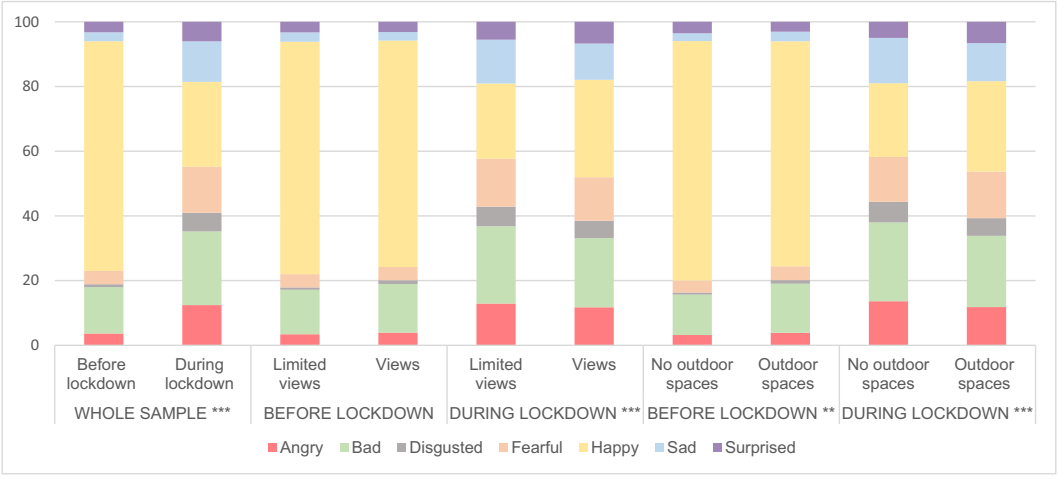

Fig. 2. Percentages of the core-emotions mentioned by the people in Spain under lockdown Level 1, to describe their mood before and during lockdown. A total of five comparisons were done: i) Before lockdown vs. during lockdown; ii) People with limited outdoor views vs. people with outdoors views before lockdown and iii) during lockdown; iv) People with no accessible outdoor spaces vs. people with accessible outdoor spaces before lockdown and v) during lockdown. Significant differences after the Chi-squared test results are presented as *** $p < 0.001$, ** $p < 0.01$, *$p < 0.05$.

4. Discussion

With rapid urbanization and the potential increase of pandemics with global change, understanding the benefits of blue-green spaces and related ecosystem services to mental health and well-being can assist decision makers to take better informed decisions for the public health. From our study, three major insights can be drawn: during the first wave of COVID-19, i) stricter lockdown levels were associated with higher probability of showing symptoms of depression and anxiety, ii) nature exposure from home was especially relevant for those under strict lockdowns, and iii) not all types of accessible outdoor spaces and views contributed to the same extend to the protection of mental health and to maintain a positive mood.

First, and supporting our first hypothesis, greater lockdown severity was associated with a greater likelihood of exhibiting symptoms of mental health disorders during the first wave of COVID-19. We found a clear negative effect of severe confinement on mental health, with people who had restricted access to outdoor public spaces (Level 1) more likely to show symptoms of mental health disorders than people who had partial (Level 2) or no restriction (Level 3) to access to outdoor spaces. This result goes in line with previous studies that have explored the physical and mental benefits of spending time outdoors (White et al., 2019), and the buffering effect of nature in individuals suffering from social isolation (Cartwright et al., 2018) or stressful life events (van den Berg et al., 2010). Furthermore, the lack of significant differences in terms of symptoms of depression and anxiety between people with partial or no-restriction to access public outdoor spaces highlights the important role of contact with nature for maintaining good mental health: even when authorities fixed a limited time to be outdoors (Level 2), this allowance had an important effect in reducing the likelihood of mental health issues.

