Social Science & Medicine 168 (2016) 239–248

Contents lists available at ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

On the move: Exploring the impact of residential mobility on cannabis use

Tim Morris [a,*], David Manley [a,b], Kate Northstone [c,d], Clive E. Sabel [a]

[a] School of Geographical Sciences, University of Bristol, University Road, Bristol BS8 1SS, UK
[b] OTB—Research for the Built Environment, Faculty of Architecture and the Built Environment, Delft University of Technology, PO Box 5030, 2600 GA Delft, The Netherlands
[c] NIHR CLAHRC West, 9th Floor, Whitefriars, Lewins Mead, Bristol BS1 2NT, UK
[d] School of Social and Community Medicine, University of Bristol, UK

ARTICLE INFO

Article history:
Received 31 January 2016
Received in revised form
13 April 2016
Accepted 28 April 2016
Available online 6 May 2016

Keywords:
United Kingdom
Residential mobility
Cannabis
Life events
Multilevel model
Within- and between-individual effects
ALSPAC

ABSTRACT

A large literature exists suggesting that residential mobility leads to increased participation in risky health behaviours such as cannabis use amongst youth. However, much of this work fails to account for the impact that underlying differences between mobile and non-mobile youth have on this relationship. In this study we utilise multilevel models with longitudinal data to simultaneously estimate between-child and within-child effects in the relationship between residential mobility and cannabis use, allowing us to determine the extent to which cannabis use in adolescence is driven by residential mobility and unobserved confounding. Data come from a UK cohort, The Avon Longitudinal Study of Parents and Children. Consistent with previous research we find a positive association between cumulative residential mobility and cannabis use when using multilevel extensions of conventional logistic regression models (log odds: 0.94, standard error: 0.42), indicating that children who move houses are more likely to use cannabis than those who remain residentially stable. However, decomposing this relationship into within- and between-child components reveals that the conventional model is underspecified and misleading; we find that differences in cannabis use between mobile and non-mobile children are due to underlying differences between these groups (between-child log odds: 3.56, standard error: 1.22), not by a change in status of residential mobility (within-child log odds: 1.33, standard error: 1.02). Our findings suggest that residential mobility in the teenage years does not place children at an increased risk of cannabis use throughout these years.

1. Introduction

1.1. Residential mobility

Residential mobility has long been of interest to academics (Rossi, 1955). The interest in this everyday process has grown greatly in the past few decades with social scientists endeavouring to uncover the complex ways in which residential mobility affects outcomes from multiple domains throughout the lifecourse. One domain that has garnered much attention is health and the ways in which exposure to mobility may affect health outcomes (Jelleyman and Spencer, 2008). Studies that focus on individuals as the units of analysis have provided an impressive amount of empirical evidence associating high levels of residential mobility with a wide range of subsequent poor health outcomes from cardiovascular disease to obesity, and depression to substance use (DeWit, 1998; Exeter et al., 2015; Morris et al., 2015; Tunstall et al., 2010).

A large proportion of research conducted on the health effects of residential mobility has focussed on children, who may suffer more from residential changes than adults (Tonnessen et al., 2013). While many household moves are made with the intention of improving family life (Rossi, 1955), these decisions are made at the parental level and children themselves have little influence over family decisions to relocate. Moves may be made specifically for the benefit of a child, for example moving into the catchment area for a 'good school', but from a child's point of view the rewards may not be perceptible and therefore far outweighed by the costs. A move may be far more distressing for a child than for an adult as they are

* Corresponding author.
E-mail address: Tim.Morris@bristol.ac.uk (T. Morris).

http://dx.doi.org/10.1016/j.socscimed.2016.04.036

likely to suffer more complete loss of social networks (Stokols et al., 1983) and experience social exclusion (Cole et al., 2006), rendering them more vulnerable to the stress that occurs from household moves (Haveman et al., 1991).

Negative life experiences in childhood may have a substantial effect on the development of psychological conditions (Rutter, 1981) and it has been shown that such early life experiences can have strong systematic influences in later life (Bailey, 2009). Additionally, the stress from events such as moving house may harm parent-child relationships because of reduced supervision, interaction and less supportive parenting (Anderson et al., 2014; Waylen et al., 2008). As children's development and well-being are largely dependent on their parent's attention and resources (Shonkoff and Phillips, 2000), adverse social events such as residential mobility may lead to psychological wear and tear (Barboza Solís et al., 2015) and have lasting long term impacts on various domains of health such as health behaviours.

1.2. Risky health behaviours

Risky health behaviours (RHBs) such as smoking, drug and alcohol use account for a major source of preventable morbidity and mortality amongst populations, particularly young people (Gore et al., 2011), and due to their modifiable nature offer an attractive target for policy intervention. For instance, the UK government has a number of policies in place designed to reduce participation in RHBs, particularly amongst children, such as an annually reviewed drug strategy (the Drugs Act, 2005) and a confidential drugs advice initiative named FRANK. Children are of particular concern because RHBs are commonly first encountered in childhood and adolescence and then track into adulthood, impacting on health, education, and employment (Chassin et al., 2004; Gruber, 2001). Participation in RHBs has a social aspect and there is a body of evidence to suggest that residential mobility is robustly associated with a range of behaviours including drug use (Brown et al., 2012; DeWit, 1998; Hoffmann and Johnson, 1998; Lee, 2007).

