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Green space and cognitive ageing: A retrospective life course analysis in the Lothian Birth Cohort 1936

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ABSTRACT

International evidence suggests that green space has beneficial effects on general and mental health but little is known about how lifetime exposure to green space influences cognitive ageing. Employing a novel longitudinal life course approach, we examined the association between lifetime availability of public parks and cognitive ageing. Lifetime residential information was gathered from the participants of the Lothian Birth Cohort 1936 using a "life-grid" questionnaire at age 78 years. Parks information from 1949, 1969 and 2009 was used to determine a percentage of parks within a 1500 m buffer zone surrounding residence for childhood, adulthood, and later adulthood periods. Linear regressions were undertaken to test for association with age-standardised, residualised change in cognitive function (Moray House Test score) from age 11 to 70 years, and from age 70 to 76 (n = 281). The most appropriate model was selected using the results of a partial F-test, and then stratified by demographic, genetic and socioeconomic factors. The local provision of park space in childhood and adulthood were both important in explaining the change in cognitive function in later life. The association between childhood and adulthood park availability and change in the Moray House Test Score from age 70 to 76 was strongest for women, those without an *APOE* e4 allele (a genetic risk factor), and those in the lowest socio-economic groups.

Greater neighbourhood provision of public parks from childhood through to adulthood may help to slow down the rate of cognitive decline in later life, recognising that such environmental associations are always sensitive to individual characteristics.

1. Introduction

With the global increase in life expectancy, there is an urgent need to identify factors that affect changes in cognitive abilities as people age. Explanatory models of cognitive ageing posit a variety of demographic, genetic, behavioural and environmental factors contributing to cognitive function (Anstey, 2014). The focus of the current research is on how environmental conditions – or more specifically local green spaces - throughout life affect people's cognitive ageing relative to one another. There have been significant advances made in understanding the range of demographic, genetic, and behavioural factors affecting cognitive ageing. For instance, women tend to have greater resilience to age-related decline (McCarrey et al., 2016). The major genetic predictor responsible for increased susceptibility to non-normative cognitive ageing is the presence of the APOE (apolipoprotein) e4 allele (Davies et al., 2014; Deary et al., 2012b; Schiepers et al., 2012). Behavioural factors, including diet, physical activity, smoking and alcohol consumption, closely related to an individual's socioeconomic status, are often associated with cognitive function in older age, although, apart from smoking, results differ between studies and some associations are prone to confounding by prior cognitive function (Deary et al., 2009; Plassman et al., 2010). Little work has considered specific built, social or environmental features of local areas, with previous research relying on aggregate measures of social deprivation (Lang et al., 2009). Yet cognitive function could be affected by a range of environmental or neighbourhood conditions including: local social capital; residential

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segregation; perceived safety and incivilities; availability of community resources such as food shops and other services; walkability; and the availability of public open space or local greenness (Y. T. Wu et al., 2015a).

It is well established that public open space and greenness is often beneficial for the physical and mental health of local residents (van den Berg et al., 2015). It is also feasible that public open space and greenness may help to optimise cognitive function. Several studies with differing population, design and outcome measures are suggestive of a direct positive benefit of natural environments to directed attention (Ohly et al., 2016). Increased support and motivation for social interaction and physical activity, reductions in stress and exposure to higher air quality offer indirect benefits to cognitive capability, evidenced by a large body of research on changes in physiological markers and emotional states (Hartig et al., 2014). Other indirect benefits such as exposure to beneficial microbiota could indirectly affect cognitive processes through facilitating a reduction in blood pressure and boost to immune function (M. Kuo, 2015). Some of these mechanisms have been shown to directly link with change in cognitive function; for example, in participants over 70 years old, low levels of leisure-time physical activity were associated with a decline in cognitive function five years later (Willey et al., 2016). The only previous longitudinal study of area-level greenness and cognitive change focused on children. The authors found that greenness surrounding a child's home, school and commute was correlated positively with improvements in memory and a reduction in inattentiveness (Dadvand et al., 2015a). However, the study only considered these associations over a 12-month period during early life, and therefore the influence of green space on cognitive function over an individual's lifetime remains unknown.