Secondly, our results suggest that contact with nature from the home reduced the likelihood of suffering from symptoms of depression and anxiety, only for people at the strict Level 1 lockdown. This result might be related to the two variables selected to explore the contact with nature, as both are related with residence characteristics (i.e. access to outdoor spaces from home (yes/no) and the presence of natural elements in views (yes/no)). These characteristics might be less relevant for individuals at Level 2 and 3 lockdowns, as their contact with nature might come from other pathways than contact from home, e.g. access to outdoor public spaces. The measures adopted in countries in Level 2 and 3 (e.g. switching to home office working or being placed on furlough) might have led to an increase in the time available and the possibility to spend it in natural outdoors setting, with positive effect on well-being (Samuelsson et al., 2020). For example, a recent study suggested that time spent outdoors increased in Norway during COVID-19 lockdown (Venter et al., 2020). In those circumstances, the available nature exposure from home is likely to be less relevant. Furthermore, nature exposure has been reported to be beneficial in times of stress (van den Berg et al., 2010); and people in Level 1 might have been exposed to a more stressful situation than individual in Levels 2 and 3, which led to a clearer effect of nature exposure in our models for Level 1, also after controlling for socio-demographic variables. But the stress of individuals in Level 1 could also be more acute as a result of living under strict binding rules, which affect many areas apart from contact with nature (e.g. socialization), or even from the awareness of the difficult situation of the public health system in their countries (e.g. Italy or Spain) (Ceylan, 2020).

Third, the positive effect of nature exposure on mental health and mood of people in the most severe lockdown in Spain was moderated by the types of accessible outdoor spaces and views from residence, which supported our second hypothesis. Private outdoor spaces such as garden/patios were perceived as the ones contributing the most to cope with the lockdown situation, in line with previous studies reporting on the important role played by private gardens for wellbeing and for promoting physical activity (de Bell et al., 2020), or as spaces offering a path to escape from daily pressures (Kingsley et al., 2009). Also, the higher perceived positive contribution of garden/patios to cope with the lockdown situation is probably linked to a higher space availability and naturalness of the space compared to balconies, and a more private and quiet space than public or shared outdoor spaces, where maintenance of the recommended social distance in times of COVID-19 might be challenging. Interestingly, differences in emotions between people with and without accessible outdoor spaces existed before lockdown, suggesting that the positive effect of those spaces is also important under normal circumstances (MacKerron and Mourato, 2013; Bratman et al., 2019).

Regarding views, people with natural element (i.e. mixed or natural) showed lower odds for symptoms of depression and anxiety and reported a more positive emotional situation during lockdown than individuals with urban or no views. These results are consistent with previous studies that reported a more positive mood in urban dwellers exposed to greenspaces through window (Elsadek et al., 2020) and how individuals exposed to natural environments were able to recover from a stressful situation faster than individuals exposed to urban settings (Ulrich et al., 1991). Finally, the effect of different view types on emotions, only significant during lockdown, suggested that the effect of indirect contact with nature (e.g. observing nature from window) is especially relevant when direct contact is severely limited (e.g. Level 1 lockdown). Indeed, active forms of nature exposure (e.g. taking care of a garden) were reported to deliver more positive outcomes for human well-being than passive forms of contact (Korpela, 2017); yet, in situations when the only possible exposure comes from passive exposure (e.g. window views, nature TV documentaries), such as in the case of people in Spain in Level 1 lockdown, the role of this type of exposure can become especially relevant and positive (Ulrich, 1984; Yeo et al., 2020).

Exploring the effect of nature exposure in people who spent the first wave of COVID-19 under strict lockdown (e.g. Spain) is especially relevant. The measures adopted in Spain to flatten the curve of the disease were very restrictive (Tobías, 2020), with inhabitants spending nearly two months (March–May 2020) under a stay-at-home order. In this context, our findings confirmed that having accessible outdoor spaces and natural elements in views from home were key factors associated with a reduced likelihood of exhibiting symptoms of depression and anxiety. Further research is needed to elucidate if under COVID-19 lockdown, there are significant differences between types of nature views, e.g. if views to blue spaces have a higher buffering effect than green spaces, as suggested by previous studies (Nutsford et al., 2016). Further research could also test whether there are significant differences between the type of contact maintained with nature during lockdown, e.g. by comparing passive contact (e.g. looking at nature through the window or sitting in the terrace) with active contact (e.g. practicing physical activities outdoors).

Apart from nature exposure, many factors might influence the prevalence of symptoms of poor mental health (van den Berg et al., 2015). In this study, we found that psychological resilience, age and gender were important factors predicting the likelihood of showing symptoms of depression and/or anxiety during COVID-19. Psychological resilience reflects the adaptative capacity of an individual to respond to current or future challenges (Masten and Barnes, 2018), and our results showed that individuals with higher resilience had lower odds of showing symptoms of depression and anxiety. Resilience is considered a developmental characteristic that can be enhanced (Kavčič et al., 2020), meaning that measures can be taken to psychologically prepare and protect individuals for future pandemics.

