Age and Ageing 2022; **51:** 1–9
https://doi.org/10.1093/ageing/afac029

RESEARCH PAPER

A vulnerable residential environment is associated with higher risk of mortality and early transition to permanent residential aged care for community dwelling older South Australians

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Abstract

Objectives: This study examined the impact of the residential environment, measured by the Healthy Ageing/Vulnerable ENvironment (HAVEN) Index, on risk of mortality or entry into Permanent Residential Aged Care (PRAC).
Design: A retrospective cohort study using data from the Registry of Senior Australians (ROSA) was conducted. HAVEN Index values were matched to the ROSA by residential postcode.
Study setting and Participants: Older individuals living in metropolitan Adelaide and receiving their first eligibility assessment for aged care services between 2014 and 2016 ($N = 16{,}944$).
Main Outcome Measure: Time to death and entry into PRAC were the main outcomes.
Results: A higher HAVEN Index value, which represents a favourable residential environment, was associated with a lower risk of mortality and delayed entry to PRAC. For every 0.1 unit increase in HAVEN Index value, the risk of mortality is 3% lower (adjusted hazard ratio [HR], 95% confidence interval [CI] = 0.97, 0.96–0.99) and the risk of entry to PRAC is 5% lower (adjusted subdistribution HR, 95%CI = 0.95, 0.94–0.97) in the first 2 years following aged care assessment. After 2 years, the HAVEN Index was not associated with the risk of transition to PRAC.
Conclusion: Place-based health inequalities were identified in Australians seeking aged care services, demonstrating that a better understanding of local neighbourhoods may provide insight into addressing ageing inequalities. Spatial indexes, such as the HAVEN Index, are useful tools to identify areas where populations are more vulnerable to adverse health outcomes, informing responses to prioritise local improvements and health interventions to enable healthy ageing.

Keywords: Healthy Ageing/Vulnerable ENvironment (HAVEN) Index, older people, frailty, aged care, age-friendly environment

Key Points

- The Healthy Ageing/Vulnerable ENvironment (HAVEN) Index is a measure of the age friendliness and vulnerability of local environments, combining socio-economic, access and physical environment measures.
- A vulnerable residential environment, identified by the HAVEN Index, is associated with earlier entry into Permanent Residential Aged Care (PRAC) and higher risk of mortality.
- Improvements to local residential environments may help older Australians age in place and delay the need for PRAC.
- Policies to delay transition into PRAC and mortality need to take into account the characteristics of the local residential environment.

Introduction

Older age is characterised by a diversity of abilities and needs, which has led researchers to try to better understand influences on ageing, particularly those that may promote healthy ageing or those negative influences that may be avoidable or modifiable. With populations around the world ageing rapidly, the goal to maximise healthy ageing has become a global objective [1, 2, 3], which has led to the United Nations declaring 2021–30 the Decade of Healthy Ageing [3]. The World Health Organization (WHO) has played a key role in promoting a better understanding of healthy ageing and the bio-psychosocial factors that influence functional ability that comprise intrinsic capacity and the environment [1].

In response to the Royal Commission into Aged Care Quality and Safety [4], the Australian government has increased funding for home care services [5] to support the desire of older Australians to stay at home in their own neighbourhoods for as long as possible [4]. At an individual level, we have previously shown in a cohort of older Australians assessed for aged care services that increasing frailty is associated with a higher risk of mortality and transition to Permanent Residential Aged Care services (PRAC or nursing homes) [6]. The goals of older people to avoid or delay transition into PRAC could possibly be further assisted by improving the local environment to facilitate healthy ageing and this requires further research.

Neighbourhood-level environmental influences on ageing are one area of research that holds promise to identify potential barriers to healthy ageing with the hope that some of these barriers are modifiable and can be targeted for intervention [7]. Disparities in neighbourhood environmental characteristics, such as an area's social and socio-economic resources, or access to nearby services, or characteristics of the physical environment, such as pollution, can influence an individual's ability to achieve healthy ageing [7]. These broad collective attributes of local neighbourhood areas will be referred to in this paper as the local environment.

