Journal Pre-proof

The impact of built environment design on mental health: A COVID-19 lockdown perspective

Jie Xiao, Jianfeng Zhao, Zhiwen Luo, Fang Liu, David Greenwood

PII: S1353-8292(22)00150-2

DOI: https://doi.org/10.1016/j.healthplace.2022.102889

Reference: JHAP 102889

To appear in: *Health and Place*

Received Date: 17 May 2022

Revised Date: 6 July 2022

Accepted Date: 2 August 2022

Please cite this article as: Xiao, J., Zhao, J., Luo, Z., Liu, F., Greenwood, D., The impact of built environment design on mental health: A COVID-19 lockdown perspective, *Health and Place* (2022), doi: https://doi.org/10.1016/j.healthplace.2022.102889.

The impact of built environment design on mental health: A COVID-19 lockdown perspective

Jie Xiao [a, b], Jianfeng Zhao [c], Zhiwen Luo [b], Fang Liu [d], David Greenwood [c]

[a] School of Construction Engineering, Yangzhou Polytechnic Institute, Yangzhou, 225 127, China.

[b] School of the Built Environment, University of Reading, Reading, RG6 6AY, Berkshire, UK.

[c] Faculty of Engineering and Environment, Northumbria University, Newcastle upon Tyne, NE1 8ST, UK.

[d] School of Psychology and Clinical Language Sciences, University of Reading, Reading, RG6 6AY, Berkshire, UK.

The impact of built environment on mental health: A COVID-19 lockdown perspective

Abstract

Tackling mental health has become a priority for governments around the world because it influences not only individuals but also the whole society. As people spend a majority of their time (i.e., around 90%) in buildings, it is pivotal to understand the relationship between built environment design and mental health, particularly during COVID-19 when people are experiencing recurrent local and national lockdowns. Despite the demonstration by previous research that the design of the built environment can affect mental health, it is not clear if the same influence pattern remains when a 'black swan' event (e.g., COVID-19) occurs. To this end, we performed logistic regression and hierarchical regression analyses to examine the relationship between built environment and mental health utilising a data sample from the United Kingdom (UK) residents during the COVID-19 lockdown while considering their social demographics. Our results show that compared with depression and anxiety, people are more likely to feel stressed during the lockdown period. Furthermore, general house type, *home workspace*, and neighbourhood environment and amenity are identified to have significantly contributed to mental health status. With the ensuing implications, this study represents one of the first to inform policymakers and built environment design professionals of how built environment should be designed to accommodate features that could mitigate mental health problems in any future crisis. As such, it contributes to the body of knowledge of built environment planning by considering mental health during the COVID-19 lockdown.

Keywords: Built environment design, COVID-19 lockdowns, Mental health, Regression analysis, the UK

1 Introduction

As maintained by the World Health Organisation (2020), mental health is one of the three basic components of health, along with physical and social well-being. People with good mental health can be defined as individuals who can: (1) realise their own abilities; (2) cope with the normal stresses of life; (3) work productively; and (4) make a contribution to their community (World Health Organisation, 2018). However, a large number of people fail to meet this standard. In England, for example, National Health Service - NHS (2021) disclosed that one in four adults experience mental illness. Data from China (Huang and Zhao, 2020 a, b; Liu *et al*., 2020; Zhang and Ma, 2020), Europe (Banna *et al*., 2020, Gualano *et al*., 2020), Australia (Fisher *et al*., 2020), and the United States (Fitzpatrick *et al*., 2020) have reported that mental health illness often appears in the form of depression, anxiety and stress. Such mental health disorders, as reported by Bloom *et al*. (2011), incurred around $2.5 trillion loss globally in 2010, and this figure will rise to $6.0 trillion by 2030. According to Rosenberg *et al*. (2020), this situation has been exacerbated by the unprecedented COVID-19 pandemic where people experience persistent mental health problems due to the considerably long lockdown/quarantine, and the health system's failure to contain it. These staggering statistics highlight that mental health has become an issue that cannot be ignored.

Studies have been conducted to investigate the causes of mental health (e.g., environment,

social relationships and employment) and subsequent countermeasures (Weich *et al*., 2002; Nurse *et al*., 2003; Hudson, 2010; Sullivan and Chang, 2011; Appelqvist-Schmidlechner *et al*., 2020). Among them, increasing attention has been paid to explore its interactions with the built environment, given that people spend 90% of their time in buildings and frequently interact with their surrounding built environment in their daily lives (Klepeis *et al*., 2001, Evans, 2003, Wright and Kloos, 2007, and Reichert *et al*., 2020). Hence, built environment design should aim to sustain mental health of the residents in addition to its physical and cognitive functions. For example, Sullivan and Chang (2011) found that the lack of green space, and crowded and noisy places are usually associated with psychological distress and even depression. In terms of housing tenure, Berglund *et al*. (2017) reported that poor psychological well-being was found to be lowest in people living in private houses. It has also been shown that good indoor environmental quality (e.g., thermal comfort, lighting, and natural view) can be conducive to decreased stress, reduced anxiety and improved mood (Santamouris *et al*., 2014; Akbari *et al*., 2021).

During COVID-19 pandemic lockdowns, people are spending much more time (i.e., 24/7) at home than before, rendering mental health an ever-increasing concern (Dawson and Golijani-Moghaddam, 2020; Singh *et al*., 2020). This is well illustrated in the doubled prevalence of moderate-to-severe depressive and generalized anxiety symptoms following the restrictions put in place to halt the spread of COVID-19 (Fisher *et al*., 2021). Markedly, the pandemic imposes greater challenges on the pre-COVID situation where disability was

mainly caused by mental health disorders in the UK (Mental Health Taskforce, 2016), and that the overall mental health condition is still deteriorating (Office for National Statistics - ONS, 2017). Although existing studies have identified built environment design as a contributing factor to mental health, its specific influence during the COVID-19 lockdowns, when people spent almost 24 hours at home, remains unclear. In addition, previous studies often focused on a single set of characteristics of the built environment, such as the construction of new roads around the neighbourhood (Egan *et al*., 2003), neighbourhood social and physical characteristics (Cerda *et al*., 2013), and indoor environment quality (Burns *et al*., 2019), without considering the agglomeration effect (i.e., how the addition of multiple built environment factors impacts their effect). More importantly, 'black swan' events similar to COVID-19 are likely to intrude in the future as had been estimated by Cabinet Office (2017), indicating an additional degree of uncertainty that surrounds the relationship between the built environment and mental health (Hoisington *et al*., 2019).

To fill this knowledge void, this work aims to examine how the built environment design affects the mental health of residents during COVID-19 lockdowns in the UK, and identify design approaches that may have been previously overlooked. Notably, the built environment is defined as ''the physical form of communities'' (Brownson *et al*., 2009), which can include land-use patterns, large- and small-scale built and natural features, and the transport system. For the purpose of economy and considering the context of the UK, this study deliberately delimited itself to three categories in the environment of residential buildings, namely,

general house type, indoor environment quality, and neighbourhood amenity quality. It also considered the residents' social demographics. To do so, this present study employed the widely-recognised Patient Health Questionnaire (PHQ-2) (Scoppetta *et al*., 2020), General Anxiety Disorder (GAD-7) (Spitzer *et al*., 2006), and Perceived Stress Scale (PSS-4) (Cohen *et al*., 1983) as proxies for mental health (i.e., the terms 'depression', 'anxiety' and 'stress' are used interchangeably with 'poor mental health' in this article), and collected information regarding the built environment design during the COVID-19 lockdowns in the UK through an online questionnaire survey. When analysing the collected data, the logistic regression model and hierarchical regression model were adopted to demonstrate the incremental changes where different combinations of independent variables exist. By addressing the question '*how does built environment, and in particular, social demographics, general house type, indoor environmental quality, and neighbourhood amenity quality, affect mental health during the COVID-19 lockdown in the UK?*', this research contributes to providing policymakers and built environment design professionals with knowledge on how built environment can be designed to mitigate mental health problems in any future crisis.

2 Literature Review

2.1 Measures of Mental Health

Mental health of the general population has been a long-standing topic in the agenda of the society and research. Depression, anxiety and stress are distinct but interrelated measures of mental health. People experiencing depression often struggle with anxiety, i.e., shouldering

intensifying feelings of anxiety, fear, worry, and/or panic, which adversely interferes with everyday activities (Centers for Disease Control and Prevention, 2021). Stress, on the other hand, can trigger physical and mental symptoms and change in behaviour, although sometimes stress can be helpful or even motivating (NHS, 2019). Bakioğlu *et al*. (2021) state that COVID-19 increases people's stress levels and further activates anxiety and depression. Over time, PHQ-9, GAD-7 and PSS have become the well-known measures of depression, anxiety and stress, respectively. According to Kroenke *et al*. (2001), the validity and brevity of the PHQ-9 make it a useful clinical and research tool in diagnosing depression and measuring its severity. The PHQ-2, in comparison, has been confirmed by Scoppetta *et al*. (2020) to be another useful method to preliminarily screen depression before PHQ-9 intervenes. Hence, studies (e.g., Gonza´lez-Sanguino *et al*., 2020, Shapiro *et al*., 2020, and Twenge and Joiner, 2020) have shown that PHQ-2 is convenient and effective to detect the early-stage mental health of residents during the pandemic. According to Spitzer *et al*. (2006), GAD-7 is one of the common approaches to diagnosing anxiety and assessing its severity, and its good reliability, validity and effectiveness have made great contributions to the clinical research. During the pandemic, scholars (e.g., Dawel *et al*., 2020, Fisher *et al*., 2020, and Huang and Zhao, 2020 a, b) have widely adopted GAD-7 in the study of residents' anxiety and their anxiety level. For stress, Cohen *et al*. (1983) state PSS-4 is characterised with briefness and management-friendly possesses, which makes assessing the individual's stress over the phone possible. As a short version of PSS, Warttig *et al*. (2013) argue that PSS-4 continues to remain good reliability and validity. A germane case is that Li and Leung

(2020) successfully apply PSS-4 to study the stress of Filipino workers in Hong Kong in view of the COVID-19.

In the research of relative importance of physical and social neighbourhood characteristics to depression, Helbich *et al*. (2019) find that personal attributes seem to be more important than neighbourhood characteristics. That means young adults and persons with low income, low education, unemployment and divorce are more likely to be depressed. Similarly, depression and anxiety seem to be negatively correlated with age (Jorm, 2000), which indicates that as people get older, the risk of feeling depressed and anxious reduces. In terms of gender, the psychological effects of housing are found to be different on men and women (McLean *et al*., 2011). In addition, the residents' income (Evans *et al*., 2003), education (Jensen *et al*., 2018), and ethnicity (Proto and Quintana-Domeque, 2021), to a large extent, impact the housing quality and/ or mental health. Nevertheless, how the social demographics interacts with mental health within residents' living built environment during the COVID-19 lockdowns has not been fully unpacked.