RHBs may appeal to certain types of children and adolescents as a means of autonomy and rebellion from parents or to those subjected to certain social environments and events. RHBs can, for example offer a psychological or pharmacological coping strategy for dealing with distress (Friedman, 2013; Hyman and Sinha, 2009) and a means to break into new peer networks (Haynie et al., 2006), both of which can occur as the result of a residential move or other adverse life event. Given that peer participation in RHBs is a strong determining factor in the likelihood of a child to participate (Cebulla and Tomaszewski, 2009; HSCIC, 2014) and that deviant peer groups may be more welcoming of newcomers than high achieving groups (Haynie et al., 2006), it is possible that mobile children may be at a far greater risk of engaging in RHBs than non-mobile children. From this point of view, major life events in childhood and adolescence can be seen as a potentially influential mechanism behind RHBs such as cannabis use.

In the UK, cannabis is the third most used drug after tobacco and alcohol with prevalence rates of 7% for 11–15 year olds and 16% for 16–24 year olds (HSCIC, 2014; Lader, 2015). It makes a considerable contribution to the burden of disease through a range of physical and mental health problems, which effect young people more than other age groups (Imtiaz et al., 2015). Mental health problems are the major issue surrounding cannabis use in both the media and academic literature, with studies suggesting that regular cannabis use at a young age is associated with mental illness, relapsed episodes of mental illness symptoms, increased criminal activity, and suicidal behaviours (Fergusson et al., 2002; Gage et al., 2014; Rubino et al., 2012). There is also evidence that cannabis use can exacerbate mental health problems amongst children that have already been subjected to the experience of adverse life events (Morgan et al., 2014). However, it should be noted that cannabis use may be beneficial for individuals with certain clinical conditions (Volkow et al., 2014). Beyond the health domain cannabis use is associated with a number of negative social outcomes including poor educational performance, unemployment, and relationship quality (Cebulla and Tomaszewski, 2009; Fergusson and Boden, 2008; Stiby et al., 2015). It is therefore important that social pathways contributing to cannabis use as a risky health behaviour are well understood. Residential mobility may be one such pathway that is currently under researched.

1.3. The influence of unobserved confounding

Pervading the vast majority of research examining the health impacts of residential mobility has been an underlying assumption that effects are independent of and not due to underlying (unobserved) differences between mobile and non-mobile individuals (Morris et al., in press). Whilst some studies have accounted for a wide range of important variables relating to the family environment (Brown et al., 2012; Morris et al., 2015) there is still a widespread implication that residential mobility has an exogenous influence upon health outcomes, with only a handful of authors explicitly acknowledging that it may be acting as a proxy for often unaccounted factors (Anderson et al., 2014; Flouri et al., 2013; Gasper et al., 2010). Given that mobile and non-mobile groups tend to differ across a wide range of characteristics and therefore this assumption is likely not satisfied, there is a strong possibility that bias due to unobserved confounding will influence findings. This is a substantial limitation because these often neglected factors, most noticeably adverse life events such as parental separation, divorce, death, and job loss which are related not only to residential mobility (Clark, 2013; Feijten and van Ham, 2010), but also to RHBs (Dong et al., 2005; Hoffmann and Johnson, 1998; Morgan et al., 2014). This raises an important question in the literature as it may not be residential mobility itself that drives the observed associations with negative health outcomes, but the underlying factors that are associated with both. If this is indeed the case then excluding these variables from analysis will result in unobserved confounding that may cause the effect of residential mobility to be erroneously inflated upwards beyond that of its own true independent effect. Put simply, because residential mobility and cannabis use share common underlying influences, it is entirely possible that the relationships observed in previous studies have been spuriously driven by unobserved confounding caused by these important unaccounted factors.

Of the studies above, only that by Dong et al. (2005) adjusted for other adverse childhood events in addition to residential mobility, although they were unable to account for unobserved factors. Their findings revealed that while residential mobility was indeed strongly related to each of depression, attempted suicide, alcoholism and cigarette use, accounting for additional adverse childhood events attenuated almost all associations (Dong et al., 2005). This is important as it highlights that it may not be residential mobility, *per se*, that causes health differences, but rather the underlying differences between individuals who are more residentially mobile or non-mobile. That is, residentially mobile children may have a greater underlying propensity for engaging in RHBs, and these unobservable differences may be what drive the mobility health relationship. This view is backed up by two recent studies utilising advanced analytical methods which both suggest that it is unobserved, underlying differences between mobile and non-mobile children that is related to delinquency and substance use rather than any causal effect of residential mobility (Gasper et al., 2010; Porter and Vogel, 2013).

In this article we aim to examine the relationship between residential mobility and cannabis use during adolescence, and to assess to what extent any observed relationships may represent causal effects of mobility or underlying differences between mobile and non-mobile children.

2. Materials & methods

2.1. Study population

In order to examine whether residential mobility leads to increased cannabis use we utilise data from a longitudinal birth cohort study, the Avon Longitudinal Study of Parents and Children (ALSPAC). All pregnant women resident in the (former) Avon Health Authority area in South West England with an expected date of delivery between April 1991 and December 1992 were eligible to enrol. After birth, data were primarily collected from the study mothers and then from children via regular self-completion questionnaires and hands on assessments from the age of seven. The ALSPAC cohort is largely representative of the UK population when compared with 1991 Census data; however there is under representation in ethnic minorities, single parent families, and those living in rented accommodation. For full details of the cohort profile and study design see Boyd et al. (2013) and Fraser et al. (2013). Fig. 1 shows the available analytical sample for our study and the causes of attrition. From the full enrolled sample of 14,775 children, 4767 have full data resulting in 21,193 person-year observations. Each individual in our sample provides between one and seven observations with a sample average of 4.4.

