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# Examining associations between area-level spatial measures of housing with selected health and wellbeing behaviours and outcomes in an urban context

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ABSTRACT

Adequate and affordable housing is a major social determinant of health; yet no work has attempted to conceptually map and spatially test area-level measures of housing with selected health and wellbeing outcomes. Sourcing data from 7,753 adults from Melbourne, Australia, we tested associations between area-level measures of housing density, tenure, and affordability with individual-level measures of neighbourhood safety, community satisfaction, and self-rated health. Compared with the reference groups, the odds of: feeling unsafe was higher for residents living in areas with less affordable housing; community dissatisfaction was ~30% higher in those living in areas with > 36% residential properties assigned as rentals, and was significantly higher in the least affordable areas (OR =1.57). Compared with the reference groups, as dwelling density, proportion of rental properties, and housing unaffordability increased, the odds of reporting poorer self-rated health increased; however these associations did not always reach statistical significance. This work highlights the benefits of evidenced-based planning spatial measures to support health and wellbeing.

## 1. Introduction

More than half of the world's population now live in cities, and this is expecting to rise to five billion people by 2030 (United Nations Population Fund, 2007), and within high income countries, the vast majority of people (~86%) already reside in urban settings (United Nations Department of Economic and Social Affairs, 2014). In these contexts, often the more desirable parts of the city are frequently served with more amenities and public transport (e.g. inner-city suburbs), and these are becoming increasingly unaffordable (Currie and Delbosc, 2011). To accommodate population growth, a frequently employed strategy in North America and Australasia since the 1950's is to release new land for development on the urban fringe of cities (Currie and Delbosc, 2011). Urban fringe developments offer lower cost, more 'affordable' housing, particularly when only the cost of the house and land package is considered (Currie and Delbosc, 2011). However, these new developments tend to be located in sprawling, low residential density communities with limited local infrastructure and poor access to local employment opportunities, shops and services and public transport infrastructure; therefore other costs, such as longer journeys to work and reduced local opportunity, are incurred (Giles-Corti et al., 2012). Hence, urban fringe developments tend to increase motor vehicle dependency and are associated with less walking, cycling, and public transport use (Badland and Schofield, 2005). In this respect, low residential urban fringe locations could be said to be providing 'affordable' housing, but are not necessarily located in 'liveable' neighbourhoods.

Liveable communities are defined as places that are: 'safe, attractive, socially cohesive and inclusive, and environmentally sustainable; with affordable and diverse housing linked via convenient public transport, walking, and cycling infrastructure employment, education, public open space, local shops, health and community services, and leisure and cultural opportunities' (Lowe et al., 2013). Therefore, to create healthy liveable communities, housing strategies that support access to local amenity are required to accommodate an increasingly urbanising population. This includes concentrating new growth in areas well served by public transport infrastructure and being able to accommodate a mix of housing types, commerce, retail, light industry, and recreation. Creating more compact higher density mixed use development is desirable as it maximises the use of existing infra-

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structure while minimising service costs and potentially commute travel times by providing local employment opportunities (ISO/TC 268, 2014). Importantly, if high-quality high density housing is made proximal to neighbourhood amenities, it has the potential to enable local living (Newton and Glackin, 2014). An Australian example from Victoria is the '20 min neighbourhood'. This strategy seeks to enable residents to live locally by providing the amenity required for daily living within a 20 min journey of home (State Government Victoria, 2014).

Higher residential densities have the potential to benefit health and wellbeing, particularly if located in neighbourhoods with accessible, frequent public transport services, and a variety of shops and services. These types of neighbourhoods have been shown to promote positive health behaviours by encouraging walking, cycling, transit use, and reduced sitting time, while supporting the provision of local shops and services (Giles-Corti et al., 2012). Proximal retail destinations attract pedestrians, and produce a range of positive social attributes and outcomes (Wood et al., 2008). More people on the streets promotes natural surveillance, which makes neighbourhoods look and feel safer, while also promoting social interactions (helping to create social capital) (Leyden, 2003; Rogers et al., 2011). Living in neighbourhoods with higher levels of social capital, regardless of neighbourhood disadvantage, has been linked to better health (Diez Roux et al., 2001; Elgar et al., 2011), with this association more pronounced in urban settings (Mohnen et al., 2011). However, areas with many destinations available tend to attract strangers from outside local communities, which may reduce social capital (Wood et al., 2008). For example, early studies indicate in areas with high levels of pedestrian activity, residents may withdraw into the private realm to regulate their exposure to strangers (Baum et al., 1978) and neighbours (Appleyard and Lintell, 1972). Hence, residents of denser urban environments may select these areas with a tacit acceptance that there may be trade-offs to living in more accessible, vibrant neighbourhoods (Foster et al., 2014).

In many developed countries home ownership is preferred over private rental tenure (Diaz-Serrano, 2009). This is often supported by government policies that ease the pathway into home ownership (Gilbert, 2016). In Australia for example, first homebuyers are offered subsidies, which in some states includes reductions in government taxes when first homes are purchased or dwellings are purchased off plans (e.g. New South Wales First Home Owner Grant schemes, Victoria Off-the-Plan Concession scheme). Compared with renting, home ownership is thought to yield individual-level social and economic benefits including financial security, access to credit, wealth generation, self-esteem, social status, housing satisfaction, as well as community benefits including neighbourhood stability, improved property upkeep and area attractiveness, community engagement (Huang et al., 2015; Rohe et al., 2001). However, home ownership can result in mortgage stress and restricted mobility, particularly when ownership constrains residents relocating 'upwards' from disadvantaged or declining neighbourhoods (Rohe et al., 2001) or when their housing needs change (e.g. requiring age-friendly housing).

