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Abstract: Background. We explored the role of relative quantity of green space in urban English neighbourhoods in predicting parent-reported emotional and behavioural problems from early to middle childhood (ages 3, 5, 7) and in buffering the effects of multiple risk factors (neighbourhood disadvantage, family poverty and adverse life events) on child adjustment. Method. We modelled data from 6,384 Millennium Cohort Study children using multilevel growth curve modelling. Neighbourhood green space was measured with the percentage of green space within a standard small area. Results. Neighbourhood green space was generally unrelated to child adjustment, but poor children in urban neighbourhoods with more greenery had fewer emotional problems from age 3 to 5 than their counterparts in less green neighbourhoods. Access to garden and use of parks and playgrounds were related to fewer conduct, peer and hyperactivity problems. Conclusion. Neighbourhood green space may promote emotional well-being in poor urban children in early childhood.

Highlights

- Green environments confer health benefits to both adults and children
- No study has tested their effects on young UK children's adjustment and resilience
- Access to garden and use of parks/playgrounds predicted fewer behavioural problems
- Poor urban children living in greener neighbourhoods had fewer emotional problems
- Neighbourhood green space may promote emotional well-being in poor children

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The Role of Urban Neighbourhood Green Space in Children's Emotional and Behavioural Resilience

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Abstract

Background. We explored the role of relative quantity of green space in urban English neighbourhoods in predicting parent-reported emotional and behavioural problems from early to middle childhood (ages 3, 5, 7) and in buffering the effects of multiple risk factors (neighbourhood disadvantage, family poverty and adverse life events) on child adjustment. **Method**. We modelled data from 6,384 Millennium Cohort Study children using multilevel growth curve modelling. Neighbourhood green space was measured with the percentage of green space within a standard small area. **Results**. Neighbourhood green space was generally unrelated to child adjustment, but poor children in urban neighbourhoods with more greenery had fewer emotional problems from age 3 to 5 than their counterparts in less green neighbourhoods. Access to garden and use of parks and playgrounds were related to fewer conduct, peer and hyperactivity problems. **Conclusion**. Neighbourhood green space may promote emotional well-being in poor urban children in early childhood.

Keywords: emotional and behavioural problems, green space, Millennium Cohort Study, neighbourhoods, socio-economic disadvantage

The role of urban neighbourhood green Space in children's emotional and behavioural resilience

1. Introduction

Green neighbourhood environments have been found to confer benefits to individual health and well-being (Ward Thompson & Aspinall, 2011). Neighbourhood green space is known to have a restorative effect (Kaplan & Kaplan, 2011), reducing stress and fatigue, and improving mood through nature immersion or mere 'views' of green space (Kinnafick & Thogersen-Ntoumani, 2014). Recent evidence suggests that the association between green space and adult health is a complex one (Cummins & Fagg, 2012), explained by social connections (Maas, Verheij, Groenewegen, De Vries, & Spreeuwenberg, 2009), and modified by urbanity, neighbourhood socio-economic status, perceptions of area (particularly safety), especially among women, and quality of green space. For example, in the UK, Mitchell and Popham (2007) reported poorer adult self-rated health with increasing percentage of green space in suburban low-income areas but not in more central urban or rural low-income areas. They suggested that this may be due to poorer quality green space in low-income suburban areas.

Natural environments are important for children, too. Although there is more evidence for the role of neighbourhood green space in children's physical rather than mental health, there are several reasons why neighbourhood green space may be related to children's emotional and behavioural adjustment. First, children's preferred environments include natural elements (Evans, 2006). Second, access to natural, outdoor settings improves a number of child outcomes that are related to adjustment, including attention (Faber Taylor, Kuo, & Sullivan, 2002; Faber Taylor, Kuo, & Sullivan, 2001; Kuo, Sullivan, Coley, & Brunson, 1998; Wells, 2000), self-regulation (Faber Tayler et al., 2002; Kaplan, 2001), and motor skills (Fjortoft, 2004). For example, Faber Taylor et al. (2002) showed that girls living in social (i.e., subsidized) housing closer to green space had better attentional abilities and emotional self-regulation, and both boys and girls played more, as well as more creatively, in green settings than in barren spaces. Third, access to neighbourhood green space might encourage physical activity, which has been associated with mental health (Wells, 2000). Fourth, green space is associated with air quality which promotes physical health (Schwartz, 2004), another correlate of behavioural adjustment. Finally, green space may impact on children via their parents (Maas, Verheij, Groenewegen, De Vries, & Spreeuwenberg, 2006; Sugiyama, Leslie, Giles-Corti, & Owen, 2008; White et al., 2013). For example, parents who have greater access to or utilise open space may be healthier and more physically active (Coombes, Jones, & Hillsdon, 2010; Giles-Corti et al., 2005), which could be related to higher levels of activity (and thereby better mental health) in their children. Furthermore, the mental health benefits of green space to parents (through, for example, views of nearby nature) may be related to better adjustment in their children through better parenting (Goodman & Gotlib, 1999).

Immersion in or views of green space in one's neighbourhood may also be related to children's resilience to risk. In other words, neighbourhood green space may be *especially* important for children experiencing risk, such as family or neighbourhood adversity. Many children who experience family adversity or neighbourhood disadvantage appear to suffer emotionally and behaviourally as a result, but many of them do not. The latter children exhibit emotional and behavioural resilience (Rutter, 2013), or fewer than expected emotional and behavioural problems given the risks they face. Various child and family factors have been associated with such resilience, including self-regulation, cognitive ability and parental warmth (Kim-Cohen, Moffitt, Caspi, & Taylor, 2004). There is also some evidence for the role of neighbourhood characteristics, such as collective efficacy (Odgers et al., 2009), in promoting children's behavioural resilience. Yet there is little research about the role of neighbourhood green space in the emotional and behavioural adjustment of children facing family adversity or disadvantaged localities. What little there is has some important limitations (Bowler, Buyung-Ali, Knight, & Pullin, 2010, for a review), but is also promising, especially in the US context. For example, a number of US studies have shown that nearby nature is beneficial for the well-being of children in disadvantaged urban neighbourhoods (Faber Taylor et al., 2001; Kuo et al., 1998). Studies focusing on cognitive outcomes tend to report similar results. For example, in a premove/postmove longitudinal study, Wells (2000) showed that American children whose homes improved the most in terms of greenness following relocation tended to have the highest post-move levels of cognitive functioning. More recent US studies have shown that nearby nature can promote positive outcomes in other groups of at-risk children, too. Wells and Evans (2003) found that the impact of life stress on child self-worth and psychological well-being was lower among children with greater proximity to nature. Although that study was carried out in a rural setting and measured greenery in the child's immediate residential surroundings rather than at the neighbourhood level, it suggests the potential for more vegetated urban areas to buffer risk effects on child mental health, including emotional and behavioural adjustment. However, no study has examined the role of green space in child well-being and resilience in the early years in the UK, a different context from the US (Konijnendijk, Ricard, Kenney, & Randrup, 2006). There is some research about the role of neighbourhood green space in health (rather than mental health) outcomes in UK children, but the evidence is mixed. For example, a study in a large Welsh city showed that children in deprived neighbourhoods had *greater* access to parks and playground facilities. Their health outcomes were poor despite this access (Rodgers et al., 2012). Like Mitchell and Popham (2007), Rodgers et al. (2012) suggested the lower quality of playgrounds and parks as a reason.