2.2. Dependent variable

2.2.1. Cannabis use

During assessment at ages 12, 13, 15, and 17, and in questionnaires sent out at ages 14, 16, and 18 study children were asked to report if they had recently used cannabis, resulting in seven waves of data. At the age 12 and 13 assessments, study children were asked if they had used cannabis in the previous six months, whereas at the age 15 and 17 clinics and the age 18 questionnaire they were asked if they had used cannabis in the previous year. Cannabis use at the age 14 questionnaire was derived from self-reported frequency of cannabis use, with responses of "only ever tried once or twice" and "used to sometimes but never now" recoded as 0 and responses of "Sometimes, but < once a week" and more frequent recoded as 1. In the age 16 questionnaire participants were asked if they had used cannabis since their 15th birthday. While the framing of the questions varied slightly, each resulted in a binary variable indicating if the child had used cannabis in the most recent measurement period. At each assessment the child answered these questions in private on a computer.

2.3. Independent variables

2.3.1. Residential mobility

We extracted information on household moves from the ALSPAC address database, a data source used primarily for administrative purposes. It has a high temporal accuracy due to detailed recoding of addresses and regular updates following direct communications with study participants. Using month and year of household moves we created a residential history for each participant and matched this to questionnaire and clinic completion dates to create a binary indicator at each wave coded 1 if a child had experienced a household move since the last wave and 0 if not. In addition to the subsequent effect of a residential move this measure also allowed us to capture the short term 'anticipatory' stress effects that can accompany a residential move (Popham et al., 2015). Given the short time intervals between data waves it was not plausible to utilise frequency of residential moves as very few study families moved more than once between waves. We also included variables for lagged residential mobility, a variable indicating the total number of moves made in the analytical period prior to the current wave, and a variable indicating the distance moved where moves occurred (categorised as <2 km, 2–15 km, 15 + km).

2.3.2 Covariates

We utilise a wide range of control variables that are related to mobility and cannabis use. Time-invariant characteristics that relate to the child's surroundings from birth through to age 11 and therefore cover exposures prior to the start of our analytical period are as follows: Family level socio-economic variables include highest parental education (categorised as common certificate of education/none/vocational, O-level [exams taken at completion of compulsory school attendance], A-level [exams taken in post-compulsory schooling at age 18], and university degree or above), highest parental Social Class based on Occupation (social classes I [Professional occupations], II [Managerial and technical occupations], and III-N [non-manual Skilled occupations] combined together into one category, and III-M [manual Skilled occupations], IV [Partly-skilled occupations], and V [Unskilled occupations] combined into another category), housing tenure (categorised as owned/mortgaged, rented from housing association, and rented from private landlord/other), and neighbourhood deprivation at age 11 as measured by quintiles of the Index of Multiple Deprivation (IMD). Whilst many studies have used income as a means to control for the financial resources of a household we used a variable indicating the level of financial difficulties that each family had experienced in affording each of food, clothing, heating, rent/mortgage and other essentials for their child. We use this measure as it may better represent the personal subjective stress experienced by a household than arbitrary income bands, which fail to capture other individual differences such as household expenditure. Demographic variables included maternal and paternal age at birth, parental relationship status throughout childhood (categorised as steady two parent family, steady single parent family, two to one parent family, and one to two parent family, therefore allowing transitions between statuses to be captured in the latter two groups), child ethnicity (categorised as white vs non-white), and child sex. We also included the number of household moves made prior to age 11, an assessment/questionnaire indicator (coded as 0 for questionnaire responses and 1 for assessment responses), and binary indicators for maternal cannabis use during pregnancy and maternal or paternal cannabis use during childhood, all reported by the study mother. In order to determine whether any effects observed due to residential changes were just reflecting school changes we included a binary variable indicating if the child had changed schools during ages 15–16, the fourth stage of compulsory schooling in the UK. We also include binary variables to indicate whether the child's family experienced a major life event in the period from birth to the start of our analytical period. These events included parental separation, divorce or marriage, sibling birth, parental job loss and death of a family member.

We also include time varying covariates (TVCs) that are measured throughout the analytical period from age 11 to age 18 at each wave of response. These include age and age squared centred around their grand means, lagged mobility, distance moved, and IMD quintile. The study website contains details of all the data that is available through a fully searchable data dictionary (http://www.bristol.ac.uk/alspac/researchers/access/).