2.2 Built Environment and Mental Health

There is an array of built environment factors that can influence mental health. It is common observation that people who reside in houses or low-rise buildings have better mental health (see, for example, Evans *et al*., 2003). This contrasts with the relatively worse mental health reflected in residents of high-rise buildings due to the poorer quality of semi-public areas

150 (e.g., shared entrances, communal space, and corridors) (Barros *et al*. 2019), which can
151 instigate a lower sense of control and greater awareness of anti-social behaviour (Gibson *et*
152 *al*., 2011). For indoor environmental quality, Al horr *et al*. (2016) consider thermal comfort to
153 be the most important variable. It is also complicated, as a warmer temperature can cause
154 fatigue and lower productivity (Tanabe *et al*., 2007) while a lower temperature has been
155 associated with depression and anxiety (Thomson and Snell, 2013). Annoyance, as the most
156 common result of aural discomfort is associated with high levels of perceived stress (Jensen
157 *et al*., 2018), indicating the importance of a suitable acoustic environment in which to live
158 and/or work (Mui and Wong, 2006). Similarly, Codinhoto *et al*. (2009) and Elsadek *et al*.
159 (2020) argue that well-designed lighting and high-quality window views (e.g., of urban and
160 green spaces) can contribute to positive physical, physiological, and psychological health.
161 For indoor air quality, exposure to $PM_{2.5}$, toxins and malodorous pollutants often directly or
162 indirectly lead to negative mental states (e.g., anxiety) (Oiamo *et al*., 2015; Power *et al*., 2015;
163 Beemer *et al*., 2019). However, this effect can be countered through ventilation by opening
164 windows, installing mechanical facilities (Beemer *et al*., 2019), and emerging technologies
165 such as sensors (Awada *et al*., 2021). Notwithstanding this, Allen *et al*. (2015) noted their
166 potential shortfalls, such as increased concentrations of pollutants indoors and energy
167 consumption. Furthermore, the neighbourhood environment - which includes surrounding
168 green spaces (Nutsford *et al*., 2013), traffic nuisance (Putrik *et al*., 2015), shops, working and
169 education amenities (Barnett *et al*., 2018) - is another element of built environment that is
170 attested to be significantly correlated with mental health performance, in which the

neighbourhood's social characteristics also have a role to play (Saarloos *et al*., 2011; Helbich *et al*., 2019).

Existing knowledge of the impacts of built environment design on mental health from the perspectives of social demographics, general house attribute, indoor environmental quality and neighbourhood amenity quality has been critically reviewed. It is identified that good built environment design can contribute to positive mental health. With the stringent restrictions in place, the probability of residents suffering from mental health problems among residents is more than incremental. Staying at home during the lockdowns has turned the built environment into a major factor affecting mental health. Although the impact of the built environment on mental health has been explored in prior studies, it is not clear whether and how the built environment design can impact mental health in extreme events, such as the COVID-19 lockdowns. It is against such a backdrop that this study becomes novel and thus contributes to the body of knowledge of built environment by examining how built environment under uncertainties (e.g., COVID-19 lockdowns) impacts people's mental health.

3 Method

3.1 Research Strategy and Design

The epistemological design of empiricism was employed to acquire knowledge on the impact of built environment design on mental health during the COVID-19 lockdown (Amaratunga

192 *et al*., 2002). Accordingly, we adopted a two-stage research design (Figure 1) to navigate the
193 research process. In stage one, a comprehensive literature review was conducted to identify
194 the built environment variables that may impact mental health during the COVID-19
195 lockdown. To ensure validity of the data collection, a pilot study was undertaken where five
196 experts who assume more than 10-year experience of built environment and psychology in
197 the UK were consulted as part of the questionnaire design. In stage two, using the random
198 sampling described in Arsham (2005), the fine-tuned questionnaire survey was administered
199 through JISC online survey, a popular online survey platform supported by the authors'
200 institutions, to residents in the UK. After that, the logistic regression model (Berglund *et al*.,
201 2017) and hierarchical regression model (Radmacher and Martin, 2001) were performed
202 using SPSS 25.0 to analyse the data. Reliability analyses were also undertaken to examine if
203 the independent variable can statistically explain the dependent variable. Based on these
204 analyses, the relationship between various parameters of built environment design and mental
205 health during the COVID-19 lockdown was unpacked, and the implications are discussed.

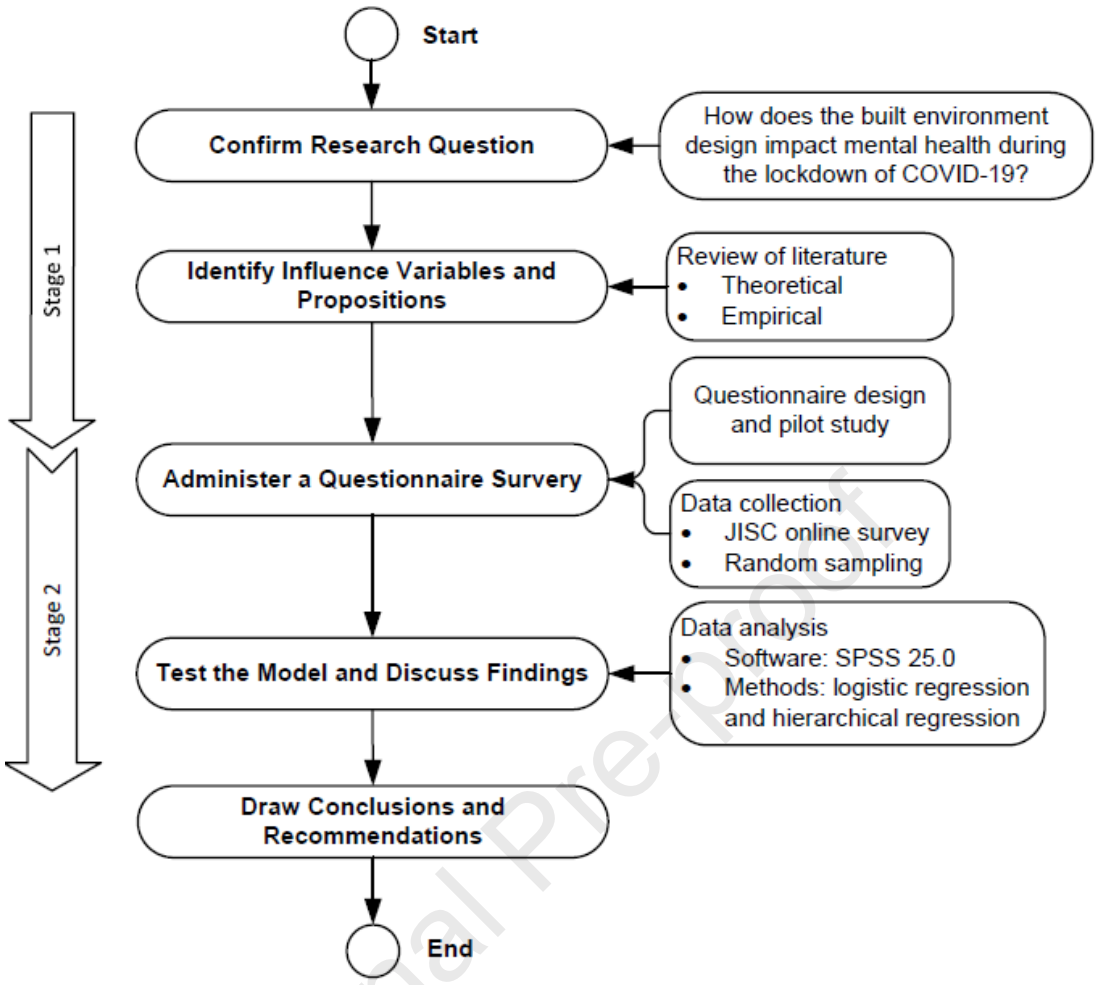


Figure 1. Research design

3.2 Data Collection

Due to the lockdown restriction, an online questionnaire survey was deployed as it is capable of generating reliable and effective results if designed carefully (Taherdoost, 2016). Approved by the ethics committee of the University of Reading, UK, the survey was carried out from May to July, 2020 when the UK was in its first lockdown. Respondents were invited to answer questions in the first part about their personal and family information, such as age, gender, ethnicity, employment status, etc., followed by the second to the fourth part regarding the conditions of the built environment they currently live in and their satisfaction with the

built environment design. For example, questions about the house size, the house type, satisfaction level (i.e., measured by a seven-point Likert scale) with indoor environmental quality, thermal comfort, acoustic environment, natural light and window view, and the surrounding open space and food and convenience shops were asked. In the fifth part, PHQ-2, GAD-7 and PSS-4 were used to test the mental health outcomes during the lockdown, given their validated clinical and research use (Gonza´lez-Sanguino *et al*., 2020; Fisher *et al*., 2020; Li and Leung, 2020). PHQ-2, consisting of two questions with four possible responses (i.e., 0 = not at all, 1 = several days, 2 = more than half the days, 3 = nearly every day), is a measurement of depression (Kroenke *et al*., 2001; Scoppetta *et al*., 2020). According to Spitzer *et al*. (2006), anxiety can be usefully evaluated using the seven-item subscales in GAD-7. The scores of the four possible responses in GAD-7 are the same as in PHQ-2. PSS-4 consists of four questions with five possible responses to measure stress (Cohen *et al*., 1983). In questions 1 and 4, the scores of the five possible responses are never = 0, almost never = 1, sometimes = 2, fairly often = 3 and very often = 4, while in questions 2 and 3, the scores are opposite from those in questions 1 and 4. In short, a higher score indicates a poorer mental health status. A comment box was provided in the last section to solicit information about what changes the respondents would like to make to their living environment. A copy of the questionnaire can be found in Appendix I.

3.3 Data Analysis and Method Justification

A total of 285 participants started and completed the survey, among whom 237 were based in

238 the UK, 46 overseas, and two preferred not to disclose their location. Given that this research
239 targets UK residents, only the 237 entries from the UK were retained for data analysis. As
240 1,000 questionnaires were distributed and expected, the response rate is 23.70%, which is
241 acceptable for research of this nature (De Vaus, 2001). In addition, a study of a similar ilk by
242 Tan *et al*. (2020) investigated the relationship between workspace design and employees'
243 well-being using a sample of 195 participants. While we acknowledge that there are studies
244 (e.g., Amerio *et al*., 2021) that have employed a much bigger sample size, it is widely
245 considered that sample sizes equal to or greater than 30 are sufficient for the central limit
246 theorem to hold (Chang *et al*., 2006). In addition, a statistical power analysis using G*Power
247 (Faul *et al*., 2007) was conducted, indicating that 214 participants (this study involved 237
248 participants) would make the regression model with 40 independent variables sensitive
249 enough to detect an effect size of $f^2 = 0.15$ ($\alpha = 0.05$; power = 0.80). Therefore, the data
250 collected were considered to be adequate for addressing the research question.
251
252 To analyse the data, regression analysis, including logistic regression and hierarchical
253 regression, was adopted because it is robust in identifying the most appropriate fit to describe
254 the relationship between the dependent variables and a set of independent variables (Pohar *et*
255 *al*., 2004). Logistic regression analysis has been widely applied in built environment and
256 psychology-related studies. For example, Lai *et al*. (2009) used logistic regression analysis to
257 find the relationship between occupants' acceptance and the indoor environmental quality in
258 residential buildings. In addition, logistic regression analysis has been applied to explore the

impacts of neighbourhood characteristics on mental health among African Americans and Whites who live in a racially integrated urban community (Gary *et al*., 2007). Another example is that the relationships between the neighbourhood environment characteristics and self-related health and depression symptoms are explored in multilevel logistic regression models (Putrik *et al*., 2015). Similar to Radmacher and Martin (2001) and Berglund *et al*. (2017), in this study, each set of variables (i.e., social demographics, general house, indoor environmental quality and neighbourhood amenity) are added into the logistic regression and hierarchical regression models step by step. For example, the first step is to study depression and social demographic information. The second step is to study depression, social demographic information and general house attribute and compare the variables' significance differences between step two and step one. It is iterative until all four sets of variables are integrated into the model and the reference category in each step is listed under the tables shown below. This process can provide a deep understanding on how each set of variables impacts mental health individually and collectively and reflects the changes in their significance.

In addition, when interpretating the mental health outcome, if the score is less than or equal to three in PHQ-2, the participant shows 'absence of significant (or major) depression', while the participant has 'major depression' if the score is 4, 5, or 6 (Lowe *et al*., 2005). Although there are four categories in GAD-7, it is usually agreed that a degree of 0 to 9 means 'no major anxiety' and '10 to 21' indicates 'major anxiety' (Spitzer *et al*., 2006). The discrete

nature of depression and anxiety also suits the logistic regression as it is appropriate to deal with this dichotomous problem (Tung, 1985). Furthermore, to perform the logistic regression analysis, the recommended number of cases per variable (*n*/*P*) should be greater than 3:1 and lower than 20:1 (Cattell, 1978; Hair *et al*., 1979). In this study, the number of samples and the variables were 237 and 40, respectively, which yields the value of *n*/*P* as 5.93:1 and thus meets the threshold. By contrast, according to Lee (2012), the interpretation of the outcome of stress in PSS-4 is continuous (i.e., the higher the score is, the more stressed the respondent is likely to be). In this instance, following the approach of Lee (2012), the hierarchical regression model was applied to cope with this situation. Given that there are four sets of variables, hierarchical regression is capable of showing if each set of variables is statistically significant in explaining the dependent variable (i.e., mental health during the COVID-19 lockdown) and measuring the significance differences by adding a set of variables (Rutter and Gatsonis, 2001). Owing to these attributes, logistic regression was selected to examine depression and anxiety whilst hierarchical regression was used to study stress.