A bi-directional relationship has been shown between housing affordability and health, suggesting physical and mental health status influences the type of housing one can afford, and vice versa (Baker et al., 2014). These effects are most pronounced for more vulnerable populations, such as single parent and low income households (Baker et al., 2014; Bentley et al., 2011). Indeed, it is likely that housing affordability impacts the health and wellbeing of residents in at least two ways. First, those with a limited budget and resources may make trade-offs between housing affordability and location and access to employment, education, and services required for daily living, including schools, recreation, retail, services, and food availability (Currie and Delbosc, 2011). This increases time spent commuting and in sedentary activities while reducing opportunities for local physical and social activities. Second, for those living within restricted budgets, the suitability of available housing may be compromised, which can lead to living in poorer quality dwellings (Howden-Chapman, 2002) or neighbourhoods (e.g. high crime and incivilities), and situations of overcrowding. A large body of literature shows that poorer quality housing (e.g. inadequate insulation, lack of heating) and overcrowding are associated with reduced housing satisfaction (Giles-Corti et al., 2012), poorer mental health, higher rates of contracting infectious diseases, respiratory problems, and injuries (Howden-Chapman, 2002; Baker et al., 2013; Krieger and Higgins, 2002). These impacts may be exacerbated for those living in unsafe neighbourhoods, who may constrain their social and physical activities (Foster and Giles-Corti, 2008).

Although this work has been conceptualised from an international perspective, it uses Australian data (from metropolitan Melbourne, Victoria) to build a case for demonstrating how a suite of housing 'liveability' indicators could be developed, applied and monitored in future to create communities that support health and wellbeing. Australia is one of the most highly urbanised countries in the world, and its capital cities are renowned for being unaffordable, particularly Sydney and Melbourne (Major Cities Unit, 2013). There is also a high rate of home ownership with the majority of the population living in suburbs, most of which are low-density (Major Cities Unit, 2013). With Australia's population expected to reach 42 million by 2050 (currently at 22 million) (Major Cities Unit, 2013), there is pressure to increase densities in the inner and middle regions of the city to provide affordable housing options to accommodate this rapid growth (Department of the Prime Minister and Cabinet, 2016).

This study sought to create and test spatial measures of housing and pathways hypothesised to be associated with health and wellbeing. From a policy perspective it remains challenging to plan cities that equitably provide housing that supports health and wellbeing; and spatial data have been rarely used to understand the delivery of housing. Working under the umbrella of liveability, this work can help build the evidence-base for urban planners and policy-makers to support city-shaping activities needed to support health-promoting housing across an urban region, and to monitor its delivery over time. Accordingly, the aims of this paper were to: 1) conceptualise the range of pathways through which housing in urban settings impact health and wellbeing behaviours and outcomes; 2) spatially operationalize measures that map to these pathways; and 3) test associations for how selected housing measures relate to health and well-being in an urban context.

## 2. Methods

### 2.1. Housing conceptual framework development

A housing conceptual framework was developed using a social determinants of health lens (Fig. 1) that considered upstream (e.g. neighbourhood attributes) and downstream (e.g. perceptions, behaviours, outcomes) determinants of the health and wellbeing impacts of housing within an urban context (Baker et al., 2014; Howden-Chapman, 2002; Strategic Review of Health Inequalities in England post-2010, 2010; Cervero and Duncan, 2006; Macintyre et al., 2003). Three different methods were used to develop the conceptual framework: 1) a review of housing-related urban planning and policy documents; 2) a review of scientific literature to identify housing measures used elsewhere; and 3) an academic assessment of the 'meaningfulness' of the identified measures from a spatial perspective. Once developed, the housing conceptual framework was used to identify suitable upstream neighbourhood-level spatial measures associated with selected housing-related behavioural, intermediate, and long-term outcomes.

There were two considerations for selecting the housing measures. First, the measures identified needed to be spatially attributable (i.e. the unit of measurement had to be within a spatially defined boundary)

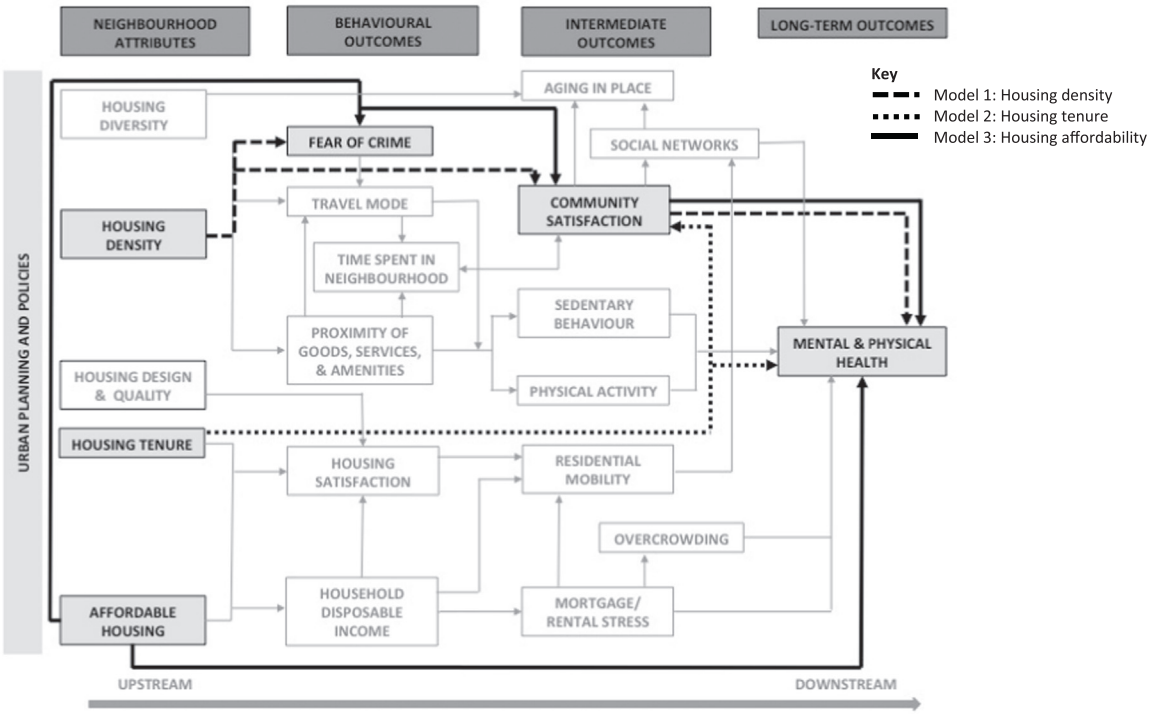


**Fig. 1.** Conceptual and analytic framework describing how housing neighbourhood attributes relate to behavioural, intermediate, and long-tem outcomes in an urban context. Shaded boxes and differing black lines indicate the housing models that were tested.