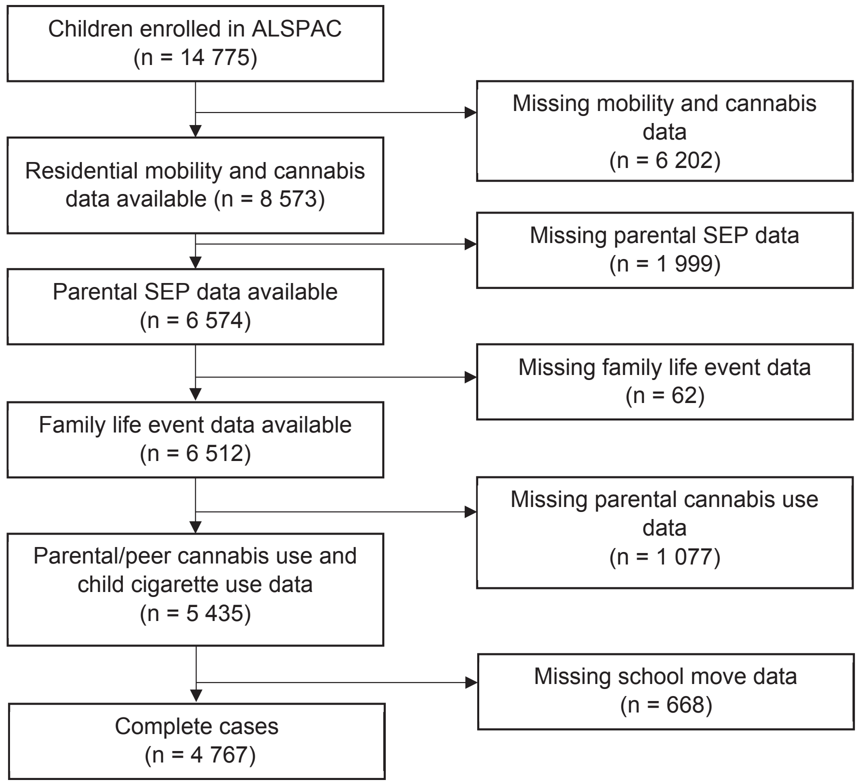

Fig. 1. Causes of attrition in the analytical sample.

2.4. Statistical analysis

To obtain a baseline analysis that is comparable to previous studies we ran a series of two-level random-intercept logistic regression models with measurement occasions (level-1) nested within children (level-2) to determine the association between residential mobility and cannabis use in adolescence.

Consider for simplicity the following two-level logistic regression where we only include residential mobility. The model expressed in terms of the log-odds or logit that individual i $(i = 1, \ldots, n)$ smokes at occasion t $(t = 1, \ldots, T_i)$ can be written as

$$\log\left(\frac{\pi_{it}}{1-\pi_{it}}\right) \equiv \text{logit}(\pi_{it}) = \beta_0 + \beta_1 x_{it} + u_i, \quad u_i \sim N\left(0, \sigma_u^2\right)$$

where π_{it} denotes the probability that they smoke at that occasion, x_{it} denotes whether they move at that occasion and u_i is a child-level random effect capturing all omitted child-specific factors (i.e., time-invariant unobserved heterogeneity).

In this model, the coefficient β_1 represents two distinct effects, a between-child effect comparing a child in a year in which they moved to a *different* child in a year in which they did not move, and a within-child effect comparing a child in a year in which they moved to the *same* child in a year in which they did not move. It seems very likely that these two effects will differ because when comparing two different children there will be many child-specific unobserved factors which also differ across the two children and which confound the estimated effect of moving. In contrast when we compare a child to themselves, we implicitly hold all child-specific unobserved factors constant. It is not clear what the single estimated coefficient from a standard model actually represents. It is neither a purely between-child comparison nor a purely within-child comparison; rather it is a combination of the two. Of the two effects, the within-child effect is typically preferred, being viewed as closer to any causal effect of a time-varying covariate because it implicitly controls for all child-level factors whether observed or unobserved. Each child truly serves as their own control. However, it is important to realise that the within-child effect may still be confounded by time-varying unobserved factors and so it is important to include such factors in the model.

In order to recover the within-child effect of residential mobility in the above model, we can decompose x_{it} into its within- and between-child components and enter these separately into the model (Neuhaus and Kalbfleisch, 1998). The between-child component is simply the individual-level average of residential mobility $\bar{x}_{i.} = \sum_{t=1}^{T_i} x_{it}$ (i.e., the proportion of years in which individual i moved) while the within-child component is the occasion-specific deviation from that average $x_{it} - \bar{x}_{i.}$. The revised model can be written as

$$\log\left(\frac{\pi_{it}}{1-\pi_{it}}\right) \equiv \text{logit}(\pi_{it}) = \beta_0 + \beta_1^W (x_{it} - \bar{x}_{i.}) + \beta_1^B \bar{x}_{i.} + u_i, \quad u_i \sim N\left(0, \sigma_u^2\right)$$

where the coefficients β_1^W and β_1^B capture the within- and between-child effects of residential mobility. Crucially, whereas $\bar{x}_{i.}$ is very likely correlated with u_i, $x_{it} - \bar{x}_{i.}$ is uncorrelated with u_i by construction and so in contrast to β_1^B, β_1^W is unaffected by child-level confounders. It should be noted that while all children contribute to the between-individual differences, the within-individual differences for mobility are identified off the subset of individuals who have two or more observations and who are observed to move in at least one period and remain stable in at least another.

Given that the relative timing of cannabis use within each questionnaire period was unknown and that as a result there was a potential for bias to be introduced if cannabis use preceded moves by a large amount of time, we ran two sensitivity analyses to test the robustness of our main results (see supplementary material). The first of these utilised only residential moves that had occurred within the first six months of the questionnaire period, and the second a measure of residential mobility that was lagged one wave behind all other variables. We fit all models in the MLwiN software (Rasbash et al., 2009) using Markov Chain Monte Carlo (MCMC) methods (Browne, 2015) for robustness. We called MLwiN from within Stata using the runmlwin function (Leckie and Charlton, 2013).

