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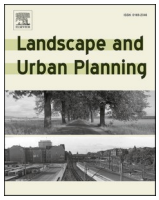

Role of the neighborhood environment in psychological resilience

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HIGHLIGHTS

- We examined the role of the neighborhood environment in psychological resilience.
- We found residents in middle-density suburbs had the best psychological resilience.
- Neighborhood walkability and vegetation cover contribute to better resilience.
- Fostering social cohesion also helps to improve psychological resilience.

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ABSTRACT

Psychological resilience of residents is an important but often neglected component of community and urban resilience. This study explores what neighborhood environment features contribute to better psychological resilience. Using a survey conducted in Greater Melbourne during a COVID-19 pandemic lockdown, we examined the role of the neighborhood physical and social environments in mitigating the psychological shock of the pandemic. Overall, we found that suburban residents are more resilient in mental health than those in the inner city. In particular, the mental health of residents living in middle-density suburbs is least likely to be severely impacted. We further found that neighborhood walkability, vegetation cover, and social cohesion all contribute to better psychological resilience. Walkability and social cohesion influence psychological resilience indirectly through affecting the perceived risks of COVID-19 infection and satisfaction with neighborhood during the lockdown, whereas neighborhood greenery has a direct and beneficial effect on psychological resilience. These findings imply that planning interventions to improve neighborhood walkability and greenness, and foster social cohesion may help improve the psychological resilience of local residents, and hence promote urban resilience. These findings also support middle-density development, which promotes walkability and proximity to nature, as well as a close-knit community.

1. Introduction

Cities in the 21st century are facing more common and more extreme natural disasters, as a result of the growing impacts of rapid climate change (Banholzer et al., 2014; Costello et al., 2009). Disasters don't just cause physical damage; they can leave communities struggling mentally and emotionally, as well. Psychological resilience is defined as the ability of community residents to cope with stress and adversity in a disaster and quickly 'bounce back' and regain mental wellbeing after a disaster (Tugade & Fredrickson, 2004). It is an important but often neglected component of urban resilience (Meerow et al., 2016; Ribeiro & Gonçalves, 2019). The neighborhood environment can play a critical role in mitigating the stress and adversity associated with disasters (Norris et al., 2008). It can also improve psychological resilience, through promoting neighborhood social support, providing accessibility to urban amenities and green spaces, and enabling walking, bicycling, and physical activity within the community (Giles-Corti et al., 2013; Koohsari et al., 2015).

The COVID-19 pandemic has taken a significant toll on people's mental wellbeing (Matthias et al., 2020), and highlighted how vital the immediate neighborhood environment is in supporting people's lives and wellbeing during a pandemic. It provides an opportunity to rethink the way we plan, design, and manage our neighborhoods and cities, and to make sure we are better prepared to protect every-one when the next

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emergency arises. Generating critical knowledge from the COVID-19 experience, we examined the role of neighborhood environments in shaping psychological resilience of community residents to disasters. With a focus on the impacts from COVID-19, this study aims to (1) understand how neighborhood environments moderate the impact on mental wellbeing; (2) identify urban planning elements that are important for improving psychological resilience. We collected survey data in Melbourne, Australia, during a pandemic lockdown, and analyzed the data using regression analysis and Structural Equation Model approaches.

We found that those who live in the suburbs have better psychological resilience than those who live in the inner city. Residents of middle-density suburbs, in particular, are least likely to experience a significant decline in their mental health due to the pandemic. We also found that neighborhood walkability, vegetation cover, and social cohesion all correlate to improved psychological resilience. Walkability and social cohesion influence psychological resilience indirectly through affecting the perceived risks of COVID-19 infection and satisfaction with neighborhood during the lockdown, whereas neighborhood greenery has a direct and beneficial effect on psychological resilience. These findings imply that improving neighborhood walkability and greenness, as well as fostering social cohesiveness, can benefit people's psychological resilience, and hence promote urban resilience. These findings also support middle-density development, which encourages walkability, natural proximity, and a close-knit community.

The evidence produced by this study contributes to the urban planning field and to practice and policy in three ways. First, this study contributes to theory in urban planning and health by linking the built environment and psychological resilience. It provides new empirical insights into how urban planning might contribute to resilience to health risks or crises. Second, this study generates empirical evidence to inform policies for resilient communities and measures to improve psychological resilience. Third, while emergencies or disasters can take various forms and require different coping methods, this study identifies several common planning elements that can be useful in dealing with COVID-19 and other disasters, such as heatwaves or floods.

2. Conceptual framework

The impact of the COVID-19 pandemic on mental well-being is a critical social issue that has drawn extensive attention from the media and research community (Thombs et al., 2020). Mental health problems were already a growing concern in a pre-COVID-19 world. According to the latest Australia National Health Survey (Australian Bureau of Statistics, 2018), one in five (20 %) or 4.8 million Australians had a mental or behavioral condition, about 13.1 % or 3.2 million had an anxiety-related condition, and about 10.4 % or 2.4 million had depression or feelings of depression. A similar pattern of mental health issues is also recorded in the US. According to the US National Institute of Health (National Institute of Health, 2021), about one in five (51.5 million in 2019) American adults live with a mental illness, and about 7.8 % (19.4 million in 2019) American adults had at least one major depressive episode. People with pre-existing mental health conditions are more at risk of experiencing increased mental-health problems as a result of a disaster (Sullivan et al., 2013). The widespread exposure to social isolation during the COVID-19 lockdown may have worsened the mental wellbeing of the population, particularly for those who were already experiencing mental health problems.

Throughout the COVID-19 pandemic, various travel restrictions and bans were implemented in different countries and between cities and regions to prevent the spread of the disease as a way to improve overall population health. Although the implementations of these measures by governments were effective in preventing the spread of COVID-19, they imposed significant burdens on people's daily lives. In Australia, for example, four levels of travel restrictions, from stage 1 to stage 4, have been implemented. Under the stage-4 lockdown, which is the highest level of travel restriction, residents are only allowed to travel within a 5-km radius of their homes and for four essential reasons, including shopping, working or studying, seeking health care, and exercising. These travel regulations significantly impacted participation in activities that are important in life, including employment, education, and social and familial interactions, as well as practices of self-care such as routine physical activity and healthy eating (Achterberg et al., 2021; Butler & Barrientos, 2020; White & Van Der Boor, 2020). The adverse impacts on life reinforced the feeling of fear and insecurity, leading to a significant increase in anxiety, depression, and stress (Pieh et al., 2020).