to facilitate contrast and comparison of diverse neighbourhoods and replication over time. Second, the measures had to be conceptualised at a fine-grained scale (i.e. available at small area unit data). Finer-grained data are regarded as being more appropriate for studying neighbourhood effects in an urban context. Small area unit data can be aggregated to larger regional administrative units (Kwan, 2012), are better predictors of an individual's behaviour (rather than regional- or city-level attributes) (Learnihan et al., 2011), and provide the flexibility for interrogating localised pockets of advantage or disadvantage.

The lead author conducted a literature search of public health and urban design research, and Victorian (state) and selected Australian (national) urban policy and planning documents related to potential spatial attributes of housing. All measures identified were included at this stage. The co-authors then reviewed these measures in relation to the following criteria: 1) Does the spatial measure fit within the proposed conceptual housing framework? 2) Are spatial data readily available at small unit level to create a measure that can be replicated over time in an urban context? The full housing conceptual and analytical framework is presented in Fig. 1. The shaded boxes and three differing black lines indicate attributes that could be tested in this study, as we were able to access the appropriate data to populate and examine these associations.

### 2.2. Neighbourhood-level spatial measures

Three neighbourhood-level housing attributes hypothesised to influence health and wellbeing were examined: 1) housing density; 2) housing tenure; and 3) affordable housing (Fig. 1). For each neighbourhood attribute, a spatial measure was identified, developed, and applied (see Table 1). All spatial data were derived from the Australian census collection undertaken in 2011 by the Australian Bureau of Statistics (ABS) (Australian Bureau of Statistics, 2011a), available at the SA1 administrative unit. There are 54,805 SA1s across Australia; they are designed to be within the population range of 200 – 800 people, and accordingly vary substantially in geographical size (i.e. rural SA1s are larger than suburban and urban SA1s) (Australian Bureau of Statistics, 2011a). As this research focussed on urban liveability, we applied a combined measure of the Sections of State (Australian Bureau of Statistics, 2011b) and Metropolitan Boundary (State Government Victoria, 2014) classifications to identify and select Victorian SA1s that were classified as both 'urban' and 'metropolitan', respectively. The SA1 geographical unit constitutes the neighbourhood-level variable used in this study, noting it can be aggregated to larger regional administrative units if required (Kwan, 2012).

**Table 1**
Housing measures and descriptive profile for SA1s in urban metropolitan Melbourne, Australia.

| Housing measure | Mean | SD |
|---|---|---|
| *Housing density* | | |
| Dwelling density / ha in the SA1 | 16.37 | 28.43 |
| *Housing tenure* | | |
| Proportion of rented dwellings in the SA1 | 0.27 | 0.17 |
| *Housing affordability* | | |
| Proportion of households $\leq$ 40% of household income spending $\geq$ 30% of household income on mortgage or rent in the SA1 | 0.34 | 0.17 |

**Key:** ha = hectare; SD = standard deviation; SA1= statistical area 1 (~400 persons/area).

Quartiles were used in our analysis for two reasons. The first was this was an exploratory analysis to see if there were 'thresholds' in the associations between the housing measures and the outcome variables. If evident, these could then be used to empirically inform planning recommendations. The second reason was because of the analysis used. Regression models rely on similar distributions amongst the groups, otherwise the confidence intervals can become very wide and lose meaning. While the groups could be split based on existing planning policies or the data distribution (e.g. Jenks natural breaks), the use of quartiles was appropriate for our purposes.

#### 2.2.1. Housing density

Dwelling density data were provided by the ABS at the mesh block unit. Mesh blocks are the smallest geographical area defined by ABS.

Mesh blocks classified as 'residential' or 'agricultural' within the urban and metropolitan catchments were included in the dwelling density classifications. The relevant mesh blocks within each SA1 were aggregated and the number of residential units extracted. The dwelling density per hectare measure was calculated by dividing the number of residential units by the size of the SA1 and collapsed into quartiles.

#### 2.2.2. Housing tenure

Customised data were provided by the ABS identifying the total number of owner occupied and rented dwellings within SA1s based on 2011 census data. Dwellings supplied by government (e.g. Territory Housing Authority) were excluded by the ABS when they customised the data. The proportion of rented dwellings in each SA1 was calculated by dividing the total number of rented dwellings by the total number of owner occupied and rented dwellings and collapsed into quartiles.

#### 2.2.3. Housing affordability

The ABS defines an area as having 'affordable' housing if the lowest 40% of household incomes in a given area spend < 30% of gross income on mortgage or rental payments (Australian Bureau of Statistics, 2013). This measure is commonly referred to as the 30/40 rule (O'Neill, 2008). Accordingly, the ABS generated this customised measure as a proportion for each SA1, which was collapsed into quartiles.

### 2.3. Individual-level measures

Ethics approval for the use of the 2011 VicHealth Indicators Survey was granted by the (then) Victorian Department of Health and The University of Melbourne approved the linking of spatial and health data. Informed consent was obtained from all study participants. Data were collected in 2011.