3. Results

3.1. Descriptive findings

Table 1 shows the rate of residential mobility and cannabis use amongst our sample at each wave. The proportion of children moving at each wave throughout the study period remains relatively stable around the overall study average of 4.6%, with 18% of our sample making at least one move during the analytical period. This is below the annual UK rate of 11% at this time (Champion, 2005) but may reflect study attrition or the fact that our study children were in the final years of compulsory education when moves are less common than in earlier years (Leckie, 2009), and that their parents are at an age at which mobility is low. Cannabis use increased with age with a sharp increase at around age 15, although this may in part be due to underlying differences in question wording at ages 14 and 15. Cannabis use in our analytical sample was higher than UK average rates for children of these ages, 7% for 11–15 year olds and 16.3% for 16–24 year olds (HSCIC, 2014; Lader, 2015).

Table 2 presents the descriptive statistics from our analytical sample. We stratify by those who made no residential moves throughout the study period and those who made at least one move in order to demonstrate the differences between mobile and non-mobile children. Table S1 in the supplementary material further breaks down the characteristics of the mobile group and Table S2 the differences between included and excluded cases. Results from chi-squared tests show that children who are mobile throughout our analytical period are more likely to be female and come from lower social class, single parent families with lower rates of home ownership. Mobile children are also more likely to have grown up in families that experienced parental separation, divorce, marriage, and job loss, as well as a greater number of household moves prior to and school moves during the analytical period. Lastly, mobile children are also more likely to grow up in households in which their mothers and fathers reported cannabis use. Mobile and non-mobile adolescents appear to have different childhood environments and we therefore can expect that bias due to unobserved confounding (unobserved differences at the child-level) is likely to be present, upwardly inflating the effect of residential mobility on cannabis use.

3.2. Cannabis use

Table 3 presents the results from our statistical analyses of residential mobility and cannabis use in adolescence. Models 1 and 2 are standard two-level random-intercept logistic regression models and indicate the change in cannabis usage that is attributable to a residential change before and after observed covariates have been accounted for. Model 1 includes only three items of data relating to residential moves; whether a move occurred since the last wave, the distance of these moves, and the number of moves made in previous waves during the analytical period. The results from Model 1 indicate that a residential move is associated with an increase in the likelihood of immediately using cannabis (log odds 1.71; standard error: 0.92, $p = 0.032$), and that each additional move made previously in the analytical period is also associated with a further increase in likelihood (0.91; SE: 0.38; $p = 0.008$). The lagged mobility variables all show a negative association with cannabis use, suggesting that while immediate cannabis use may differ between mobile and non-mobile children, this relationship dissipates over time following a move. A weak association is observed with distance moved whereby children who move <2 km are less likely to use cannabis than those who did not move (−1.57; SE: 0.92; $p = 0.045$). Model 2 includes all covariates in addition to residential mobility. The association between residential mobility and immediate cannabis use is explained by these covariates, as is that between distance moved and cannabis use. The effect of cumulative exposure to mobility throughout the study period is also attenuated but remains (1.16; SE: 0.36; $p = <0.001$), indicating that children exposed to a greater level of residential mobility are more likely to use cannabis than those exposed to a low level of residential mobility.

The results from Model 2 also indicate the importance of certain child and family covariates. Cannabis use is strongly and positively related to age and males are more likely to use than females, as are children who changed school during the final two years of compulsory education. Children who grew up in families that had experienced parental separation were more likely to use cannabis but there was an inverse 'protective' trend for sibling birth. Exposure to financial difficulties and higher levels of neighbourhood deprivation in early childhood was also positively associated with cannabis. Maternal and paternal cannabis use in childhood were both strongly associated with increased likelihood of cannabis use, but these effects were far smaller than those for peer use which dominated all other covariates in the model. Children who smoked cigarettes at the start of the analytical period were also more likely to use cannabis. Lastly, and of importance to data collection in future studies, children were more likely to report cannabis use when asked during assessment sessions than in questionnaires. It is likely that this reflects the possible presence of parents when filling out questionnaires (they are absent during the assessment computer sessions). Our conclusions from Model 2 follow those previously found in the literature; that although there appears to be no immediate effect, there is evidence that high levels of residential mobility increase the likelihood of cannabis use amongst children.

However, because these models only account for observed covariates, if we wish to interpret these results causally, we must assume that omitted variables do not influence these results. Even though we have accounted for a wide range of covariates relating to both mobility and cannabis use such assumptions would be inappropriate to claim that unobserved differences do not influence our results. Model 3 presents the results from our model which additionally decomposes residential mobility into its within- and between-child components. The within-effect implicitly accounts for all observed and unobserved child-level factors and is therefore considered as lying closer to the causal effect of mobility than the pooled coefficient reported in Model 2. However, like the pooled coefficient in Model 2, it is still susceptible to confounding from unobserved time-varying factors. Focussing on the between-child coefficient of mobility of 3.22 (standard error 1.16), we can see that children who move more frequently are on average more likely to use cannabis than children who move less frequently, that is, they have a higher underlying tendency towards cannabis use after accounting for all observed covariates. Turning to the within-child coefficient of 0.83 (SE 1.08) we can see that there is no evidence that a residential move for a specific child leads to a change in cannabis use. In other words, our results show that there is no effect of

Table 1
Proportion of movers and cannabis users at each wave.