This study utilised a new spatial index, the Healthy Ageing/Vulnerable Environment Index (HAVEN Index) (manuscript under preparation), to investigate place-based health inequalities among older populations despite universal health care provision. The newly developed HAVEN Index is a composite spatial index that quantifies the age friendliness of postcode areas, combining over 40 indicator variables across six themes: income and employment; education; health and housing; social connectedness; geographic access and physical environment. Variables included in the index were drawn from the eight WHO age friendly cities topic areas also referred to as domains [8, 9], and the age friendly cites literature [7, 10, 11] relevant to neighbourhood scale measures of age friendliness. The index identifies disparities between areas scoring highly (most age friendly) grading through to those that are most vulnerable (least age friendly) and aims to identify areas where older populations may be more vulnerable to poorer health outcomes. The modelling approach used to construct the HAVEN Index employs the deficit accumulation method used for developing frailty indices [12], using spatial area-level data instead of individual level, allowing values of contributing variables to be evaluated and compared. Older people residing in more vulnerable areas, indicated by lower HAVEN Index scores, are more likely to attend public hospital emergency departments than those residing in areas with higher HAVEN Index scores.

The aims of this study were to examine whether the local environment, as measured by the HAVEN Index, was associated with the adverse health outcomes of mortality and early entry into PRAC for older adults seeking access to aged care services through the national Australian Aged Care Assessment Program [13].

Methods

Study design

This is a retrospective cohort study using data obtained from the Historical Cohort of the Registry of Senior Australians (ROSA) [14] linked to the HAVEN Index data using residential postcode. ROSA consists of datasets from the Australian Institute of Health and Welfare National Aged Care Data Clearinghouse, which includes the National Death Index, linked to the Australian Government's Pharmaceutical Benefits Scheme and Medicare Benefits Schedule, and four states' health authorities' hospitalisation records. Specifically, in this study the following datasets from ROSA were used: aged care assessment program (ACAT), home care package episodes of care, residential aged care episodes of care and National Death Index. In addition, frailty index values previously calculated for each individual from the aged ACAT data contained within the Historical Cohort of the ROSA were used in the analysis [6].

Study cohort

The study cohort was older South Australians aged 65 years or older, non-Indigenous, without a Department of Veterans' Affairs (DVA) card who were living in the community and receiving their first assessment for aged care services' eligibility between 2014 and 2016. The total sample size was 16,944, of which 16,864 (99.5%) had complete data and were included in the adjusted analysis. DVA card holders (~17–20% of aged care recipients in Australia) were excluded because they are eligible for additional health care benefits/subsidies, which affects how they use and access government subsidised health care services.

In Australia, access to Commonwealth government subsidised services such as home care packages and residential aged care services requires an aged care eligibility assessment [15]. Consumers with lower care needs can access basic services (e.g. gardening, cleaning and meals) without an aged care eligibility assessment. Consumers, carers or clinicians are able to make a referral for an aged care eligibility assessment and means testing is used to determine how much consumers need to contribute towards their care.

Setting

The study area is the city of Adelaide, the capital city of South Australia, and its surrounding metropolitan area. Adelaide has a large ageing population; in 2016 17.2% (223,487 people) of the Adelaide Greater Capital City Statistical Area (GCCSA) was aged 65 years or over [16]. Modelled frailty estimates [17], based on the age and gender prevalence [18], identify that in 2016 ~26,469 people within the Adelaide GCCSA were frail and by 2032 this figure is projected to increase by more than 50% [19].