In the present study, we examined whether availability of green space (using a measure of nearby public parks) was associated with age-related changes in cognitive function between age 11 and 70 years, and between age 70 and 76 years. Three life course models (critical periods, accumulation, and effect modification) were used to address three key hypotheses. First, early childhood has been shown to be a critical period for brain growth due to heightened brain plasticity (Lyu and Burr, 2016). Therefore, we hypothesised that greater public park availability during childhood has positive associations with cognitive change in later life (critical period model). Second, we hypothesised that a greater accumulation of park availability over life is required to promote successful cognitive ageing in later life (accumulation model). This was based on the assumption that cross-sectional effects of access to parks on cognitive function are consistent, albeit weaker, over time (Dadvand et al., 2015a) and that for significant cognitive ageing to be observed a threshold must be surpassed (Anstey, 2014). Finally, by combining the critical periods and accumulation models, we hypothesised that availability during adulthood is important for determining the extent of cognitive reserve, with the capacity to modify the effect of exposure on the sensitive childhood period (effect modification model). As mentioned previously, demographic, genetic and behavioural factors will set an individual on a unique cognitive health trajectory. Therefore, with the aim to determine which groups would benefit most from greater park availability, we stratified the life course model by sex, the presence of an *APOE* e4 allele, and occupational social class (as a marker of individual socioeconomic status).

2. Methods

2.1. Study design and setting

A retrospective life course study was designed using data from the Lothian Birth Cohort 1936 (LBC1936) (Deary et al., 2007, 2012a). The participants, who were all born in 1936, were recruited from Edinburgh and the Lothians in Scotland. Most had taken part in a nationwide assessment of their general intelligence in 1947 (Scottish Mental Survey, 1947; N = 70,805) (SCRE, 1949). The cohort participants were recontacted in 2004 and, from 2318 responses, 1091 were eligible for wave 1 data collection (Deary et al., 2012a). Cohort participants were subsequently contacted and tested at mean ages of approximately 70 years (Jul 2004–May 2007), 73 (Oct 2007–May 2010) and 76 (Jul 2011–Nov 2013). At mean age 78, a stand-alone questionnaire booklet was posted out with returns received between July 2014 and April 2015.

2.2. Operationalising change in cognitive function

We operationalised the outcome of cognitive ageing using the participant's Moray House Test No. 12 (MHT) scores from mean ages of 11, 70 and 76 years (SCRE, 1949). The MHT is a validated measure of cognitive function, which correlates highly with the current "gold standard" cognitive tests (Deary et al., 2004). The MHT is a general intelligence test that is composed of 71 items, measuring the participant's ability on a variety of mental tasks including verbal reasoning, arithmetic, and following directions. Each score was adjusted for age in days at the time of examination by taking the standardised residuals from a linear regression with age as the independent variable. The score was then standardised to have a mean of 100 and standard deviation of 15. Change was calculated by generating the standardised residual from a linear regression model with previous MHT score (e.g. change from 11 to 70 calculated by taking age 70 score as the dependent and age 11 as the independent variable). This statistical technique to calculate change in score is superior to an arithmetic difference as the outcome is independent of baseline level (Prochaska et al., 2008), and has been used in relation to changes in cognitive function previously (Gow et al., 2005). The procedure above provided two outcomes: residualised change in MHT score from age 11 to 70 and residualised change in MHT score from age 70 to 76.

2.3. Operationalising LBC1936 covariates

During the structured interview as part of the cognitive testing appointment at age 70, respondents provided the information required for all the covariates except for father's social class, which was obtained via a questionnaire, and BMI, which was obtained during the physical examination. Covariates were selected *a priori* based on previous literature (Deary et al., 2009), including sex, Occupational Social Class (OSC) (Office of Population Censuses and Surveys, 1980) of participant's father, people per room in childhood household, childhood smoking status, OSC of participant, smoking status and alcohol consumption (Deary et al., 2007). OSC of the participant's father was used as a measure of socioeconomic status from childhood and dichotomised into Professional-managerial (I and II) and Skilled, partly skilled, unskilled (III, IV and V). Additionally, we used childhood overcrowding as a secondary measure of socioeconomic status, defined as the number of people per household room. Participants were asked at what age they started smoking and were categorised as a childhood smoker if they responded that they had started before age 16, as per convention (Hopkinson et al., 2014). Smoking status at age 70 was dichotomised as smoker or non-smoker. Similarly, alcohol consumption was dichotomised as drinks alcohol or doesn't drink alcohol. BMI at age 70 was calculated as weight divided by height squared. Socioeconomic status during adulthood was defined by OSC of the participant's main job from their career and dichotomised in the same way as their father's OSC. For females, husband's OSC was used if higher than their own. We selected a number of variables as effect modifiers *a priori* including sex, adulthood OSC and *APOE* e4 allele. Sex and adulthood OSC at age 70 were operationalised as above. Blood samples were taken during examination and participants were genotyped for *APOE* allele status using TaqMan technology at the Wellcome Trust Clinical Research Facility Genetics Core (Deary et al., 2012a). Participants were dichotomised into having at least one *APOE* e4 allele or having none. In addition to the variables above, we selected several variables to act as auxiliary