Demographic, perception, behaviour, and outcome data were sourced from the 2011 VicHealth Indicators Survey. This self-report population health survey assessed a range of social determinants of health and community wellbeing factors in adults (≥18 years) residing in Victoria, Australia. The survey was conducted across the 79 Victorian Local Government Authorities (LGA) using computer assisted telephone interviews. Overall, there were 25,075 participants with residential address data (geo-coded) from across Victoria (overall response rate 53.5%).

Those living in non-urban, non-metropolitan areas were excluded (n =15,580), as were those with missing household income data (n =1,742). This was because income was regarded as an important contributor of determining where people could afford to purchase a dwelling (Strategic Review of Health Inequalities in England post-2010, 2010). Survey respondent residential address geocodes were assigned to SA1s for those living in urban areas. From this, the 'housing measures' described earlier, housing density, housing tenure, and affordable housing, were calculated at the SA1 for each participant using ArcGIS 10.2 (ESRI, Redlands) geographic information systems (GIS) software.

Three items were used to populate the individual-level 'behavioural', 'intermediate', and 'long-term' outcomes to test components of the framework hypothesised in Fig. 1. Each attribute is described in more detail below.

#### 2.3.1. Behavioural outcome

Fear of crime was assessed using the item: 'How safe do you feel walking in your local area alone after dark? ' This was assessed using a five-point likert scale, where 1= very safe, 5= very unsafe. The scale was collapsed and recoded into 'safe' and 'unsafe' (1= safe (safe + very safe), 2= unsafe (very unsafe + unsafe + neutral)).

#### 2.3.2. Intermediate outcome

Community satisfaction was assessed by the item: 'How satisfied are you with feeling part of your community? ' Possible responses ranged from 0= completely dissatisfied to 10= completely satisfied. These scores were collapsed and recoded into 'satisfied' and 'dissatisfied' (1= satisfied (5 – 10), 2= dissatisfied (0 – 4)).

#### 2.3.3. Long-term outcome

Chronic mental and physical health conditions were assessed through a self-rated health item (5-point likert scale; 1= excellent, 5= poor). Participants were collapsed and recoded into a binary measure of 'better' or 'poorer' self-rated health (1= better (very good + excellent), 2= poorer (poor + fair + good)).

### 2.4. Analysis approach

Multivariate multilevel logistic regression models were used to compare exposure and outcome measures for the three hypothesised pathways identified in Fig. 1. All analyses were adjusted for sex, age, employment status, and household income and composition. Analyses were conducted using Stata IC v.13.1, and statistical significance was α=0.05.

## 3. Results

The final analytical sample included 7753 VicHealth survey respondents who lived in urban metropolitan areas and reported household income. Table 2 presents the demographic profile of this sample.

**Table 2**
Demographic profile of urban metropolitan VicHealth survey respondents.

| Demographic variable | | n | % |
|---|---|---|---|
| *Sex* | | | |
| | Male | 3192 | *41.2* |
| | Female | 4561 | *58.8* |
| *Age (years)*[a] | | | |
| | 18–34 | 957 | *12.3* |
| | 35–54 | 2908 | *37.4* |
| | 55–74 | 2920 | *37.7* |
| | ≥ 75 | 960 | *12.4* |
| *Highest education attainment*[a] | | | |
| | ≤ Secondary | 3214 | *41.6* |
| | ≥ Tertiary | 4525 | *58.5* |
| *Employment status*[a] | | | |
| | Employed | 4373 | *56.4* |
| | Unemployed / not in the labour force | 3377 | *43.6* |
| *Annual household income (AUD)* | | | |
| | < $40,000 | 2892 | *37.3* |
| | $40,000 - < $80,000 | 2150 | *27.7* |
| | $80,000 - < $120,000 | 1420 | *18.3* |
| | ≥ $120,000 | 1291 | *16.7* |
| *Children in the household* | | | |
| | Yes | 3338 | *43.1* |
| | No | 4415 | *56.9* |
| *Perceptions of night-time neighbourhood safety*[a] | | | |
| | Safe | 3980 | *64.8* |
| | Unsafe | 2166 | *35.2* |
| *Perceptions of community satisfaction*[a] | | | |
| | Satisfied | 7078 | *92.5* |
| | Dissatisfied | 571 | *7.5* |
| *Self-rated heath*[a] | | | |
| | Better health | 3736 | *48.3* |
| | Poorer health | 4004 | *51.7* |

**Key:** AUD = Australian Dollar.
[a] = missing data.

**Table 3**
Multivariate multilevel regression models examining direct associations of the odds of feeling unsafe, community dissatisfaction, and poorer self-rated health with housing measures in urban metropolitan VicHealth survey respondents.[a].