4 Results

4.1 Overall Descriptive Analysis

4.1.1 Social demographics outcome

Among the received responses, 71.73% of the participants were female and the majority of the participants (i.e., 92.83%) lived in England during the COVID-19 lockdown. For ethnicity distribution, 'White-British, Irish and other' took up 59.92%, followed by 'Chinese/

Chinese British' at 18.57%. In addition, 48.52% of the participants were between 18 and 29 years old, whereas the percentage of participants over 60 years old was only 5.49%. Participants were mainly students and full-time employees, accounting for 34.18% and 32.49%, respectively. The total household net income of most participants was no more than £90,000 per year. A minority of participants lived in houses with more than five people and 64.56% participants had no children in their houses during the lockdown. Moreover, the proportion of tenants and houseowners were almost evenly divided. In terms of COVID-19 issues, 87.34% participants reported that nobody was infected with COVID-19 in their houses during the lockdown. This is consistent with the data provided by the UK's ONS (2020) where around 6.2% of people tested positive for COVID-19 between 26 April and 26 July 2020 (Data in this study were collected from May to July 2020 as mentioned earlier). Although 'infections' seem to be slightly higher, there could be time lapse when cases were reported. In addition, among the 12.66% who reported 'positive' in this study, 10% chose the option 'suspected and recovered'. This again validates the reliability of the data collected. A visualised demographic analysis of participants can be found in Appendix II.

4.1.2 Mental health outcome

Based on the interpretation of the scores as mentioned above, Figure 2 presents the mental health conditions of the participants. Of the 237 participants, the percentage that have no depression was 80.17%, which implies that only a minority of respondents (i.e., 19.83%) felt depressed during the COVID-19 lockdown. For anxiety, 102 participants had no-minimal

anxiety and 81 had mild anxiety. The numbers of the participants with moderate anxiety and severe anxiety were similar, at 29 and 25, respectively. The proportion of the participants with no-minimal anxiety and mild anxiety (i.e., no major anxiety) was 77.22%, which suggests that most participants did not feel anxious or had slight sense of anxiety during the COVID-19 lockdown. Stress was evaluated using continuous numeric variables as PSS-4 has no formal cut-off points. As can be seen in Figure 2c, the stress score of most participants (i.e., 71.73%) is between 4 and 9. Notably, the number of participants with a stress score of 8 (i.e., 55) is the highest. Compared with anxiety and depression, stress is revealed to be the most obvious mental health problem of residents during the COVID-19 lockdown.

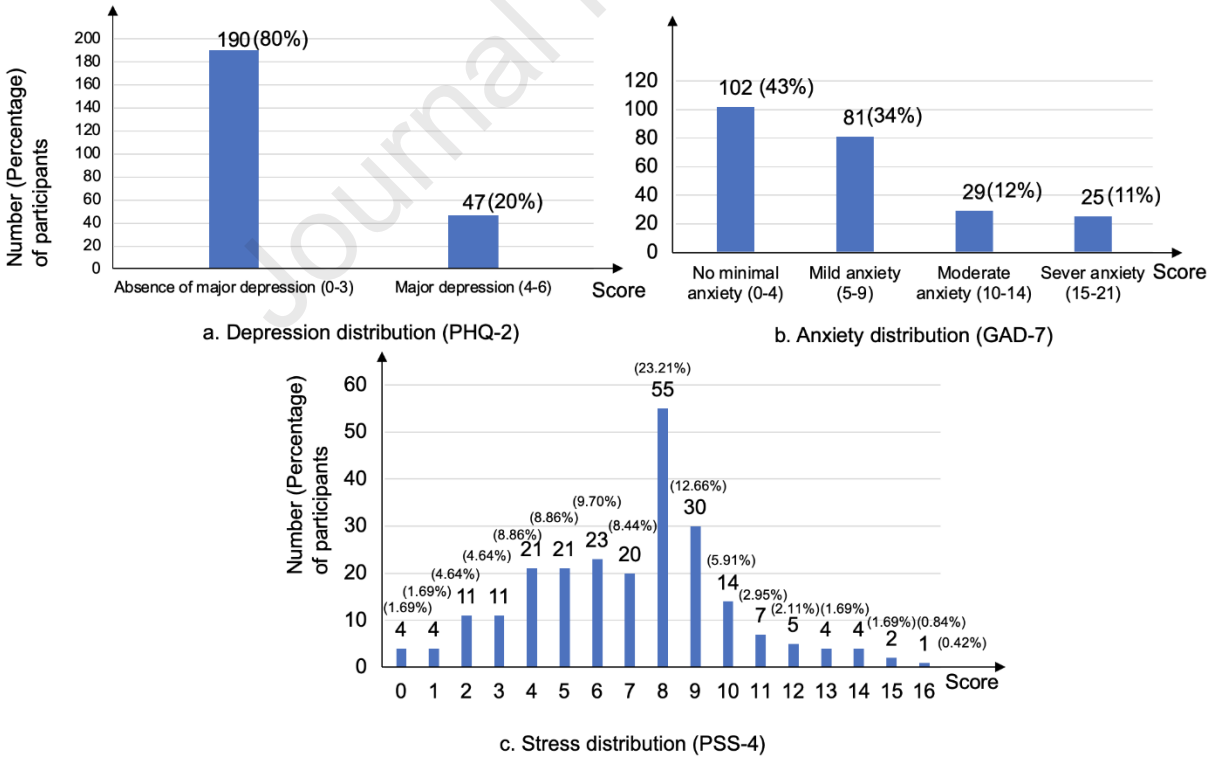


Figure 2. Distribution analysis of the mental health outcomes of residents

335 **4.2 Reliability Analysis**

336 Cronbach's alpha is selected as an indicator of scale reliability to measure the internal
337 consistency. Among the 20 items tested, the Cronbach's alpha index is calculated to be 0.730,
338 which exceeds the minimum acceptable level (Nunnally and Bernstein, 1994). Furthermore,
339 in order to investigate whether the independent variables (i.e., social demographics, general
340 house, indoor environmental quality, and neighbourhood amenity quality) can statistically
341 explain the dependent variable (i.e., depression, anxiety, or stress), three separate reliability
342 analyses are conducted as shown in Table 1 and Table 2.

Table 1. Model reliability for depression and anxiety

			Predicted Depression (Anxiety)		
	Observed		No Depression (No)	Major depression (Yes)	Percentage Correct (%)
Step 1	Depression (Anxiety)	No Depression (No)	123 (119)	7 (8)	94.6 (93.7)
		Major depression (Yes)	27 (28)	11 (13)	28.9 (31.7)
	Overall Percentage				79.8 (78.6)

343 Note: data in brackets are that of anxiety.
344

345 Table 2. Model reliability for stress

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.435	.189	.066	2.94421	
2	.489	.239	.086	2.91182	
3	.534	.286	.096	2.89604	
4	.557	.310	.093	2.90072	1.915

346

347 Table 1 shows that the logistic regression analysis model can significantly explain the
348 relationship between built environment design and depression as well as anxiety with the
349 correct prediction rate being 79.8% and 78.6%, respectively. This means that the possibility

of failing to simulate the interrelation is only 20.2% or 21.4% if a variable is statistically significant in explaining the dependent variable (i.e., mental health). Similarly, the hierarchical regression analysis model demonstrates a satisfactory performance in showing the relationship between built environment design and stress (Table 2). The Durbin-Watson value is calculated as 1.915, suggesting that the model is statistically significant (i.e., no autocorrelation in the sample). Usually, if the value is closer to 2, the model is more effective (Liberopoulos and Tsarouhas, 2005).

4.3 Relationship between Built Environment Design and Mental Health

4.3.1 Depression during the COVID-19 lockdown

Table 3 shows the outcome of the logistic regression analysis model for depression and the differences between each model. For the sake of brevity, only the regression coefficient and significance of each variable are presented as they are sufficient to identify if a certain variable is statistically significant in explaining depression. The same principle applies to the rest of the models. In addition, all models are performed at the 95% confidence intervals.

Table 3. Results of regression models on built environment design and depression

Variables	Step 1		Step 2		Step 3		Step 4	
	B	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**
Social demographics								
Ethnicity [a]								
Black/Black British-Caribbean, African, other	-20.370	1.000	-20.017	1.000	-20.615	1.000	-21.657	1.000
Mixed race – other	.940	.589	1.880	.304	2.023	.274	2.490	.199
White – British, Irish, other	-.237	.762	.064	.940	-.028	.975	-.331	.728
Chinese/Chinese British	-1.082	.238	-1.269	.193	-1.382	.173	-1.435	.177
Middle Eastern/Middle Eastern British – Arab, Turkish, other	.334	.757	.781	.510	.893	.465	1.021	.421
Other	-20.560	.999	-20.162	.999	-20.191	.999	-21.518	.999
Gender [b]	.115	.809	.214	.679	.146	.790	.263	.653
Age	**-.525**	**.037***	-.483	.073	-.506	.078	-.432	.174
Employment status [c]								
Self-employed	1.217	.206	1.002	.303	1.292	.209	1.066	.356
In part-time employment	.143	.862	.120	.886	.144	.869	-.238	.799
In full-time employment	.399	.502	.197	.755	.167	.801	.239	.742
Unable due to disability	21.910	1.000	22.510	1.000	22.782	1.000	22.090	1.000
Homemaker/ full-time parent	-19.485	.999	-19.844	.999	-20.142	.999	-20.650	.999
Unemployed and seeking work	.314	.693	.384	.636	.502	.559	.573	.522
Furlough	-.972	.408	-.177	.885	-.184	.885	-.328	.799
Retired	2.981	.090	2.798	.122	3.003	.117	2.277	.277
Household income	-.108	.068	-.088	.673	-.044	.847	.076	.747
The number of people in the house	-.007	.962	.097	.599	.102	.605	.120	.560
Rent or own the house [d]	-.305	.542	.015	.978	.072	.906	.062	.923
Has anyone in your household had COVID-19								
Suspected and recovered [e]	-41.445	.999	-60.676	.999	-60.399	.999	-62.768	.999

Table 3. (Continued)

Variables	Step 1		Step 2		Step 3		Step 4	
	B	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**
Suspected and still ill	-61.588	.999	-81.291	.999	-81.533	.999	-84.520	.999
No	-41.976	.999	-61.230	.999	-61.001	.999	-63.366	.999
General house [f]								
House size			-.242	.260	-.272	.238	-.255	.287
House type								
A house without a garden			1.475	.233	1.655	.188	2.370	.080
An apartment with a balcony			.368	.778	.452	.741	.899	.520
An apartment with no balcony			.689	.284	.487	.474	.400	.597
A home with access to an outdoor communal area			-.543	.691	-.547	.707	-.147	.924
Other			-19.681	.999	-19.359	.999	-19.600	.999
Indoor environmental quality								
Natural light					-.077	.655	-.026	.889
Thermal comfort					-.059	.735	-.110	.560
Indoor air quality					.029	.892	.053	.811
Acoustic environment					-.031	.853	.004	.980
Window view					.061	.717	.021	.905
Indoor physical activity space					-.095	.606	-.111	.565
Home workspace					-.061	.694	-.090	.588
Neighbourhood amenity quality								
Neighbourhood type [g]								
Town							**1.774**	**.015***
Suburb							.351	.681
Rural							1.341	.198
Proximity to the nearest open space							-.008	.978

Table 3. (Continued)

Variables	Step 1		Step 2		Step 3		Step 4	
	B	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**
Proximity to the nearest shops							.087	.772

Note: [a] 'Asian/British-Indian, Pakistani, Bangladeshi, other' is used as the reference category; [b] 'Male' is used as the reference category; [c] 'Still at school' is used as the reference category; [d] 'Rent' is used as the reference category; [e] 'Yes, diagnosed and recover' is used as the reference category; [f] 'A house with a garden' is used as the reference category; and [g] 'City' is used as the reference category.