Wave	Sample size	Age in years[a]	Moved		Used cannabis	
			No (%)	Yes (%)	No (%)	Yes (%)
2	3852	12.8	3647 (94.7)	205 (5.3)	3811 (98.9)	41 (1.1)
3	3572	13.8	3419 (95.7)	153 (4.3)	3458 (96.8)	114 (3.2)
4	3334	14.2	3192 (95.7)	142 (4.3)	3249 (97.5)	85 (2.6)
5	3125	15.4	2965 (94.9)	160 (5.1)	2544 (81.4)	581 (18.6)
6	2936	16.7	2803 (95.5)	133 (4.5)	2259 (76.9)	677 (23.1)
7	2432	17.7	2328 (95.7)	104 (4.3)	1721 (70.8)	711 (29.2)
8	1942	18.7	1858 (95.7)	84 (4.3)	1462 (75.3)	480 (24.7)

[a] Age is given in decimal years and refers to the average age at each data wave for our sample.

residential mobility on subsequent cannabis use. Thus children were no more likely to use cannabis in the years in which they moved than in the years in which they did not move. The lack of precision of the within effect (due partially to the fact that it was estimated using only the 18% of our sample who moved at least once) indicates that within the same individuals, increases in residential mobility over time do not lead to changes in cannabis use. This is an important finding and it highlights the fallacy of making any form of causal (or even directional) interpretation from Model 2. We are therefore able to draw more meaningful conclusions from the data presented in Model 3 than the earlier models and conclude that it is not the process of residential mobility that leads to increased cannabis use, but bias due to unobserved confounding: Cannabis use is more common amongst mobile than non-mobile children, who have a greater propensity for RHBs. The results from the sensitivity analyses (see supplementary material) confirmed the results from our main analyses.

4. Discussion

Consistent with previous research (Brown et al., 2012; DeWit, 1998; Lee, 2007) we find a positive association between residential mobility and cannabis use using conventional regression models. These studies each categorised mobility by the number of moves made over a set period of time meaning that the natural comparison in our study is the measure of cumulative moves, for which we observed a positive relationship with cannabis use even after adjustment for covariates. However, because our study utilised a longitudinal design with data collected over a number of waves we were able to extend our analysis beyond that which these studies were able to. Our more detailed analysis, utilising models which decomposed the effects of mobility into their within- and between-child components, reveals that these conventional models are underspecified and erroneously lead to misleading over interpretations that are not supported by a more detailed analysis of our data. The implications of our results for previous studies are therefore considerable as they highlight the likelihood that unobserved confounding may have significantly influenced their results.

Our approach decomposes the relationship between residential mobility and cannabis use enabling us to determine between underlying propensities for cannabis use amongst children with different mobility profiles and true ‘cause and effect’ changes. We find that mobile and non-mobile children do indeed differ in their cannabis use but that this is due to underlying unobserved confounding as opposed to changes following a residential move; crucially, we can conclude that residential mobility itself in the teenage years does not place children at an increased risk of cannabis use throughout these years. However, our measure of residential mobility prior to the analytical period showed a positive relationship with cannabis use, suggesting that mobility in early childhood may have an important role on the development of cannabis use in adolescence and that the early years may offer a critical period in forming attitudes to such behaviours (Gasper et al., 2010). It is possible for instance that a tendency for RHBs may develop from residential mobility in early childhood and track into adolescence. The between within model may be further applied to early childhood or other outcomes of interest when considering residential mobility or other social processes that may be susceptible to considerable bias due to unobserved confounding.

Beyond residential mobility there are further implications from our results that previous studies have been unable to draw out. Firstly, there is some indication that positive changes to neighbourhood environments may act as a buffer against cannabis use, and this relationship warrants further research. It is possible however that the lack of precision in our estimate is because our study window covers only a relatively short period and contextual influences may require longer time periods to accumulate (Oakes, 2014). Secondly, the effect of parental divorce on cannabis use was protective after parental separation had been included in our models. This highlights the importance of accounting for these two different events separately, an approach rarely used in the residential mobility literature (Clark, 2013; Morris et al., 2015). We also observed an interesting protective effect of subsequent sibling birth. It is possible that the presence of younger siblings influences children's participation in RHBs and makes them more aware of being positive role models.

While we utilised richer data and better specified analytical models than many previous studies, a number of limitations must be acknowledged. Firstly, due to data limitations we were only able to separate between and within effects for a small range of variables and therefore we are unable to explore what may be confounding the relationship between mobility and cannabis use. This is a particular problem for other childhood life events that may act as time-varying confounders of both mobility and cannabis use. Because we accounted for the occurrence of life events prior to our analytical period we were able to partially offset this problem but the possibility remains that bias may be present. Future research with time-varying data on such life events in addition to residential mobility would provide useful additional detail and may be able to determine the presence and effect of such bias. Secondly, because we use an administrative database instead of self-reports to determine residential mobility some moves may have been missed or there may be some error in the move dates that we used. Given the lack of mobility self-reports available through our analytical period it is not possible to measure the extent to which such error may exist. However, the richness of the ALSPAC address database means that we were able to measure all reported moves regardless of distance, an approach that has not been possible in some previous studies where residential mobility was only measured by inter- rather than intra-city or region moves (see for example Gasper et al. (2010)). Thirdly, because we did not have data on all school moves made between waves we were unable to determine

Table 2
Demographic characteristics of analytical sample.