In this paper we hypothesize that neighborhood environments could play an important role in moderating the impact of a pandemic on mental wellbeing, thereby supporting psychological resilience. Neighborhoods' spatial accessibility to urban amenities, such as shops, markets, pharmacies, parks, etc., largely determined how well the neighborhood could meet the necessary life needs of its residents during the lockdown. A highly walkable neighborhood may better meet the life needs of its residents during the lockdown by reducing the negative impact of the pandemic. However, a highly walkable neighborhood usually has a relatively higher population density, and this may have well increased the perceived risk of COVID-19 infection.

Neighborhood walkability also matters for social capital, which is relevant to the level of social support that individuals can draw upon to cope with daily problems (Carpiano, 2007). Residents with greater social capital may have had better psychological resilience in the pandemic. Many studies have concluded that walkable environments help foster social capital by enabling active travel and increasing opportunities for social interactions within a neighborhood (Leyden, 2003; Rogers et al., 2011; van den Berg et al., 2017). However, research evidence on the relationship between walkability and social capital is far from consistent. Several studies have found that walkability is not necessarily supportive or even negatively associated with social capital (Jun & Hur, 2015; Koohsari et al., 2021). While walkable areas provide better accessibility and infrastructure that facilitates active travel and social interactions, these areas may also be associated with overcrowding, high crime rates, more traffic, and more strangers, preventing local residents from social interactions. The role of walkability on psychological resilience during the pandemic, therefore, can be hypothesized to be a tradeoff between the potential benefits of accessibility and social interactions, and the possible negative impacts associated with the high-density living and high COVID-19 infection risk.

In addition to walkability, neighborhood green and open spaces are also important in moderating the psychological impact of the pandemic. The positive effects of greenness and open spaces on reducing stress and improving the moods of residents have been well studied (Abraham et al., 2010; Fan et al., 2011). Further, neighborhood greenness encourages social interactions and thus promotes social capital (Jennings & Bamkole, 2019), though the social interactions are restricted as a result of social distancing requirements during the lockdown. Residents living in neighborhoods with higher vegetation cover, therefore, may have had better coping abilities to deal with depression and negative moods associated with the pandemic.

Further, the neighborhood social environment also matters for the psychological impact of the pandemic. Socially cohesive neighborhoods encourage social interactions (Carpiano, 2007). Residents living in cohesive neighborhoods are more likely to offer and receive support from their neighbors. During the lockdown when people's daily life was restricted to their neighborhoods, a socially cohesive community may have helped alleviate anxiety and depression and boost mood by encouraging social interaction and social support.

In their latest book, Roe and McCay (2021) also highlighted that green and blue spaces, a cohesive neighborhood environment, and an active living environment are important pillars of a "restorative city", which provides a restorative environment that supports people's mental wellbeing. According to Roe and McCay (2021), each of these elements can enhance various aspects of mental health, such as reducing stress

and depression, improving cognitive function and sleep quality, fostering social interaction and belonging, and promoting altruism and empathy. For example, green spaces offer opportunities for relaxation, recreation, and socialization, while blue spaces can evoke positive emotions and aesthetic appreciation. Active living environments can encourage physical activity and mobility, while cohesive neighborhoods can create a sense of community and safety. A restorative city, therefore, not only improves livability but also nurtures mental health and well-being for all its inhabitants.

This study focuses on an Australian city to discuss the role of the neighborhood environment in psychological resilience. Urban sprawl is pervasive in Australia, where low-density land use is a constraining factor in the delivery of effective transport access. Together with a built environment that favors private car travel, and luring of low-income populations to outer urban areas, Australian cities have been planned in a way that produces vulnerability to transport disadvantage and social exclusion (Dodson & Sipe, 2008). Social exclusion has a strong and negative effect on mental wellbeing, and transport disadvantage could contribute to social exclusion and thus lead to lower levels of mental wellbeing (Currie & Delbosc, 2010). Many outer suburbs of Australia's major cities have poor accessibility (Delbosc & Currie, 2011). Due to the imposed travel restrictions, the COVID-19 lockdown likely exacerbated transport disadvantage and social exclusion, which could have had negative impacts on residents' mental wellbeing. On the other hand, the lower population density in the middle and outer suburbs may have reduced the perceived risk of infection. Furthermore, in Greater Melbourne, green and open spaces are disproportionately distributed in the eastern areas, while the western and southeastern suburbs, where low-income populations tend to cluster, have relatively poor access to green space (Sharifi et al., 2021). The diverse characteristics of Greater Melbourne in terms of the urban form and neighborhood environment serve as an appealing case to examine the link between the neighborhood environment and psychological resilience.

A growing number of studies have investigated the impact of the neighborhood environment on mental wellbeing. For example, several studies have concluded that neighborhood walkability is positively associated with subjective wellbeing (Ma & Ye, 2018; Ma & Ye, 2022; Makarewicz & Németh, 2018; Pfeiffer & Cloutier, 2016; Pfeiffer et al., 2020). None of these studies, however, have examined the relationship between the neighborhood environment and the impact on mental wellbeing during a public health disaster. It is important to better understand this relationship to determine how urban planning can provide psychological support during a disaster. The COVID-19 experience has imposed new perspectives on the role of neighborhood environments in shaping resilience interventions and capacities focusing on mental wellbeing. Psychological resilience, acknowledged as one of the main constructs of societal resilience (Eachus, 2014; Norris et al., 2008), its relation to urban planning has been little studied. Further, the role of the neighborhood environment, including both the physical and social environment, in mitigating the mental wellbeing impact of a disaster is poorly known. Urban planning has rarely been targeted in the development of policy-actionable indicators for psychological resilience. Through learning from the COVID-19 pandemic, this study aims to investigate how a neighborhood's physical and social environment can better support residents to cope with the psychological impacts. By discussing and identifying the common planning elements that help improve resilience in this COVID-19 pandemic and other types of disasters or emergencies, this study expects to generate new knowledge for policymakers to build more resilient and healthier cities.