368 The first step is to explore the relationship between social demographics and depression.
369 Results suggest that age (B = -0.525, p = 0.037) is significantly associated with depression,
370 with younger people reporting being more depressed than older people. Although all other
371 variables are not significant, household income is marginally significant (B = -0.108, p =
372 0.068), with people having higher annual income reporting less depression symptoms. In the
373 second step and third step, after adding variables of general house attribute and indoor
374 environmental quality, there is no significant variable shown to be associated with depression.
375 Interestingly, even age becomes insignificant with the p values rising to 0.073 and 0.078.
376 However, in the final step the neighbourhood type is significantly related to depression after
377 adding the neighbourhood amenity quality variables. Living in a town (B = 1.774, p = 0.015)
378 is associated with greater depression compared with living in a city. This could be because it
379 is easier and faster for residents in the city to access neighbourhood amenities. Supporting
380 evidence can also be found in Medlock *et al*. (2021), where concerns for COVID-19
381 transmission have considerably reduced the use of public transport. In the current study,
382 residents of towns may need to spend more time outside and using public transport to buy
383 food during the lockdown, which may lead to worries about contracting the disease.
384

385 **4.3.2 Anxiety during the COVID-19 lockdown**

386 Table 4 shows the outcome of the logistic regression analysis model for anxiety and the
387 differences between each model. Similarly, the first step is to explore the relationship
388 between social demographics and anxiety. Age (B = -0.543, p = 0.039) is significantly

associated with anxiety, indicating that older people are less anxious than younger people. Differing from depression, age (B = -0.623, p = 0.024) remains to be significant after adding the general house variables in the second step. This is perhaps because older people are less sensitive to the house type and house size when it comes to anxiety. It is possible that older people who live in a bigger house suffer less from anxiety than younger people during the lockdown. In the third model, both age and house type are significantly related to anxiety after adding indoor environmental quality variables. Such a phenomenon reveals that those who are younger (B = -0.741, p = 0.014) or living a house without a garden (B = 2.562, p = 0.037) manifest greater anxiety compared with those older or living in a house with a garden. In the fourth step, however, after adding neighbourhood amenity quality variables, age is no longer significant, whereas house type and neighbourhood type become significantly associated with anxiety. Here, despite the social background, people living in a house without a garden (B = 3.240, p = 0.018) are more likely to feel anxious compared with those living in a house with a garden. In addition, living in the town (B = 2.277, p = 0.002) is associated with greater anxiety compared with living in the city.

404 Table 4. Results of regression models on built environment design and anxiety

Variables	Step 1		Step 2		Step 3		Step 4	
	B	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**
Social demographics								
Ethnicity								
Black/Black British-Caribbean, African, other	-20.373	1.000	-19.494	1.000	-19.744	1.000	-22.151	1.000
Mixed race – other	1.297	.451	2.101	.246	2.385	.198	2.269	.253
White – British, Irish, other	-.417	.580	.058	.943	.127	.884	-.143	.884
Chinese/Chinese British	-1.714	.068	-1.565	.116	-1.718	.095	-1.979	.084
Middle Eastern/Middle Eastern British – Arab, Turkish, other	.383	.719	.943	.406	1.152	.329	1.029	.434
Other	.036	.975	.049	.971	-.024	.987	-.662	.682
Gender	.292	.542	.467	.364	.477	.380	.645	.271
Age	**-.543**	**.039***	**-.623**	**.024***	**-.741**	**.014***	-.682	.050
Employment status								
Self-employed	1.194	.223	1.162	.237	1.492	.154	.865	.478
In part-time employment	-.387	.674	-.303	.745	-.392	.690	-1.197	.283
In full-time employment	-.023	.969	-.104	.864	-.059	.925	-.233	.746
Unable due to disability	21.423	1.000	20.397	1.000	20.264	1.000	19.130	1.000
Homemaker/ full-time parent	-19.642	.999	-19.472	.999	-18.931	.999	-19.306	.999
Unemployed and seeking work	.141	.861	.140	.866	.156	.857	.218	.816
Furlough	1.259	.170	1.575	.110	1.792	.096	1.132	.309
Retired	-17.442	.999	-17.232	.999	-16.950	.999	-18.236	.999
Household income	.035	.851	.095	.644	.136	.539	.301	.201
The number of people in the house	-.079	.596	-.177	.340	-.247	.227	-.218	.326
Rent or Own the house	-.637	.213	-.521	.355	-.332	.590	-.464	.490
Has anyone in your household had COVID-19								

Suspected and recovered	-41.267	.999	-42.134	.999	-42.313	.999	-45.527	.999

Table 4. (Continued)

Variables	Step 1		Step 2		Step 3		Step 4	
	B	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**
Suspected and still ill	-63.607	.999	-65.598	.999	-65.931	.999	-69.888	.999
No	-41.935	.999	-42.846	.999	-42.963	.999	-46.224	.999
General house								
House size			-.029	.883	-.035	.866	.017	.941
House type								
A house without a garden			2.196	.060	**2.562**	**.037***	**3.240**	**.018***
An apartment with a balcony			.425	.747	.584	.662	1.307	.366
An apartment with no balcony			-.079	.907	-.103	.886	-.355	.666
A home with access to an outdoor communal area			.953	384	1.350	.239	2.418	.070
Other			-.874	.660	-.941	.653	-.076	.977
Indoor environmental quality								
Natural light					-.055	.769	-.117	.574
Thermal comfort					.115	.527	.118	.554
Indoor air quality					-.109	.614	-.041	.858
Acoustic environment					.041	.815	.069	.709
Window view					-.121	.480	-.091	.624
Indoor physical activity space					.045	.812	.037	.855
Home workspace					-.120	.456	-.146	.399
Neighbourhood amenity quality								
Neighbourhood type								
Town							**2.277**	**.002***
Suburb							.561	.506
Rural							.537	.614

Proximity to the nearest open space							.263	.370

Table 4. (Continued)

Variables	Step 1		Step 2		Step 3		Step 4	
	B	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**
Proximity to the nearest shops							.451	.151

Note: The same reference categories as Table 3 are used.

406 **4.3.3 Stress during the COVID-19 lockdown**

407 Table 5 shows the outcome of the hierarchical regression analysis model for stress and the
408 differences between each model. In the first model, the relationship between social
409 demographics and stress is studied. Compared with the models for depression (Table 3) and
410 anxiety (Table 4), it is not age but the household income (B = -0.479, p = 0.029) that is
411 significantly associated with stress. Specifically, households with higher annual income
412 report less stress. In addition, as household income is marginally significant in Table 3, it can
413 be inferred that income is more of a stressor rather than a cause for depression during the
414 lockdown. Put simply, people with lower income are more likely to be stressed instead of
415 being depressed and a lower income is usually associated with a worse living environment in
416 reality.

417

418 In the second model, the household income remains significant after adding the extra general
419 house attribute. Surprisingly, ethnicity and employment status have for the first time become
420 significant. Based on the statistics, 'Chinese/Chinese British' (B = -2.299, p = 0.043) are less
421 likely to feel stressed than 'Asian/British-Indian, Pakistani, Bangladeshi, other'. People who
422 are in part-time employment (B = -1.983, p = 0.035) have less stress compared with students.
423 In addition, house type is also significantly associated with stress in this model. Living in an
424 apartment with no balcony (B = 1.819, p = 0.022) is associated with greater stress than living
425 in a house with a garden. As people have to stay at home every day during the lockdown,
426 those with a garden can sometimes go out in the garden for some fresh air and natural views.

427 However, if there is no access to a garden or a balcony, it is understandable that people may
428 feel more stressed.
429
430 In the third model, household income, ethnicity, employment status and house type remain
431 significant as in the second model. Moreover, 'black/black British' (B = -6.776, p = 0.038) is
432 also shown to have less stress than 'Asian/British-Indian, Pakistani, Bangladeshi, other'. In
433 the fourth model, after adding the neighbourhood amenity variables, the relationship between
434 social demographic variables (i.e., household income, ethnicity and employment status) and
435 stress is consistent with the results in the third model. In addition, both house type and home
436 workspace are significantly correlated with stress. Residents who live in an apartment with
437 no balcony (B = 1.525, p = 0.044) have higher levels of stress than those who live in a house
438 with a garden. Moreover, the home workspace (B = -2.99, p = 0.015) has a significant impact
439 on stress. As residents' satisfaction with the home workspace increases, their stress decreases.
440 This can be because people are required to work from home during the lockdown and a
441 satisfying home workspace can provide residents with proper facilities without having to
442 worry about having no place to work. Furthermore, the proximity to the nearest open space
443 (B = 0.578, Sig. p = 0.043) is associated with stress, which suggests that residents who live
444 near the green and open space are less likely to feel stressed.

445 Table 5. Results of regression models on between built environment design and stress

Variables	Model 1		Model 2		Model 3		Model 4	
	B	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**
Social demographics								
Ethnicity								
Black/Black British-Caribbean, African, other	-5.037	.111	-6.145	.055	**-6.776**	**.038***	**-8.098**	**.017***
Mixed race – other	.777	.748	1.077	.659	.978	.688	-.002	.999
White – British, Irish, other	-.678	.502	-.560	.587	-.817	.438	-1.068	.319
Chinese/Chinese British	-1.791	.108	**-2.299**	**.043***	**-2.575**	**.024***	**-2.656**	**.021***
Middle Eastern/Middle Eastern British – Arab, Turkish, other	-1.855	.204	-2.238	.134	-2.342	.119	-2.411	.113
Other	-1.659	.314	-1.789	.289	-2.180	.200	-2.474	.153
Gender	-.647	.247	-.692	.224	-.857	.145	-.756	.202
Age	-.261	.311	-.138	.601	-.168	.531	-.147	.610
Employment status								
Self-employed	-.111	.921	-.297	.791	.055	.961	-.183	.880
In part-time employment	-1.787	.058	**-1.983**	**.035***	**-2.072**	**.030***	**-2.348**	**.016***
In full-time employment	-.010	.988	-.266	.712	-.184	.799	-.334	.663
Unable due to disability	.834	.788	2.040	.536	1.994	.550	2.475	.471
Homemaker/ full-time parent	.283	.900	.190	.934	.273	.907	-.258	.914
Unemployed and seeking work	-.146	.885	-.024	.981	.129	.899	.077	.940
Furlough	-.706	.555	-.759	.538	-.512	.686	-1.126	.396
Retired	-1.799	.398	-2.055	.335	-1.777	.409	-2.704	.240
Household income	**-.479**	**.029***	**-.602**	**.010***	**-.530**	**.031***	**-.485**	**.043***
The number of people in the house	.072	.667	.279	.171	.173	.408	.228	.286
Rent or Own the house	-.813	.173	-.557	.379	-.201	.768	-.151	.828
Has anyone in your household had COVID-19								

Suspected and recovered	-4.092	.347	-2.663	.580	-3.397	.492	-4.747	.348

Table 5. (Continued)

Variables	Model 1		Model 2		Model 3		Model 4	
	B	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**
Suspected and still ill	-1.978	.682	.256	.962	-.011	.998	-1.756	.757
No	-4.128	.336	-2.591	.589	-3.152	.520	-4.421	.378
General house								
House size			-.022	.926	-.010	.968	.044	.858
House type								
A house without a garden			.111	.938	.487	.733	.153	.916
An apartment with a balcony			2.463	.060	1.983	.136	2.131	.119
An apartment with no balcony			**1.819**	**.022***	**1.768**	**.028***	**1.525**	**.044***
A home with access to an outdoor communal area			-.674	.612	-.323	.810	.112	.936
Other			2.152	.276	1.538	.443	1.801	.380
Indoor environmental quality								
Natural light					.091	.638	.097	.625
Thermal comfort					-.025	.890	-.059	.756
Indoor air quality					-.063	.782	-.034	.881
Acoustic environment					-.071	.708	-.078	.683
Window view					-.271	.151	-.221	.247
Indoor physical activity space					.233	.272	.236	.271
Home workspace					-.296	.115	**-.299**	**.015***
Neighbourhood amenity quality								
Neighbourhood type								
Town							.368	.591
Suburb							-.114	.886
Rural							-.285	.785

Proximity to the nearest open space							**.578**	**.043***

Table 5. (Continued)

Variables	Model 1		Model 2		Model 3		Model 4	
	B	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**
Proximity to the nearest shops							-.056	.857

Note: The same reference categories as Table 3 and Table 4 are used.