Our study had two main aims: 1) To examine longitudinally the potential for urban green space in England to promote child adjustment in early to mid childhood, and 2) to assess whether urban green space ‘protects’ children from the negative consequences of family adversity and neighbourhood disadvantage. To meet our first aim, we modelled the main effects of urban green space on children’s trajectories of emotional and behavioural problems from early to middle childhood (ages 3, 5 and 7), while accounting for selective sorting into neighbourhoods. We excluded rural (but not suburban) areas because neighbourhood green space may be confounded with levels of rurality (Mitchell & Popham, 2007; White, Alcock, Wheeler, & Depledge, 2013). We hypothesized that green space would influence children’s adjustment above and beyond their families’ social and economic backgrounds associated with selection into neighbourhoods. To meet our second aim, we examined the role of urban neighbourhood green space in buffering (i.e., ‘moderating’) the effects of family poverty, adverse life events and neighbourhood disadvantage on children’s trajectories of problems. We also tested a series of potential pathways (i.e., ‘mediators’) of any protective (i.e., ‘moderator’) effects that were identified. Based on previous research cited above, we hypothesized that green space would build resilience in children via their parents’ mental and physical health, and via their own physical health and level of physical activity.

2. Methods

2.1. Participants and Procedure

The Millennium Cohort Study (MCS; www.cls.ioe.ac.uk/mcs) is a longitudinal survey drawing its sample from all births in the UK over a year, beginning on 1 September 2000 (Plewis, 2007). The MCS sample design effectively under-represents rural areas, which account for 20% of the re-weighted sample of families. Ethical approval for the MCS was gained from NHS Multi-Centre Ethics Committees, and parents gave informed consent before interviews took place. Sweeps (i.e., waves) 1-4 took place when the children were around 9 months, and 3, 5, and 7 years, respectively. Emotional and behavioural problems were measured at Sweeps 2-4. We used data on families in England whose children had emotional and behavioural problem data in at least one of Sweeps 2-4 and who were living in urban English neighbourhoods, consistently over Sweeps 2-4 (n = 6,348). We excluded 66 England families missing data on children's emotional and behavioural problems in all three of Sweeps 2-4, and 1,394 England families living in rural neighbourhoods in at least one of Sweeps 2-4. Two of these families met both criteria. We confined our analysis to families in England because comparable measures of green space are not available from the devolved governments of Wales, Scotland and Northern Ireland. 'Neighbourhoods' were Lower layer Super Output Areas (LSOAs). LSOAs are built from groups of Census Output Areas (typically 4-6), and are constrained by the boundaries of the Standard Table wards used for 2001 Census outputs. They have, on average, 1,500 residents. Urban settlements, including suburban areas, are defined as having a population of over 10,000 (Bibby & Shepherd, 2004).

2.2. Measures

The following were measured at ages 3, 5 and 7, unless otherwise noted.

Neighbourhood green space was measured using the 2001 Generalised Land Use Database (GLUD; Office of the Deputy Prime Minister, 2005). The GLUD classifies land use at high geographical resolution across England into nine categories: green space, domestic gardens, fresh water, domestic buildings, nondomestic buildings, roads, paths, railways, and other (largely hard standing). The data are presented in thousands of square metres (000 m^2), to 2 decimal places. Hence, the statistics are accurate to the nearest $10m^2$. We defined neighbourhood green space as the % of space within LSOA that was green. To be able to better inform urban policy, we excluded domestic gardens. In our analytic sample, urban LSOAs contained between 0% and 97% green space.

Emotional and behavioural problems were assessed with the 20 items (on 3-point response scales) of the parent-reported Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) measuring hyperactivity (α = .71-.76 across sweeps), emotional symptoms (α = .52-.56), conduct problems (α = .55-.68), and peer problems (α = .48-.57). Scores for each scale may range 0-10.

Family socio-economic disadvantage (SED) was parent-reported and measured as the summary of four binary indicators of the family's level of material or economic deprivation: 1) overcrowding (>1.5 people per room excluding bathroom and kitchen), 2) not owning the home, 3) receipt of means-tested income support, and 4) household income poverty (below a poverty line, set at 60% of the UK national median income). This combined measure has been shown in previous research to strongly predict children's emotional and behavioural problems (Malmberg & Flouri, 2011; Schoon, 2006).

Life adversity was the sum of eleven potentially adverse life events (*ALE*) occurring between consecutive sweeps, derived from available MCS data and based on Tiet et al.'s (1998) Adverse Life Events Scale, a well-validated 25-item self-report measure. In our study, ALE, like SED, was constructed by compiling data available in the MCS. The eleven events, reported by the parent, were: family member died, negative change in financial situation, new step-parent, sibling left home, cohort child got seriously sick or injured, divorce or separation, family changed address, parent lost job, new natural sibling, new step-sibling, and maternal depression (currently treated or having been diagnosed for depression).

Neighbourhood disadvantage was measured with the 2004 Index of Multiple Deprivation (IMD) score of families' LSOAs. Scores are based on information from the 2001 Census and apply to 2001 LSOA boundaries even in Sweeps 2-4 if families moved LSOA since Sweep 1. The IMD is a complex, weighted aggregation of specific domains of deprivation measured at LSOA-level. Higher IMD scores indicate greater deprivation.

Child covariates were sex, ethnicity and age. *Family covariates* were binary indicators of mother's education and family structure. Mothers whose highest academic qualification by Sweep 4 was a University degree were contrasted with the rest. Maternal education stands in for a host of other indicators of socio-economic advantage (Hansen, Jones, Joshi, & Budge, 2010). Family structure contrasted two parents with one. Given our focus on green space, we also controlled for whether the family had sole access to a garden to factor out any protective effects of having access to private green space. Finally, we adjusted for the frequency with which the mother took her child to a park or playground, reported at Sweep 3 (age 5), to account for differences in the use of green space. We wanted to reduce the chance that the effect of our green space indicator was driven only by families who use green space frequently. We therefore allowed green space to also influence families who do not use the space often, but who may benefit from it via other means, such as 'views' of nature or good air quality.