| | | Odds of feeling unsafe[b] | | | Odds of community dissatisfaction[b] | | | Odds of poorer self-rated health[b] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pathway** | **n** | *OR* | *95% CI* | *p-value* | *OR* | *95% CI* | *p-value* | *OR* | *95% CI* | *p-value* |
| **Pathway 1: Housing density** | | | | | | | | | | |
| *Dwelling density / ha* | | | | | | | | | | |
| Q1 (< 9.67) (lowest) | 1873 | 1.00 | ref | | 1.00 | ref | | 1.00 | ref | |
| Q2 (9.67–12.30) | 1863 | 1.11 | 0.93–1.34 | 0.26 | 1.04 | 0.80–1.36 | 0.77 | **1.14** | **1.00–1.31** | ≤ 0.05 |
| Q3 (12.31–15.80) | 1928 | 1.15 | 0.95–1.41 | 0.16 | 1.14 | 0.87–1.49 | 0.33 | **1.16** | **1.00–1.33** | ≤ 0.05 |
| Q4 (≥ 15.81) (highest) | 1916 | 0.87 | 0.69–1.11 | 0.26 | 1.14 | 0.85–1.53 | 0.39 | 1.12 | 0.97–1.30 | 0.12 |
| **Pathway 2: Housing tenure** | | | | | | | | | | |
| *Rental properties (proportion)* | | | | | | | | | | |
| Q1 (< 0.14) (lowest) | 1716 | | | | 1.00 | ref | | 1.00 | ref | |
| Q2 (0.14–0.22) | 1714 | | | | 1.05 | 0.78–1.40 | 0.75 | **1.19** | **1.03–1.37** | ≤ 0.05 |
| Q3 (0.23–0.35) | 1857 | | | | 1.30 | 0.98–1.72 | 0.07 | 1.08 | 0.94–1.25 | 0.23 |
| Q4 (≥ 0.36) (highest) | 1954 | | | | **1.34** | **1.00–1.79** | ≤ 0.05 | **1.20** | **1.03–1.39** | ≤ 0.05 |
| **Pathway 3: Housing affordability** | | | | | | | | | | |
| *Unaffordable housing (proportion)* | | | | | | | | | | |
| Q1 (< 0.24) (lowest) | 1894 | 1.00 | ref | | 1.00 | ref | | 1.00 | ref | |
| Q2 (0.24–0.32) | 1928 | **1.26** | **1.05–1.51** | ≤ 0.05 | 1.01 | 0.75–1.35 | 0.95 | 1.00 | 0.87–1.15 | 0.99 |
| Q3 (0.33–0.43) | 1880 | **1.30** | **1.08–1.57** | ≤ 0.01 | 1.14 | 0.86–1.51 | 0.36 | 1.08 | 0.94–1.25 | 0.26 |
| Q4 (≥ 0.44) (highest) | 1908 | 1.19 | 0.98–1.44 | 0.08 | **1.57** | **1.20–2.05** | ≤ 0.001 | **1.15** | **1.00–1.32** | ≤ 0.05 |

**Key:** employment status, household income and composition; CI = confidence interval; ha = hectare; OR = odds ratio; Q = quartile; ref = reference category; bold indicates α ≤0.05.
[a] = associations conceptualised in Fig. 1.
[b] = adjusted for sex, age.

There were slightly more women (58.8%) than men, the majority were aged 35–74 years (75.1%), held a tertiary qualification (58.5%), were employed (56.4%), earned less than $80,000 per annum (65.0%), and did not have children living with them (56.9%). The majority of respondents perceived their neighbourhood to be safe (64.8%) and were satisfied with their community (92.5%). Slightly more respondents reported poorer (51.7%), rather than better self-rated health.

As per the conceptual framework, data in Table 3 show the associations between the spatially derived housing measures and outcomes. Dwelling density was not associated with perceived neighbourhood safety. The odds of feeling unsafe was higher for residents living in areas with less affordable housing available, compared with residents living in neighbourhoods with more affordable housing.

When community satisfaction was considered, significant associations were observed with rental properties and housing affordability. Compared with those with the fewest rental properties available, the odds of community dissatisfaction was around 30% higher in those living in areas with 36% or more residential properties assigned as rentals. Similarly, the odds of community dissatisfaction were significantly higher in the least affordable areas compared with the most affordable areas (OR =1.57).

Significant associations were shown for some categories of housing density, tenure, and affordability with self-rated health. Overall, compared with the reference categories, as dwelling density, proportion of rental properties, and housing unaffordability increased, the odds of reporting poorer self-rated health also increased; however these associations did not always reach statistical significance.

## 4. Discussion

Using a liveability lens based on the social determinants of health, this paper sought to conceptualise how multiple housing characteristics in an urban context are associated with downstream behaviours, and intermediate, and long-term outcomes. Through this process we identified a suite of potential (and readily available) spatial measures that could be operationalized and applied to assess selected housing attributes with selected outcomes. This is important for three reasons. First, the conceptual framework hypothesised the complex and various pathways through which housing impacts health and wellbeing. In future, this framework may facilitate the potential downstream impacts of housing-related interventions to be identified, and in turn, could help mitigate any unintended consequences. Second, the spatial measures we were able to test relied on routinely available census data that were generated at the smallest available administrative scale in Australia. Using such an approach allows the data to be fairly easily sourced and applied, thus enabling future potential for comparing and monitoring housing attributes across different areas and over time. This information can also be used to advocate for building 'more liveable' communities, which is important from equity and health and wellbeing perspectives. Third, notwithstanding the multitude of actors who shape housing, the proposed spatial measures could be used to monitor the implementation of urban housing-related policies over time to understand how these, in part, impact a range of behaviours and outcomes. In brief, using spatial measures of housing we found significant associations between dwelling density and poorer self-rated health. Living in an area with a higher proportion of rental properties was associated with higher levels of community dissatisfaction and poorer self-rated health. While those living in areas with less affordable housing available tended to perceive the area as more unsafe, reported higher levels of community dissatisfaction, and had poorer self-rated health.

Our non-linear associations shown between dwelling density and safety perceptions suggest there may be a threshold at which medium-high densities influence perceptions of safety. Although not specifically examined in this paper, higher levels of dwelling density likely stimulate co-location of shops, services and public transport. Urban planning and criminology offer competing perspectives on the safest neighbourhood designs (Foster et al., 2013). The former advocates for diverse neighbourhoods that generate 'eyes on the street' (Duany et al., 2000; Jacobs, 1961), whereas the latter emphasises the safest neighbourhoods are low density settings that attract few people (Beavon et al., 1994; Bowes, 2007). Indeed, both arguments have support.

Higher densities generally increase the incidence of crime (Cozens and Hillier, 2012), but the presence of other people appears to limit fear of crime (Jorgensen et al., 2013; Maruthaveeran and Konijnendijk van den Bosch, 2014). Actual crime and fear of crime are distinct but related constructs (Schneider and Kitchen, 2007), and both have been associated with poorer physical and mental health (Lorenc et al., 2012). Fear of crime, however, is far more widespread than actual victimisation and can impact populations who have minimal exposure to actual crime (Schneider and Kitchen, 2007).