5 Discussion and Implications

While there is a wealth of reasons that can cause these mental health problems, current literature has established their relationship with built environment (see, for example, Evans *et al*., 2003, Power *et al*., 2015, Wang *et al*., 2021). Importantly, there are both similarities and differences between this research and the extant studies on built environment design and mental health that may advance existing understanding and knowledge. Specific to the context of COVID-19, age is negatively correlated with depression and anxiety, which is consistent with Khan *et al*. (2021). The impact on the daily routine of young people and adults during the COVID-19 lockdown may be more drastic because young people and adults are forced to stay at home when they should be studying and working, which may be one of the reasons for their depression and anxiety. In comparison, the elderly has become accustomed to staying at home for long periods before the COVID-19 lockdown. Contrasting with Evans *et al*. (2003) who found older people are less sensitive to housing quality than young adolescents, the association between age and mental health becomes insignificant after adding the factors of built environment design in this study. This suggests that age is not an important factor influencing the relationship between the built environment design and mental health during the COVID-19 lockdown.

Employment status and household income can significantly affect the levels of stress. For instance, people who work part-time are more stressed, which may be because their jobs become more unstable during the lockdown. Individuals who lost their jobs during the

pandemic are associated with worse mental health and feel pessimistic about life (Fisher *et al*., 2021). In addition, we find that income is an important factor mediating the relationship between built environment design and mental health, i.e., low-income families tend to live in poor-quality houses and feel more stressed during the COVID-19 lockdown. Evans *et al*. (2003) report a similar case where the quality of the built environment design, to a large extent, can affect the mental health of the general population. However, our study provides empirical evidence on the direct and indirect relationship between social demographics and mental health when it is mandatory to stay at home during extreme events (e.g., COVID-19), and thus addresses this gap in the literature.

Gardens and balconies are important design elements of the built environment, which have a positive effect on mental health during the COVID-19 lockdown. In this study, residents who live in a house without a garden show a greater anxiety level than those who live in a house with a garden. Additionally, apartments with no balcony can make occupants feel more stressed. These results concur with Akbari *et al*. (2021) and Zarrabi *et al*. (2021), indicating that open and semi-open spaces can boost individuals' wellbeing due to better access to fresh air, sunshine and natural views. This further explains our findings that residents who live a house with a garden are less likely to feel anxious and stressed. Compared with Corley *et al*. (2021) in which it is the time spent in the garden that is more important, we suggest that private gardens themselves offer an opportunity for the residents to deviate, relax and cultivate and maintain plants, which results in better mental health during the COVID-19

lockdown. This way, we ascertain that private gardens have a great impact on mental health. In light of the frequent occurrence of uncertain events, this advocates for the idea of gardens and/or more open space in built environment design because they act as outlet for psychological catharsis and alleviates the feelings of isolation and loneliness.

In terms of the indoor environmental quality, home workspace has a significant impact on stress but not on anxiety or depression. The level of stress of residents decreases when their satisfaction with the home workspace improves. Interestingly, four other basic components of indoor environmental quality (i.e., thermal comfort, indoor air quality, acoustic and visual comfort) are not significantly correlated with mental health in this study. This somewhat counter-intuitive finding contradicts existing studies (see, for example, Evans, 2003, Lai *et al*., 2009, Tanabe *et al*., 2007, Thomson and Snell, 2013, Beemer *et al*., 2019) where these components were found to have effects on mental health. For example, Amerio *et al*. (2021) report students in Italy who live in apartments with poor indoor quality experienced increased depression during lockdown. However, as people reconfigure their rooms to create home workspace, its corresponding thermal comfort, light, ventilation, visual comfort, etc. may have been adjusted to their comfortable level, thus decreasing their significance to mental health during the lockdown period. In fact, Lovec *et al*. (2021) report that indoor air quality becomes better during the pandemic because of the ventilation guidelines put in place. The lack of a proper home workspace with comfortable indoor environmental quality also explains the worsened working performance and depression reported by participants in

Amerio *et al*. (2021). In addition, the genial weather in the UK during the first lockdown when data were collected (i.e., May to July, 2020) may have contributed to the satisfactory indoor environmental quality.

Neighbourhood type and the proximity to the nearest open space are significantly associated with mental health in this research. In particular, residents who live in cities are less likely to feel depressed and anxious than those who live in towns. Moreover, residents who live near green spaces show lower levels of stress. This is COVID-19-specific, as Hartig *et al*. (2003) and Peen *et al*. (2010) propose that urban populations are more likely to have negative emotions. However, in the case of COVID-19 lockdown, the medical and health facilities and amenities are better in the city, which provides a sense of security that can mitigate anxiety and depression of residents (Sharifi and Khavarian-Garmsir, 2021). In terms of the distance to open space, these results are similar to Sturm and Cohen (2014) and Völkern and Kistemann (2015) who argue that green environment settings in the cities can help release negative emotions. However, Helbich *et al*. (2019) propose that the effects of open space on depression should not be exaggerated and are minor. This is corroborated by our study: open space is identified to have no significant impact on residents' depression and anxiety during the COVID-19 lockdown. Nevertheless, given its significant role in relieving residents' stress, planners need to accommodate open space close to the residents. Finally, the significant correlation between shopping facilities, social demographics and mental health is not detected.

Our study could provide some design implications for policymakers and built environment design professionals in the case of a future crisis. First, it is imperative that the awareness of built environment design's impact on mental health should be fostered (Galea *et al*., 2005). Although to what degree the built environment design affects mental health can be further quantitatively explored, we have provided an aggregate view on their interaction. Second, we do not support the consideration of all variables as there is always a balance to be made between built environment design and its cost (Guo and Gandavarapu, 2010). Also, better design quality usually means a higher property transaction price, which some people cannot afford. As a result, potential mental health problems can be engendered by this tension between the two. However, attention to the factors identified here as more important could offset this tension. Third, engaging public opinion would be a sustainable solution to public demands (Kua and Lee, 2002). Typically, there is a discrepancy between what the policymakers and architects think is best for residents' mental health and what residents think for themselves. Therefore, an ideal way can be to cover parts of the general public's concerns. Reflecting on this research, a comment box regarding the question "if you want to make a change to your current physical environment, what would the change be?" was provided at the end of the questionnaire. A majority of participants preferred to have a better home workspace and a larger indoor physical activity place, and some expressed the desire to live away from any main road. Therefore, architects and engineers may need to consider the rationality and practicality of the house type and the location. Although individual differences

552 will not disappear, such public engagement trailblazer can make overall progress.

553

554 ## 6 Conclusions

555 By performing two step-by-step regression models (i.e., logistic and hierarchical) with survey
556 data collected in the UK, this research illustrates the influence of individual and collective
557 built environment features on the depression, anxiety and stress of residents, respectively.
558 While studies on this are not scarce, our timely research is conducted within the context of
559 COVID-19 lockdown to address the consideration of uncertainties in future built environment
560 design. Compared with depression and anxiety, residents are more likely to show symptoms
561 of stress during the COVID-19 lockdown. To mitigate this, our empirical evidence suggests
562 the consideration of open space detached to the property (e.g., gardens and balconies), home
563 workspace, neighbourhood type, and houses' distance to green space is important to people's
564 mental health during the COVID-19 lockdown period. However, residents' social
565 demographics should be considered simultaneously as they can exert a fluctuating effect on
566 the relationship between mental health and built environment design. As such, policymakers
567 and architects can be better equipped with an enhanced awareness of mental health,
568 significant built environment factors, and sense of public engagement in their long-term
569 practice.

570

571 Despite our following of a rigorous research design (Figure 1), there are limitations that form
572 the basis for future work. We employ PHQ-2, GAD-7 and PSS-4 to assess residents'

early-stage mental health during the COVID-19 lockdown. While this fits the unprecedented nature of the crisis and ensures initial actions, we acknowledge the importance of a longitudinal study of this phenomenon, particularly as some local lockdown restrictions are recurrent. The comparison with a post-COVID-19 mental health and built environment study will together underpin more solid design decisions. Such a comparison can also include 'social demographics' so that a deeper understanding of its interaction with built environment and mental health can be garnered. Despite the fact that existing studies have adopted a similar sample size as ours, this future longitudinal research could consider a larger sample to extrapolate the results on a larger population. On the other hand, our study focuses on the housing type in which people spend most of their time during COVID-19. However, future studies can configure the setting to other building types (e.g., offices and classrooms) as people are estimated to live with the 'new normal' but with some restriction rules. Finally, although we manage to consider social demographics, the indoor built environment (internal) and the surrounding environment people reside within (external), and identify the new home workspace in combating stress, this is not a 'panacea' to de-mystify the complex mental health working mechanism. Therefore, we call for multi-disciplinary studies (e.g., economics, architecture, engineering, urban planning, and psychology) to acquire a better understanding of the relationship between built environment and mental health.

References

Akbari, P., Yazdanfar, S.-A., Hosseini, S.-B. and Norouzian-Maleki, S. (2021). Housing and mental health during outbreak of COVID-19. *Journal of Building Engineering*, 43,

595 102919.
596 Al horr, Y., Arif, M., Katafygiotou, M., Mazroei, A., Kaushik, A. and Elsarrag, E. (2016).
597 Impact of indoor environmental quality on occupant well-being and comfort: A
598 review of the literature. *International Journal of Sustainable Built Environment*, 5,
599 1-11.
600 Allen, J.G., MacNaughton, P., Laurent, J.G.C., Flanigan, S.S., Eitland, E.S. and Spengler, J.D.
601 (2015). Green buildings and health. *Current Environmental Health Reports*, 2,
602 250-258.
603 Amaratunga, D., Baldry, D., Sarshar, M. and Newton, R. (2002). Quantitative and qualitative
604 research in the built environment: application of "mixed" research approach. *Work*
605 *study*, 51(1), 17-31.
606 Amerio, A., Brambilla, A., Morganti, A., Aguglia, A., Bianchi, D., Santi, F., Costantini, L.,
607 Odone, A., Costanza, A., Signorelli, C. and Serafini, G. (2020). COVID-19 lockdown:
608 housing built environment's effects on mental health. *International Journal of*
609 *Environmental Research and Public Health*, 17(16), 5973.
610 Appelqvist-Schmidlechner, K., Lamsa, R. and Tuulio-Henriksson, A. (2020). Factors
611 associated with positive mental health in young adults with a neurodevelopmental
612 disorder. *Research in Developmental Disabilities*, 106, 103780.
613 Arsham, H. (2005). Questionnaire design and surveys sampling. Available at:
614 https://www.researchgate.net/profile/Dr-Hossein-Arsham/publication/344638672_Qu
615 estionnaire_Design_and_Surveys_Sampling/links/5f866791458515b7cf7f657e/Questi
616 onnaire-Design-and-Surveys-Sampling.pdf (Accessed: 1-2-2020).
617 Awada, M., Becerik-Gerber, B., Hoque, S., O'neill, Z., Pedrielli, G., Wen, J. and Wu, T.
618 (2021). Ten questions concerning occupant health in buildings during normal
619 operations and extreme events including the COVID-19 pandemic. *Building and*
620 *Environment*, 188, 107480.
621 Banna, M. H. A., Sayeed, A., Kundu, S., Christopher, E., Hasan, M. T., Begum, M. R.,
622 Kormoker, T., Dola, S. T. I., Hassan, M. M., Chowdhury, S. and Khan, M. S. I. (2020).
623 The impact of the COVID-19 pandemic on the mental health of the adult population
624 in Bangladesh: a nationwide cross-sectional study. *International Journal of*
625 *Environmental Health Research*, 1-12.
626 Barnett, A., Zhang, C.J.P., Johnston, J.M., Cerin, E. (2018). Relationships between the
627 neighborhood environment and depression in older adults: a systematic review and
628 meta-analysis. *International Psychogeriatrics*, 30(8), 1153-1176.
629 Barros, P., Fat, L.N., Garcia, L.M.T., Slovic, A.D., Thomopoulos, N., de Sá, T.H., Morais, P.
630 and Mindell, J.S. (2019). Social consequences and mental health outcomes of living
631 in high-rise residential buildings and the influence of planning, urban design and
632 architectural decisions: A systematic review. *Cities*, 93, 263-272.
633 Beemer, C.J., Stearns-Yoder, K.A., Schuldt, S.J., Kinney, K.A., Lowry, C.A., Postolache, T.T.,
634 Brenner, L.A. and Hoisington, A.J. (2019). A brief review on the mental health for
635 select elements of the built environment. *Indoor and Built Environment*, 0(0), 1-14.
636 Berglund, E., Westerling, R. and Lytsy, P. (2017). Housing Type and Neighbourhood Safety