3. Methods

3.1. Data

For this study we relied on data from a self-administered survey of adult residents who were aged 18 and over (there was no upper age limit) in Greater Melbourne of Australia, collected during the COVID-19 lockdown period. Because of the travel restrictions of the lockdown, we worked with a local panel company (Pureprofile) that helped recruit participants. Before distributing the survey, we set up sampling quotas on age, gender, home location, and ethnicity, according to the census data. Home location was measured by calculating the linear distance from the centroid of each neighborhood to the city center (i.e., Melbourne Central Station). Based on the calculated distance, the home locations of the respondents were divided into four categories: inner city (within 5-km), inner suburbs (5–10 km), middle suburbs (10–20 km), and outer suburbs (20+ km) (see Fig. 1). These sampling quotas helped improve the representativeness of our sample and the diversity of the sampling neighborhood environment. Potential eligible participants were first randomly selected by the panel company from their database, and were then invited to participate in this study by email. The survey was formally conducted between September 1 and 18, 2020. This period was the second stage-4 lockdown imposed in Greater Melbourne. As the panel company provided a direct monetary incentive for the participants, for quality assurance purposes, two "trap" questions were included in the survey to identify "speedsters" providing inaccurate information. Those who failed to correctly answer either of the two questions were screened out. Further, a minimum time requirement for filling out the survey was embedded to identify "speedsters" who rushed through the questionnaire without reading questions and giving considered answers.

In total, 1,827 residents responded to the survey. Of those, 323 were removed because of ineligibility or "speedster activity" and 372 were screened out because of the sampling quotas on age, gender, home location, and ethnicity which we set up based on the general population census data, making the final number of valid responses 1,132. Even using sampling quotas, our sample is not perfectly representative of the population. The respondents are younger (89 % aged under 55 years old vs 81 % in the region), have more females (53 % vs 51 % in the region), and have a higher median annual income ($80,000-$99,000 vs about $80180 in the region), but have the same average household size as the region (2.7 persons per household). However, this limitation is not expected to materially affect the analysis and results; this is because our focus is on investigating the association between the neighborhood environment and psychological resilience, rather than on describing the patterns and characteristics of psychological resilience of the region (Babbie, 2007).

3.2. Outcome variables

This study examines the impact of the neighborhood environment on psychological resilience. We measured psychological resilience by simply asking respondents to rate how the COVID-19 pandemic was affecting their mental health using a five-point Likert scale: 1-became much better during the pandemic, 2-became slightly better during the pandemic, 3-no impact, 4-became slightly worse during the pandemic, 5-became much worse during the pandemic. We plotted the distribution of this variable by different locations in Fig. 2. Overall, most of the respondents (about 61 %) reported that their mental health had been negatively impacted by the COVID-19 pandemic, around 33 % reported there were no impacts on their mental health, and about 6 % reported better mental health. Fig. 2 also suggests that residents living in the inner city were more likely to suffer from mental health impacts, compared to those living in the suburbs.

This study focused on the negative impacts of the pandemic on mental health. We then combined the categories of "slightly better" and "much better" into the "no impact" category. We created two outcome variables for the following regression analyses. The first is a dummy variable that indicates whether the respondent's mental health was negatively impacted by this pandemic (i.e., no impact vs became worse). The second is an ordinal variable that measured the extent of this negative impact on mental wellbeing (i.e., no impact vs slightly worse vs

Fig. 1. Location of suburbs in Greater Melbourne.

much worse).

3.3. Explanatory variables

We included four sets of explanatory variables to predict psychological resilience: neighborhood environment, personal and household factors, housing conditions, and COVID-19 related factors. Neighborhood environment includes both the built and social environment. We measured the built environmental characteristics in each participant's neighborhood (also called state suburbs in Australia). The state suburbs are geographic subdivisions with clear and definite boundaries. We measured the land-use and street network characteristics within each neighborhood. The spatial data used to calculate these objective built-environment variables came from DataVic, Victoria's open data platform. These measures included bike lane density (including both on-street and off-street lanes), population density, entropy index[1] for land use mix, percentage of commercial land use, connected node ratio[2] for street connectivity, bus stop density, train station density, and percentage of vegetation cover within the neighborhood. To reduce the dimensions of these built environment variables, we applied a principal component analysis to all of the above except the percentage of

[1] *Entropy* $= \{-\sum[(p_i)(\ln p_i)]/(lnk)$. p_i is proportion of each land-use type, k is the number of land uses. Five land-use types including park, residential, education, industrial, and commercial were used to calculate this index.

[2] Connected Node Ratio = # street intersections with 3+ valences divided by # street intersections with 3+ valences plus culs-de-sac.

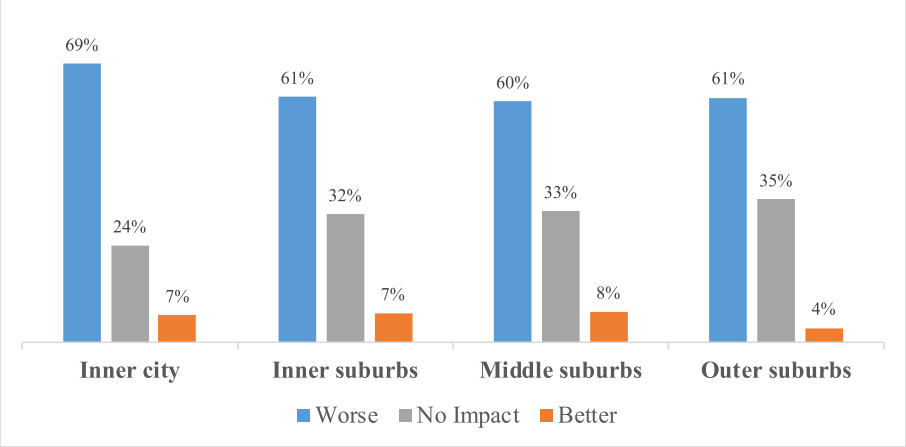

Fig. 2. COVID-19 impact on mental health by location.

vegetation, which was treated as an independent variable. One principal factor was extracted and named as *walkability*. The loadings of each item are in Table 1. The one extracted component explains about 60 % of the variance. We created this composite measure of walkability for three reasons. First, as discussed in the conceptual framework, for the built environment we focus on walkability, which is considered to be an important factor that may influence the mental health impact of the pandemic. Second, the composite measure avoids multi-collinearity among the individual built environmental measures. Third, it allows the conceptual variable (i.e. walkability) to be defined in terms of the commonalities among the measured variables, thereby removing error and unique variance of the individual built environment variables.

Our construct of walkability is based on the walkability index developed in previous studies (Frank et al., 2010; Frank et al., 2005; Kuzmyak et al., 2006; Manaugh & El-Geneidy, 2011). Most of the indices include the 4Ds of the built environment: density, diversity, design (focusing on street connectivity), and destination accessibility. In the latest national walkability index developed by US EPA (Thomas & Reyes, 2021), proximity to transit stops was included as a measure of walkability. Our walkability factor also includes these built environment dimensions.