Regarding age, younger people had higher odds of depression and anxiety symptoms than older people. This is interesting, since this age group had been less severely hit by the disease, with generally milder physical symptoms and fewer severe cases than older people. This is also particularly relevant given that under normal circumstances, the odds of presenting symptoms of mental health disorders, such as

anxiety, increase with age (Lieb et al., 2005). Yet, our results for age are consistent with studies on mental health carried out during the COVID-19 (Fancourt et al., 2020; Valiente et al., 2020). Despite social media communication having potentially played a role in socialization of younger respondents, this age group may have a higher natural demand for physical socialization, which was lacking during lockdown. For gender, the prevalence of depression and anxiety pre-COVID-19 has been previously reported as higher among women than men (World Health Organization, 2001), and our study suggests that this higher prevalence continues under extreme situations such as lockdown. Our study might be showing a confounding effect of age and gender, as during lockdown, domestic duties, such as childcare responsibilities, had more likely fall on young women (Burki, 2020).

Some personal characteristics were relevant for certain lockdown levels and for depression and/or anxiety, i.e. individuals who suffered a change in employment after COVID-19 and pet owners. Many people have lost their jobs during the pandemic,[6] and under the expected economic crisis in the years to come it is not surprising to find a higher risk of mental health disorders among people who are undergoing an unstable employment situation (Bartley, 1994). Even if pet owners in Level 1 of lockdown could spend extra time outdoors to walk their pet, they had higher odds for depression and anxiety. This result could be related to the fact that they were proportionally more restricted, if compared to their standard pre-pandemic walks (e.g. in some countries there were limitations on the times that one could go out to walk the pet), transforming the usually-pleasant activity into an obligation with potential health risks.

All in all, this study provides evidence that maintaining contact with nature in extreme situations such as the COVID-19 pandemic may be important for the mental health of people with different socio-demographic conditions. This beneficial effect is linked to the idea of ecosystem services, which are defined as the ecological characteristics, functions and processes that contribute to human well-being (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005). The human benefits obtained from contact with nature are classified as cultural ecosystem services, i.e. the non-material outputs that promote physical and mental health and have positive effect on social relationships (Abraham et al., 2010; Haines-Young and Potschin, 2018). The "restorative effect of nature" analyzed in psychological studies and "non-material outputs from nature" analyzed from the ecosystem services perspective appear to be two bodies of knowledge studying the same concept from different disciplines (Bratman et al., 2019). Ecosystem services assessments can be expanded to include their potential benefits on human mental health and well-being (Bratman et al., 2019), which in fact can supported by a growing body of evidence revealing the value of nature experiences for mental health (Gascon et al., 2015, 2017; de Bell et al., 2017; Cartwright et al., 2018; Garrett et al., 2019). For example, longstanding research has shown that, all else being equal, people are willing to pay more for houses and hotel rooms with nature views (Lange and Schaeffer, 2001; White et al., 2010), which can be interpreted in terms of benefits from cultural ecosystem services. In extreme situations such as the COVID-19 pandemic, the importance of cultural ecosystem services to protect human health and well-being is more evident than ever. Indeed, the extreme situation that we all underwent (and continue to be responsive to) both individually and as a society, as well as the apparent role of nature to protect us, can be used to increase awareness of the tremendous challenges we are facing. The increasing pressures and degradation of the environment, which its most evident consequence is climate change, are risking the ecosystem services we obtain from nature as well as humans' survival. Indeed, the appearance of the COVID-19 pandemic has been linked to the degradation of the environment and the situation is expected to worsen with more frequent and more rapidly spreading disease outbreaks (Settele et al., 2020). Therefore, it is important to support transformative changes that protect nature and reduce the risk of suffering from new pandemics, but also to be ready to face them in the future.

4.1. Policy implications

The first wave of COVID-19 has been an unwanted experiment from which lessons can be learnt if we analyse the (un)intended outcomes of the implemented measures. Critical analysis of lessons will help individuals and societies prepare for future coronavirus-like situations.