Key *mediators* of the expected effect of neighbourhood green space were maternal and child general health, maternal and child physical activity (all measured at Sweep 3, when children were aged 5 years), and maternal psychological distress (measured in all three sweeps). Mother's psychological distress was measured with the 6-item Kessler scale (Kessler et al., 2003), which assesses the experience of recent non-specific psychological distress (α = .81-.84 across sweeps). Mother's general health was measured with her response to 'How would you describe your health generally?' Child's general health was measured with mother's response to 'In general, would you say [cohort child's name]'s health is...?' The response options for both items ranged from 1 (*excellent*) to 4 (*poor*). Child's physical activity was measured with mother's response to how often the child does sport/exercise.

Response options ranged from 1 (*five or more days a week*) to 6 (*less often* [than one day a week] *or not at all*). To assess mother-child physical activity, the mother was asked how often she does sport/exercise with the child. Responses ranged from 1 (*Every day or almost every day*) to 7 (*Less often* [than at least once a year] *or never*).

2.3. Analytic Strategy

First, we investigated whether families in our analytic sample (n = 6,384) were different on our study variables from families in our non-analytic sample (n = 1,458). Next we inspected the correlations between risk factors, neighbourhood green space, mediators and outcomes. We then explored levels and patterns of missingness in our covariates to decide on our approach to dealing with missing data. Finally, to avoid the underestimation of standard errors due to the hierarchical nature of our data (Goldstein, 2003) by having repeated measures (at ages 3, 5 and 7) of problems (Level 1) nested in children (Level 2) nested in electoral wards[1] (Level 3), we fitted three-level growth curve models. We accounted for area clustering at the level of pre-2001 electoral ward on which the MCS survey design was built. To allow for changes in problems across time to vary between children, we specified a random slope on the child's age. All models adjusted for stratum of pre-2001 ward to reflect the stratified sampling design of MCS.

The full sequence of models estimated is outlined in Table 1. Model 1 - the unconditional model - investigated the average levels and growth of problems by regressing them on age in years (grand mean centred at age 5.13 years) and its square (as the children's average trajectories of problems were U-shaped; see below). Grand mean centring age at the 'midpoint' minimises the correlation between age and age-squared thus stabilising the

[1] Electoral wards are the key building block of UK administrative geography. They are the spatial units used to elect local government members. Population sizes vary considerably, with a national average of 5,500 residents per ward.

estimation (Raudenbush & Bryk, 2002). To meet our first aim of examining the effects of urban green space in England on child adjustment, Model 2 added the neighbourhood green space indicator, allowing it to predict the intercept and slopes of problems, along with an indicator of neighbourhood (LSOA) size and our measure of use of parks and playgrounds. Model 3 introduced the child/family covariates. Models 4-10 allowed us to meet our second aim of assessing whether urban green space 'protects' children from risk (i.e., from the negative consequences of family adversity and neighbourhood disadvantage). To establish the effects of risk, Model 4 added the three risk factors (SED, IMD and ALE), specified to be related to the intercept and slopes (linear and non-linear) of problems. This enabled us to examine whether levels of problems at around age 5 and change in problems before and after shifted with SED, IMD and ALE. Model 5 investigated the interaction between each risk factor and the neighbourhood green space indicator on problems at the average age and on change in problems over time, to test for moderation of risk by green space exposure. Models 6-10 added each of the five mediators (maternal psychological distress, maternal general health, child general health, child physical activity, and physical activity of the mother with the child) separately to Model 5, and Model 11 included all five mediators together.

Table 1

Model Summary

Model	**Variables**
1 (unconditional)	Age (grand mean centred) in years and age-squared
2	Model 1 + sampling design variables ('stratum') + %green + %green*age + %green*age^2 + LSOA size[a] + park/playground use[b]
3	Model 2 + child control factors[c] + parent control factors[d]
4	Model 3 + IMD + IMD*age + IMD*age^2 + SED + SED*age + SED*age^2 + ALE + ALE*age + ALE*age^2
5	Model 4 + %green*IMD + %green*IMD*age + %green*IMD*age^2 + %green*SED + %green*SED*age + %green*SED*age^2 + %green*ALE + %green*ALE*age + %green*ALE*age^2
6	Model 5 + maternal psychological distress + maternal psychological distress*age + maternal

	psychological distress*age2
7	Model 5 + maternal general health
8	Model 5 + child general health
9	Model 5 + child physical activity
10	Model 5 + physical activity of mother with the child
11	Model 5 + maternal psychological distress + maternal psychological distress*age + maternal psychological distress*age^2 + maternal general health + child general health + child physical activity + physical activity of mother with the child

*Note***:** All models were run for the four SDQ domain scores. SED = Socio-economic disadvantage; ALE = Adverse life events; IMD = Index of Multiple Deprivation (England); LSOA = Lower layer Super Output Area.

[a] measured in hectares

[b] how often the parent takes the child to a park or playground, measured at Sweep 3

[c] sex and ethnicity

[d] two-parent family (time-varying), mother's education (whether University-educated or not by Sweep 4), and whether the family has sole access to a garden (time-varying)

3. Results

3.1. Bias Analysis and Missing Data Analysis and Imputation

The families in our analytic sample were more disadvantaged than those in the non-analytic sample. This was expected given that the majority of families in our non-analytic sample were rural, who, in England, tend to be more affluent. Further descriptives on the key study variables in our analytic sample and our non-analytic sample are in supplementary Tables A.1 and A.2. As can seen in Table 2, which shows the correlations between neighbourhood green space and the risk and outcome variables, there was evidence for the expected covariation of childhood problems and for interrelationships between risk factors, neighbourhood green space and outcomes. Neighbourhood green space was inversely related to family poverty and area deprivation at each timepoint, was unrelated to life adversity, and was weakly associated (*r*s ranging .02-.09) with all five mediators (maternal psychological distress, maternal general health, child general health, child physical activity and physical activity of the mother with the child).