In addition to the built environment, we also included measures on neighborhood cohesion as a measure of the social environment. These measures, adapted from Sampson et al. (1997), include "People around my neighborhood are willing to help their neighbors"; "This is a close-knit neighborhood"; "People in this neighborhood can be trusted"; "People in this neighborhood generally don't get along"; and "People in this neighborhood do not share the same values". These statements were coded using a five-point Likert scale from strongly disagree to strongly agree. We then applied a principal component analysis to these statements. One principal factor was extracted and it explains about 62 % of the variance. The loadings of each statement are in Table 1. In addition to the above physical and social environment measures, we also measured how well the neighborhood environment met the needs of people's daily life during the COVID-19 lockdown (called neighborhood satisfaction for simplicity). This measure is a subjective evaluation by the local residents on their neighborhood environment, and is assumed to be directly associated with the psychological resilience of residents during the lockdown. It was coded using a seven-point Likert scale from "extremely poor" (1) to "extremely well" (7). Considering the significant correlation between the neighborhood environment and neighborhood satisfaction, we did not include this variable in the regression models. Rather, we used this variable as a mediating variable of the relationship between the neighborhood environment and psychological resilience in the structural equation model.

Further, we accounted for various personal factors that may influence psychological resilience including age, gender, marital status, household income, number of children under 6 years old in the household, number of older adults aged 65 and over in the household, and property ownership. The housing type and size were also considered as important factors that influence psychological resilience during the lockdown. We asked the respondents to report the type of housing they were living in, including high-rise apartments, middle-rise apartments, low-rise apartments, townhouses, detached houses, and others. Further, we also asked about the number of bedrooms in the housing unit as a measure of housing size. In addition, we accounted for factors that were directly linked with the pandemic. We asked the respondents to report whether they had been treated with less respect during the pandemic, and this variable was coded using a five-point Likert scale from "definitely not" (1) to "definitely yes" (5). We also asked the respondents to rate their perceived probability of getting infected with COVID-19, and this variable was coded using a seven-point Likert scale from "extremely unlikely" (1) to "extremely likely" (7).

Table 1
Factor loadings of walkability and social environment.

	Walkability
Bike lane density	0.845
Population density	0.905
% commercial land use	0.725
Entropy index	0.669
Connected Node Ratio	0.607
Bus stop density	0.908
Train station density	0.707
	Social environment
People around my neighborhood are willing to help their neighbors	0.827
This is a close-knit neighborhood	0.802
People in this neighborhood do not share the same values	−0.743
People in this neighborhood can be trusted	0.799
People in this neighborhood generally don't get along	−0.749

3.4. Modeling methods

We applied a binary logit model to investigate the factors that are associated with the propensity of worsening mental health during the pandemic. We then applied a multinomial logit model to examine the factors that are associated with the extent of the COVID-19 impact on mental health. For the latter outcome variable, we also estimated an ordered logit model, but a Brant test suggested the parallel assumption has been violated. The data presents a hierarchical structure, with individuals clustered within neighborhoods. We therefore used cluster-robust standard errors in these models to account for

heteroscedasticity and correlation in the error terms within each cluster.

We then applied a structural equation model (SEM) to examine the possible causal pathways between neighborhood environment and psychological resilience. The SEM enabled us to investigate the direct effects of the neighborhood environment on psychological resilience, as well as indirect effects through affecting intermediate factors. According to our conceptual framework, we hypothesized that the neighborhood environment has a direct impact on such intermediate factors as neighborhood satisfaction during the COVID-19 lockdown, and the perceived risk of getting infected with COVID-19. These intermediate variables then have a direct effect on psychological resilience. As the outcome variable, the mental health impact of COVID-19, is an ordered categorical variable, we applied the WLSMV (weighted least squares mean and variance adjusted) estimation method.

4. Results and discussion

A description of all measured variables is in Table 2. Table 3 provides the group mean values of some key variables by different home locations. As shown by the ANOVA tests, the inner city had a higher level of walkability and vegetation cover compared with the suburbs. However, the inner and middle suburbs had a more cohesive neighborhood environment than the inner city and the outer suburbs. Further, there was not a significant difference in perceived discrimination between different neighborhood locations. Finally, residents in the inner city had a higher level of perceived infection risk compared with their suburban counterparts, however, this difference was not statistically significant.

Table 4 presents the results of both the binary logit model and the multinomial logit model. The binary logit model predicts the odds of worsening mental health during the pandemic, while the multinomial logit model predicts the extent of the COVID-19 impact on mental health.

4.1. Built environment and psychological resilience

First, at the regional level, the above descriptive analysis (Fig. 2) has shown that the suburbs had a relatively lower percentage of residents who suffered from mental health impact compared with the inner city. The binary logit model results further suggest that the mental wellbeing of residents who lived in the suburbs was less likely to be negatively impacted by the pandemic, even after accounting for neighborhood walkability, vegetation cover, social environment, and perceived COVID-19 infection risk. That is, suburban residents had better psychological resilience compared with those living in the inner city during the COVID-19 pandemic. On the one hand, this is probably associated with the relatively higher density of the inner city, leading to a greater level of anxiety and fear of COVID-19. On the other hand, the inner city of Greater Melbourne has a higher crime rate before and during the pandemic lockdown (Crime Statistics Agency, 2021), and the negative impact of the high crime rate on mental health may have been amplified during the pandemic. Family violence incidents, for example, have significantly increased after the outbreak of the pandemic, and the inner city has the highest number of incidents (Rmandic et al., 2020). Further, results of the multinomial logit model suggest that residents in the middle suburbs were least likely to be severely impacted by the COVID-19 pandemic. This is probably because the middle suburbs feature a relatively low-medium residential density that is associated with a lower level of fear of COVID-19 infection, but also provides a relatively higher level of walkability and social cohesion compared with the outer suburbs. Fig. 3 illustrates the building density of a typical inner-city suburb, middle suburb, and outer suburb in Greater Melbourne.

Second, at the neighborhood level, the binary logit model results indicate that neighborhood walkability and percentage of vegetation cover are both negatively associated with the odds of worsening mental health. In other words, those living in neighborhoods with high levels of walkability and more green space had better psychological resilience.

Table 2
Summary statistics of all variables.