Although non-significant, our density-safety trends support early theories that crime is a function of the intensity of land use, and balance between potential 'targets' and would-be 'guardians' (Jacobs, 1961; Angel, 1968). Angel suggested that most crime occurred in a 'critical intensity zone', where land-use intensity was sufficient to attract offenders to an area, but insufficient to ensure there were enough guardians to protect against crime. Less crime is likely to occur when land-use intensity is either very low (i.e. offenders are not attracted to the area), or very high (i.e. enough guardians to protect against crime) (Angel, 1968). While subsequent environmental criminology studies indicate that higher densities generally increase crime (Cozens and Hillier, 2012), and that large volumes of people can serve to mask low-level offences (Loukaitou-Sideris, 1999), the concept of a density 'threshold' may nonetheless remain relevant to residents' perceptions of, and concerns about, crime. Although the relationships did not reach significance, the directions of associations suggest dwelling densities of ~10 – 15 dwellings / hectare may fall within the proposed 'critical intensity zone', where there are too few guardians to positively impact feelings of safety, whereas our top quartile of density ($\geq$15 dwellings / hectare) may provide enough 'eyes on the street' to limit crime occurrences.

Our findings suggest dwelling densities of ~10 – 15 dwellings / hectare was related to poorer global health, as measured by self-rated health. However, the evidence base is mixed when specific markers of health are considered. On one hand, higher levels of dwelling density have been linked to more walking for transport, reduced rates of cardiovascular mortality, and lower risk of pedestrian traffic incidents. On the other hand, higher dwelling densities have been associated with greater air and noise pollution exposure, and potentially poorer mental health. Findings suggest the quality, design, and location of housing, as well as the population being investigated, play important roles in the strength and direction of these associations (Giles-Corti et al., 2012).

Notably, we did not find significant associations between dwelling density and community satisfaction. We anticipated that our top quartile of density (although low by planning standards) would support a more liveable community, thereby higher levels of community satisfaction, by providing better access to amenities and public transport infrastructure (Lowe et al., 2013). Yet, it could be that the density categories examined in this study were insufficient to encourage appropriate levels of mixed use development. Some of our recent analysis in metropolitan Melbourne suggests densities need to be at least 20 dwellings per hectare to generate substantial walking for transport behavioural changes *(manuscript under review, details available upon request)*. Yet, our present analysis classified dwelling densities by quartiles, with the highest stratum being >15 dwellings per hectare. Future work should seek to investigate how higher residential density thresholds (i.e. >15 dwellings / ha) are associated with a broader range of outcomes, including community satisfaction.

Indeed, there have been attempts to quantify appropriate dwelling densities in Australia. A 2006 South Australian planning document categorised net dwelling density as: very low (<17 dwellings / hectare), low (17 – 33 dwellings / hectare), medium (34 – 67 dwellings / hectare), and high (>67 dwellings / hectare) (Building South Australia). More recently, the New South Wales Planning & Environment Department made subdivision layout and housing type recommendations in growth areas for net densities of 15, 20, 25, and 30 dwellings / hectare (New South Wales Planning & Environment, 2014). The densities tested in this paper are much lower than these planning recommendations. This suggests a mismatch between policy and delivery. Future research could first, examine if and where the recommended densities are being delivered, and second, in areas were density recommendations are being met, test for associations with a range of outcomes.

Earlier research identified higher numbers of rental properties were associated with more transient populations, and therefore decreased community satisfaction and poorer health (Rohe et al., 2001). Our findings concur with this evidence base. Housing affordability is a major, and increasing concern in Australian cities (Infrastructure Australia, 2016), and renting from private landlords has traditionally been the housing tenure choice of lower income or more disadvantaged groups (Gilbert, 2016). Therefore, areas with higher proportions of rental properties may be concentrated in less 'desirable' suburbs (Rohe et al., 2001). More disadvantaged neighbourhoods generally have poorer aesthetics and more incivilities present compared with less disadvantaged neighbourhoods (Thornton et al., 2016). Furthermore, those with poorer self-rated health are more likely to be from disadvantaged groups; this can then contribute to a 'double disadvantage' when these people are located in deprived neighbourhoods (Badland et al., 2013). Following on, in our study, living in less affordable areas was associated with greater odds of feeling unsafe and being dissatisfied with the community. One potential explanation for these associations is that cost limits where people can purchase their house, and therefore opportunities for upwards housing mobility (Rohe et al., 2001). Consequently, those who are more disadvantaged may be forced through the housing market to remain in less desirable neighbourhoods. Further work needs to be undertaken to test this pathway.

Our findings build on the importance of the relationship between housing affordability and mental health identified previously (Bentley et al., 2011; Infrastructure Australia, 2016; Thornton et al., 2016), supported by the significant association shown between living in areas with the least affordable housing and poorer self-rated health. A measure of mental health was not available through the VicHealth Indicators survey, therefore we tested housing affordability with the broader measure of self-rated health (a marker of both physical and mental health (Infrastructure Australia, 2016)). Indeed, we suggest that the association between housing affordability and self-rated health would have been stronger if we were further able to isolate those who were experiencing housing affordability stress. That is, we did not measure respondents' direct exposure to housing affordability stress; rather we modelled individual outcomes against an area-level exposure. In future we recommend that the housing affordability spatial measure be tested with more specific outcomes. Alternatively, median house and rental prices within an area could be compared against household income to more directly assess the relationship between households and housing affordability.