The spatial units used for the study were postal areas, which are defined by the Australian Bureau of Statistics to approximate postcode areas [20]. Since the GCCSA boundary for Adelaide did not align perfectly with the postal area boundaries, the study area was defined as those postal areas, which were located completely within or had the majority of their area within the Adelaide GCCSA [21] and had >10 residents aged 65 years or older. There were 142 postal areas included in the study area; four postal areas were excluded from the analysis due to small populations, which could make HAVEN Index values for these areas unreliable. A map of the study area showing the HAVEN Index quintiles by postal area is shown in Figure 1. The average number of people in each postal area, based on the 2016 Australian Census of Population and Housing (Census), was 9,083 and the average number aged 65 years or over was 1,570 [16].

Exposures of interest

The main exposure of interest was the vulnerability of the local residential environment, as measured by the HAVEN Index, for older people having their first aged care eligibility assessment (i.e. HAVEN Index value or HAVEN Index Quintiles). A table detailing the 42 variables included in the HAVEN Index and the six index themes is included in Appendix 1.

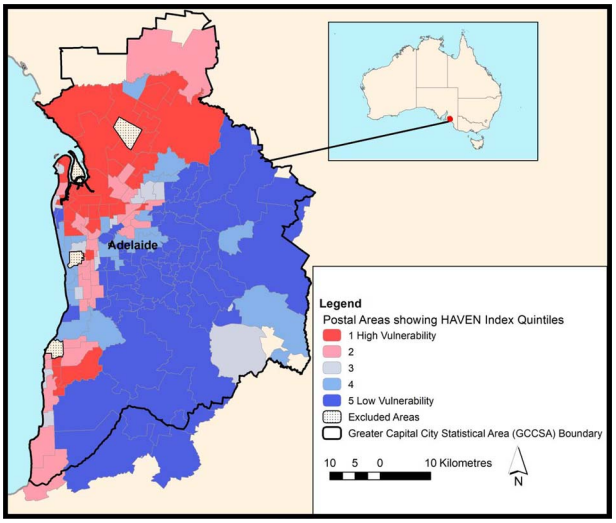

Figure 1. Adelaide study area showing the HAVEN Index quintile classification for postal areas.

While completed in 2020, the HAVEN Index predominantly uses data from 2016, which aligns with the most recent 2016 Census [21] from which a large number of HAVEN Index variables have been drawn. The 2016 date also aligns with the ROSA data. HAVEN Index values were standardised to have a value between 0 and 1, with lower values representing those areas that are more vulnerable and high values indicating areas that were less vulnerable and more supportive.

Outcomes of interest

The primary outcomes of this study were risk of mortality and entry into PRAC.

Covariates

Study covariates included age, sex and frailty index score at the time of aged care eligibility assessment [6].

Data analysis

The characteristics of the study cohort were described by the HAVEN Index quintiles (Table 1). A Cox Proportional Hazards regression model was employed to investigate the effect of residential environment, as measured by the HAVEN Index, on risk of mortality. Cumulative survival probability estimates and 95% confidence intervals (CIs) were reported and a Kaplan–Meier plot describes the survival probability by HAVEN Index quintiles (Figure 2). The use of the continuous HAVEN Index in the final models was supported by the Cox Proportional Hazards linearity assumption test of the continuous HAVEN Index versus the outcomes. To assess the effect of the HAVEN Index on entry into PRAC, a Fine and Gray model accounting for the competing risk of death

was employed [22]. Cumulative incidence estimates and 95%CIs were estimated and cumulative incidence functions were presented (Figure 3). For both models, the proportional hazards assumption was assessed using a Schoenfeld test and scaled Schoenfeld residuals plot and time-dependent estimates were included when this assumption was violated. Final models were adjusted for age, sex and frailty index score. Adjusted hazard ratio (aHR) (95%CIs) and subdistribution aHR (95%CIs) were reported accordingly (Table 2). The threshold for statistical significance was set at alpha = 0.05; all tests were two sided. R version 3.5.2 was used for the data analysis.

Ethics

Ethics approval for the ROSA data was obtained from the University of South Australia Human Research Ethics Committee (ID 200489) and AIHW EO2018/1/418.