Because of missingness on our study variables in the analytic sample (see Table 2), we multiply imputed missing data. As .04-18% of values were missing overall, we generated 20 imputed datasets (Graham, Olchowski, & Gilreath, 2007) in SPSS20 using the Markov Chain Monte Carlo procedure. In the imputation model we included all covariates as predictor and predicted variables. We fitted our models in Stata12 using the MI estimate command which performs individual analyses for each of the imputed datasets, collects estimates of coefficients and their Variance-Covariance estimates, applies Rubin's combination rules (Rubin, 1996) to the collected estimates, and reports pooled results.

Table 2

Correlations between risk factors, % of neighbourhood green space, and child outcomes in the analytic sample

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Emotional symptoms																								
1. 3yr	-																							
2. 5yr	**.44**																							
3. 7yr	**.36**	**.49**																						
Conduct problems																								
4. 3yr	**.30**	**.23**	**.24**																					
5. 5yr	**.21**	**.32**	**.28**	**.50**																				
6. 7yr	**.18**	**.21**	**.38**	**.43**	**.58**																			
Hyperactivity																								
7. 3yr	**.25**	**.19**	**.19**	**.48**	**.36**	**.33**																		
8. 5yr	**.18**	**.28**	**.24**	**.37**	**.53**	**.43**	**.57**																	
9. 7yr	**.16**	**.19**	**.30**	**.34**	**.43**	**.56**	**.50**	**.66**																
Peer problems																								
10. 3yr	**.34**	**.27**	**.25**	**.26**	**.20**	**.19**	**.24**	**.21**	**.20**															
11. 5yr	**.26**	**.40**	**.31**	**.21**	**.29**	**.23**	**.21**	**.29**	**.25**	**.39**														
12. 7yr	**.21**	**.27**	**.42**	**.21**	**.28**	**.35**	**.21**	**.26**	**.32**	**.35**	**.51**													
IMD																								
13. 3yr	**.17**	**.15**	**.13**	**.18**	**.16**	**.17**	**.14**	**.14**	**.13**	**.20**	**.21**	**.18**												
14. 5yr	**.17**	**.14**	**.13**	**.18**	**.16**	**.17**	**.15**	**.14**	**.12**	**.19**	**.20**	**.18**	**.93**											
15. 7yr	**.16**	**.14**	**.12**	**.18**	**.16**	**.17**	**.14**	**.13**	**.12**	**.18**	**.19**	**.17**	**.90**	**.95**										
SED																								
16. 3yr	**.12**	**.12**	**.09**	**.09**	**.11**	**.10**	**.09**	**.09**	**.08**	**.12**	**.12**	**.12**	**.27**	**.27**	**.27**									
17. 5yr	**.14**	**.15**	**.11**	**.08**	**.10**	**.08**	**.09**	**.07**	**.07**	**.12**	**.15**	**.12**	**.29**	**.28**	**.28**	**.54**								
18. 7yr	**.13**	**.13**	**.10**	**.07**	**.10**	**.06**	**.08**	**.08**	**.04**	**.11**	**.11**	**.10**	**.26**	**.25**	**.26**	**.43**	**.56**							
ALE																								

19. 3yr	**.08**	**.08**	**.09**	**.12**	**.09**	**.09**	**.11**	**.11**	**.09**	**.05**	**.06**	**.08**	**.07**	**.07**	**.07**	**.07**	**.06**	**.05**						
20. 5yr	**.09**	**.11**	**.11**	**.11**	**.13**	**.11**	**.08**	**.10**	**.08**	**.07**	**.09**	**.07**	**.10**	**.07**	**.08**	**.06**	**.07**	**.08**	**.22**					
21. 7yr	**.08**	**.07**	**.14**	**.11**	**.10**	**.13**	**.09**	**.10**	**.10**	**.07**	**.08**	**.09**	**.10**	**.09**	**.09**	**.07**	**.06**	**.08**	**.23**	**.28**				
% NGS																								
22. 3yr	**-.04**	**-.04**	**-.04**	.01	-.01	-.01	-.02	-.02	-.01	**-.05**	**-.04**	**-.04**	**-.15**	**-.14**	**-.13**	**-.08**	**-.08**	**-.10**	.02	-.01	-.01			
23. 5yr	**-.05**	**-.05**	**-.04**	-.01	-.01	-.01	-.02	-.02	-.01	**-.06**	**-.04**	**-.03**	**-.15**	**-.14**	**-.15**	**-.09**	**-.09**	**-.10**	.01	.01	-.01	**.88**		
24. 7yr	**-.05**	**-.04**	**-.04**	-.02	-.02	-.01	-.02	-.03	-.00	**-.06**	**-.04**	-.03	**-.15**	**-.14**	**-.15**	**-.10**	**-.10**	**-.10**	.01	-.00	-.01	**.80**	**.90**	
N	5959	6156	6194	5977	6167	6214	5910	6125	6188	5939	6155	6202	6384	6384	6384	5413	5436	6328	6266	6383	6384	6384	6384	6384

Note: Coefficients in bold are significant at $p < .05$. NGS = Neighbourhood green space.

3.2. Model Results

In Model 1, conduct, hyperactivity and peer problems dropped at an annual rate of 0.35, 0.14 and 0.07 points on the SDQ scale, respectively. The significant positive age^2 terms for these domain scores (0.14, 0.08 and 0.05, respectively) demonstrated an additional slight upward curve at older ages above and beyond the negative linear slope, suggesting U-shaped trajectories. The average trajectory of emotional symptoms was also non-linear, but both age and age^2 terms were positive (0.04, and 0.02, respectively), suggesting that scores steadily increased at a low rate until there was a slight acceleration of problems near the end of the trajectory. All random effects were statistically significant with the most variation found within children and between children at central age.

In Model 2 (Table 3), percentage of green space in the LSOA was not significantly associated with any of the four problems at central age or with the linear or non-linear change in problems over time. The size of the LSOA was similarly unrelated to children's problem trajectories. (We also tested the effect of percentage of green space without adjusting for LSOA size, also nonsignificant.) The frequency with which the mother took her child to a park/playground was, however, significantly related to fewer problems in three of the four problem domains. (We also considered that the positive effects of green space may be larger for those families who actually use green spaces. We therefore viewed the frequency with which the mother takes the child to green space as a possible moderator of green space effects. However, in these models, we did not find significant moderator effects)