	Code or Unit	Mean	Std. Dev.	Min	Max
Outcome variables					
Whether mental health was negatively impacted by the pandemic	1 = yes; 0 = no impact	0.61	–	0	1
The extent of the negative impact on mental health	0 = no impact; 1 = slightly worse; 2 = much worse	0.81	0.74	0	2
Personal and household factors					
Age	1 = Aged 18–24; 2 = 25–34; 3 = 35–44; 4 = 45–54; 5 = 55–64; 6 = 65–74; 7 = 75–84; 8 = 85 or older	3.36	1.60	1	8
Female	1 = yes; 0 = otherwise	0.53	–	0	1
HH Income					
Less than $100,000 per year	1 = yes; 0 = otherwise	0.49	–	0	1
$100,000 per year or more	1 = yes; 0 = otherwise	0.40	–	0	1
Prefer not to say	1 = yes; 0 = otherwise	0.11	–	0	1
# children under 6 years old		0.17	–	0	3
# older adults aged 65 and over		0.26	–	0	3
Property owned	1 = yes; 0 = otherwise	0.56	–	0	1
Marital status					
Single, never married	1 = yes; 0 = otherwise	0.29	–	0	1
Married or domestic partnership	1 = yes; 0 = otherwise	0.61	–	0	1
Widowed	1 = yes; 0 = otherwise	0.02	–	0	1
Separated	1 = yes; 0 = otherwise	0.02	–	0	1
Divorced	1 = yes; 0 = otherwise	0.06	–	0	1
COVID-19 related factors					
Have you been treated with less respect	1 = Definitely not; 2 = Probably not; 3 = Might or might not; 4 = Probably yes; 5 = Definitely yes	2.06	1.10	1	5
Your own probability of getting infected with COVID-19	1 = Extremely unlikely; 2 = Moderately unlikely; 3 = Slightly unlikely; 4 = Neither likely nor unlikely; 5 = Slightly likely; 6 = Moderately likely; 7 = Extremely likely	3.12	1.58	1	7
Housing conditions					
Housing types					
Apartment/unit	1 = yes; 0 = otherwise	0.25	–	0	1
Townhouse	1 = yes; 0 = otherwise	0.16	–	0	1
Detached house	1 = yes; 0 = otherwise	0.57	–	0	1
Other	1 = yes; 0 = otherwise	0.01	–	0	1
# bedrooms within housing unit		2.89	–	0	6

(continued on next page)

Table 2 (*continued*)

	Code or Unit	Mean	Std. Dev.	Min	Max
Neighborhood environment					
Residential location					
Inner city	1 = yes; 0 = otherwise	0.09	–	0	1
Inner suburb	1 = yes; 0 = otherwise	0.28	–	0	1
Middle suburb	1 = yes; 0 = otherwise	0.27	–	0	1
Outer suburb	1 = yes; 0 = otherwise	0.36	–	0	1
Walkability	Factor score	1.11	1.26	−1.27	5.56
Percentage of vegetation	Percentage	15 %	12 %	0 %	91 %
Social environment	Factor score	0.00	1.00	−3.12	2.19
Neighborhood satisfaction during the COVID-19 lockdown	1 = Extremely poor; 2 = Very poor; 3 = Poor; 4 = Neutral; 5 = Well; 6 = Very well; 7 = Extremely well	4.78	1.34	1	7

Table 3
ANOVA test of the difference in group mean.

	Inner city	Inner suburbs	Middle suburbs	Outer suburbs	p-values
Walkability score	3.66	1.87	0.71	0.12	<0.01
Percentage of vegetation	25 %	12 %	15 %	15 %	<0.01
Social environment	−0.23	0.11	0.02	−0.04	0.02
Have you been treated with less respect (1–5)	2.04	2.07	2.11	2.05	0.91
Your own probability of getting infected with COVID-19 (1–7)	3.38	3.12	3.00	3.17	0.17

Note: p-value is derived from ANOVA tests.

While previous studies have linked walkability and green space with mental wellbeing (Astell-Burt & Feng, 2019; Ma & Ye, 2022; Pfeiffer & Cloutier, 2016; Roe & McCay, 2021), we are one of the first to highlight the important role of these neighborhood features in moderating people's psychological resilience during a pandemic lockdown. The multinomial logit model results further suggest that these two variables may play different roles in psychological resilience. It seems that neighborhood walkability only helps prevent mental wellbeing from getting slightly worse in the pandemic, while neighborhood greenness may be more important in preventing mental wellbeing from getting much worse. Overall, these findings highlight the important role of the built environment in shaping the psychological resilience of the local residents.

4.2. Neighborhood social environment and psychological resilience

In addition to the built environment, the neighborhood social environment is also correlated with psychological resilience. Overall, residents living in socially cohesive neighborhoods were less likely to be negatively impacted in mental health by the pandemic, and therefore have higher levels of psychological resilience. Particularly, a cohesive neighborhood environment helps reduce the extent of the pandemic shock on mental health. Under the pandemic lockdown, social interactions were significantly reduced because of the travel restrictions. In Melbourne's stage-4 lockdown, local residents were not allowed to visit family members, friends, and colleagues, or classmates. Though people could still contact each other virtually during the lockdown via email, phone calls, or social media tools, the lack of face-to-face

Table 4
Factors associated with the mental health impact of the pandemic.

	Model 1: Binary logit model		Model 2: Multinomial logit model			
	Worse vs No impact/better		Slightly worse vs No impact/better		Much worse vs No impact/better	
	Coef.	P > z	Coef.	P > t	Coef.	P > t
Personal and household factors						
Age	−0.123	0.021	−0.100	0.095	−0.189	0.013
Female	0.345	0.016	0.205	0.175	0.687	0.001
HH Income						
Less than $100,000 per year	Ref.		Ref.		Ref.	
$100,000 per year or more	−0.024	0.871	0.095	0.544	−0.276	0.199
Prefer not to say	0.464	0.030	0.573	0.012	0.223	0.440
# children under 6 years old	0.086	0.590	0.042	0.811	0.165	0.397
# older adults aged 65 and over	−0.390	0.001	−0.414	0.001	−0.307	0.126
Property owned	−0.418	0.006	−0.397	0.013	−0.465	0.017
Marital status						
Single, never married	Ref.		Ref.		Ref.	
Married or domestic partnership	−0.200	0.248	−0.261	0.138	−0.036	0.881
Widowed	−0.612	0.285	−0.735	0.263	−0.280	0.695
Separated	−0.023	0.967	0.037	0.945	−0.176	0.843
Divorced	−0.045	0.890	0.022	0.948	−0.265	0.590
COVID-19 related factors						
Have you been treated with less respect	0.161	0.014	0.015	0.838	0.466	0.001
Your own probability of getting infected with COVID-19	0.103	0.022	0.129	0.005	0.055	0.408
Housing conditions						
Housing types						
Apartment/ unit	Ref.		Ref.		Ref.	
Townhouse	0.253	0.308	0.287	0.283	0.171	0.572
Detached house	0.128	0.530	0.183	0.392	−0.018	0.947
Other	0.723	0.251	0.381	0.609	1.325	0.073
# bedrooms within housing unit	0.073	0.425	0.054	0.581	0.116	0.329
Neighborhood environment						
Walkability score	−0.243	0.018	−0.298	0.013	−0.124	0.351
Percentage of vegetation	−1.204	0.049	−0.840	0.201	−2.399	0.006
Residential location						
Inner city	Ref.		Ref.		Ref.	
Inner suburbs	−0.796	0.004	−0.897	0.007	−0.607	0.077
Middle suburbs	−1.054	0.004	−1.123	0.008	−1.012	0.040
Outer suburbs	−1.133	0.004	−1.382	0.003	−0.614	0.260
Social environment	−0.126	0.090	−0.095	0.239	−0.212	0.024
constant	1.529	0.010	1.507	0.025	−0.460	0.543
n	1,059		1,059			
McFadden R^2	0.09		0.10			
Log-likelihood intercept-only	−706.84		−1112.40			
Log-likelihood full model	−647.15		−1015.32			