	Non movers (n = 3914)		Movers (n = 853)	
	n (mean)	% (SD)	n (mean)	% (SD)
Child factors				
Male	1929	49.28	343	40.21
White	3811	96.72	825	96.72
Family factors				
Mothers age at birth (years)	(29.18)	(4.36)	(28.10)	(4.43)
Fathers age at birth (years)	(31.28)	(5.36)	(30.28)	(5.34)
High social class	3391	86.64	726	85.11
Highest parental education				
CSE	93	2.38	22	2.58
Vocational	142	3.63	23	2.70
O level	892	22.79	203	23.80
A level	1594	40.73	358	41.97
Degree	1193	30.48	247	28.96
Parental relationship status				
Steady relationship	2793	71.36	502	58.85
Steady single	278	4.55	31	3.63
Separated single	664	16.96	252	29.54
New relationship	279	7.13	68	7.97
Housing tenure				
Owned/mortgaged	3586	91.62	702	82.30
Social rented	232	5.93	73	8.56
Private rented	96	2.45	78	9.14
Neighbourhood deprivation at 11				
Q1 – Lowest	1337	34.16	283	33.18
Q2	821	20.98	176	20.63
Q3	745	19.03	172	20.16
Q4	569	14.54	124	14.54
Q5 – Highest	442	11.29	98	11.49
Number of household moves prior to age 11	(1.11)	(1.20)	(1.60)	(1.56)
Financial difficulties				
None	611	15.61	88	10.32
Some	2322	29.33	502	58.85
Moderate	803	20.52	209	24.50
Great	178	4.55	54	6.33
Childhood events				
Parental separation	665	16.99	248	29.07
Parental divorce	321	8.20	145	17.00
Parental marriage	399	10.19	125	14.65
Sibling birth	1945	49.69	449	52.64
Father lost job	1235	31.55	332	38.92
Mother lost job	796	20.34	221	25.91
Family death	74	1.89	14	1.64
Substance use				
Mother cannabis use in pregnancy	70	1.79	19	2.23
Mother used cannabis	231	5.90	68	7.97
Father used cannabis	309	7.89	99	11.61
Cigarettes use at age 12	41	1.05	7	0.82
Peers use drugs				
Never	1704	43.54	394	46.19
At one time point	1777	30.07	225	26.38
At two time points	722	18.45	164	19.23
At three time points	244	6.23	51	5.98
At four time points	67	1.71	19	2.23
Child changed school	40	1.02	41	4.81
Distance moved (movers only)				
<2 km			302	35.40
2-15 km			35	4.10
15 km+			20	2.34

the extent to which the effects we observed may have been due to school mobility rather than residential mobility (Leckie, 2009). Our inclusion of school moves as a time-invariant variable may have reduced this problem, but being able to separate these into between and within effects would offer a more powerful method for determining the importance of school mobility; this is an area that future research studies can examine. Fourth, we did not have data on the reasons that people made residential moves and therefore were unable to determine if moves could be considered as positive or negative. It is entirely plausible that such differences in the way that household moves are experienced have differential effects on the likelihood of a child using cannabis. Lastly, because data limitations prevented us from determining exactly when cannabis use started within each questionnaire period, there is a possibility that our results could be biased if children systematically started at the beginning of the periods. However, our sensitivity analyses suggest that our results are robust to any such bias.

Unlike previous studies, our findings suggest that residential mobility does not have a causal effect on cannabis use, however our results do not make this social phenomenon redundant. The very

Table 3
Log-odds coefficients from two-level random-intercept logistic regression and models (n = 21193 person-year observations).