In Model 3 (not shown), the null green space effects on all problem domains were robust to adjustment for the covariates. Model 4 (Table 4) added the three risk factors (SED, ALE and IMD). All three were related to the four problems at central age, except for SED to hyperactivity. IMD was related to linear (i.e. age) and non-linear (i.e. age^2) change in conduct problems over time and to linear change in emotional symptoms and peer problems over time. SED was related to non-linear change in emotional symptoms and to linear change in hyperactivity, and ALE was linked to a linear increase in both emotional symptoms, and to a non-linear change in conduct problems. As in Model 3, both access to garden and use of parks or playgrounds were related to fewer peer, hyperactivity and conduct problems. As the three-level model showed that the between-ward variation was no longer significant for emotional and conduct problems, we dropped Level 3 (capturing ward clustering) from subsequent models for emotional and conduct problems. Model 5 (not shown) which examined moderator effects of risk by green space showed only one significant moderator effect. Neighbourhood green space was associated with linear change in emotional symptoms over time for those in poverty (t = 3.13). Figure 1, which plots this interaction effect, shows that, compared to a high-SED boy in an urban neighbourhood with more green space, a high-SED boy in an urban neighbourhood with less green space has more emotional symptoms at age 3. His emotional problems increase between age 3 and 5, and then decrease between age 5 and 7, whereas his counterpart in a greener area steadily increases in emotional problems from age 3 to 7. Low-SED boys in neighbourhoods with more and less green space follow very similar trajectories to each other, both steadily increasing. The positive effect of neighbourhood green space on high-SED boys, therefore, seems to be more prominent earlier in the trajectory. Yet we were unable to explain this interaction effect with our five mediators (i.e., maternal psychological distress, child general health, maternal general health, child physical activity, and physical activity of the mother with the child; Models 6-10; not shown), although all five were significantly associated with emotional symptoms in the expected direction. With the addition of maternal psychological distress in Model 6, the interaction between neighbourhood green space and IMD became borderline significant (t = 1.93, p = .053), and statistically significant in Model 11 (supplementary Table A.3), which included all mediators.

Table 3

Fixed Effect Estimates and Variance Covariance Estimates of Problem Trajectories (Model 2)

Predictors	Conduct problems	Hyperactivity	Peer problems	Emotional symptoms
	Fixed Effects			
Age	-0.352***(0.011)	-0.157***(0.013)	-0.085***(0.010)	0.038***(0.010)
Age^{2}	0.134***(0.007)	0.069***(0.008)	0.059***(0.007)	0.016* (0.007)
% green space	0.001 (0.001)	0.000 (0.001)	0.000 (0.001)	-0.000 (0.001)
% green space x age	-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
% green space x age^{2}	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)
LSOA size	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Less park/playground use	0.036* (0.017)	0.052*(0.025)	0.047** (0.015)	0.023 (0.016)
Stratum (ref. = England-advantaged)				
England-disadvantaged	0.363***(0.049)	0.410***(0.077)	0.353*** (0.044)	0.254***(0.045)
England-ethnic	0.272*** (0.067)	0.467*** (0.106)	0.729***(0.061)	0.548***(0.061)
Wales-advantaged	-0.829 (0.774)	-0.763 (1.169)	-0.506 (0.693)	-0.693 (0.749)
Wales-disadvantaged	-0.093 (0.319)	1.159* (0.483)	0.312 (0.286)	0.338 (0.308)
Scotland-advantaged	-0.113 (0.529)	0.503 (0.766)	0.210 (0.458)	-0.338 (0.486)
Scotland-disadvantaged	0.241 (0.674)	0.304 (1.024)	-0.348 (0.610)	-0.908 (0.662)
Constant	1.225**(0.073)	2.964***(0.109)	0.809***(0.066)	1.196***(0.071)
	Random Effects			
Level 3 (ward)				
Intercept	0.028 (0.008)	0.079 (0.020)	0.025 (0.007)	0.020(0.006)
Level 2 (child)				
Intercept	1.483 (0.035)	3.359 (0.074)	1.008 (0.027)	1.236 (0.032)
Slope	0.096 (0.005)	0.121 (0.008)	0.062 (0.005)	0.053 (0.005)
Intercept/slope covariance	-0.169 (0.009)	0.121 (0.016)	0.019 (0.007)	0.112 (0.008)
Level 1 (occasion)				
Intercept	1.167 (0.022)	1.997 (0.037)	1.191 (0.022)	1.388 (0.026)

Note: $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$. The Celtic countries' 'strata' are included in all conditional models because some families in the analytic sample lived in these countries in Sweep 1 before they migrated to urban England by the time of Sweep 2.

Table 4

Fixed Effect Estimates and Variance Covariance Estimates of Problem Trajectories (Model 4)

Predictors	Conduct problems	Hyperactivity	Peer problems	Emotional symptoms

	Fixed Effects			
Age	-0.264***(0.033)	-0.090*(0.042)	0.0151 (0.031)	0.006***(0.001)
Age^2	0.055*(0.021)	0.028 (0.028)	0.032 (0.021)	0.028 (0.023)
% green space	-0.000 (0.001)	-0.000 (0.001)	0.001 (0.001)	-0.000 (0.001)
% green space x age	-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
% green space x age^2	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
LSOA size	-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)
Less park/playground use	0.047**(0.016)	0.063**(0.024)	0.047**(0.014)	0.025 (0.016)
IMD	0.008***(0.001)	0.009***(0.002)	0.008***(0.001)	0.006***(0001)
IMD x age	-0.002***(0.000)	-0.000 (0.001)	-0.001**(0.000)	-0.001*(0.000)
IMD x age^2	0.001***(0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
SED	0.054*(0.027)	-0.043 (0.037)	0.063*(0.027)	0.134***(0.030)
SED x age	-0.010 (0.010)	-0.043**(0.013)	-0.015 (0.010)	-0.019 (0.010)
SED x age^2	-0.010 (0.007)	0.006 (0.009)	-0.000 (0.007)	-0.018*(0.008)
ALE	0.077***(0.015)	0.079***(0.020)	0.057***(0.015)	0.075***(0.016)
ALE x age	-0.008 (0.006)	-0.004 (0.008)	0.005 (0.006)	0.029***(0.006)
ALE x age^2	0.010*(0.004)	0.000 (0.006)	-0.002 (0.004)	0.008 (0.005)
Girl	-0.309***(0.032)	-0.652***(0.049)	-0.225***(0.029)	0.006 (0.032)
Child ethnicity (ref. = White)				
Mixed	-0.065 (0.084)	-0.147 (0.128)	0.054 (0.076)	0.019 (0.083)
Indian	-0.014 (0.089)	0.106 (0.139)	0.533***(0.082)	0.237**(0.089)
Pakistani/Bangladeshi	-0.027 (0.070)	0.511***(0.130)	0.728***(0.066)	0.601***(0.070)
Black	-0.404***(0.083)	-0.511***(0.130)	0.099 (0.077)	-0.169*(0.083)
Other	-0.147 (0.118)	0.075 (0.181)	0.513***(0.108)	0.383**(0.117)
Mother has University degree	-0.319***(0.079)	-0.463***(0.121)	-0.231***(0.072)	-0.200*(0.078)
Two-parent family	-0.425***(0.045)	-0.572***(0.063)	-0.282***(0.043)	-0.225***(0.047)
Two-parent family x age	0.023 (0.017)	-0.021 (0.021)	-0.073***(0.015)	-0.035*(0.016)
Two-parent family x age^2	0.007 (0.010)	0.020 (0.013)	0.022*(0.010)	-0.001 (0.011)
Garden access	-0.153*(0.065)	-0.225*(0.092)	-0.152*(0.062)	0.035 (0.067)
Garden access x age	-0.036 (0.021)	0.007 (0.027)	-0.008 (0.020)	-0.026 (0.021)
Garden access x age^2	-0.035*(0.014)	0.011 (0.018)	0.007 (0.014)	-0.006 (0.015)
Stratum (ref. = England-advantaged)				
England-disadvantaged	0.108**(0.040)	0.160***(0.028)	0.123**(0.041)	0.060 (0.040)
England-ethnic	0.044 (0.065)	0.100 (0.113)	0.126*(0.064)	0.119 (0.064)
Wales-advantaged	-0.536 (0.741)	-0.253 (1.124)	-0.301 (0.666)	-0.621 (0.728)
Wales-disadvantaged	-0.160 (0.303)	0.860 (0.463)	0.122 (0.274)	0.137 (0.298)