637 Behaviour Predicts Self-rated Health, Psychological Well-being and Frequency of
638 Recent Unhealthy Days: A Comparative Cross-sectional Study of the General
639 Population in Sweden. *Planning Practice & Research*, 32(4), 444-465.
640 Bloom, D., Cafiero, E., Jane-Llopis, E., Abrahams-Gessel, S., Bloom, L., Fathima, S., Feigl,
641 A., Gaziano, T., Mowafi, M.; Pandya, A. (2011). *The Global Economic Burden of*
642 *Noncommunicable Diseases*. Geneva, Switzerland: WHO.
643 Brownson, R.C., Hoehner, C.M., Day, K., Forsyth, A. and Sallis, J.F. (2009). Measuring the
644 built environment for physical activity: state of the science. *American journal of*
645 *Preventive Medicine*, 36(4), S99-S123.
646 Burns, J., Boogaard, H., Polus, S., Pfadenhauer, L.M., Rohwer, A.C., Van Erp, A.M., Turley,
647 R. and Rehfuess, E. (2019). Interventions to reduce ambient particulate matter air
648 pollution and their effect on health. *Cochrane Database of Systematic Reviews*, 5,
649 CD010919.
650 Cabinet Office. 2017. National Risk Register of Civil Emergencies. Available at:
651 https://www.gov.uk/government/publications/national-risk-register-of-civil-emergenci
652 es-2017-edition (Accessed: 12-9-2020).
653 Cattell, R.B. (1978). *The Scientific Use of Factor Analysis in Behavioral and Life Sciences*.
654 New York: Plenum Press.
655 Centers for Disease Control and Prevention (2021). Mental health conditions: depressio
656 n and anxiety. Available at: https://www.cdc.gov/tobacco/campaign/tips/diseases/d
657 epression-anxiety.html (Accessed: 11-9-2021).
658 Cerda, M., Ransome, Y., Keyes, K.M., Koenen, K.C., Tardiff, K., Vlahov, D. and Galea, S.
659 (2013). Revisiting the role of the urban environment in substance use: the case of
660 analgesic overdose fatalities. *American Journal of Public Health*, 103(12),
661 2252-2260.
662 Chang, H.J., Huang, K. and Wu, C. (2006). Determination of sample size in using central
663 limit theorem for weibull distribution. International journal of information and
664 management sciences, 17(3), 31-46.
665 Codinhoto, R., Tzortzopoulos, P., Kagioglou, M., Aouad, G. and Cooper, R. (2009). The
666 impacts of the built environment on health outcomes, *Facilities*, 27(3/4), 138-151.
667 Cohen, S., Kamarck, T. and Mermelstein, R. (1983). A global measure of perceived stress.
668 *Journal of Health and Social Behavior*, 24 (4), 385-396.
669 Corley, J., Okely, J. A., Taylor, A. M., Page, D., Welstead, M., Skarabela, B., Redmond, P.,
670 Cox, S. R. and Russ, T. C. (2021). Home garden use during COVID-19: Associations
671 with physical and mental wellbeing in older adults. Journal of Environmental
672 Psychology, 73, 101545.
673 Dawel, A., Shou, Y., Smithson, M., Cherbuin, N., Banfield, M., Calear, A. L. and Farrer, L. M.
674 (2020). The effect of COVID-19 on mental health and wellbeing in a representative
675 sample of Australian adults. *Frontiers in Psychiatry*, 11,579985.
676 Dawson, D. and Golijani-Moghaddam, N. (2020). COVID-19: Psychological flexibility,
677 coping, mental health, and wellbeing in the UK during the pandemic. *Journal of*
678 *Contextual Behavioral Science*, 17, 126-134.

De Vaus, D. (2001). *Research design in social research*. London: SAGE.

Egan, M., Petticrew, M., David Ogilvie, D. and Hamilton, V. (2003). New roads and human health: a systematic review. *American Journal of Public Health*, 93(9), 1463-1471.

Elsadek, M., Liu, B. and Xie, J. (2020). Window view and relaxation: Viewing green space from a high-rise estate improves urban dwellers' wellbeing. *Urban Forestry & Urban Greening*, 55, 126846.

Evans, G.W. (2003). The Built Environment and Mental Health. *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, 80(4), 536-555.

Evans, G.W., Wells, N.M. and Moch, A. (2003). Housing and Mental Health: A Review of the Evidence and a Methodological and Conceptual Critique. *Journal of Social Issues*, 59(3), 475-500.

Faul, F., Erdfelder, E., Lang, A.G. and Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behavior research methods, 39(2), 175-191.

Fisher, J. R., Tran, T. D., Hammarberg, K., Sastry, J., Nguyen, H., Rowe, H., Popplestone, S., Stocker, R., Stubber, C. and Kirkman, M. (2020). Mental health of people in Australia in the first month of COVID-19 restrictions: a national survey. *Medical Journal of Australia*, 213(10), 458-464.

Fisher, J., Tran, T., Hammarberg, K., Nguyen, H., Stocker, R., Rowe, H., Sastri, J., Popplestone, S. and Kirkman, M. (2021). Quantifying the mental health burden of the most severe COVID-19 restrictions: A natural experiment. *Journal of Affective Disorders*, 293, 406-414.

Fitzpatrick, K.M., Drawve, G. and Harris, C. (2020). Facing new fears during the COVID-19 pandemic: The state of America's mental health. Journal of Anxiety Disorders, 75, 102291.

Galea, S., Ahern, J., Rudenstine, S., Wallace, Z. and Vlahov, D. (2005). Urban built environment and depression: a multilevel analysis. *Journal of Epidemiology and Community Health*, 59, 822-827.

Gary, T.L., Stark, S.A. and Laveist, T.A. (2007). Neighborhood characteristics and mental health among African Americans and whites living in a racially integrated urban community. *Health Place*, 13, 569-75.

Gibson, M., Thomson, H., Ade Kearns, A. and Petticrew, M. (2011). Understanding the psychosocial impacts of housing type: Qualitative evidence from a housing and regeneration intervention. *Housing Studies*, 26(4), 555-573.

Gonza´lez-Sanguino, C., Ausín, B., Castellanos, M.A´., Saiz, J., Lo´pez-Go´mez, A., Ugidos, C. and Mun˜oz, M. (2020). Mental health consequences during the initial stage of the 2020 Coronavirus pandemic (COVID-19) in Spain. *Brain, Behavior, and Immunity*, 87, 172-176.

Gualano, M. R., Lo Moro, G., Voglino, G., Bert, F. and Siliquini, R. (2020). Effects of COVID-19 Lockdown on Mental Health and Sleep Disturbances in Italy. *International Journal of Environmental Research and Public Health*, 17, 4779.

Guo, J.Y. and Gandavarapu, S. (2010). An economic evaluation of health-promotive built

environment changes. *Preventative Medicine*, 50, 44-49.
Hair, J.F., Anderson, R.E., Tatham, R.L. and Grablowsky, B.J. (1979). *Multivariate Data Analysis*. Tulsa, Oklahoma: Pipe Books.
Hartig, T., Evans, G.W., Jamner, L.D., Davis, D.S. and Garling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology*, 23 (2), 109-123.
Helbich, M., Hagenauer, J. and Roberts, H. (2019). Relative importance of perceived physical and social neighborhood characteristics for depression: a machine learning approach. *Social Psychiatry and Psychiatric Epidemiology*, 55, 599-610.
Hoisington, A.J., Stearns-yoder, K.A., Schuldt, S.J., Beemer, C.J., Maestre, J.P., Kinney, K.A., Postolache, T.T., Lowry, C.A. and Brenner, L.A. (2019). Ten questions concerning the built environment and mental health. *Building and Environment*, 155, 58-69.
Huang, Y. and Zhao, N. (2020a). Chinese mental health burden during the COVID-19 pandemic. *Asian journal of psychiatry*, 51, 102052.
Huang, Y. and Zhao, N. (2020b). Mental health burden for the public affected by the COVID-19 outbreak in China: Who will be the high-risk group? *Psychology, Health & Medicine*, 1-12.
Hudson, C.G. (2010). Socioeconomic status and mental illness: tests of the social causation and selection hypotheses. *American Journal of Orthopsychiatry*, 75(1), 3-18.
Jensen, H.A.R., Rasmussen, B. and Ekholm, O. (2018). Neighbour and traffic noise annoyance: a nationwide study of associated mental health and perceived stress. *European Journal of Public Health*, 28, 1050-1055.
Jorm, A.F. (2000). Does old age reduce the risk of anxiety and depression? A review of epidemiological studies across the adult life span. *Psychological Medicine*, 30(1), 11-22.
Khan, M. A. S., Debnath, S., Islam, M. S., Zaman, S., Ambia, N. E., Barshan, A. D., Hossain, M. S., Tabassum, T., Rahman, M. and Hasan, M. J. (2021). Mental health of young people amidst COVID-19 pandemic in Bangladesh. *Heliyon*, 7, e07173.
Klepeis, N. E., Nelson, W. C., Ott, W. R., Robinson, J. P., Tsang, A. M., Switzer, P., Behar, J. V., Hern, S. C. and Engelmann, W. H. (2001). The national human activity pattern survey (NHAPS): A resource for asses- sing exposure to environmental pollutants. *Journal of Exposure Analysis and Environmental Epidemiology*, 11, 231-252.
Kroenke, K., Spitzer, R. L. and Williams, J. B. W. (2001). The PHQ-9: validity of a brief depression severity measure. *Journal of General Internal Medicine*, 16(9), 606-613.
Kua, H.W. and Lee, S.E. (2002). Demonstration intelligent building—a methodology for the promotion of total sustainability in the built environment. *Building and Environment*, 37(3), 231-240.
Lai, A.C.K., Mui, K.W., Wong, L.T. and Law, L.Y. (2009). An evaluation model for indoor environmental quality (IEQ) acceptance in residential buildings. *Energy and Buildings*, 41, 930-936.
Lee, E.H. (2012). Review of the Psychometric Evidence of the Perceived Stress Scale. *Asian Nursing Research*, 6(4), 121-127.