In this sense, our results can be valuable in the design of future lockdown measures and urban plans. We found that the lockdown measures adopted led to negative consequences in people's mental health, with clear differences across the levels of lockdown. Therefore, future measures should be designed to protect individuals from the disease and from the mental and physical consequences of social isolation and stay-at-home orders. We acknowledge that the first criteria to be considered when trying to control an epidemic or pandemic should be medical and epidemiological. But if future studies do not find clear differences in flattering the curve of the infections between countries in Level 1 and Level 2 lockdowns, the less strict Level 2 could be a more adequate approach to control the disease, while at the same time reducing the likelihood of suffering mental health disorders. However, if epidemiologic studies confirm that the spread of the disease is only avoidable under strict lockdown, we recommend health authorities to be ready for a higher prevalence of mental health disorders, especially focusing on vulnerable subgroups such as women, young people or people with no contact with nature from home.

Finally, an important aspect to be considered is the difference in accessibility to nature across the population. We found that house characteristics, such as outdoor spaces and views, played an important role on people's mental health during the first wave of COVID-19, with important differences across types of spaces and views. When designing future urban plans, and similar to the plans to make cities more resilient to climate change (Hunt and Watkiss, 2011), houses and cities should be adapted to ensure that we live in healthy spaces, and that we are resilient to the consequences of future pandemics. For example, at the house level, it can be appropriate to ensure that new houses in densely populated areas include terrace and/or balconies.[7] At the city level, the plans to restore, protect and promote the public green-blue spaces and their ecosystem services, and advances towards equal accessibility to these spaces (Ma et al., 2019; Elliott et al., 2020), should be accompanied with measures to guarantee greater space that allows for physical distancing in times of pandemics.

4.2. Limitations

When interpreting our results, the limitations of the study, especially the ones related with sampling, should be considered. Due to the limited time to prepare and conduct the study, the survey could only be translated and distributed in English and Spanish; and it was self-administered online. Also, to capture a sample from as many countries as possible and while the lockdown measures were in place, the snow-ball sampling technique was used. These decisions influenced the composition of the sample, with a bias towards responses from Spain and an over-representation of highly educated people.

Other limitations of our study relate to the use of self-reported data for the lockdown level, nature exposure and the mental health measures. As explained in the Materials and methods, mm self-reported lockdown level was considered a better option than country of residence, due to i) the highly variability of the measures adopted per country and region, which changed quickly; and ii) the global nature of our study, which made it impossible to capture and classify the lockdown measures for each country. However, this focus made impossible to

[6] https://www.brookings.edu/research/the-effects-of-covid-19-on-international-labor-markets-an-update/

[7] https://www.deia.eus/actualidad/sociedad/2020/06/19/pisos-euskadi-tendran-35-metros/1046587.html

account for other potential covariates such as incidence of psychopathology diagnoses at country level. Regarding nature exposure, it was analyzed in terms of reported lockdown level and reported nature exposure from the home (i.e. accessible outdoor spaces and views from residence). Exposure can come from other pathways (especially for those in Level 2 and Level 3) e.g. commuting to work. However, these additional pathways of nature exposure were not considered, which means that exposure was probably better assessed for those under strict lockdown (Level 1) as they could leave home only for very limited tasks. Also, we tried to control for possible socio-economic and other potential confounders, but given the essentially cross-sectional data collection, reverse causation is a potential bias.

Despite these limitations, our results are consistent with other studies published on mental health during time of COVID-19 and on the effect of blue-green spaces on well-being.

5. Conclusions

Contact with nature provides us with many intangible benefits and can act as a protection against the negative consequences of lockdown measures in mental health. Maintaining contact with nature (blue-green spaces) during COVID-19 lockdown was found to reduce the likelihood of reporting symptoms of depression and anxiety. Sociodemographic variables, residence characteristics and personal characteristics were also found to affect the likelihood of these two conditions. The current study provides an analysis of the important role that nature exposure played during the first wave of COVID-19, which can be helpful in avoiding undesired negative effects on mental health when designing future measures to control the spread of an infectious disease.

Author contributions

SP had the initial idea; SP, AB and MCU developed the initial idea and proposed a draft survey contents; LEF, EGB and MPW amended the survey; all authors distributed the survey; SP undertook the initial data analyses; all authors made suggestions and helped in the analyses; SP wrote the initial draft and all authors contributed to the draft and discussions.

Declaration of competing interest

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

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Appendixes. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2020.143984.

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