Scotland-advantaged	-0.246 (0.506)	0.315 (0.736)	0.044 (0.440)	-0.444 (0.471)
Scotland-disadvantaged	-0.073 (0.646)	-0.124 (0.986)	-0.550 (0.588)	-1.064 (0.644)
Constant	1.606*** (0.109)	3.786*** (0.160)	0.998** (0.104)	1.005*** (0.112)
		Random Effects		
Level 3 (ward)				
Intercept	-	0.042 (0.016)	0.008 (0.005)	-
Level 2 (child)				
Intercept	1.356 (0.032)	3.084 (0.070)	0.915 (0.025)	1.161 (0.031)
Slope	0.096 (0.005)	0.123 (0.008)	0.060 (0.005)	0.051 (0.005)
Intercept/slope covariance	-0.161 (0.009)	0.118 (0.015)	0.020 (0.007)	0.111 (0.008)
Level 1 (occasion)				
Intercept	1.150 (0.021)	1.991 (0.037)	1.19 (0.022)	1.390 (0.026)

Note: $^{*}p < .05$; $^{**}p < .01$, $^{***}p < .001$.

Figure 1. Predicted Trajectories of Emotional Symptoms by Neighbourhood Green Space for Poor and Non-Poor Families (Model 5)

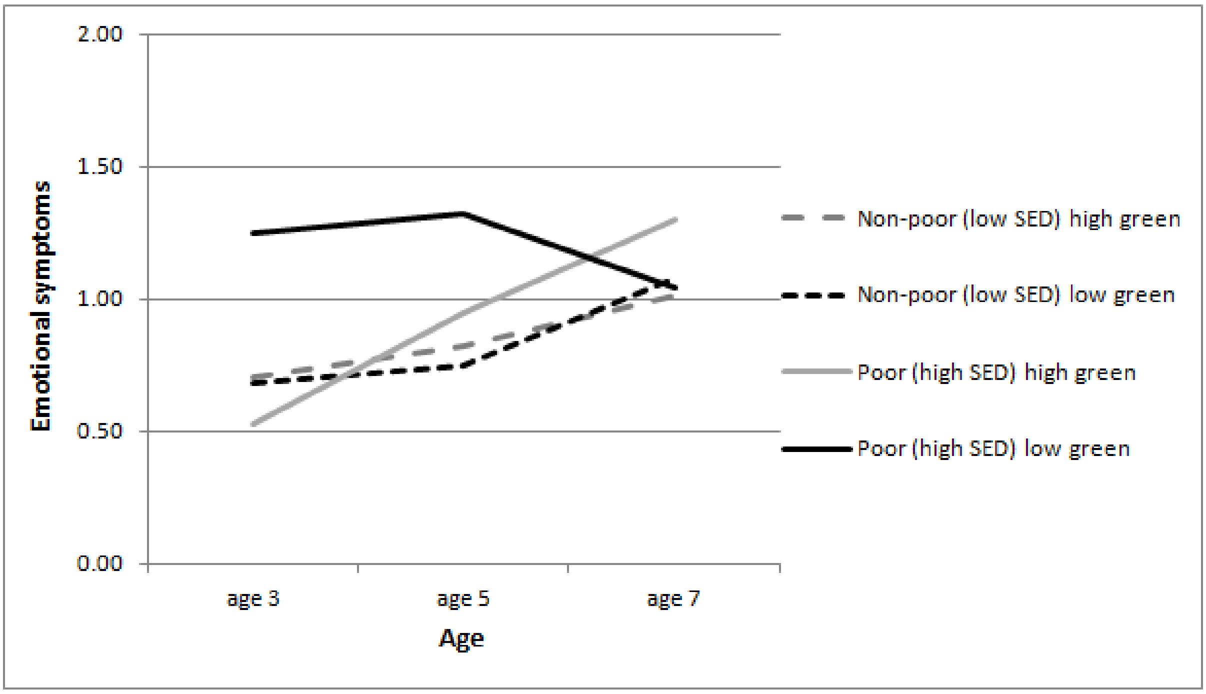

Figure 1. ‘Non-poor (low SED)’ is having none of the four elements of socio-economic disadvantage (SED), (at the 10^{th} percentile of families in our sample). ‘Poor (high SED)’ is having three of the four elements of SED (at the 90^{th} percentile of families in our sample). ‘Low green’ neighbourhoods have 6% of green space (at the 10^{th} percentile of neighbourhoods where our sample families lived) and ‘high green’ neighbourhoods have 71% of green space (at the 90^{th} percentile of neighbourhoods where our sample families lived). Predictions are

plotted for children with two parents, and whose mothers' highest academic qualification is a degree, and otherwise the reference group for each categorical variable, and at the mean of each continuous variable.

