Environment and Cognitive Ageing: A Cross-Sectional Study of Place of Residence and Cognitive Performance in The Irish Longitudinal Study on Ageing

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Funding was provided to Marica Cassarino by the Strategic Research Fund Postgraduate Scholarship 2014, University College Cork, Ireland. TILDA is funded by The Atlantic Philanthropies, the Irish Department of Health and Children, Irish Life, and the Health Research Board. The authors wish to thank Dr. Sean Hammond, Dr. Cathal McCrory and Dr. Neil O'Leary for their comments on previous versions of this manuscript, and the TILDA team for data collection.

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Abstract

Objectives - Stimulating environments foster cognitive vitality in older age. However, it is not known whether and how geographical and physical characteristics of lived environments contribute to cognitive ageing. Evidence of higher prevalence of dementia in rural rather than urban contexts suggests that urban environments may be more stimulating either cognitively, socially or in terms of lifestyle. The present study explored urban/rural differences in cognition for healthy community-dwelling older people while controlling for a comprehensive spectrum of confounding factors.

Methods – Cognitive performance of 3,765 healthy Irish people aged 50+ participating in Wave 1 of The Irish Longitudinal Study on Ageing was analysed in relation to current location of residence - urban, other settlements, or rural areas – and its interaction with childhood residence. Regression models controlled for socio-demographic, health, and lifestyle factors.

Results – Urban residents showed better performance than the other two residence groups for global cognition and executive functions after controlling for covariates. Childhood urban residence was associated with a cognitive advantage especially for currently rural participants.

Conclusions – Our findings suggest higher cognitive functioning for urban residents, although childhood residence modulates this association. Suggestions for further developments of these results are discussed.

Keywords: cognitive ageing, executive functions, environment, urbanisation, childhood

Introduction

Global ageing, coupled with increasing urbanisation, poses the challenge to create lived environments promoting successful ageing, or ageing well (World Health Organization, 2007). The association between the socio-physical environment and ageing processes has long been investigated in Environmental Gerontology (Barker, 1968; Bronfenbrenner, 1979; Lawton & Nahemow, 1973; Wahl, Iwarsson, & Oswald, 2012), promoting attempts to help older people to live in their communities in autonomy for as long as possible, such as “ageing-in-place” initiatives (Black, 2008; Oswald & Wahl, 2004).

Although multiple factors influence ageing well (Baltes & Baltes, 1993), maintaining cognitive health is crucial to live independently and efficiently for as long as possible (World Health Organization, 2007). It is therefore a priority to identify individual and environmental influences on cognitive ageing, both in terms of protective factors against the increasing prevalence of dementia and cognitive impairment (Sachs et al., 2011; World Health Organization, 2012), and in terms of opportunities to enhance cognitive vitality and capitalise on brain plasticity in older age (Fillit et al., 2002; Hertzog, Kramer, Wilson, & Lindenberger, 2008). There is evidence that lived environments can influence social interactions and promote active lifestyles which in turn benefit cognition (de Frias & Dixon, 2014; Hertzog et al., 2008; Kelly et al., 2014; Kramer et al., 2003). The neuropsychological underpinning of these environmental effects could relate to the functional and structural brain enhancing properties of enriched environments shown in both animals and humans (Diamond, 1988; Nithianantharajah & Hannan, 2006), suggesting that the lived environment can impact cognition not only indirectly, for example through lifestyle, but also directly via cognitive and sensory stimulation (Engineer et al., 2004; Kempermann, 2008; Nithianantharajah & Hannan, 2009; Wells, 2009). This is in line with extensive literature showing environmental effects on cognitive reserve - the ability of cognitive systems to function in spite of brain damage (Stern, 2002, 2009, 2012).

Despite the plausibility of the association between physical aspects of the environment and cognition, this topic is understudied (Dunwoody, 2006), possibly due to methodological difficulties (Wu, Prina, & Brayne, 2014). Nonetheless, epidemiological studies report geographical variations in dementia and cognitive impairment (Bae et al., 2015; Cahill, O'Shea, & Pierce, 2012; Contador, Bermejo-Pareja, Puertas-Martin, & Benito-Leon, 2015; Gavrila et al., 2009; Iyer et al., 2014; Klich-Rączka et al., 2014; Nunes et al., 2010; Russ, Batty, Hearnshaw, Fenton, & Starr, 2012), with better cognitive performance for older urban than rural dwellers, suggesting that urban environments may be more stimulating either cognitively, socially or in relation to lifestyle. Robertson (2013, 2014) for example, linked novelty in the environment (more likely to be found in urban environments) with enhanced cognitive reserve through the activation of the noradrenergic brain system. In turn, rural dwelling seems to be associated with a cognitive disadvantage in relation to both current and childhood residence (Gupta et al., 2011; Nguyen, Couture, Alvarado, & Zunzunegui, 2008).

One the other hand, experimental studies report poorer cognitive outcomes in association with urban living (Caparos et al., 2012; Linnell, Caparos, de Fockert, & Davidoff, 2013), suggesting that environments with complex visual and auditory stimulation may impose higher cognitive load (Wais & Gazzaley, 2011) and become too challenging for older adults (Baltes & Baltes, 1993; Baltes & Lindenberger, 1997; de Fockert, Ramchurn, van Velzen, Bergström, & Bunce, 2009; Singer, Verhaeghen, Ghisletta, Lindenberger, & Baltes, 2003), potentially impairing cognitive function. Attentional or executive processing (Linnell et al., 2013; Wais & Gazzaley, 2011, 2014), speech processing (Pichora-Fuller, 1996), and spatial navigation (Cantin, Lavallière, Simoneau, & Teasdale, 2009; Lövdén, Schellenbach, Grossman-Hutter, Krüger, & Lindenberger, 2005) decline in older age, especially in noisy and complex environments which require some form of dual tasking. In fact, there is evidence that exposure to natural, green settings (more likely to be found in rural environments) restores attentional resources both in young and older individuals by imposing fewer demands on visual or auditory processing (Berman, Jonides, & Kaplan, 2008; Berto, 2005; Gamble, Howard, & Howard, 2014; Hartig, Evans, Jamner, Davis, & Gärling, 2003; Ottosson & Grahn, 2006). Based on these studies, it might be argued that urban and rural environments contribute differently to cognitive stimulation, particularly in older age when fluid cognitive skills are in decline (Hedden & Gabrieli, 2004; Schneider & Kathleen, 2000; Singer et al., 2003). However, little is known about which aspects of the built environment act as a source of optimal cognitive stimulation for older people, and which specific cognitive benefits are associated with urban or rural living, given current contrasting evidence from epidemiological studies on dementia and experimental studies on attention and executive functions.