Results

Study cohort

The mean (standard deviation [SD]) age of the cohort was 83.0 (7.3) years (Table 1). The majority were females 10,207 (60.2%) who were born in Australia 10,201 (60.2%) and the mean (SD) frailty index score was 0.24 (0.06).

The median (interquartile range [IQR]) HAVEN Index value for each HAVEN Index quintile ranged from 0.35 (0.28–0.36) for quintile 1 to 0.68 (0.66–0.73) for quintile 5. There was a consistent sequential increase in HAVEN Index theme scores across all HAVEN Index quintiles for the Education, Health and Housing, Income and Employment and Social Connectedness themes. The HAVEN Index theme scores for Geographic Access and Physical Environment did not increase sequentially from HAVEN Index quintile 1–5 within the study area.

The effect of the HAVEN Index on mortality

Our study cohort was followed for a median time of 2.4 (IQR: 1.0–3.4) years and 47.3% (n = 8,015) were alive at the end of the study period (Supplementary Table 1, Figure 2). After adjusting for age, sex and frailty index score, a 3% lower risk of mortality was observed for every 0.1 unit increase in HAVEN Index value (aHR, 95% CI = 0.97, 0.96–0.99) (Table 2).

The effect of the HAVEN Index on entry into PRAC

The median time from aged care eligibility assessment to PRAC entry was 0.63 (IQR 0.14–2.27) years and 58.5% (n = 9,910) of people transitioned during the study period. The cumulative incidence of entry into PRAC (95%CI) was 48% (0.48–0.49) at 1 year; 59% (0.59–0.60) at 2 years; 66% (0.65–0.67) at 3 years and 70% (0.69–0.71) at 4 years. (Supplementary Table 2, Figure 3). The HAVEN Index score was associated with time-dependent risk of

Table 1. Study cohort characteristics

			HAVEN groups				
Characteristics	Categories	All, *N* (%)	Quintile 1, *N* (%)	Quintile 2, *N* (%)	Quintile 3, *N* (%)	Quintile 4, *N* (%)	Quintile 5, *N* (%)
HAVEN Index Value Range			0.235–0.406	0.407–0.478	0.479–0.541	0.542–0.637	0.638–0.879
N (%)		16,944 (100)	3,908 (23.1)	4,616 (27.2)	1,567 (9.2)	3,867 (22.8)	2,986 (17.6)
Age in years at ACA	Mean (SD)	83.0(7.3)	82.1(7.5)	82.9(7.2)	82.95(7.3)	83.63(7.2)	83.68(7.1)
Sex	Female	10,207(60.2)	2,333(59.7)	2,767(59.9)	956(61.0)	2,339(60.5)	1812(60.7)
	Male	6,695(39.5)	1,563(40.0)	1840(39.9)	610(38.9)	1,516(39.2)	1,166(39.0)
	Unknown	42(0.2)	12(0.3)	9(0.2)	1(0.1)	12(0.3)	8(0.3)
Country of birth	Australia	10,201(60.2)	1976(50.6)	2,735(59.3)	980(62.5)	2,440(63.1)	2070(69.3)
Frailty score	Mean (SD)	0.24(0.06)	0.25(0.06)	0.25(0.06)	0.24(0.07)	0.24(0.06)	0.23(0.07)
HAVEN score	Median (IQR)	0.47(0.41–0.62)	0.35(0.28–0.36)	0.43(0.42–0.46)	0.50(0.48–0.53)	0.59(0.57–0.62)	0.68(0.66–0.73)
HAVEN score geographic access	Median (IQR)	0.81(0.68–0.88)	0.72(0.68–0.87)	0.84(0.69–0.92)	0.82(0.77–0.83)	0.83(0.66–0.93)	0.75(0.68–0.88)
HAVEN score education	Median (IQR)	0.58(0.42–0.75)	0.23(0.13–0.33)	0.50(0.46–0.54)	0.58(0.58–0.58)	0.75(0.63–0.83)	0.88(0.83–0.92)
HAVEN score health housing	Median (IQR)	0.29(0.21–0.50)	0.18(0.14–0.21)	0.25(0.21–0.29)	0.36(0.21–0.54)	0.46(0.36–0.57)	0.57(0.46–0.75)
HAVEN score income employment	Median (IQR)	0.39(0.21–0.71)	0.11(0.04–0.18)	0.32(0.25–0.39)	0.43(0.32–0.54)	0.68(0.54–0.75)	0.82(0.75–0.86)
HAVEN score physical environment	Median (IQR)	0.56(0.48–0.63)	0.55(0.41–0.59)	0.53(0.43–0.60)	0.60(0.51–0.64)	0.58(0.54–0.69)	0.63(0.51–0.65)
HAVEN score social connectedness	Median (IQR)	0.31(0.17–0.42)	0.17(0.08–0.28)	0.19(0.17–0.36)	0.28(0.22–0.42)	0.36(0.28–0.44)	0.53(0.44–0.67)