4. Discussion

In this study, we explored the effect of urban neighbourhood green space on young children's emotional and behavioural adjustment and resilience. Green space was unrelated to child adjustment on the whole, but it predicted emotional resilience: poor children with a higher percentage of green space in their neighbourhood had fewer emotional problems from age 3 to 5, relative to their counterparts in less green neighbourhoods. However, none of our mediators (i.e., maternal psychological distress, child and maternal general health, physical activity of the child, and mother's physical activity with the child) explained the mechanism underlying this relationship. Perhaps by having more places where neighbours might interact, neighbourhoods with more green space may have more social cohesion (Sugiyama et al., 2008), which we were unable to measure in our study. The finding that this protective effect disappeared after age 5 is more difficult to explain. An explanation may be that as children grow older, they are exposed to several neighbourhoods (e.g., those of their schools, which children in England start attending full-time at age 5), which dilutes the effect of the immediate home neighbourhood on outcomes.

Our findings about the protective effect of green space for child well-being are similar to those of Wells and Evans (2003). However, Wells and Evans (2003) showed that green space buffered the effect of life stress rather than poverty on child adjustment. In our study, green space did not moderate the effect of life adversity (or neighbourhood disadvantage). One reason for this difference may be due to the way green space was measured in the two studies. Wells and Evans (2003) measured it with a third party's assessment of the immediate home environment (including questions about the amount of nature in the window view, the number of live plants indoors, and the material of the outdoor yard), whereas in our study it was measured by an objective measure of greenery in the family's immediate neighbourhood. A more direct presence of greenery in and around the home may be required for children experiencing life stressors to benefit from the natural environment. Moreover, Wells and Evans (2003) measured life stress as perceived by the child, and included items related to the child's experiences, such as being bullied at school. Our measure of life adversity measured more broadly stressors experienced (and reported) by the child's family. However, both that study and ours point to the importance of access to outdoor green environments for children. In our sample, peer, hyperactivity and conduct problems were fewer in children who were frequent users of parks and playground and whose homes had access to a garden.

Our study is not without limitations. First, as a correlational study, it was unable to prove that green space caused children to be resilient to family poverty. Second, some of our measures, such as the peer problems scale of the SDQ, had weak reliability. Others had weak construct validity, particularly our 1-item parent-reported measures of general health of mother and of child, physical activity of child, and physical activity of the mother with the child. Third, some of our results could have been produced by regression to the mean, in which extremely high (and low) values affected by measurement error are likely to be closer to the sample mean at repeat assessments. Fourth, with only three timepoints of data on emotional and behavioural problems, we could not model a more elaborate functional form of children's individual trajectories. Fifth, we did not account for change in the characteristics of neighbourhoods over the course of the study period, making, instead, an assumption that area characteristics were fixed over time. There is little research on the extent of area change in the UK due to the limited availability of longitudinal data on areas and the lack of comparability of area boundaries and data over time (Lupton & Power, 2004). Although neighbourhood green space is unlikely to have changed drastically during the study period, neighbourhoods could undergo changes over time in resident composition and employment opportunities, neither of which would have been captured by IMD, our time-invariant measure of relative area deprivation. Resident composition and employment opportunities are related to the social profile of the neighbourhood, in turn associated both to quantity and use of green space. Finally, we measured green space at the level of small area, without taking into account the amount and type of green space available in neighbouring small areas. Related to this, we did not take into account the quality of green space, which may be a stronger predictor of its use and benefits, especially among young families.

Despite these limitations, our study suggests that neighbourhood green space may help urban children living in poor families to have better emotional health early in life. Future studies should use more fine-grained measures of locality and greenery to assess more precisely the proximity of families to green sites, and to account for the influence of neighbouring green space, not just green space in children's immediate neighbourhoods. This would be possible with the use of geographic information systems (GIS). Utilising data on the quality of green sites in a GIS framework may also capture access to high quality green spaces. Future studies should also take into account that school-age children may not only be exposed to the neighbourhood where they live. With these changes and follow ups of the MCS cohort as it approaches adolescence, future research will be able to determine how immersion in and access to green space may relate to the longer term development of children's emotional and behavioural adjustment and resilience.

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Appendix. Supplementary Tables.

Table A.1

Descriptives of Continuous Study Variables in the Analytic and Non-analytic Samples

Variable	Analytic sample (n = 6,384)		Non-analytic sample (n = 1,458)	
	M (SE)	95% CI	M (SE)	95% CI
Conduct problems				
Age 3	2.89 (0.03)	[2.84, 2.94]	2.55 (0.05)	[2.45, 2.66]
Age 5	1.53 (0.02)	[1.50, 1.57]	1.29 (0.04)	[1.22, 1.36]
Age 7	1.43 (0.02)	[1.39, 1.46]	1.22 (0.04)	[1.14, 1.30]
Hyperactivity				
Age 3	4.03 (0.03)	[3.97, 4.09]	3.64 (0.06)	[3.52, 3.76]
Age 5	3.38 (0.03)	[3.32, 3.44]	2.97 (0.06)	[2.85, 3.08]
Age 7	3.44 (0.03)	[3.38, 3.50]	3.08 (0.07)	[2.95, 3.21]
Emotional symptoms				
Age 3	1.44 (0.02)	[1.40, 1.48]	1.17 (0.04)	[1.10, 1.24]
Age 5	1.46 (0.02)	[1.42, 1.50]	1.25 (0.04)	[1.18, 1.33]
Age 7	1.62 (0.02)	[1.58, 1.67]	1.36 (0.04)	[1.28, 1.45]
Peer problems				
Age 3	1.63 (0.02)	[1.59, 1.67]	1.39 (0.04)	[1.31, 1.47]
Age 5	1.24 (0.02)	[1.20, 1.28]	0.91 (0.04)	[0.84, 0.97]
Age 7	1.34 (0.02)	[1.30, 1.38]	1.02 (0.04)	[0.95, 1.10]
% Neighbourhood green space				
Age 3	32.12 (0.30)	[31.52, 32.71]	71.03 (0.78)	[69.50, 72.56]
Age 5	32.79 (0.31)	[32.19, 33.39]	74. 36 (0.73)	[72.94, 75.79]
Age 7	33.31 (0.31)	[32.71, 33.92]	76.15 (0.68)	[74.81, 77.49]
LSOA size (hectares)				
Age 3	83.88 (3.10)	[77.80, 89.96]	1505.26 (53.84)	[1399.73, 1610.79]
Age 5	87.83 (3.20)	[81.55, 94.11]	1603.37 (53.31)	[1498.86, 1707.88]
Age 7	90.61 (3.20)	[84.33, 96.89]	1649.17 (53.66)	[1543.98, 1754.35]
Adverse life events				
Age 3	1.65 (0.02)	[1.62, 1.68]	1.64 (0.03)	[1.58, 1.69]
Age 5	1.45 (0.01)	[1.42, 1.47]	1.52 (0.03)	[1.47, 1.58]
Age 7	1.41 (0.01)	[1.38, 1.43]	1.44 (0.03)	[1.38, 1.49]
Family SED				
Age 3	1.19 (0.01)	[1.17, 1.21]	1.05 (0.02)	[1.02, 1.08]
Age 5	1.21 (0.01)	[1.19, 1.23]	1.05 (0.02)	[1.02, 1.08]
Age 7	1.18 (0.01)	[1.17, 1.20]	1.02 (0.01)	[0.10, 1.05]
Neighbourhood IMD				
Age 3	27.64 (0.23)	[27.19, 28.08]	15.25 (0.32)	[14.63, 15.88]
Age 5	26.97 (0.23)	[26.53, 27.42]	14.83 (0.32)	[14.21, 15.45]
Age 7	26.44 (0.22)	[26.00, 26.88]	14.31 (0.31)	[13.71, 14.91]
Maternal psychological distress				
Age 3	3.09 (0.04)	[3.00, 3.18]	2.59 (0.07)	[2.45, 2.74]
Age 5	3.00 (0.04)	[2.92, 3.09]	2.45 (0.07)	[2.31, 2.59]
Age 7	2.94 (0.04)	[2.86, 3.02]	2.47 (0.08)	[2.32, 2.62]
(Little) Park/playground use	3.36 (0.01)	[3.33, 3.38]	3.39 (0.03)	[3.33, 3.44]
(Poor) Maternal general health	2.47 (0.01)	[2.44, 2.49]	2.27 (0.03)	[2.22, 2.32]
(Poor) Child general health	1.78 (0.01)	[1.55, 1.64]	1.59 (0.02)	[1.55, 1.64]
(Infrequent) Physical activity of mother with child	3.58 (0.02)	[3.54, 3.62]	3.12 (0.04)	[3.04, 3.19]
(Infrequent) Child physical activity	5.21 (0.01)	[5.19, 5.24]	4.94 (0.03)	[4.88, 4.99]