To address this issue, the present study aimed to explore urban/rural differences for a wide range of cognitive processes in community-dwelling people aged 50 and over residing in the Republic of Ireland, while considering the role of socioeconomic, health, and lifestyle factors known to be strongly associated with enhanced cognitive health in ageing (Hertzog et al., 2008; Kelly et al., 2014). To our knowledge, this is the first study that allows for such a broad assessment of cognition while taking into account relevant confounding factors. In the light of the existing literature on cognitive functions, the study tested the hypothesis that, if urban environments are more stimulating and engaging than rural areas, urban older dwellers would show better cognitive performance than rural dwellers, especially in terms of executive functions (Robertson, 2014) when confounding factors are accounted for. Vice versa, if urban environments are over-stimulating and impose cognitive load in older age (Linnell et al., 2013), urban older people should have poorer cognitive performance than rural dwellers.

Moreover, based on the evidence that early life residence circumstances can influence late-life cognition (Contador et al., 2015; Fors, Lennartsson, & Lundberg, 2009; Hall, Gao, Unverzagt, & Hendrie, 2000; Nguyen et al., 2008; Zhang, Gu, & Hayward, 2008), the present study explored whether interactions between current and childhood location of residence influenced cognitive scores.

Methods

Participants

Data were obtained from The Irish Longitudinal Study on Ageing (TILDA), a large cohort study on the health, well-being and socioeconomic circumstances of approximately 8,000 healthy Irish residents aged 50 and over (Kearney et al., 2011; Kenny, 2013) which began in 2009 and is conducted every two years. Participants in TILDA are asked to complete a computer-assisted personal interview (CAPI) and a self-completion questionnaire (SCQ) in their homes, as well as a physical and cognitive health assessment conducted by trained study nurses in one of two dedicated health centres or at home (Cronin, O'Regan, Finucane, Kearney, & Kenny, 2013). The present study analysed data from the First Wave of TILDA, conducted between July 2009 and June 2011. A flow chart of the population included in the analyses is shown in Figure 1: 8,175 participants aged 50 and over participated in Wave 1, and 5,898 of these who underwent health assessment were included. Of these, 5 participants were excluded because no information on current location of residence had been recorded during data collection, and 636 were excluded because of missing data in one or more of the considered cognitive measures. Further 1,492 observations were excluded from the analyses in order to have a fixed sample size for all statistical models, leaving a final sample of 3,765 observations (Fig. 1). The final sample size was heavily influenced by the missing data for covariates such as income, which had around

1,400 missing values: despite this high level of non-response, the covariate was kept in the analyses to give a better account of socioeconomic status, strongly associated with cognitive health in older age. Specific sampling methodology and sampling weights based on the distribution of socio-demographic characteristics at population level (Kearney et al., 2011; Kenny et al., 2010; Whelan & Savva, 2013) were used to ensure the representativeness of the TILDA sample. The sampling weights were applied to the analyses in the present study to ensure the representativeness of our subsample (see Statistical analyses section for further details). Moreover, the distribution of participants per area of residence (the explanatory variable in our study) in the sample included in this study did not differ significantly from that of participants taking part in the health assessment, further supporting the representativeness of the subsample. Further details on the design and methodology of TILDA in relation to representativeness of the sample are available elsewhere (Cronin et al., 2013; Kenny et al., 2010; Whelan & Savva, 2013), and comparability with other longitudinal studies has been demonstrated (Savva, Maty, Setti, & Feeney, 2013).

Insert Figure 1 here

Design

Cross-sectional analyses were conducted on measures of cognitive performance in relation to current location of residence, while controlling for socio-demographic circumstances, health and lifestyle. An anonymised version of the dataset for the First Wave released by TILDA (see http://www.ucd.ie/issda/data/tilda/) was used in order to maintain confidentiality and data protection. Ethical approval was obtained at the beginning of the data collection, and all respondents provided signed informed consent before participation (Kenny et al., 2010) excluding therefore individuals with severe cognitive impairment (Whelan & Savva, 2013).

Explanatory variable

The independent variable for this study was the geographical location of residence of the respondent at the time of the interview as assessed by the interviewer according to three categories: (a) Urban; (b) Other settlements; (c) Rural areas. Based on the Irish Census 2011 (www.cso.ie), the “Urban” category refers to the Dublin area, which is the only urban settlement with more than one million inhabitants in the Republic of Ireland, while the category “Other settlements” include five Cities, five Boroughs, and 75 Towns with a population ranging from 1,500 to less than 200,000 inhabitants; lastly, rural areas are settlements with a population of less than 1,500.

Outcome variables

The dependent variables for the study included measures of cognitive performance collected during the CAPI interview and the health assessment in TILDA (Kenny et al., 2010), and are related to global cognition, memory, speed of processing, attention, and executive functions (Table 1). Measures of global cognition included the Montreal Cognitive Assessment Test (MOCA) (Nasreddine et al., 2005) and the Mini Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975). Memory was measured in terms of: immediate and delayed recall of a list of 10 words based on the Consortium to Establish a Registry for Alzheimer’s Disease (CERAD) battery (Morris et al., 1989; Welsh et al., 1994), derived from the Health & Retirement Study and used across several longitudinal studies (Shih, Lee, & Das, 2011); recall and recognition in a Picture Memory Test taken from the Cambridge Mental Disorders of the Elderly Examination, or CAMDEX (Roth et al., 1986); prospective memory based on the Rivermead Behavioural Memory Test (Wilson, Cockburn,

& Baddeley, 1991). Speed of processing was assessed through the cognitive mean reaction time (in seconds) for the Choice Reaction Time test, and through the mean completion time (seconds) for the Colour Trail Making Test Part 1 (CTT 1), while attention was assessed through self-rated absentmindedness, and the Sustained Attention to Response Task (SART) (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) in terms of reaction time (milliseconds, SART RT), standard deviation from the mean reaction time (a measure of variability of performance, SART SD), number of commission errors (SART Commissions), and number of omissions (SART Omissions). Lastly, measures of executive functions included a verbal fluency test (Lezak, 2004), a 6-items test of visual reasoning from the CAMDEX (Roth et al., 1986), the mean completion time (seconds) for the Colour Trail Making Test 2 (D'Elia, Satz, Uchiyama, & White, 1996), and the mean change in completion time from CTT 1 to CTT2 (CTT delta), this last considered a measure of executive function adjusted for biases due to differences in visuo-motor functioning (Ble et al., 2005). CTT errors were not analysed due to the very low error rate (less than 10% for one error and less than 2% for two or more errors) (Cavaco et al., 2013).