IQR = inter quartile range.

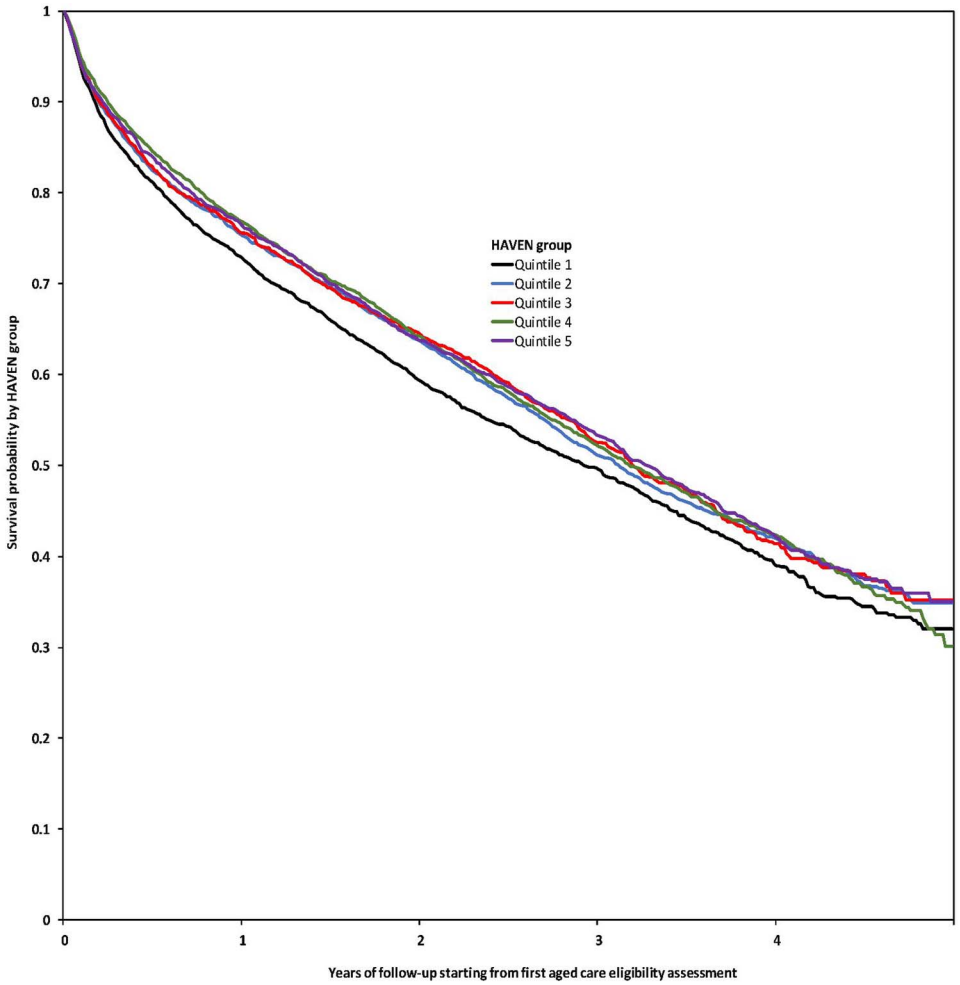

Figure 2. Kaplan–Meier cumulative survival probability curve by HAVEN Index quintile after the first aged care eligibility assessment.