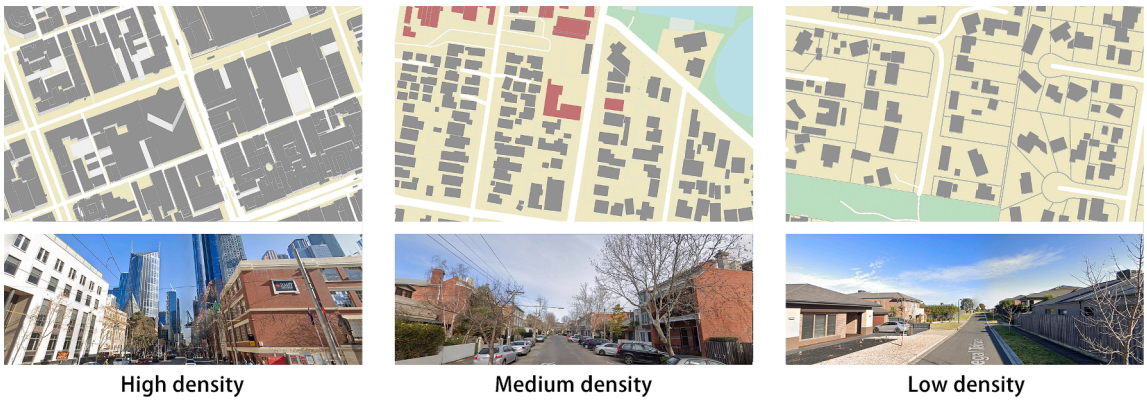

Fig. 3. Building density of a typical inner-city suburb, middle suburb, and outer suburb in Greater Melbourne.

socializing could increase the risk of developing depressive symptoms. For example, Teo et al. (2015) found that while it is known that social bonds are important for mental health, the type of communication also matters. They found that face-to-face communication plays a much more important role in mental health than virtual forms, particularly for older adults. A socially cohesive neighborhood environment may well have increased face-to-face interactions among neighbors during the lockdown, helping to relieve the mental stress associated with the pandemic.

Further, a socially cohesive neighborhood also provides social support that helps boost mental wellbeing during a lockdown. During the Melbourne lockdown, we saw various types of innovative local connection activities. For example, residents living on the same street or in the same neighborhood created Facebook groups to share interesting things, ask for help or offer help to neighbors, and cheer each other up. We saw a rise in give-and-take boxes in local neighborhoods during the lockdown period. Local residents use these boxes to share books, give goods (e.g., homegrown fruits and flowers) to neighbors, and exchange items. Some neighborhoods have initiated community care programs that provide free takeaway meals and groceries to help families heavily impacted by the pandemic. These neighborhood initiatives are important to help people cope with the negative impacts of the pandemic on their life and mental health.

4.3. *Causal pathways that the neighborhood environment could influence psychological resilience*

An SEM was estimated to further examine the causal pathways from the neighborhood environment that could mediate the impact of the COVID-19 on mental wellbeing. The results of SEM are presented in Fig. 4. The model fit indices, CFI (0.97) and RMSEA (0.04), indicate a good fit, based on Hu and Bentler (1999), who suggest a cutoff value close to 0.95 for CFI and a cut-off value close to 0.06 for RMSEA are needed to conclude there is a relatively good fit between the hypothesized model and the observed data. As shown in Fig. 3, neighborhood