Insert Table 1 here

Covariates

Covariates for statistical analyses (see details in Table 2) included variables associated in the literature with changes in cognitive outcomes in older age and with different geographical distributions in terms of place of residence: socio-demographic data, including sex, age, educational attainment, employment status, and household income; physical and mental health, in terms of Body Mass Index, self-rated hearing problems, presence of disabilities in activities of daily living (ADL) and/or instrumental activities of daily living (IADL), number of chronic conditions, use of polypharmacy, and clinical symptoms of depression measured through the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff, 1977); social engagement measured through household composition, participation in clubs, and participation in lifelong learning; behavioural health, including exercise as measured through the International Physical Activity Questionnaire (IPAQ) short form (Craig et al., 2003), and smoking habits; lastly, childhood circumstances, including father social class as per Irish Census, childhood urban or rural residence, and self-rated childhood health. Specifically, the measure of household income was log-transformed to inform on the percentage of increase. Number of chronic conditions was a composite variable informing on the presence of one or more among the following: high blood pressure or hypertension, angina, heart attack, congestive heart failure, diabetes or high blood sugar, stroke, mini-stroke or transient ischemic attack (TIA), high cholesterol, heart murmur, abnormal heart rhythm, other heart trouble, chronic lung disease, asthma, arthritis, osteoporosis, cancer or malignant tumour, Parkinson's disease, emotional/nervous/psychiatric problem, alcohol or substance abuse, stomach ulcers, varicose ulcers, cirrhosis or serious liver damage. Household composition and participation in clubs, two components from the Berkman-Syme Social Engagement Index (Berkman & Syme, 1979) together with attendance at religious events and the presence of at least two close friends or relatives, were the only two components to be significantly associated with cognitive scores for this sample, and were thus included in the analyses, while the global Index itself and its other two components were excluded.

Insert Table 2 here

Statistical analyses

Statistical analyses were performed using Stata version 12 (StataCorp LP). Survey data analyses were conducted by applying sampling weights which provided estimates correcting for distribution of socio-demographic characteristics at national level, and for differential responses to the health assessment (Barrett et al., 2011). Descriptive statistics and regression models explored differences in cognitive performance among the three categories of current residence. Linear regression models were used for continuous variables, Poisson regression for count variables, and Chi-square test and logistic regression for categorical variables. Regression analyses included two models, where Model 1 explored the association between current residence and cognitive performance in univariate analyses, while Model 2 consisted of multivariate analyses including all covariates. Post-estimation analyses looked at the interaction between current and childhood location of residence in regression models which controlled for all covariates, in order to explore a possible modulation of childhood residence on the association between environment and cognitive outcomes.

Results

Descriptive data for the study sample are shown in Table 3 and Table 4. In this sample (Mean age 62.5, 48.5% female), 24.9% lived in urban areas at the time of data collection, 26.8% in other settlements, and 48.2% in rural areas.

Insert Table 3 here

The distributions of cognitive scores among the three categories of current residence (see Table 4) showed poorer performance for rural than urban participants in relation to measures of global cognition, memory (except the recall score in the Picture Memory test and prospective memory), absentmindedness, and all measures of executive functions, but no significant differences emerged for speed of processing (CRT and CTT1). Urban participants had slower responses in the SART RT, but no significant differences were found for SART SD, Omissions or Commissions. Participants living in other settlements had poorer performance than urban dwellers for global cognition, recognition score in the Picture Memory test and for some measures of executive functions, while they were slightly faster in the SART.

Insert Table 4 here

The results of regression analyses in Model 1 (univariate analyses) and Model 2 (adjusted for all covariates) are shown in Table 5, where the cognitive scores of participants living in other settlements or rural areas were compared to those of urban dwellers, the reference category. Regression models are not presented for PIC recall, prospective memory, CRT, CTT 1, SART SD, Omissions and Commissions, as these did not show significant differences in the descriptive analyses (see Table 4). In the regression models, unstandardized b coefficients are shown as differences in score between urban dwellers and each of the other two categories of residence for continuous variables, while absentmindedness was analysed in terms of Odds Ratios (O.R.) of being absentminded most or all the time for participants in other settlements or rural areas as compared to urban residents. Lastly, PIC recognition and

Visual reasoning were analysed in terms of Incident Rate Ratios (I.R.R.) of success in the task.

After controlling for all covariates, rural dwelling, as compared to urban residence, was significantly associated with poorer cognitive performance in terms of global cognition (MOCA b = -0.442, $p < .01$; MMSE b = -0.287, $p < .001$), verbal fluency (b = -1.829, $p <. 001$), completion time for the CTT 2 (b = 3.945, $p < .05$), and increase in completion time from CTT part 1 to part 2 (CTT delta, b = 5.386, $p < .001$); in addition, rural participants reported higher likelihood of being absentminded (O.R. = 2.146, $p < .001$) and showed worse scores in the Picture Memory recognition task (I.R.R. = 0.987, $p < .05$). On the other hand, rural dwellers showed faster reaction times than urban participants at the SART (b = -11.12, $p < .05$). Participants living in other settlements showed significant worse performance than urban residence in the MMSE (b = -0.222, $p < .001$), PIC recognition (I.R.R. = 0.984, $p < .01$), absentmindedness (O.R. = 1.565, $p < .05$), verbal fluency (b = -1.642, $p < .001$), and CTT delta (b = 2.921, $p < .05$), but faster response time in the SART RT (b = -12.56, $p < .05$).

Insert Table 5 here

Interactions between Past and Current Residence

The percentage of participants currently living either in urban, other settlements, or rural areas differed significantly by childhood residence, $\chi^2(2, N = 3,765) = 799.95$, p <.001 (see Table 3), and participants with rural rather than urban childhood had significantly worse cognitive performance for most measures in the multiple regression models (see Table 1s, supplemental material). Analyses of interactions between childhood and current residence were therefore conducted to explore the potential modulation of childhood environment on the association between place of residence and cognitive outcomes.

After controlling for covariates, significant interactions were found for MOCA (b = 0.521, $p < .05$, Figure 2a), verbal fluency (b = 1.16, $p < .05$, Figure 2b), and CTT 2 (b = 6.84, $p < .05$, Figure 2c), where participants who were currently rural but with an urban childhood showed a cognitive advantage with similar scores than those of participants currently residing in urban areas, while participants with rural residence both currently and in childhood showed the worst performance. Moreover, participants in the ‘other settlements’ group but with a rural childhood had significant lower rate of success than urban residents (I.R.R. = 0.973, $p < .05$) or rural participants (I.R.R. = 0.965, $p < .01$) in the PIC recognition task (Figure 2d).