PRAC entry, with a 5% lower risk (adjusted subdistribution HRs, 95%CI = 0.95, 0.94–0.97) for each 0.1 unit increase in the HAVEN index within the first 2 years after aged care eligibility assessment and no statistically significant association after 2 years (Table 2).

Discussion

The vulnerability of the local living environment as measured by the HAVEN Index was significantly associated with risk of mortality and early transition into PRAC. Our findings endorse the WHOs concept that healthy ageing and functional ability are influenced not only by a person's intrinsic capacity but also the environment and interaction between them [1] and provide a basis for future investigations to determine if area level interventions offer opportunities to improve health outcomes for older populations.

Associations between lower neighbourhood socio-economic status (SES) and individuals' higher risk of mortality have been found by previous studies after adjusting for individual level SES [23–26], with an even larger

Table 2. Association of HAVEN score and risk of mortality or transition from home to PRAC

	Mortality, HR (95%CI)	
	Crude	Adjusted[a]
n	16,944	16,864
	cHR (95% CI)	aHR (95% CI)
HAVEN score, every 0.1 increase	0.97(0.96, 0.99)	0.97(0.96, 0.99)
	Transition into PRAC, sHR (95% CI)	
	Crude	Adjusted[1]
Within 2 years of follow-up	11,735	11,668
HAVEN score, every 0.1 increase	0.96 (0.94, 0.97)	0.95 (0.94, 0.97)
After 2 years of follow-up	5,209	5,196
HAVEN score, every 0.1 increase	1.06 (1.01, 1.12)	1.04 (0.99, 1.09)

cHR = crude Hazard Ratio; sHR = subdistribution Hazard Ratio; [a]Adjusted for age, gender and frailty index.