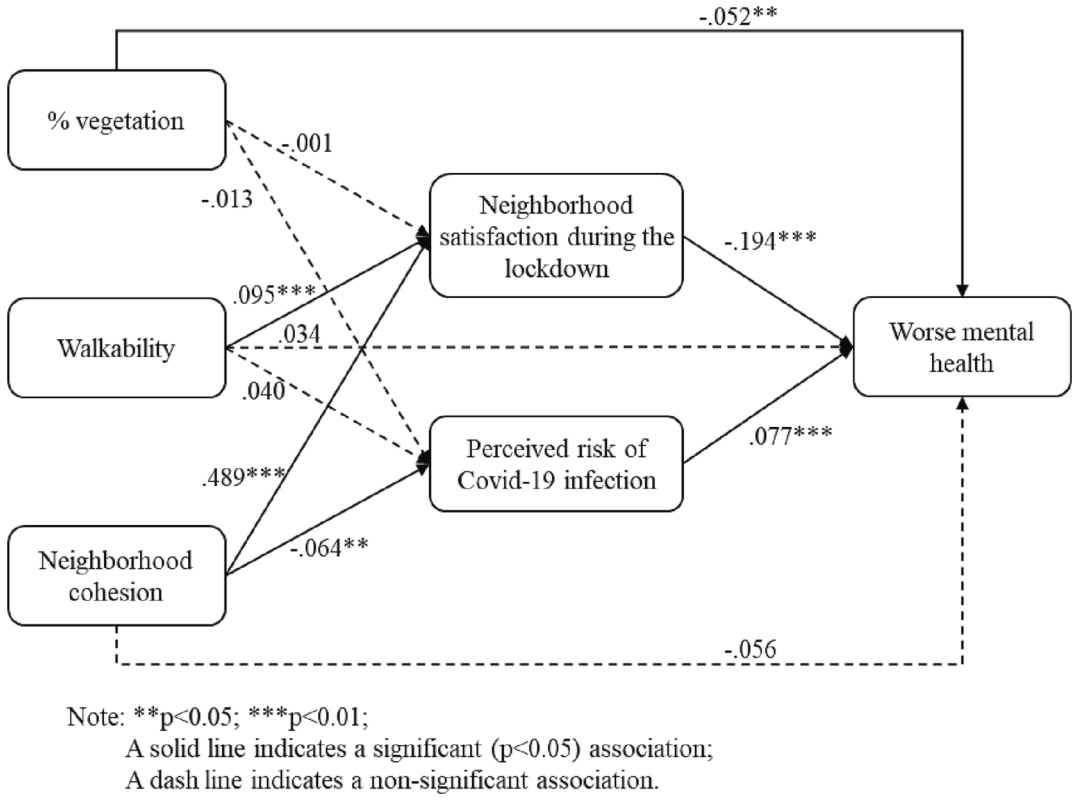

Fig. 4. SEM model results.

vegetation cover had a direct effect on mediating the negative impacts of COVID-19 on mental health. Walkability and neighborhood social cohesion, however, were only indirectly associated with the COVID-19 impact on mental health. For neighborhood walkability, it was positively associated with neighborhood satisfaction during the lockdown. In other words, walkable neighborhoods better meet the daily needs of local residents during a lockdown, compared to sprawling neighborhoods. Further, highly walkable neighborhoods were positively associated with perceived infection risk, however, this association was not statistically significant. Neighborhood social cohesion was also positively associated with neighborhood satisfaction, suggesting that a cohesive neighborhood environment can better support the daily life of local residents during a lockdown. In addition, neighborhood cohesion was negatively associated with perceived infection risk, suggesting that a cohesive neighborhood environment may help to reduce the anxiety of being infected with COVID-19. A recent study (Svensson & Elntib, 2021) also found that neighborhood social cohesion helped to alleviate health anxiety and perceived stress associated with the imposed COVID-19 lockdown in the UK. Finally, how well the neighborhood environment can meet people's daily needs during the lockdown and perceived risks of getting infected were both directly associated with the mental health impact of the COVID-19 lockdown.

While in this study we focus on the mediating roles of neighborhood satisfaction and perceived infection risk, there are other causal pathways that neighborhood environment could also influence psychological resilience. Physical activity, for example, can help to reduce stress and anxiety and improve mental health, and thus contribute to psychological resilience. Previous research has suggested that neighborhood greenness, walkability, and social cohesion can help create a viable and safe environment for residents to engage in physical activity (Kaczynski & Henderson, 2007; McNeill et al., 2006; Sallis et al., 2016).

4.4. Other factors that are associated with psychological resilience

In addition to the neighborhood environment, we have also examined the role of personal and household factors, COVID-19 related factors, and housing conditions on psychological resilience. Compared with older adults, younger adults were more likely to suffer negative mental impacts from the pandemic. Women were at greater risk of worsening mental health during the pandemic compared with men. There was no linear correlation between household income and the odds of worsening mental health during the pandemic, suggesting that household income is not an important factor for psychological resilience. This is probably because the effect of income on mental health may be heterogeneous, depending on the education levels of individuals. Income has a weaker impact on the mental health of well-educated individuals than on the mental health of less-educated individuals (Yang et al., 2022). Also, the variable household income is significantly associated with property ownership, housing types, and number of bedrooms which have been controlled in the model, and these variables can mediate the effects of the income on psychological resilience. Though we thought that the lockdown would significantly increase the mental burden of parents because of the closure of childcare centers, the number of children under six years old within the household was not associated with mental health impacts. This is probably because women take more responsibility for the care of the young children than men, and therefore are more likely to suffer from the increased caring demand during the lockdown. Indeed, we tested this hypothesis by estimating a model using the women sample only, and found a significant and positive association between the number of younger children and the odds of experiencing worsening mental health during the lockdown. These findings align well with recent studies (Fitzpatrick et al., 2020; Qiu et al., 2020; Varma et al., 2021) that also reported that younger people, women, and families with children have been more vulnerable to stress, anxiety, and depression during COVID-19 pandemic. It is also interesting to note that those in households with more older adults were less likely to be negatively impacted in mental health during the lockdown. This is probably because older adults provide some mental support to the younger ones in the household. Further, home property owners were less likely to experience worsening mental health during lockdown compared with renters. Marital status was not significantly associated with the mental impact of the pandemic.

Regarding the COVID-19 related factors, we found that those who felt discriminated against during the pandemic had significantly higher odds of experiencing worsening mental health during the lockdown. Further, the housing type was not significantly associated with the mental health impacts of the pandemic, though we expected apartment living might contribute to worse mental health because of the higher living density. While the majority of previous studies have linked high-rise residential living with worse mental health outcomes, several studies reported no association between housing type and psychological distress and loneliness (Barros et al., 2019; Kearns et al., 2015).

5. Limitations and future directions

This study has several limitations. There could be potential measurement errors as the built-environment variables were measured at the neighborhood rather than the household level, particularly for those living near neighborhood boundary lines. Further, psychological resilience was measured using a single item. Single-item measures are more vulnerable to random measurement errors and often raise reliability, sensitivity, and validity issues. While there are several validated scales for psychological resilience, they focus on factors that develop resilience and are usually used in normal circumstances rather than in an emergency event. Our measure is a direct measure of psychological resilience to the impact of the COVID-19 pandemic. Further, our measure of psychological resilience focused more on how well individuals coped with the stress and adversity resulting from the pandemic, not their ability to 'bounce back' from the negative impacts. Further, there may have been other unmeasured confounders that influenced both the neighborhood environment and psychological resilience, and this might have biased the model results. Considering the recall bias, we did not ask the respondents to recall their mental health conditions before the pandemic, rather we asked them to report how their mental health has been changed since the pandemic lockdown. We therefore adopted difference score (i.e., changes in mental health) modelling method, which answers the question: "Whose mental health is most likely to increase or decrease over time". This method is valid if pre-test scores remain stable in the absence of treatment (Gollwitzer et al., 2014; Mattes & Roheger, 2020). In our case, we assumed that mental health conditions would not change if the pandemic did not occur. However, including pre-Covid mental health may help improve statistical power of our regression models, as suggested by Mattes and Roheger (2020). Finally, future research that examines how and to what extent that COVID-19 has influenced the neighborhood environment (e.g., changes in social cohesion and greenness) and the dynamic relationship between changes in neighborhood environment and changes in mental health could be enlightening.