MMSE showed independent main effects for childhood and current residence without interactions, with an advantage for urban childhood as well as urban current residence. Main effects of current residence with no interactions were maintained for CTT delta, absentmindedness, and SART RT, with significantly poorer performance of rural participants as compared to urban residents in CTT delta (b = 4.08, $p < .05$) and absentmindedness (O.R. = 2.236, $p < .01$), but slightly faster RTs in the SART (b = -14.77, $p < .05$). Main effects of childhood residence with no interactions, with significantly lower scores for rural than urban childhood, emerged for immediate recall (Urban b = -0.318, $p < .01$; Other settlements b = -0.291, $p < .01$; but no differences for rural) and delayed recall (Urban b = -0.338, $p < .05$; Other settlements b = -0.532, $p < .01$; Rural b = -0.670, $p < .001$), and visual reasoning (Urban I.R.R. = 0.936, $p < .05$; Other settlements I.R.R. = 0.931, $p < .01$; Rural I.R.R. = 1.06, $p < .05$).

Interactions with social and lifestyle covariates were not significant. Specifically, the interaction between current residence and the Berkman-Syme Social Engagement Index, and between current residence and the IPAQ did not provide any significant results.

Insert Figure 2 here

Discussion

Our results suggest that residing in a highly urbanised area was associated with better cognitive performance than living in less urbanised or rural areas in terms of global cognition and executive functions, and that this association was moderated by childhood residence for some of the explored measured. Analyses of speed of processing and attention did not show clear patterns for this sample.

The results on global cognition (MOCA and MMSE) are broadly in line with epidemiological studies which report an association between prevalence of dementia and cognitive impairment in older age and rural residence, either current (Bae et al., 2015; Cahill et al., 2012; Gavrila et al., 2009; Klich-Rączka et al., 2014; Nunes et al., 2010; Russ et al., 2012) or past (Hall et al., 2000; Nguyen et al., 2008; Zhang et al., 2008). It is to note that while these studies attribute urban/rural differences to socio-demographic factors such as education and income (except Hall et al., 2000), in our study geographical differences were maintained even after controlling for a comprehensive set of covariates including education, occupation, income, and father social class, considered to be the main indicators of socio-demographic inequalities. While analyses of MOCA showed significant interactions for current and childhood location of residence, the MMSE did not show significant interactions: this result might be due to differences between the two tests in the sensitivity to specific cognitive measures (e.g. executive functions) which have been reported in the literature (Dong et al., 2010; Nasreddine et al., 2005; Zadikoff et al., 2008).

Measures of executive functions which showed significantly higher scores for urban residents as compared to participants living in other settlements or rural areas were verbal fluency and CTT delta (increase in completion time from CTT Part 1 to CTT Part 2). In addition, urban/rural differences emerged in the CTT 2 (completion time in CTT Part 2), where again, rural participants with rural childhood had significantly poorer performance. An association between poorer verbal fluency and rural living has been suggested in studies on older people (Chávez-Oliveros et al., 2014), while Gupta and colleagues (2011) reported urban/rural differences in executive functions and fluency in a sample of Chinese middle-aged participants, differences which however disappeared after controlling for self-rated academic skills. On the contrary, such differences remained significant in our study after controlling for educational attainment, a discrepancy possibly due to the older age of our sample.

The results on global cognition and executive functions suggest that people living in highly urbanised areas such as Dublin may be accustomed to higher levels of perceptual and cognitive stimulation due to traffic, intense noise, and increased visual complexity (Cantin et al., 2009; Linnell et al., 2013; Stansfeld, Haines, & Brown, 2011), which stimulate high-level cognitive abilities such as executive functions, involving skills like shifting between multiple tasks, updating and monitoring mental representations of our surroundings, paying attention to important stimuli, and inhibiting maladaptive or wrong responses (Miyake et al., 2000; Repovš & Baddeley, 2006). Urbanisation might therefore stimulate executive functions independently of socio-economic and lifestyle circumstances, and its effects could even be long-term for those who lived in urban areas early in life but are currently living in less urbanised environments (as shown in our interactions). It is interesting to note that the MOCA test includes several tasks involving executive functions, as for example, a version of the CTT 2 and verbal fluency; although the available dataset for this sample reported no scores for the subtests of MOCA, it might be argued that the differences in MOCA scores between urban participants and the other two residence groups depend on differences in executive functions, an argument supported by the fact that group differences for MOCA and MMSE in our sample were not equal. The MOCA test has been reported to have higher sensitivity to cognitive impairment related to executive functions (Dong et al., 2010; Nasreddine et al., 2005; Zadikoff et al., 2008), thus the differences between MOCA and MMSE scores might actually reflect performance differences in terms of executive functions. Moreover, scores in the CTT 2, CTT delta and verbal fluency in this study explained 33.7% of the variance in MOCA scores but 23% of the variance in MMSE scores, further supporting our hypothesis. Therefore, differences in scores between groups of residence in verbal fluency, CTT delta, CTT 2 and MOCA are plausibly due to more efficient executive functions in people who live or have lived in urban contexts.

In contrast, immediate and delayed recall showed an association only with childhood residence when analysing current/childhood residence interactions. These results may indicate that memory is more influenced by past circumstances than current place of residence, possibly due to the fact that current urban living does not impose a specific load on memory, or in other words it does not, to a certain extent, stimulate memory directly, but indirectly via stimulation of executive functions emerged in our analyses. Studies on distractibility and recall in older adults (Wais & Gazzaley, 2011, 2014; Wais, Rubens, Boccanfuso, & Gazzaley, 2010) showed in fact that retrieval of verbal information is impaired in the presence of task-irrelevant visual or auditory distractors, and suggested that these distractors impacted frontal control processes which in turn affected recall. Associations between current living circumstances and cognitive performance in older age might thus be more evident for executive and control processes. On the other hand, verbal abilities such as recall may be more associated with learning circumstances which affect cognition mainly during childhood (Deary & Brett, 2015; Manly, Touradji, Tang, & Stern, 2003).

Although our results do not provide information on causality of the effects or the direction of the interaction between childhood and current residence, they emphasise the relevance of considering changes in the environment of residence across the lifespan to understand cognitive outcomes later in life. While exploring patterns of migration at different points in time could be more informative than comparing childhood with older age, our analyses are in line with other studies which have compared childhood and current environment of residence to explore health and cognitive outcomes later in life (Contador et al., 2015; Fors et al., 2009; Nguyen et al., 2008). Our findings may be interpreted as an association between migration and enhanced cognitive performance, in line with studies (Gist & Clark, 1938; Jokela, 2014; Lehmann, 1959; Tucker-Drob, Briley, & Harden, 2013) which propose that higher cognitive abilities, as measured through IQ, predict migration in the sense that people with higher IQ would create more opportunities for themselves to move to stimulating environments. However, the interpretation of the interaction between childhood and current residence along those lines needs caution because the absence of measures of childhood cognitive performance or IQ in the present study, and the cross-sectional nature of the analyses, limit the possibility to isolate the influence of environmental stimulation on cognitive health from potential genetic predisposition. Therefore, while urbanisation has been suggested as a potential cause for gains in intelligence (Flynn, 1998, 2007), we are not in the position to draw conclusions in this regard from our analyses. Nonetheless, current and past environment of residence in the present study were differently associated with executive functions and memory when controlling for educational attainment and other socioeconomic factors, both in childhood and in older age. Considering that these covariates are strongly associated with IQ in the literature (Crawford, Stewart, Garthwaite, Parker, & Besson, 1988; Rindermann, Flores-Mendoza, & Mansur-Alves, 2010), this might suggest that environmental factors could play a specific role in stimulating cognitive functions. Moreover, our models controlled for self-rated childhood health, which has been reported in the literature as a good predictor of morbidity later in life (Blackwell, Hayward, & Crimmins, 2001), and of socioeconomic and health circumstances in adulthood (Case, Fertig, & Paxson, 2005). Self-rated childhood health, despite the limitations related to self-reports, might be indicative of a health status early in life which may also have hypothetically impacted the possibility to migrate or change environment.