763 Li, D. C. Y. and Leung, L. (2020). Psychometric data on knowledge and fear of coronavirus
764 disease 2019 and perceived stress among workers of filipino origin in Hong Kong. *Data*
765 *in Brief*, (33), 106395.
766 Liberopoulos, G. and Tsarouhas, P. (2005). Reliability analysis of an automated pizza
767 production line. *Journal of Food Engineering*, 69(1), 79-96.
768 Liu, N., Zhang, F., Wei, C., Jia, Y., Shang, Z., Sun, L., Wu, L., Sun, Z., Zhou, Y., Wang, Y.
769 and Liu, W. (2020). Prevalence and predictors of PTSS during COVID-19 outbreak in
770 China hardest-hit areas: Gender differences matter. *Psychiatry Research*, 287, 112921.
771 Lovec, V., Premrov, M. and Leskovar, V.Ž. (2021). Practical impact of the COVID-19
772 pandemic on indoor air quality and thermal comfort in kindergartens. A case study of
773 Slovenia. *International Journal of Environmental Research and Public Health*, 18,
774 9712.
775 Lowe, B., Korennke, K. and Grafe, K. (2005). Detecting and monitoring depression with a
776 two-item questionnaire (PHQ-2). *Journal of Psychosomatic Research*, 58(2), 163-171.
777 McLean, C.P., Asnaani, A., Litz, B.T. and Hofmann, S.G. (2011). Gender differences in
778 anxiety disorders: prevalence, course of illness, comorbidity and burden of illness.
779 *Journal of Psychiatric Research*, 45, 1027-1035.
780 Medlock, K.B., Temzelides, T. and Hung, S. (2021). COVID-19 and the value of safe
781 transport in the United States. *Scientific Report*, 11, 21707.
782 Mental Health Taskforce (2016). The Five Year Forward View for Mental Health. Available at:
783 https://www.england.nhs.uk/wp-content/uploads/2016/02/Mental-Health-Taskforce-F
784 YFV-final.pdf (Accessed: 20-8-2020).
785 Mui, K.W. and Wong, L.T. (2006). A method of assessing the acceptability of noise levels in
786 air-conditioned offices. *Building Services Engineering Research and Technology*,
787 27(3), 249-254.
788 National Health Service (2021). *Mental Health*. Available at:
789 https://www.england.nhs.uk/mental-health/ (Accessed: 3-3-2021).
790 NHS (2019). *Stress*. Available at:
791 https://www.nhs.uk/mental-health/feelings-symptoms-behaviours/feelings-and-sympt
792 oms/stress/ (Accessed: 11-9-2021).
793 Nunnally, J.C. and Bernstein, I.H. (1994). The Assessment of Reliability. *Psychometric*
794 *Theory*, 3, 248-292.
795 Nurse, J., Woodcock, P. and Ormsby, J. (2003). Influence of environmental factors on mental
796 health within prisons: focus group study. *The BMJ*, 327, 480-484.
797 Nutsford, D., Pearson, A. L. and Kingham, S. (2013). An ecological study investigating the
798 association between access to urban green space and mental health. *Public Health*,
799 127 (11), 1005-1011.
800 Office for National Statistics (2017). Measuring National Well-being: Life in the UK, Apr
801 2017. Available at:
802 https://www.gov.uk/government/statistics/measuring-national-well-being-life-in-the-u
803 k-apr-2017 (Accessed: 1-7-2020).
804 Office for National Statistics (2020). Coronavirus (COVID-19) infection survey pilot:

England, 31 July 2020. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/bulletins/coronaviruscovid19infectionsurveypilot/31july2020 (Accessed: 21-6-2022).

Oiamo, T.H., Luginaah, I.N. and Baxter, J. (2015). Cumulative effects of noise and odour annoyances on environmental and health related quality of life. *Social Science & Medicine*, 146, 191-203.

Peen, J., Schoevers, R.A., Beekman, A.T. and Dekker, J. (2010). The current status of urban-rural differences in psychiatric disorders. *Acta Psychiatr Scand*, 121, 84-93.

Pohar, M., Blas, M. and Turk, S. (2004). Comparison of logistic regression and linear discriminant analysis: a simulation study. *Metodoloski Zvezki*, 1(1), 143-161.

Power, M.C., Kioumourtzoglou, M.A., Hart, J.E., Okereke, O.I., Laden, F. and Weisskopf, M.G. (2015). The relation between past exposure to fine particulate air pollution and prevalent anxiety: observational cohort study. *The BMJ*, 350, 1-9.

Proto, E. and Quintana-Domeque, C. (2021). COVID-19 and mental health deterioration by ethnicity and gender in the UK. *PloS One*, 16(1), e0244419.

Putrik, P., de Vries, N.K., Mujakovic, S., van Amelsvoort, L., Kant, I., Kunst, A.E., van Oers, H. and Jansen, M. (2015). Living environment matters: relationships between neighborhood characteristics and health of the residents in a Dutch municipality. *Journal Community Health*, 40, 47-56.

Radmacher, S.A. and Martin, D.J. (2001). Identifying significant predictors of student evaluations of faculty through hierarchical regression analysis. *The Journal of Psychology*, 135(3), 259-268.

Reichert, M., Braun, U., Lautenbach, S., Zipf, A., Ebner-Priemer, U., Tost, H. and Meyer-Lindenberg, A. (2020). Studying the impact of built environments on human mental health in everyday life: methodological developments, state-of-the-art and technological frontiers. *Current Opinion in Psychology*, 32, 158-164.

Rosenberg, S., and Mendoza, J., Tabatabaei-Jafari, H., Pan-MHIN and Salvador-Carulla, L. (2020). International experiences of the active period of COVID-19 - Mental health care, *Health Policy and Technology* (In press). DOI: https://doi.org/10.1016/j.hlpt.2020.08.016.

Rutter, C.M. and Gatsonis, C.A. (2001). A hierarchical regression approach to meta-analysis of diagnostic test accuracy evaluations. *Statistics in Medicine*, 20, 2865-2884.

Saarloos, D., Alfonso, H., Giles-Corti, B., Middleton, N., Almeida, O.P. (2011). The built environment and depression in later life: the health in men study. *The American Journal of Geriatric Psychiatry*, 19(5), 461-470.

Santamouris, M., Alevizos, S.M., Aslanoglou, L., Mantzios, D., Milonas, P., Sarelli, I., Karatasou, S., Cartalis, K. and Paravantis, J. A. (2014). Freezing the poor—Indoor environmental quality in low and very low income households during the winter period in Athens. *Energy and Buildings*, 70, 61-70.

Scoppetta, O., Cassiani-Miranda, C. A., Arocha-DÃ-az, K. N., Cabanzo-Arenas, D. F. and Campo-Arias, A. (2020). Validity of the Patient Health Questionnaire-2 (PHQ-2) for the

Detection of Depression in Primary Care in Colombia. *Journal of Affective Disorders*, 278, 576-582.

Shapiro, E., Levine, L. and Kay, A. (2020). Mental health stressors in Israel during the coronavirus pandemic. *Psychological Trauma: Theory, Research, Practice and Policy*, 12, 499-501.

Sharifi, A. and Khavarian-Garmsir, A.R. (2020). The COVID-19 pandemic: Impacts on cities and major lessons for urban planning, design, and management. *Science of The Total Environment*, 749, 142391.

Singh, S., Roy, D., Sinha, K., Parveen, S., Sharma, G. and Joshi, G. (2020). Impact of COVID-19 and lockdown on mental health of children and adolescents: A narrative review with recommendations. *Psychiatry Research*, 293, 113429.

Spitzer, R.L., Kroenke, K., Williams, J.B.W. and Lowe, B. (2006). A Brief Measure for Assessing Generalized Anxiety Disorder: The GAD-7. *Archives of Internal Medicine*, 166(10), 1092-1097.

Sturm, R. and Cohen, D. (2014). Proximity to Urban Parks and Mental Health. *The Journal of Mental Health Policy and Economics*, 17 (1), 19-24.

Sullivan, W.C. and Chang, C. (2011). Mental Health and the Built Environment. In: Dannenberg A.L., Frumkin H., Jackson R.J. (eds) *Making Healthy Places*. Island Press, Washington, DC.

Taherdoost, H. (2016). Validity and Reliability of the Research Instrument; How to Test the Validation of a Questionnaire/Survey in a Research. *International Journal of Academic Research in Management*, 5(3), 28-36.

Tan, Z., Roberts, A.C., Lee, E.H., Kwok, K.W., Car, Josip., Soh, C.K. and Christopoulos, G. (2020). Transitional areas affect perception of workspaces and employee well-being: A study of underground and above-ground workspaces. *Building and Environment*, 179, 106840.

Tanabe, S.I., Nishihara, N. and Haneda, M. (2007). Indoor Temperature, Productivity, and Fatigue in Office Tasks. *HVAC&R Research*, 13, 623-633.

Thomson, H. and Snell, C. (2013). Quantifying the prevalence of fuel poverty across the European Union. *Energy Policy*, 52, 563-572.

Tung, Y.K. (1985). Channel scouring potential using logistic analysis. *Journal of Hydraulic Engineering*, 111(2), 194-205.

Twenge, J. M. and Joiner, T. E. (2020). U.S. Census Bureau-assessed prevalence of anxiety and depressive symptoms in 2019 and during the 2020 COVID-19 pandemic. *Depress and Anxiety*, 37, 954-956.

Völkern, S. and Kistemann, T. (2015). Developing the urban blue: Comparative health responses to blue and green urban open spaces in Germany. *Health & Place*, 35, 196-205.

Wang, L., Zhou, Y., Wang, F., Ding, L., Love, P.E. and Li, S. (2021). The Influence of the Built Environment on People's Mental Health: An Empirical Classification of Causal Factors. *Sustainable Cities and Society*, 74, 103185.

Warttig, S. L., Forshaw, M. J., South, J. and White, A. K. (2013). New, normative,

English-sample data for the Short Form Perceived Stress Scale (PSS-4). *Journal of Health Psychology*, 18(12), 1617-1628.

Weich, S., Blanchard, M., Prince, M., Burton, E., Erens, B. and Sproston K. (2002). Mental health and the built environment: cross-sectional survey of individual and contextual. *British Journal of Psychiatry*, 180, 428-433.

World Health Organisation (2018). *Mental health: Strengthening our response.* Available at: https://www.who.int/news-room/fact-sheets/detail/mental-health-strengthening-our-response (Accessed: 6-6-2020).

World Health Organisation (2020). Basic documents: forty-ninth edition. Available at: https://apps.who.int/gb/bd/pdf_files/BD_49th-en.pdf (Accessed: 3-3-2021).

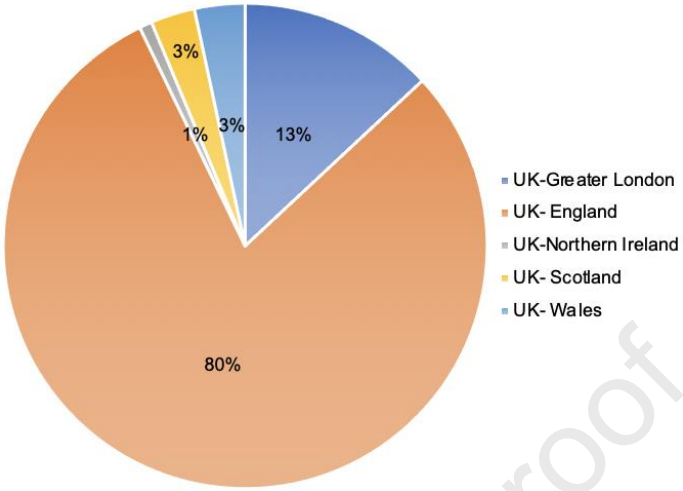
Wright, P.A. and Kloos, B. (2007). Housing environment and mental health outcomes: A levels of analysis perspective. *Journal of Environmental Psychology*, 27(1), 79-89.

Zarrabi, M., Yazdanfar, S.-A. and Hosseini, S.-B. (2021). COVID-19 and healthy home preferences: The case of apartment residents in Tehran. *Journal of Building Engineering*, 35, 102021.