6. Concluding remarks and implications for planners

We examined the role of the neighborhood environment in psychological resilience through a survey analysis of local residents of the Melbourne metropolitan area during one of the COVID-19 pandemic lockdowns. Overall, we found that the neighborhood environment, including both the physical and social environment, played an important role in buffering the psychological shock of the pandemic. This study contributes to the growing literature linking the built environment and psychological resilience, and it also provides new insights into resilience planning.

Most of the respondents reported that their mental health was negatively impacted by the pandemic lockdown, this impact, however,

was not equally distributed. We found that residents living in the suburbs were less likely to be negatively impacted in mental health, thus were more psychologically resilient during the pandemic lockdown compared with those living in the inner city. In particular, we found that residents of middle suburbs were the most resilient group, and this is partially attributed to the middle residential density of these neighborhoods. We further found that neighborhood walkability and green spaces were important in mitigating the negative impact of the pandemic lockdown on mental health. Residents living in neighborhoods with high levels of walkability and greater vegetation cover had better psychological resilience, even after accounting for their sociodemographics, residential locations, and housing types. We also found that neighborhood walkability may help mitigate overall mental health impacts, while neighborhood greenness is more important for reducing the extreme psychological impact of the pandemic lockdown. In addition to the physical environment, we also found that neighborhood social cohesion matters. Socially cohesive neighborhoods foster social interactions and offer community-level initiatives to support individuals facing challenges. As a result, residents in these areas were better equipped to cope with the psychological impact of the pandemic.

In addition, we investigated the potential mechanisms through which the neighborhood environment may impact psychological resilience. Our analysis revealed that neighborhood vegetation coverage has a direct effect on psychological resilience, while neighborhood walkability and social cohesion have an indirect effect through residents' satisfaction with their neighborhood and perception of COVID-19 infection risks. In particular, we found that residents living in highly walkable and socially cohesive neighborhoods perceive their neighborhood environment as better suited to meet their needs during pandemic lockdowns, and thus experience less negative mental health impacts. Further, a cohesive neighborhood environment can lower the perceived risk of being infected, thereby decreasing the psychological impact of the pandemic. We also found that high levels of walkability do not necessarily increase perceived infection risk.

This study has implications for planning practice. First, interventions aimed at enhancing neighborhood walkability, greenery, and social cohesion can improve the psychological resilience of local residents, ultimately enhancing urban resilience. These planning interventions have also been recognized as important measures for coping with other types of disasters. For example, several previous studies have highlighted the important roles of collective action and community social capital in managing climate change-induced disasters such as heat waves and extreme weather events (Adger, 2003; Browning et al., 2006), as well as other natural disasters like mountain hazards and flooding (Babcicky & Seebauer, 2020). According to Kwok et al. (2016), neighborhood social cohesion is among the essential features of the social resilience of communities.

Further, the role of greenery in building urban resilience has also been extensively discussed in the context of various types of disasters, ranging from natural disasters like extreme heat, earthquakes, and cyclones, to man-made ones like terrorist attacks and wars (Aram et al., 2019; Pascal et al., 2021; Tidball & Krasny, 2013). Neighborhood green spaces not only alleviate mental stress and promote mental wellbeing, but also serve as gathering places during disasters where local residents can form social coalitions and provide support to one another (Roe & McCay, 2021). In addition to large parks, neighborhood planning should consider green roofs, pocket parks, neighborhood gardens, and green streets, which have the potential to improve neighborhood greenness (Bell et al., 2008; Dadvand et al., 2016). The feasibility of these approaches may vary depending on factors such as design, funding, and local policies (Kabisch et al., 2016; Wolch et al., 2014). For example, while green roofs have been shown to provide a range of environmental and social benefits, they can be costly to install and maintain, and may require supportive policies or incentives to promote widespread adoption (Teotónio et al., 2021). Similarly, pocket parks and green streets can help increase access to green spaces and improve walkability, but their success depends on factors such as site selection, design, and maintenance (Adkins et al., 2012; Kerishnan & Maruthaveeran, 2021). Therefore, neighborhood planners and policymakers should work closely with community members to identify and prioritize the most effective and feasible strategies.

It is already well known that a walkable environment helps to lower greenhouse gas emissions and thus mitigate climate change by reducing car dependence (Ewing et al., 2007). More importantly, our study suggests that planning efforts to improve neighborhood walkability can also help improve psychological resilience because they can better meet the basic needs of local residents when people's daily travel is significantly restricted as a result of a disaster or emergency event. Planning interventions including high quality pedestrian and cycling infrastructure, safe and convenient access to parks and recreational facilities, mixed and transit-oriented development all could help to make communities more walkable (Frank et al., 2010; Manaugh & El-Geneidy, 2011). It is also important to note that the impact of walkability interventions on psychological resilience may vary depending on several factors, including the socioeconomic characteristics of the community, and the individual experiences of residents (Wen et al., 2006). Moreover, interventions solely focused on the built environment may not adequately address the complex and multifaceted challenges that communities face during and after disasters or emergency events (Cutter et al., 2008). Overall, while greening and walkability approaches show promise in promoting mental health and resilience, more research is needed to understand the circumstances under which they are most effective. Nonetheless, these interventions represent an important step towards creating more social resilient communities that prioritize the health and well-being of their residents.

Second, our study suggests that lower-density suburbs are more supportive of psychological resilience than higher-density inner-city areas. One possible reason for this finding is that COVID-19 is a highly contagious disease, and people living in higher-density areas tend to have a higher perceived susceptibility to the COVID-19 threat (Hamidi et al., 2020). Additionally, it is important to note that this result may not necessarily apply similarly outside Australia. However, this finding adds to the ongoing debate regarding what constitutes an optimal density for a resilient neighborhood. In preparing for future emergency events like the COVID-19 pandemic, planners should ensure that residential density in suburbs meets the requirement of creating high levels of walkability while retaining the advantages of lower-density living. These include closeness to nature, a quiet and peaceful environment, and a close-knit community.

CRediT authorship contribution statement

Liang Ma: Conceptualization, Investigation, Methodology, Formal analysis, Writing - original draft. **Runing Ye:** Conceptualization, Funding acquisition, Investigation, Writing - review & editing. **Dick Ettema:** Investigation, Writing - review & editing. **Dea van Lierop:** Investigation, Writing - review & editing.

Data availability

Data will be made available on request.

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