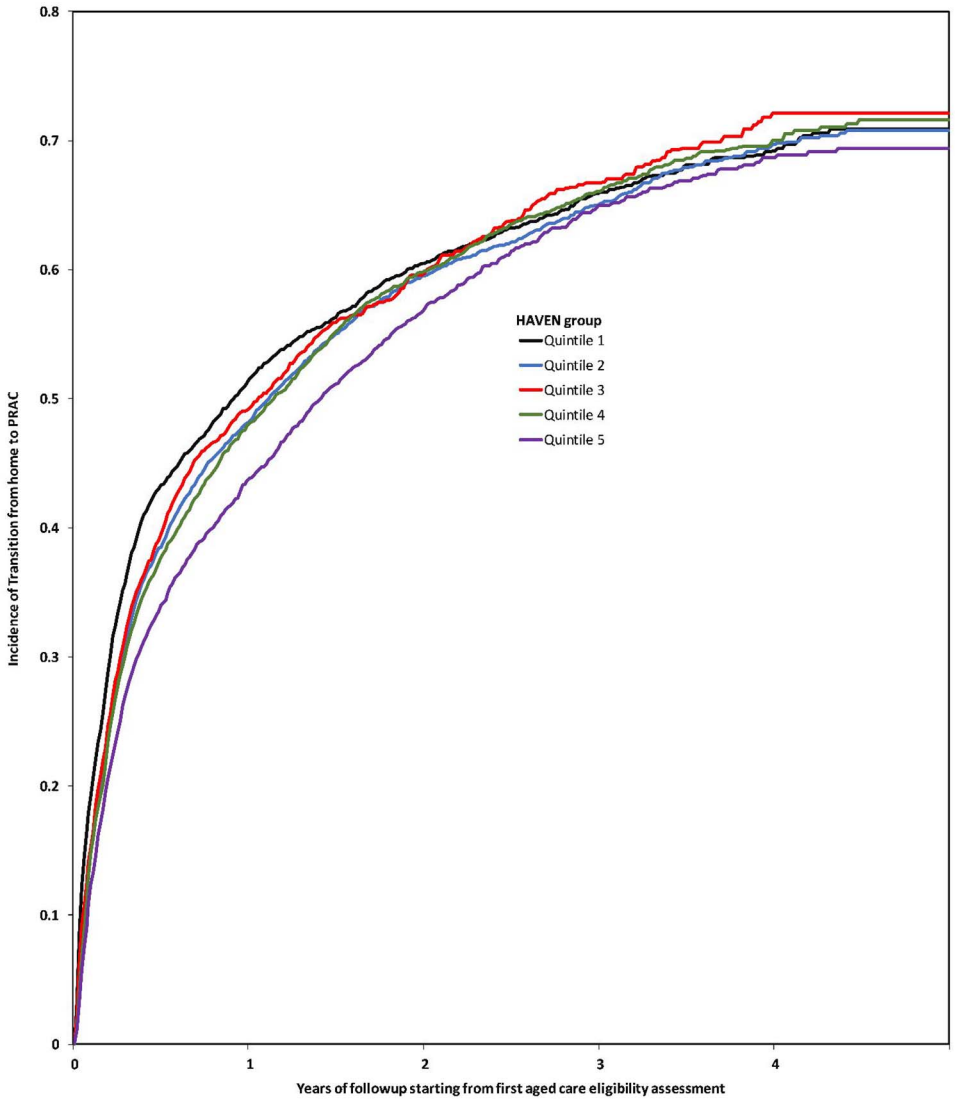

Figure 3. Cumulative incidence of transition from home to a PRAC service by HAVEN score quintile after the first aged care eligibility assessment.

effect in metropolitan as opposed to rural areas [27]. Studies have, however, reported a diminished association between neighbourhood's SES and mortality among older age groups [28]. Health and environment interactions are complex and different study areas, units of measurement and different environmental measures can yield different results. While the majority of studies have confirmed the influence of neighbourhood SES on mortality there have been some that have found no relationship [26]. In addition to SES, Yen and Kaplan's [29] study found strong support for the influence of the neighbourhood environment including access to commercial stores and neighbourhood environment/housing on mortality. A recent scoping review examining neighbourhood characteristics and frailty, a condition associated with higher mortality, also found evidence that both social and physical aspects of neighbourhoods contributed to frailty [30].

Reduced physical function can influence the transition of older adults into PRAC and reduced physical function has been associated with problematic neighbourhood conditions, comprising excessive noise, inadequate lighting, heavy traffic, crime, an abundance of trash and litter and inadequate public transport [31]. The influence of the built or natural environment has also been identified as an important factor influencing the decision making of older frail adults to stay at home or move [32], suggesting that neighbourhood directed interventions could reduce the transition into PRAC for older adults living in problematic/vulnerable areas.

The diminished relationship between HAVEN and transition into PRAC beyond 2 years is likely to reflect the individuals' changeable health status. It is typical for the health status of older people to change beyond 2 years, requiring re-assessment of their needs for aged care services [33].

The use of HAVEN Index quintiles in the Kaplan–Meier plots, Figures 2 and 3, make it difficult to clearly show the small but statistically significant association of the HAVEN Index with mortality or transition into PRAC. In addition, the plots show the effects before adjusting for confounding factors, which are accounted for in the final adjusted models.

Local environment interventions may be particularly effective for older adults as they are often less mobile than younger age groups and spend more time in their local environment [34, 35]. There is emerging evidence that changes to the environment can support behaviour change. A targeted intervention study, implemented in the Netherlands, investigated the effects of social (a walking group) and environmental (a designated walking route) interventions aimed at encouraging older people from deprived areas to walk more [36]. The results found an increase in time spent walking, at 3 and 9 months, in areas where a walking route was designated, providing support for the effectiveness of environmentally targeted approaches [36]. However, the results of the social and combined approaches were less successful, indicating that other contextual factors, such as social cohesion, may influence the effectiveness of the interventions [36]. Targeted area-level interventions could be informed through a consideration of the HAVEN Index and the underlying indicator and theme values, which allow for the characteristics of areas to be viewed and compared. Area-level interventions have the advantage of improving conditions for whole communities, not only benefiting older people but also those living with disabilities and in many instances younger people.