Interestingly, some significant differences in cognitive performance were found between urban dwellers and participants living in other settlements for MMSE, SART RT, CTT delta, verbal fluency, absentmindedness and PIC recognition: These differences might suggest a dose-response relationship between levels of urbanisation and cognitive health, in the sense that living in a large metropolitan area or in a relatively smaller city seems to make a difference in cognitive performance, which deserves further exploration. It is to note, however, that the category “Other settlements” defined by the Irish Census includes areas with varying population which might actually show variations in cognitive performance as well as different environmental effects. This limits the interpretation of comparisons of the “Urban” and “Other settlements” groups, and urges further exploration using variables such as population density as well as measures related to micro-level characteristics of the area of residence (e.g.: neighbourhood). It is plausible that characteristics of the environment of residence at a micro level, such as in the neighbourhood or proximal community, may contribute to the macro-differences in cognitive performance between individuals living in urban areas or other settlements found in the study (Cassarino & Setti, 2015; Wu et al., 2014). Moreover, environmental characteristics at a micro level could better address the differences in cognitive performance between urban and rural areas, which, given the gap in their population size, might not be equivalent to urban/rural differences in other countries. Specific environmental effects independent of level of urbanisation need therefore further exploration in relation to variables that have already been reported to influence geographical variations of health in older age, such as population density (Russ et al., 2012), presence of green areas (Alcock, White, Wheeler, Fleming, & Depledge, 2014; Gamble et al., 2014), noise (Babisch, 2003; Correia, Peters, Levy, Melly, & Dominici, 2013; Selander et al., 2009, 2013), walkability (Neckerman et al., 2009), or accessibility to services (Charreire et al., 2010), and diet (Inagami, Cohen, Finch, & Asch, 2006; Layte et al., 2011; Santos, Rodrigues, Oliveira, & Almeida, 2014; Winkler, Turrell, & Patterson, 2006).

In addition, a micro-level analysis could address the potential limitation that the association found between environment and cognition is due to a bias in the selection of individuals with different cognitive abilities living in different areas, as well as allowing for a more precise assessment of the impact of geographical variations in cognitive health associated with exposure to environmental toxins, disease risk, diet, socio-economic status and opportunities for social interaction (see Cassarino & Setti, 2015 for a review). While acknowledging the limitations of the broad environmental categories used in the present study, we note that our analyses controlled for a set of covariates in line with the literature on urban/rural differences in mental health (Gavrila et al., 2009; Klich-Rączka et al., 2014; Lederbogen et al., 2011; Russ et al., 2012). Education, income and occupational status were used as measures of socioeconomic status, while Body Mass Index was controlled for as a measure of obesity, which is influenced by a poor diet and unhealthy lifestyle (Hu et al., 2001; Mozaffarian, Hao, Rimm, Willett, & Hu, 2011), and associated with cognition both directly or indirectly (Łojko et al., 2014; Profenno, Porsteinsson, & Faraone, 2010; Wang et al., 2014). No data were available for exposure to risk factors for disease or environmental toxins within the sample, but our analyses controlled for health conditions which could be related both to environmental exposure and to a higher risk of disease, and these did not alter our findings. In addition, the Irish Environmental Protection Agency has reported no geographical variations in air quality, radiation, or soil contamination, and the general Irish environmental quality is within the standards set by the European Commission (reports from 2013 are available at http://www.epa.ie/pubs/reports/).

The selection of a small final sample size due to the high number of missing data for the covariate income (around 1,400 missing observations) is a potential limitation for the study because it might have caused biased estimates in our models, despite the use of sampling weights which ensured representativeness. Although we are aware that such a loss of observations might have affected our results, adding this variable to our analyses was in our opinion crucial because income is a measure of socioeconomic status which has been shown in the literature to correlate strongly with cognitive outcomes in older age (Fors et al., 2009; Glymour & Manly, 2008).

The present study suggests urban/rural differences in the cognitive performance of healthy community-dwelling older people in relation to global cognition, and executive functions. Although the cross-sectional design does not inform causality, our results suggest an association between environment of residence and cognitive functioning in older age after controlling for socio-economic, health and lifestyle factors, and causal pathways will be tested when longitudinal data is available. These findings advance the knowledge on the association between environment and cognition, which is still under-explored (Dunwoody, 2006), encourage further research to explore environmental factors for cognitive health, and have policy implications supporting the identification of environmental resources that can be modified or optimised to promote cognitive health in older age and to protect against cognitive decline. As urbanisation is changing the places in which we live (World Health Organization, 2007), understanding whether cities or rural environments are more supportive of cognitive ageing is crucial to identify contextual resources which make an age-friendly community from a cognitive perspective.

Conclusions

Demographic changes and urbanisation worldwide pose a challenge to identify lived environments which support healthy ageing (World Health Organization, 2007), particularly in relation to protective factors for the risk of dementia and cognitive impairment. The present study represents a first step in understanding the factors through which environment contributes to cognitive ageing in a representative sample of older people in the Republic of Ireland.