There are limitations of our work. First, the use of the SA1 administrative unit as a proxy for neighbourhoods is problematic, and is known as the uncertain geographic context problem (UGCoP). The UGCoP focuses on how 'contextual' units differ from 'geographic' units (Kwan, 2012). In our case an example is the perception of neighbourhood safety (context) being compared with housing density within the SA1 (geography). As such, it is likely there are discrepancies between 'perceived' and ' administrative' neighbourhoods, which translate to measurement error. For example, people have diverse neighbourhood 'shapes' depending on their demographic profile and the local built environment, and this informs their perceptions (Ivory et al., 2015). Future research should seek to quantify the extent of this measurement error, and identify the spatial units (or units) that are most appropriate for the outcome variable(s) of interest. Second, we have to be mindful of the ecological fallacy when drawing individual-level conclusions based on area-level exposures (Subramanian et al., 2009). Third, urban planning policies and initiatives that likely

contribute to housing and location selection were not included in our conceptual framework. Examples include: the 20 min city; planning controls such as local area planning and zoning laws, and the creation and enforcement of urban growth boundaries; provision of planning bonuses and concessions for affordable housing developments; use of sustainable building materials and energy systems; fast tracking planning approvals that provide affordable, adaptable, or diverse housing; different lending or repayment structures (Rowley and Phibbs, 2012); and rental agreement modifications (e.g. provision of long-term leases, lease-hold land). Although these may affect the availability, location and quality of housing, these were not included in our analysis as they could not be measured and applied spatially. Fourth, compared with planning recommendations, dwelling densities were low in our sample. Therefore our analysis was comparing across a range of low density areas. Fifth, we relied on cross-sectional data from a data set with a limited set of outcome measures to explore the selected pathways, and in future the housing measures need to be tested with longitudinal data and more diverse and specific outcomes to determine causality. Other limitations include the reliance on self-report population survey data to test a limited number of components in the conceptual framework and potential selection bias in the VicHealth survey (non-respondent data were unavailable). Accordingly we recommend testing these housing measures with another population sample with a more diverse range of outcomes. Finally, other than a metropolitan urban setting, we did not consider the location of this housing. Future research might consider distance to the central business district and other such employment or activity clusters as additional housing variables that provide proxies for other variables relevant to liveability.

## 5. Conclusions

It is not surprising that spatial measures are increasingly being used to map inequities and understand associations between the built environment and health and wellbeing. Our three proposed housing measures are straightforward to calculate and apply, and their objectivity and potential capacity to compare various urban settings simultaneously provide efficiencies. Data driven city indicators are critical to monitor planning as we move towards an increasingly urbanising world. Future research will explore additional pathways in our conceptual model and the interrelationships between neighbourhood attributes. However, future work is dependent on sourcing appropriate survey data, which can be challenging to obtain. This work lends weight to the need for evidenced-based spatial measures of planning to maximise the liveability of residential urban environments. This will help meet the health and wellbeing needs of urban populations.

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## References

Angel, S., 1968. Discouraging Crime Through City Planning. Institute of Urban and Regional Development, Berkeley.
Appleyard, D., Lintell, M., 1972. The environmental quality of city streets: the residents' viewpoint. J. Am. Inst. Plan. 38, 84–101.
Australian Bureau of Statistics, 2013. Measures of Australia's progress, 2013. Australian Bureau of Statistics, Canberra.
Australian Bureau of Statistics Australian Statistical Geography Standard (ASGS) 2011, 2011b Australian Bureau of Statistics Canberra.
Australian Bureau of Statistics Census 2011, 2011a Australian Bureau of Statistics Canberra.
Badland, H., Schofield, G., 2005. Transport, urban design, and physical activity: an evidence based-update. Transp. Res. Part D: Transp. Environ. 10 (3), 177–196.
Badland, H., Turrell, G., Giles-Corti, B., 2013. Who does well where? Exploring how self-rated health differs across diverse people and neighbourhoods. Health Place 22, 82–89.
Baker, E., et al., 2014. Exploring the bi-directional relationship between health and housing in Australia. Urban Policy Res. 32, 71–84.
Baker, E., Bentley, R., Mason, K., 2013. The mental health effects of housing tenure: causal or compositional? Urban Stud. 50, 426–442.
Baum, A., Davis, G., Aiello, J., 1978. Crowding and neighborhood mediation of urban density. Popul. Environ. 1, 266–279.
Beavon, D., Brantingham, P., Brantingham, P., 1994. The influence of street networks and the patterning of property offences. In: Clarke, R. (Ed.), Crime prevention studies. Criminal Justice Press, New York, 115–148.
Bentley, R., et al., 2011. Association between housing affordability and mental health: a longitudinal analysis of a nationally representative household survey in Australia. Am. J. Epidemiol. 174, 753–760.
Bowes, D., 2007. A two-stage model of the simultaneous relationship between retail development and crime. Econ. Dev. Q. 21, 79–90.
Building South Australia, Understanding residential densities: A pictorial handbook of Adelaide examples. Government of South Australia: Adelaide.
Cervero, R., Duncan, M., 2006. Which reduces vehicle travel more: Jobs-housing balance or retail-housing mixing? J. Am. Plan. Assoc. 72 (4), 475–490.
Cozens, P., Hillier, D., 2012. Revisiting Jane Jacob's 'eyes on the street' for the twenty-first century: evidence from environmental criminology. In: Hirst, S., Zahm, D. (Eds.), The urban wisdom of Jane Jacobs. Routledge, Oxfordshire, 313–344.
Currie, G., Delbosc, A., 2011. Mobility vs. affordability as motivations for car ownership choice in urban fringe, low income Australia. In: Lucas, K., Blumenberg, E., Weinberger, R. (Eds.), Auto motives: Understansing car use behaviours. Emerald Publishing Group, Bingley, 193–208.
Department of the Prime Minister and Cabinet Smart cities plan 2016 Australian Government Canberra.
Diaz-Serrano, L., 2009. Disentangling the housing satisfaction puzzle: does home ownership really matter? J. Econ. Psychol. 30, 745–755.
Diez Roux, A., et al., 2001. Neighborhood residence and incidence of coronary heart disease. New Engl. J. Med. 345 (2), 99–106.
Duany, A., Plater-Zyberk, E., Speck, J., 2000. Suburban nation: The rise of sprawl and the decline of the American dream. North Point Press, New York.
Elgar, F., et al., 2011. Social capital, health and life satisfaction in 50 countries. Health Place 17, 1044–1053.
Foster, S., et al., 2013. Suburban neighbourhood design: associations with fear of crime versus perceived crime. J. Environ. Psychol. 36, 112–117.
Foster, S., et al., 2014. Does walkable neighbourhood design influence the association between objective crime and walking? Int. J. Behav. Nutr. Phys. Act. 11, 100.
Foster, S., Giles-Corti, B., 2008. The built environment, neighborhood crime and constrained physical activity: an exploration of inconsistent findings. Prev. Med. 47 (3), 241–251.
Gilbert, A., 2016. Rental housing: the international experience. Habitat Int. 54 (Part 3), 173–181.
Giles-Corti, B., Ryan, K., Foster, S., 2012. Increasing density in Australia: maximising the health benefits and minimising harm. National Heart Foundation, Canberra.
Howden-Chapman, P., 2002. Housing and inequalities in health. J. Epidemiol. Community Health 56, 645–646.
Huang, Z., Du, X., Yu, X., 2015. Home ownership and residential satisfaction: Evidence from Hangzhou. China Habitat Int. 49, 74–83.
Infrastructure Australia, Australian infrastructure plan: Priorities and reforms for our nation's future. 2016, Infrastucture Australia: Canberra.
ISO/TC 268, 2014. Sustainable development of communities: indicators for city services and quality of life. ISO, Switzerland.
Ivory, V., et al., 2015. What shape is your neighbourhood? Investigating the micro geographies of physical activity. Soc. Sci. Med. 133, 313–321.
Jacobs, J., 1961. The Death and Life of Great American cities. Random House, New York.
Jorgensen, L., Ellis, G., Ruddell, E., 2013. Fear perceptions in public parks: Interactions of environmental concealment, the presence of people, and gender. Environ. Behav. 45, 803–820.
Krieger, J., Higgins, D., 2002. Housing and health: Time again for public health action. Am. J. Public Health 92 (5), 758–768.
Kwan, M.-P., 2012. The uncertain geographic context problem. Ann. Assoc. Am. Geogr. 102 (5), 958–968.
Learnihan, V., et al., 2011. Effect of scale on the links between walking and urban design. Geogr. Res. 49 (2), 183–191.
Leyden, K., 2003. Social capital and the built environment: the importance of walkable neighbourhoods. Am. J. Public Health 93 (9), 1546–1551.