This study has several limitations. It is an observational study and uses a geographic/area-level index of vulnerability, so causality between HAVEN Index values and health outcomes cannot be inferred. Not all individuals assessed for aged care services included in this study were approved for PRAC, and some approved for PRAC may not use this service. There are slight differences in the uptake of PRAC by State, with South Australia being most similar to Victoria and Western Australia [37]. Metropolitan location is also associated with increased use of PRAC [37].

These results are specific to the Adelaide metropolitan study area, and there is a need to generate similar indexes for other areas and countries to further validate the ability of the HAVEN Index to predict health outcomes. The choice of a metropolitan study area has resulted in a small range of values in the Geographic Access theme, because most locations within a metropolitan area, assessed at postal area scale, are moderately or highly accessible. The generalisability of these findings to non-metropolitan areas is therefore limited and further validation of the index in regional and remote settings is warranted. The results indicate that the relationship between Geographic Access and Physical Environment themes is complex, for example, not all vulnerable areas have a lack of accessible services or a poor quality physical environment. The HAVEN Index is derived from area-level data and therefore may be subject to the modifiable areal unit problem [38] care must also be taken in interpreting the results to avoid the ecological fallacy.

The strengths of this study include the use of the comprehensive ROSA data collection, which includes data from all people having their first aged care assessment during the study period. The use of the newly developed HAVEN Index for the whole of metropolitan Adelaide, the first geographic index that has brought together a broad range of social and environmental factors to assess the vulnerability of local areas in a standard and objective way is a further strength.

For older people to achieve and maintain their best functional ability and attain the goal of healthy ageing, both intrinsic health capacities and influences of their environment need to be understood and optimised. The identification of geographic differences in mortality and entry into PRAC provides a basis to the argument that targeted local environment interventions to improve vulnerable areas could potentially lead to improved well-being and reduced inequities. Further research to understand the mechanisms driving these geographic differences and the relationships between individual HAVEN Index themes and PRAC and mortality outcomes is warranted in this decade of healthy ageing.

Supplementary Data: Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

Acknowledgment: We would like to acknowledge the Registry of Senior Australians (ROSA), South Australian Health and Medical Research Institute (SAHMRI) Research Team for their support with this study. We would also like to acknowledge the South Australian Government who provided the ROSA with support (2017–21) through the Department for Innovation and Skills, the Australian Institute of Health and Welfare for the provision of the raw data used in the ROSA and the people seeking aged care services whose data are included in this study.

Declaration of Sources of Funding: The Hospital Research Foundation Mid-Career Fellowship (MCF-01-2017 to D.T.), The National Health and Medical Research Council Centre of Research Excellence Scheme (APP1102208 to R.V., D.T.); Adelaide GTRAC-Resthaven Grant (to DT). the South Australian Government, Premier's Research and Industry Fund and the Department for Innovation and Skills; The Hospital Research Foundation Mid-Career Fellowship (MCF-27-2019 to M.I.); National Health and Medical Research Council (NHMRC) Investigator Grant (APP119378 to M.I.).

Declaration of Conflicts of Interest: Professor Visvanathan is a member of a clinical consortium of healthy ageing and is on the governance committee of Resthaven Inc., a not for profit aged care organisation. She was previously a chief investigator to the Registry of Senior Australians and was a member of its executive and steering

committee. Dr Taylor was a member of the Registry of Older Australians (ROSA) Research and Data Committee (2017-2021). All other authors have no conflicts of interest to declare.

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Received 3 October 2021; editorial decision 14 December 2021