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Table 1
Measures of Cognitive Performance Analysed in the Study

Cognitive dimension	Measure	Operationalisation
Global cognition	Montreal Cognitive Assessment Test (MOCA)	Mean total score (0 to 30)
	Mini Mental State Examination (MMSE)	Mean total score (0 to 30)
Memory	Immediate recall (10-words list learning)	Mean number of recalled words (0 to 10)
	Delayed recall	Mean number of recalled words after delay (0 to 10)
	Picture Memory Test (PIC) – Recall	Number of recalled objects (0 to 6)
	Picture Memory Test (PIC) – Recognition	Number of identified objects (0 to 6)
	Prospective memory	Success/failure (0, 1) in reminding the interviewer to do something at a certain time.
Speed of processing	Choice Reaction Time – Cognitive score (CRT)	Mean cognitive reaction time (milliseconds)
	Colour Trail Making Test Part 1 (CTT 1)	Mean completion time (seconds)
Attention	Sustained Attention to Response Task (SART)	Mean response time (milliseconds) (RT)
		Standard deviation of response time (milliseconds) (SD)
		Number of omissions
		Number of commission errors
	Self-rated absentmindedness	Frequency of absentmindedness (0=sometimes/never, 1=most/all times)
Executive Functions	Verbal fluency	Mean number of animal names provided
	Colour Trail Making Test Part 2 (CTT 2)	Mean completion time (seconds)
	CTT delta	Increase in completion time from CTT 1 to CTT 2 (seconds)
	Visual reasoning	Number of correct answers (0 to 6)

Table 2

Measures used as Covariates in the Study

Dimension	Measure	Operationalisation
Socio-demographic	Sex	1 = Male 2 = Female
	Age group	1 = 50-64 2 = 65-74 3 = 75+
	Educational attainment	1 = None/Primary 2 = Secondary 3 = Third/Higher
	Employment status	1 = Working 2 = Retired 3 = Other (not working, not retired)
	Household income	Continuous (log transformed)
Physical and mental health	Body Mass Index	Continuous (18 to 45)
	Self-rated hearing	0 = Poor/Fair 1 = Good/Very good
	Number of chronic conditions	Continuous (0 to 10)
	Use of polypharmacy (more than 5 medications)	0 = No 1 = Yes
	IADL[a] and/or ADL[b] disabilities	0 = Not disabled 1 = IADL only 2 = ADL only 3 = IADL and ADL
	Clinical symptoms of depression (CES-D[c])	0 = None/mild (0-7) 1 = Moderate (8-15) 2 = Severe (16-70)
Social engagement	Household composition	0 = Not cohabiting 1 = Cohabiting (spouse or others)
	Participation in social clubs or groups	0 = Not participating 1 = Participating
Lifelong learning	Participation in courses, education or training	0 = Not participating 1 = Participating
Behavioural health	Physical exercise (IPAQ[d] short form)	0 = None 1 = Moderate 2 = Vigorous
	Smoking habits	1 = Never 2 = Current 3 = Past
Childhood circumstances	Father social class	1 = Professional/managerial 2 = Non Manual 3 = Manual 4 = Farmer 5 = Unemployed 6 = Unknown
	Childhood residence	0 = Urban residence 1 = Rural residence
	Childhood self-rated health	0 = Poor/Fair 1 = Good/Excellent

Note. [a] IADL (Instrumental activities of daily living) disabilities refer to managing money, shopping, using the telephone, housekeeping, preparing meals, and taking medications correctly. [b] ADL (Activities of daily living) disabilities refer to basic tasks of everyday life, such as eating, bathing, dressing, toileting, and moving about. [c] The CES-D (Center for Epidemiologic Studies Depression Scale) is a self-administered 20-items scale which assesses the presence of depressive symptoms in the general population [d] The IPAQ (International Physical Activity Questionnaire) asks participants to indicate the amount of physical activity undertaken in the past seven days.

Table 3

Descriptive analyses: Estimates of Socio-demographic, Health and Lifestyle Characteristics for Total Sample and Current Residence

Characteristic	Total sample (n = 3,765)	Urban (n = 980)	Other settlements (n = 1,021)	Rural (n = 1,764)	Effect size
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	
Age	62.5 (0.20)	63.3 (0.46)	62.5 (0.35)	62.0 (0.26)*	0.035
Household income	10.05 (.03)	10.13 (.07)	10.09 (.04)	9.9 (.04)	
BMI	28.6 (.08)	28.4 (.16)	28.4(.14)	28.9 (.11)**	0.004
No. chronic conditions	1.9 (.03)	2.08 (.06)	1.97 (.06)	1.84 (.04)**	0.0035
	n (%)	n (%)	n (%)	n (%)	
Age group					
50-64	2,391 (63.2)	585 (58.7)	642 (62.9)	1,164 (65.6)	
65-74	981 (23.2)	272 (25)	269 (23.4)	440 (22.1)	
75+	393 (13.6)	123 (16.3)	110 (13.6)	160 (12.3)	
Gender					
Male	1,841 (51.5)	500 (52.1)	490 (50.9)	851 (51.5)	
Female	1,924 (48.5)	480 (47.9)	531 (49.1)	913 (48.5)	
Education					
Primary	902 (34.9)	233 (35.9)	223 (31.9)	446 (36)	0.078
Secondary	1,539 (44.4)	322 (36.9)	447 (47.9)**	770 (46.3)	
Third/Higher	1,324 (20.7)	425 (27.2)	351 (20.2)	548 (17.7)**	
Employment					
Employed	1,540 (39.5)	386 (36.9)	386 (35.7)	768 (42.8)	0.086
Retired	1,350 (34.9)	416 (42.1)	391 (38.4)	543 (29.2)***	
Unemployed	875 (25.6)	178 (21)	244 (25.9)	453 (28)	
Polypharmacy					
No	3,075 (80.2	793 (78.7)	814 (78.4)	1,468 (81.8)	
Yes	690 (19.9)	187 (21.3)	207 (21.6)	296 (18.2)	
Self-rated hearing					
Poor/Fair	518 (15.1)	130 (14.8)	145 (14.8)	243 (15.4)	
Good/Excellent	3,247 (84.9)	850 (85.2)	876 (85.2)	1,521 (84.6)	
Disabilities					
None	3,401 (89.4)	886 (88.4)	903 (87.4)	1,612 (90.8)	0.064
IADL	93 (2.9)	32 (4.7)	31 (3.5)	30 (1.7)***	
ADL	179 (4.9)	45 (5.1)	59 (6.1)	75 (4.2)	
ADL + IADL	92 (2.8)	17 (1.7)	28 (2.9)	47 (3.2)	
Depressive symptoms					
None	2,806 (74)	729 (73)	744 (72.4)	1,333 (75.4)	
Moderate	645 (17.4)	170 (18.5)	173 (17.1)	302 (17.1)	
Severe	314 (8.6)	81 (8.6)	104 (10.5)	129 (7.5)	
Cohabiting					