Lorenc, T., et al., 2012. Crime, fear of crime, environment, and mental health and wellbeing: mapping reviews of theories and causal pathways. Health Place 18, 757–765.
Loukaitou-Sideris, A., 1999. Hot spots of bus stop crime. J. Am. Plan. Assoc. 65, 395–411.
Lowe, M., et al., Liveable, Health, Sustainable: What are the key indicators for Melbourne neighbourhoods?, in Place, Health, and Liveability Research Program. 2013, University of Melbourne
Macintyre, S., et al., 2003. What features of the home and the area might help to explain observed relationships between housing tenure and health? Evidence from the west of Scotland. Health Place 9, 207–218.
Major Cities Unit, State of Australian Cities 2013, 2013 Department of Infrastructure and Transport Canberra.
Maruthaveeran, S., Konijnendijk van den Bosch, C., 2014. A socio-ecological exploration of fear of crime in urban green spaces: a systematic review. Urban For. Urban Green. 13, 1–18.
Mohnen, S., et al., 2011. Neighborhood social capital and individual health. Soc. Sci. Med. 72, 660–667.
New South Wales Planning & Environment Housing diversity - Sydney's growth areas 2014 New South Wales Planning & Environment Sydney.
Newton, P., Glackin, S., 2014. Understanding infill: Towards new policy and practice for urban regeneration in the established suburbs of Australia's cities. Urban Policy Res. 32, 121–143.
O'Neill, P., 2008. Housing affordability literature review and affordable housing program audit. Urban Research Centre, Sydney.
Rogers, S., et al., 2011. Examining walkability and social capital as indicators of quality of live at the municipal and neighborhood scales. applied Research in Quality of life. 6, 201–213.
Rohe, W., Van Zandt, S., McCarthy, G., 2001. *The social benefits and costs of homeownership: A critical assessment of the research*, in *Low-income Homeownership Working Paper Series*. 2001. Joint Center for Housing Studies of Harvard University, Boston.
Rowley, S., Phibbs, P., 2012. Delivering diverse and affordable housing on infill development sites. Australian Housing and Urban Research Institute, Sydney.
Schneider, R., Kitchen, T., 2007. Crime prevention and the built environment. Routledge, New York.
State Government Victoria, 2014. Plan Melbourne. Metropolitan planning strategy 2014. State Government Victoria, Melbourne.
Strategic Review of Health Inequalities in England post-2010 Fair society, healthy lives 2010 Department of Health London.
Subramanian, S., et al., 2009. Revisiting Robinson: the perils of individualistic and ecological fallacy. Int. J. Epidemiol. 38, 342–360.
Thornton, C., et al., 2016. Disparities in pedestrian streetscape environments by income and race/ethnicity. SSM - Popul. Health 2, 206–216.
United Nations Department of Economic & Social Affairs, 2014. World Urbanization Prospects: 2014 revision. United Nations, New York.
United Nations Population Fund, 2007. State of world population 2007: unleashing the potential of urban growth. United Nations Population Fund, New York.
Wood, L., et al., 2008. The anatomy of the safe and social suburb: an exploratory study of the built environment, social capital and residents' perceptions of safety. Health Place 14 (1), 15–31.