Note. Means, standard errors and Confidence Intervals (CI) are unweighted. IMD = Index of Multiple Deprivation; SED = Socio-economic disadvantage; LSOA = Lower layer Super Output Area.

Table A.2

Descriptives of Categorical Study Variables in the Analytic and Non-analytic Samples

Variable	**%**			
	Analytic sample (n = 6,384)	**Non-analytic sample (n = 1,458)**	χ^2	***df***
Girl	49.64	49.45	0.02	[1]
Child ethnicity			**249.01**	[5]
White	74.26	93.07		
Mixed	4.03	1.85		
Indian	4.37	0.75		
Pakistani/Bangladeshi	10.07	3.02		
Black	5.04	0.55		
Other	2.22	0.75		
Mother has University degree	17.24	27.76	**79.71**	1
Two-parent family				
Age 3	80.80	89.05	**55.30**	1
Age 5	76.60	84.29	**41.00**	1
Age 7	72.76	80.93	**41.50**	1
Garden access				
Age 3	88.76	94.84	**54.17**	**2**
Age 5	89.63	95.73	**58.24**	2
Age 7	90.10	95.86	**57.44**	2

Note. Proportions are unweighted. Chi-square values in bold indicate statistically significant differences.

Table A.3

Fixed Effect and Variance Covariance Estimates of Emotional Symptoms Trajectories (Model 11)

	Fixed Effects	
	B	*SE*
Age	0.1269**	0.0377
Age^2	-0.0088	0.0275
% green space	-0.0005	0.0020
% green space x age	-0.0020**	0.0007
% green space x age^2	0.0005	0.0005
LSOA size	0.0000[a]	0.0001
Less park/playground use	-0.0057	0.0151
IMD	-0.0007	0.0021
IMD x age	-0.0008	0.0006
IMD x age^2	0.0011*	0.0005
SED	0.1544**	0.0480
SED x age	-0.0607***	0.0164
SED x age^2	-0.0233	0.0123
ALE	0.0325	0.0274
ALE x age	0.0100	0.0103

ALE x age^2	0.0129	0.0077
Girl	0.0340	0.0302
Child ethnicity (ref. = White)		
Mixed	-0.0382	0.0783
Indian	0.0683	0.0841
Pakistani/Bangladeshi	0.2523***	0.0689
Black	-0.2637**	0.0792
Other	0.0851	0.1128
Mother has University degree	-0.1128	0.0737
Two-parent family	-0.1390**	0.0466
Two-parent family x age	-0.0248	0.0158
Two-parent family x age^2	-0.0096	0.0111
Garden access	0.0621	0.0658
Garden access x age	-0.0227	0.0210
Garden access x age^2	-0.0052	0.0151
% green space x IMD	0.0001*	0.0001
% green space x IMD x age	-0.0000[b]	0.0000[c]
% green space x IMD x age^2	-0.0000*[d]	0.0000[e]
% green space x SED	-0.0018	0.0012
% green space x SED x age	0.0014**	0.0004
% green space x SED x age^2	0.0002	0.0003
% green space x ALE	0.0004	0.0007
% green space x ALE x age	0.0004	0.0002
% green space x ALE x age^2	-0.0002	0.0002
Maternal psychological distress	0.0737***	0.0078
Maternal psychological distress x age	0.0121***	0.0028
Maternal psychological distress x age^2	0.0005	0.0017
(Poorer) Child general health	0.0354*	0.0164
(Poorer) Maternal general health	0.2319***	0.0181
(Less frequent) Mother-child physical activity	0.0218*	0.0091
(Less frequent) Child physical activity	0.0735***	0.0157
Stratum (ref. = England-advantaged)		
England-disadvantaged	0.0297	0.0380
England-ethnic	0.0521	0.0614
Wales-advantaged	-0.4086	0.6863
Wales-disadvantaged	0.0956	0.2812
Scotland-advantaged	-0.5134	0.4457
Scotland-disadvantaged	-1.0202	0.6079

Constant	0.0424	0.1483
Random effects		
Level 2 (child)		
Intercept	0.9746	0.0283
Slope	0.0503	0.0051
Intercept/slope covariance	0.0913	0.0074
Level 1 (occasion)		
Intercept	1.3731	0.0259

Note. $^{*}p < .05$; $^{**}p < .01$, $^{***}p < .001$. The Celtic countries' 'strata' are included because some families in the analytic sample lived in these countries in Sweep 1 before they migrated to urban England by the time of Sweep 2. [a] 0.00000569. [b] 0.00000478. [c] 0.00002. [d] 0.00002. [e] 0.00001