No	814 (22.4)	231 (24.7)	274 (28.3)	309 (18)	0.107
Yes	2,951 (77.6)	749 (75.3)	747 (71.7)	1,455 (82)**	
Participating in clubs					
No	1,768 (49.9)	422 (46.3)	490 (51.5)	856 (50.9)	
Yes	1,997 (50.1)	558 (53.7)	531 (48.5)	908 (49.1)	
Lifelong learning					
No	3,178 (86.9)	789 (83.9)	856 (86.2)	1,533 (88.9)	0.061
Yes	587 (13.1)	191 (16.1)	165 (13.8)	231 (11.1)**	
Exercise					
None	1,104 (30.3)	274 (29.3)	299 (30)	531 (30.9)	0.053
Moderate	1,340 (34.8)	388 (39.3)	378 (36.9)	574 (31.4)*	
Vigorous	1,321 (34.9)	318 (31.4)	344 (33.1)	659 (37.7)	
Smoking status					
Never	1,676 (43.1)	421 (40.5)	424 (40.5)	831 (45.7)	0.050
Current	603 (17.4)	155 (18.5)	194 (20.6)	254 (15.2)*	
Past	1,486 (39.5)	404 (41)	403 (38.9)	679 (39.1)	
Father social class					
Professional	520 (10.7)	188 (15.2)	148 (11.5)	184 (7.9)	0.223
Non Manual	303 (6.99)	127 (11.9)	98 (8.6)	78 (3.5)**	
Manual	1,674 (47.7)	477 (54.7)	498 (52.5)	699 (41.5)*	
Farmer	844 (22.7)	94 (8.1)	168 (15.6)***	582 (34.1)***	
Unemployed	272 (7.7)	41 (4.7)	63 (6.6)*	168 (9.8)*	
Unknown	152 (4.2)	53 (5.2)	46 (5.1)	53 (3.1)	
Childhood residence					
Urban	1,572 (40.1)	690 (71.4)	525 (50.8)	357 (18)	0.461
Rural	2,193 (59.9)	290 (28.6)	496 (49.2)***	1,407 (82)***	
Childhood self-rated health					
Poor/Fair	235 (6.5)	56 (6.1)	78 (8.4)	101 (5.7)	
Good/Excellent	3,530 (93.5)	924 (93.9)	943 (91.6)	1,663 (94.3)	

Note. SE = standard error; BMI = Body Mass Index; ADL = activities of daily living; IADL = instrumental activities of daily living. Effect sizes are shown for variables with significant differences between areas of residence, and are expressed as R-squared for continuous variables while Cramer's V for categorical variables. Percentages and means are estimated based on study weights.

Significant differences between Other settlements and Urban or Rural and Urban are indicated at the level * p <.05, ** p < .01 and *** p < .001.

Table 4

Descriptive Analyses: Estimates of Cognitive Performance for Total Sample and Current Residence

Cognitive measure	Total sample (n = 3,765)	Urban area (n = 980)	Other settlements (n = 1,021)	Rural areas (n = 1,764)	Effect size
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	
Global cognition					
MOCA	24.7 (0.06)	25.4 (0.13)	24.7 (0.11)***	24.4 (0.10)***	0.015
MMSE	28.4 (0.03)	28.7 (0.07)	28.4 (0.07)**	28.2 (0.05)***	0.012
Memory					
Immediate recall	6.6 (0.03)	6.7 (0.06)	6.8 (0.06)	6.5 (0.05)*	0.006
Delayed recall	5.9 (0.05)	6.15 (0.10)	6.15 (0.10)	5.7 (0.07)**	0.009
PIC recall	3.21 (0.02)	3.21 (0.04)	3.16 (0.04)	3.23 (0.03)	
PIC recognition	5.60 (0.01)	5.70 (0.02)	5.60 (0.02)**	5.56 (0.02)***	0.005
Prospective memory, success, n (%)[a]	3,075 (79.5)	792 (78.5)	815 (76.9)	1,464 (81.5)	
Speed of processing					
CRT[b] (ms)	522.1 (3.1)	518 (5.9)	522.5 (6.3)	523.5 (4.2)	
CTT 1[b] (sec)	57.8 (.53)	57.2 (1.2)	58.1 (1.02)	57.9 (.70)	
Attention					
SART RT[b] (ms)	384.2 (1.8)	392.2 (3.9)	379.3 (3.4)*	382.8 (2.4)*	0.002
SART SD[b] (ms)	126.8 (1.5)	122.8 (3.2)	124.0 (3.0)	130.4 (1.9)	
SART Omissions[b]	8.5 (0.22)	7.87 (0.44)	8.46 (0.45)	8.97 (0.30)	
SART Commissions[b]	4.44 (0.08)	4.27 (0.20)	4.28 (0.15)	4.6 (0.11)	
Absentmindedness, most times/always, n (%)[a]	298 (8.4)	48 (1.27)	82 (2.18)*	168 (4.95)***	0.076
Executive functions					
Verbal fluency	20.6 (0.18)	22.2 (0.42)	20.3 (0.29)***	20.1 (0.25)***	0.019
CTT 2 (sec)[b]	115.1 (0.8)	109.9 (1.7)	114.6 (1.7)	118.2 (1.2)***	0.006
CTT delta[b]	57.3 (0.56)	52.7 (1.05)	56.4 (1.11)*	60.3 (0.78)***	0.012
Visual reasoning	2.95 (0.02)	3.09 (0.05)	2.94 (0.05)*	2.88 (0.03)**	0.005

Note. SE = standard error. Effect sizes are shown for variables with significant differences between areas of residence, and are expressed as R-squared for continuous variables while Cramer's V for categorical variables. Percentages and means are estimated based on study weights.

[a] Categorical variables shown in terms of number of observations and percentages.

[b] Higher values for these measures indicate worse performance.

Significant differences between Other settlements and Urban or Rural and Urban are indicated at the level * p <.05, ** p < .01 and *** p < .001.

Table 5

Regression Analyses: Estimates of Cognitive Scores for Current Residence ("Other settlements" and "Rural" as compared to "Urban") in Model 1 (univariate analysis) and Model 2 (all Covariates accounted for).

		Model 1			Model 2		
Cognitive measure	Current residence (Ref: Urban)	Estimates	95% CI	R^2	Estimates	95% CI	R^2
Global cognition							
MOCA[a]	Other settlements	-0.647***	[-1.002,-0.291]	0.015	-0.381	[-0.661,-0.102]	0.237
	Rural	-1.007***	[-1.343,-0.671]		-0.442**	[-0.713,-0.171]	
MMSE[a]	Other settlements	-0.313***	[-0.509,-0.117]	0.012	-0.222**	[-0.390,-0.0534]	0.204
	Rural	-0.497***	[-0.675,-0.319]		-0.287***	[-0.453,-0.121]	
Memory							
Immediate recall[a]	Other settlements	0.0793	[-0.0990,0.258]	0.007	0.143	[0.00025,0.287]	0.237
	Rural	-0.202*	[-0.362,-0.0421]		-0.0665	[-0.206,0.0726]	
Delayed recall[a]	Other settlements	0.00514	[-0.276,0.286]	0.009	0.138	[-0.108,0.384]	0.201
	Rural	-0.419***	[-0.663,-0.175]		-0.104	[-0.318,0.110]	
PIC recognition[b]	Other settlements	0.981**	[0.969,0.992]		0.984**	[0.973,0.995]	
	Rural	0.977***	[0.966,0.987]		0.987*	[0.976,0.998]	
Attention							
SART RT[a]	Other settlements	-12.84*	[-23.13,-2.546]	0.002	-12.56**	[-21.87,-3.253]	0.106
	Rural	-9.321*	[-18.53,-0.112]		-11.12*	[-20.14,-2.099]	
Absentmindedness[c]	Other settlements	1.645*	[1.120,2.415]		1.565*	[1.041,2.353]	
	Rural	2.135***	[1.491,3.056]		2.146***	[1.439,3.199]	
Executive functions							
Verbal fluency[a]	Other settlements	-1.962***	[-2.976,-0.947]	0.019	-1.642***	[-2.564,-0.720]	0.158
	Rural	-2.230***	[-3.204,-1.257]		-1.829***	[-2.808,-0.849]	