	Model 1:	Model 2:	Model 3: Between within	
	Move data only	Covariate adjusted	Between	Within
Residential move	1.71 (0.92)*	1.46 (1.19)	3.22 (1.16)**	0.83 (1.08)
Cumulative moves	0.91 (0.38)**	1.16 (0.36)***		
Lag of residential move ($t+1$)	−0.75 (0.38)*	−0.93 (0.37)**	−0.38 (0.21)*	
Lag of residential move ($t+2$)	−0.74 (0.41)*	−1.07 (0.41)**	−0.38 (0.22)*	
Lag of residential move ($t+3$)	−0.55 (0.44)	−1.01 (0.44)**	−0.26 (0.25)	
Lag of residential move ($t+4$)	−0.84 (0.45)*	−1.30 (0.46)**	−0.56 (0.29)*	
Lag of residential move ($t+5$)	−0.71 (0.51)	−1.23 (0.50)**	−0.38 (0.35)	
Lag of residential move ($t+6$)	−0.77 (0.77)	−1.15 (0.72)*	−0.22 (0.67)	
Moved <2 km	−1.57 (0.92)*	−1.22 (1.19)	−1.23 (1.09)	
Moved 2–15 km	−1.35 (1.06)	−0.98 (1.29)	−1.16 (1.20)	
Moved 15 km+	−1.30 (1.14)	−1.08 (1.37)	−1.15 (1.29)	
Age	0.71 (0.03)***	0.74 (0.05)***	0.79 (0.04)***	
Age^2	−0.01 (0.00[a])***	−0.01 (0.00[a])***	−0.01 (0.00[a])***	
IMD			0.11 (0.17)	−0.22 (0.14)
IMD at age 11				
Q1 – least deprived				
Q2		−0.35 (0.15)**	−0.49 (0.23)*	
Q3		−0.14 (0.14)	−0.39 (0.36)	
Q4		−0.03 (0.18)	−0.38 (0.51)	
Q5 – most deprived		−0.38 (0.19)*	−0.85 (0.66)	
Male		0.32 (0.11)**	0.33 (0.11)**	
Maternal age		0.03 (0.01)*	0.02 (0.02)	
Paternal age		0.02 (0.01)	0.02 (0.01)	
Non-White		−0.2 (0.26)	−0.05 (0.32)	
Highest parental education: CSE/none/vocational				
O-level		0.14 (0.23)	0.07 (0.28)	
A-level		0.12 (0.22)	0.07 (0.28)	
Degree		0.39 (0.23)*	0.35 (0.29)	
Low social class		0.16 (0.18)	0.16 (0.18)	
Family status: Steady two parent				
Steady one parent		0.43 (0.26)*	0.40 (0.26)	
Two to one parent		−0.18 (0.49)	−0.25 (0.43)	
One to two parent		0.37 (0.39)	0.31 (0.40)	
Household tenure: Owned/mortgaged				
Social rented		0.38 (0.29)	0.34 (0.26)	
Private rented		0.10 (0.32)	0.06 (0.30)	
Number of moves birth to age 11		0.07 (0.05)	0.06 (0.05)	
Financial difficulty				
None				
Some		0.21 (0.15)	0.21 (0.16)	
Moderate		0.41 (0.19)*	0.41 (0.20)*	
Great		0.41 (0.29)	0.43 (0.29)	
Assessment (vs questionnaire)		0.37 (0.07)***	0.37 (0.07)***	
Separated		0.84 (0.47)*	0.87 (0.40)**	
Divorced		−0.35 (0.23)	−0.37 (0.24)	
Married		0.03 (0.33)	0.10 (0.33)	
Sibling birth		−0.29 (0.11)**	−0.29 (0.12)**	
Mother lost job		0.13 (0.13)	0.14 (0.13)	
Father lost job		0.10 (0.11)	0.12 (0.12)	
Family death		0.42 (0.43)	0.48 (0.40)	
Mother pregnancy cannabis use		0.01 (0.38)	0.09 (0.40)	
Mother used cannabis		1.45 (0.25)***	1.41 (0.25)***	
Partner used cannabis		0.82 (0.19)***	0.83 (0.21)***	
Moved schools		0.94 (0.41)**	0.82 (0.41)*	
Peers use drugs: Never				
At one time point		1.52 (0.15)***	1.56 (0.15)***	
At two time points		2.68 (0.16)***	2.76 (0.16)***	
At three time points		3.57 (0.19)***	3.69 (0.22)***	
At four time points		4.63 (0.33)***	4.74 (0.33)***	
Cigarette use at 12		1.79 (0.47)***	1.95 (0.45)***	
Constant	−4.66 (0.13)	−8.20 (0.54)	−8.50 (0.56)	
Estimated level 2 variance	0.71	0.62	0.63	
Bayesian DIC	9513.03	9169.54	9139.32	

Standard errors in parentheses.
[a] Standard Errors for Age^2 are 0.00008; 0.0001; and 0.00009 respectively. IMD, Index of Multiple Deprivation; Q1, Quintile 1; CSE, Common Certificate of Education; DIC, Deviance Information Criterion. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

fact that such clear differences exist between mobile and non-mobile children highlights the potential significance of residential mobility as an indicator for children that may be more susceptible to participation in RHBs and therefore at greater risk of the negative outcomes that occur as a result. This has implications beyond the academic literature as it may inform the policy arena, for example by permitting schools and other institutions to identify at-risk children and apply appropriate interventions. Given that residential mobility is a common process (Champion, 2005), these findings highlight one potential avenue through which it may be possible to reduce morbidity among vulnerable groups in society.

Acknowledgements

We are extremely grateful to all the families who took part in this study, the midwives for their help in recruiting them, and the whole ALSPAC team, which includes interviewers, computer and laboratory technicians, clerical workers, research scientists, volunteers, managers, receptionists and nurses. Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committees. The UK Medical Research Council and the Wellcome Trust (Grant ref: 102215/2/13/2) and the University of Bristol provide core support for ALSPAC. TM is funded by an ESRC PhD Studentship (ES/J50015X/1) in Advanced Quantitative Methods. DM's time on this project was funded by the European Research Council under the European Union's Seventh Framework Programme (FP/2007–2013)/ERC Grant Agreement No. 615159 (ERC Consolidator Grant DEPRIVEDHOODS, Socio-spatial inequality, deprived neighbourhoods, and neighbourhood effects). KN is funded by the National Institute for Health Research Collaboration for Leadership in Applied Health Research and Care (NIHR CLAHRC) West at University Hospitals Bristol NHS Foundation Trust. We are also grateful to George Leckie for helpful comments on an earlier version of this manuscript. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health. The authors declare no conflict of interest. This publication is the work of the authors and TM will serve as guarantor for the contents of this paper.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.socscimed.2016.04.036

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