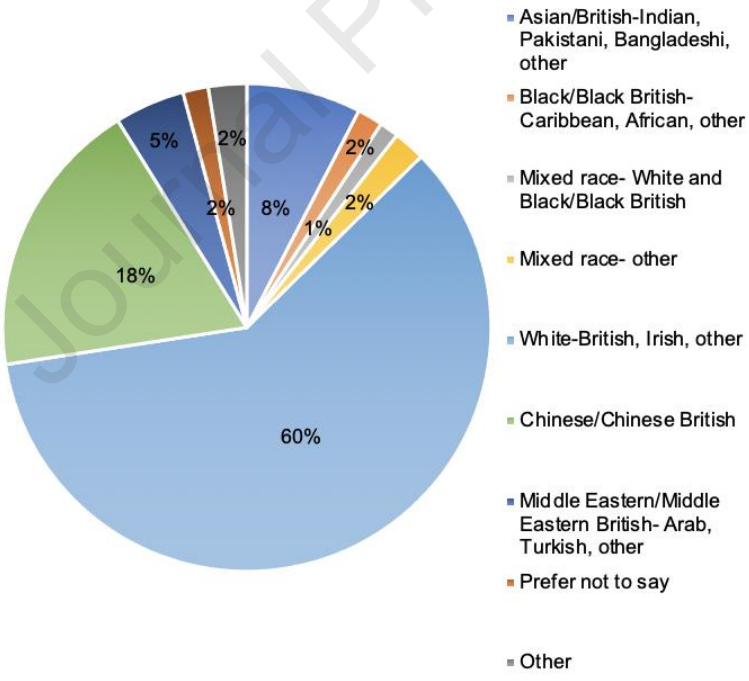
Zhang, Y. and Ma, Z. F. (2020). Impact of the COVID-19 Pandemic on Mental Health and Quality of Life among Local Residents in Liaoning Province, China: A Cross-Sectional Study. *International Journal of Environmental Research and Public Health*, 17, 2381.

Appendix

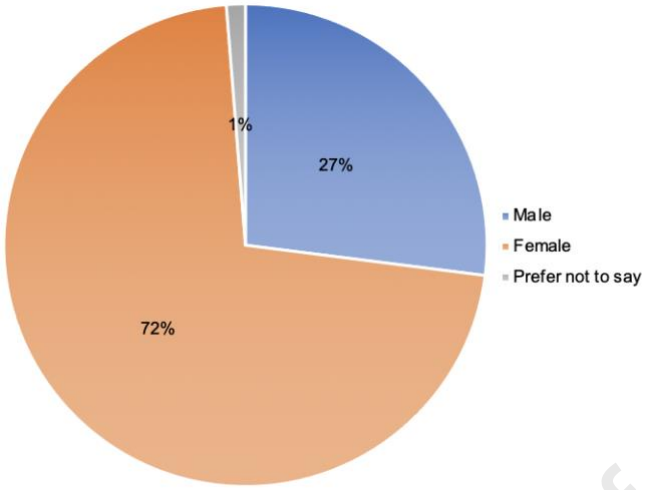
Demographic analysis of participants



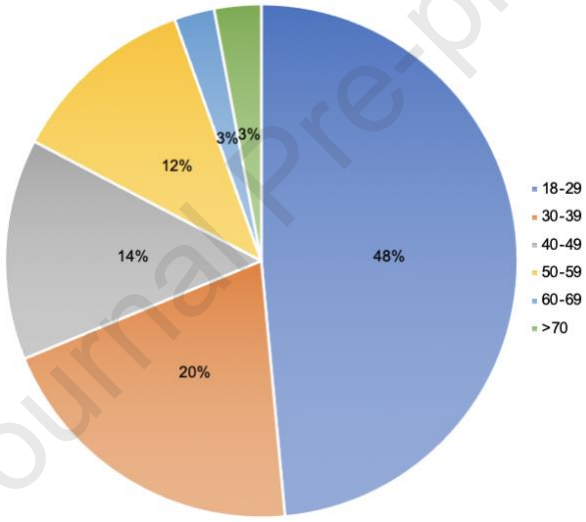
a. Country and region



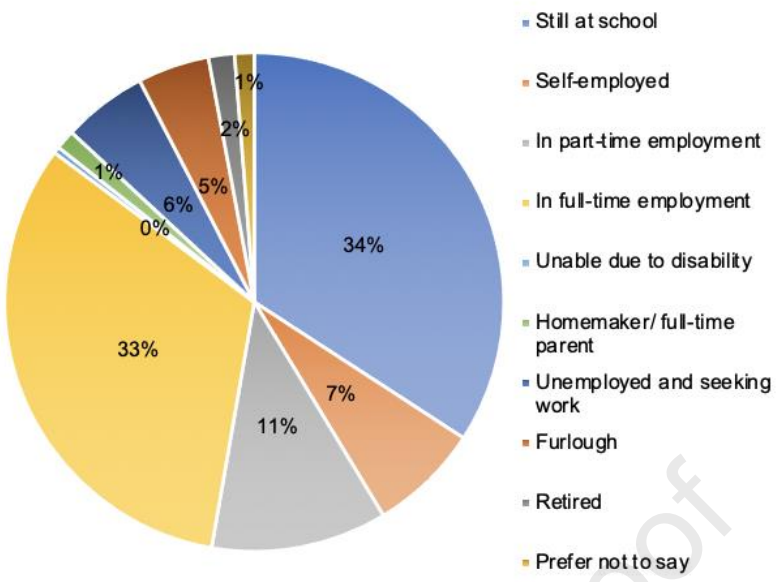
b. Ethnicity



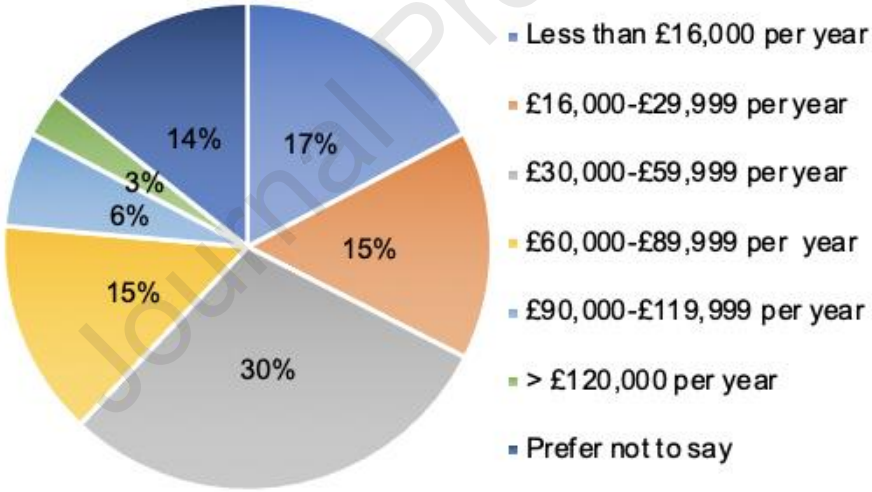
c. Gender



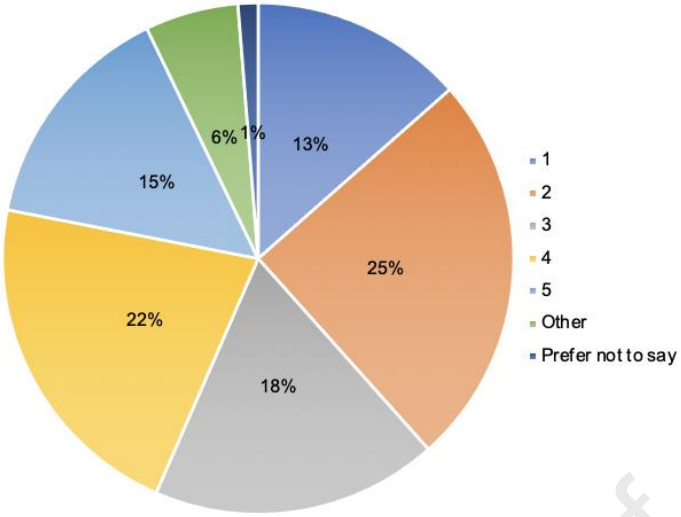
d. Age



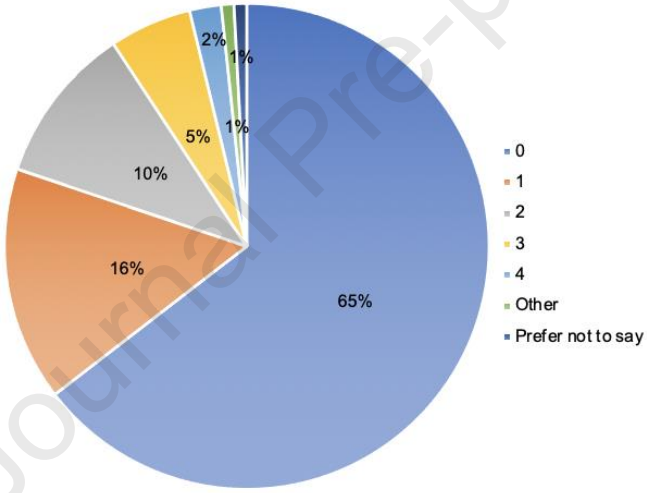
e. Employment status



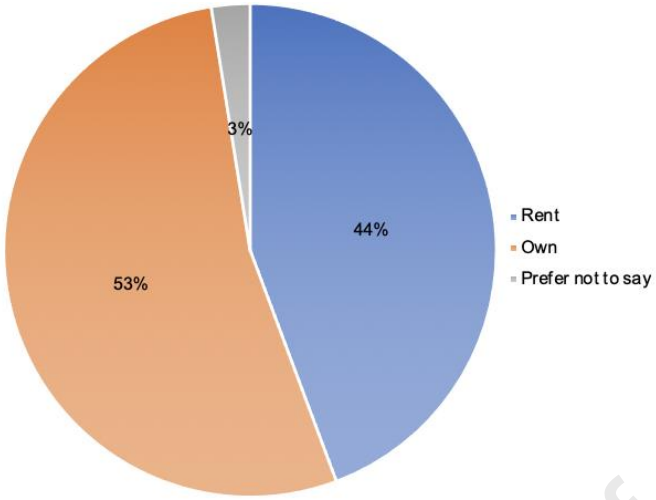
f. Household income



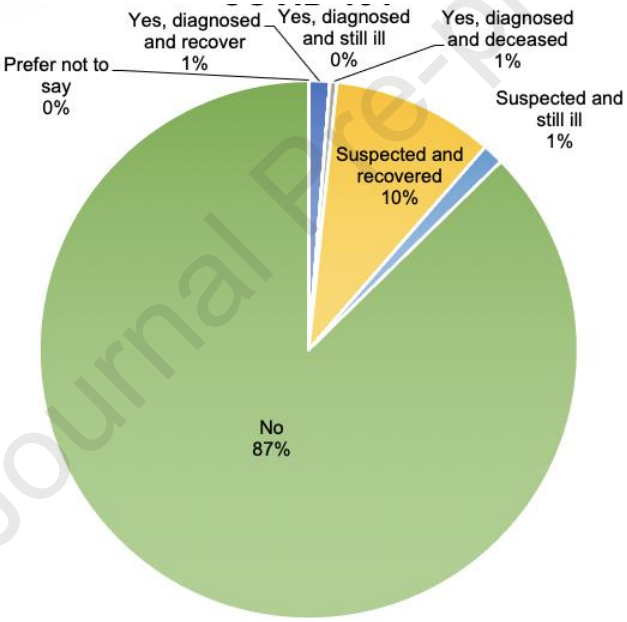
g. Number of people



h. Number of children



i. Ownership



j. COVID-19 status

Highlights

- The relationship between mental health and built environment design during the COVID-19 lockdown was identified.
- Compared with depression and anxiety, people were more likely to feel stressed during the lockdown period.
- General house type, home workspace, and neighbourhood environment and amenity were shown to have significantly contributed to mental health status at this period of time.
- Implications were provided to inform policymakers and built environment design professionals of how built environment should be designed to accommodate features that could mitigate mental health problems in any future crisis.