CTT 2[a]	Other settlements	4.682	[-0.238,9.602]	0.006	2.615	[-0.809,6.039]	0.351
	Rural	8.265***	[4.011,12.52]		3.945*	[0.748,7.142]	
CTT delta[a]	Other settlements	3.750*	[0.728,6.771]	0.011	2.921*	[0.272,5.569]	0.164
	Rural	7.578***	[4.988,10.17]		5.386***	[2.841,7.930]	
Visual reasoning[b]	Other settlements	0.951*	[0.906,0.998]		0.974	[0.939,1.011]	
	Rural	0.932**	[0.893,0.974]		0.984	[0.949,1.021]	

Note. N = 3,765. CI = confidence interval. Reference category for predictor: Urban residence. Estimates indicate differences in cognitive performance between Other settlements and Urban or between Rural and Urban. Model 2 includes all demographic, health, social, lifestyle, and childhood covariates. Data are weighted.
[a] Unstandardized b coefficients are shown for linear regressions. [b] Incident Rate Ratios shown based on Poisson regressions. [c] Odds Ratios shown based on Logistic regressions.
* p <.05, ** p <.01, *** p <.001.

Figures

Figure 1

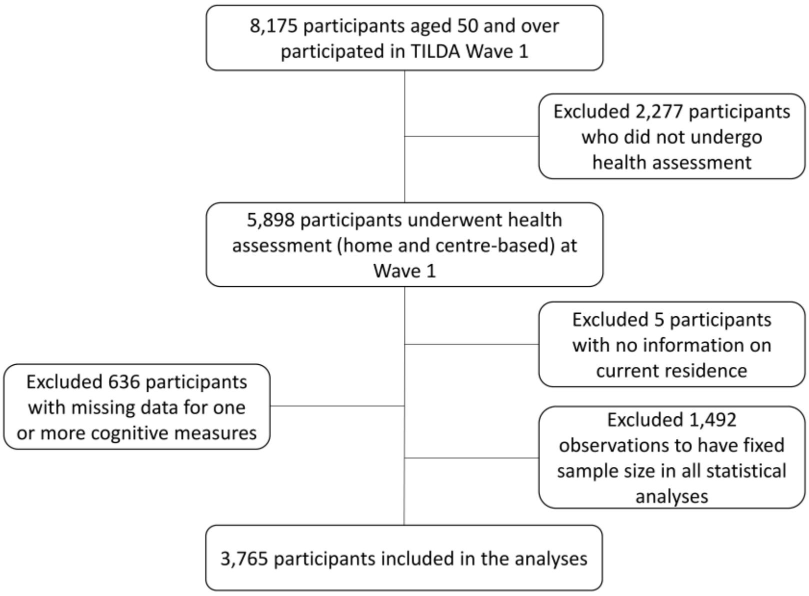

Figure 1. Participants included in the analyses.

Figure 2

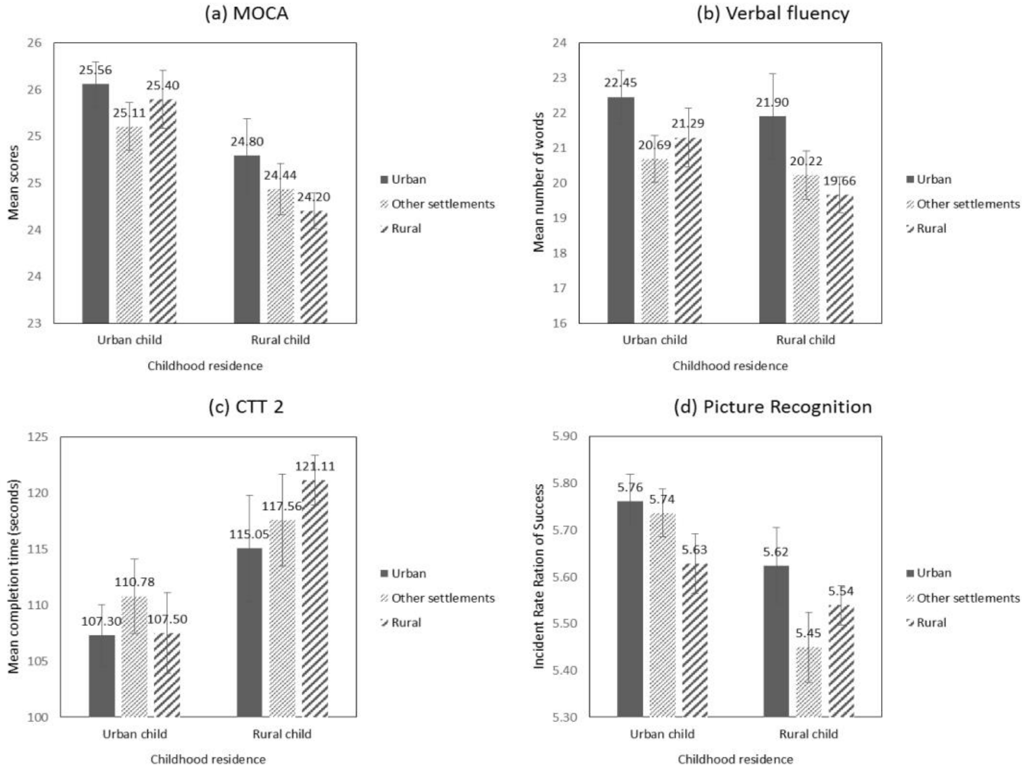

Figure 2. Predicted cognitive performance for interaction between childhood and current residence. Errors bars represent 95% confidence intervals. All covariates are controlled for. Predicted mean scores shown for MOCA (a) and verbal fluency (b), while predicted mean completion time is shown for the Colour Trail Making Test Part 2 (c), and predicted Incident Risk Ratios of Success are shown for the Picture Recognition Task (d).