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Link to published version (if available):
10.1017/S0033291713000743

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Individual and area level influence on suicide risk: a multilevel longitudinal study of Swedish school children

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Funding: We thank the Swedish Research Council for Working Life and Social Research for their funding. This body had no further role in the collection, analysis or interpretation of data, the writing of this manuscript, or in the decision to submit this manuscript for publication.
ABSTRACT

Background: Characteristics related to the areas where people live have been associated with suicide risk, though these might reflect aggregation into these communities of individuals with mental health or social problems. No studies have examined whether area characteristics during childhood are associated with subsequent suicide, or whether risk associated with individual characteristics varies according to childhood neighbourhood context.

Methods: We conducted a longitudinal study of 204,323 individuals born in Sweden in 1972 & 1977 with childhood data linked to suicide (N = 314; 0.15%) up to age 26-31 years. Multilevel modelling was used to examine: i) whether school-, municipality- or county-level characteristics during childhood are associated with later suicide, independently of individual effects, and; ii) whether associations between individual characteristics and suicide vary according to school context (reflecting both peer group and neighbourhood effects).

Results: Associations between suicide and most contextual measures, except for school-level gender composition, were explained by individual characteristics. There was some evidence of cross-level interactions between individual- and school-level markers of ethnicity and deprivation on suicide risk, with qualitative interaction patterns. For example, having foreign-born parents increased risk for individuals raised in areas where they were in a relative minority, but protected against suicide in areas where larger proportions of the population had foreign-born parents.
Conclusions: Characteristics that define individuals as being different from most people in their local environment as they grow up may increase suicide risk. If robustly replicated these findings have potentially important implications for understanding aetiology of suicide, and informing social policy.
In an effort to understand more about the aetiology of suicide, and inform potential strategies for prevention, research has focused not only on characteristics of individuals that increase risk of suicide but also on characteristics of the environments in which they live. Neighbourhood characteristics associated with suicide risk include population density, income inequality, and markers of social fragmentation and deprivation (Galea et al., 2003, Gunnell et al., 1995, Rehkopf and Buka, 2006, Whitley et al., 1999). Possible explanations put forward to explain the association between neighbourhood characteristics such as social fragmentation or deprivation and suicide risk in ecological studies relate to characteristics of either the individuals living in such areas (compositional effects), or the areas in which they live (contextual effects).

Individual characteristics associated with suicide risk include male sex, living alone, divorce, unemployment, physical illness, substance misuse and psychiatric illness (Li et al., 2011, Yoshimasu et al., 2008), and it is difficult to know to what extent these explain, through confounding, the area characteristics associated with suicide in ecological studies.

Statistical methods such as multilevel modelling that allow us to tease out the effects of area independently of the characteristics of individuals living there have only been widely accessible in recent years, and few studies have examined both area and individual influences on suicide risk. Although some of these studies found that associations between suicide and area markers of deprivation, social fragmentation and ethnicity were explained by individual-level characteristics.
(Agerbo et al., 2007, Collings et al., 2009, O'Reilly et al., 2008), other studies found that area-
level associations persisted (Cubbin et al., 2000, Martikainen et al., 2004).

All these studies examined area characteristics measured around the time of suicide and these
associations might therefore reflect aggregation into these communities of individuals with
mental health or social problems. Neighbourhood characteristics measured a long time before
suicide outcomes, such as during childhood, will avoid this problem, and can be informative
about long-term contextual effects on suicide risk. Such effects have been described for
schizophrenia, for example in relation to urbanicity (Lewis et al., 1992, Pedersen and Mortensen,
2001) and it is possible that where people live when they are growing up also has long-term
effects on mood, ability to cope with adversity, or other risk factors that ultimately increase
suicide risk. However no studies have examined the association between contextual effects
during childhood and subsequent risk of suicide.

Neighbourhood context during childhood could impact on long-term psychological development,
personality, and mental health (Hart et al., 2008, Leventhal and Brooks-Gunn, 2003, Xue et al.,
2005) through, for example, exposure to local drug-use or violence cultures, increased social
defeat, and reduced social cohesion (McKenzie et al., 2002, Selten and Cantor-Graae, 2005).
Such stressors could have a long-term impact on suicide risk mediated through psychological
(eg: negative self-worth or control schema (Evans et al., 2005, Goodyer, 2002)) and biological
(eg: epigenetic control of HPA reactivity (Labonte and Turecki, 2012)) mechanisms that persist
throughout adult life.
There has also been increasing interest over recent years as to how the effects of individual-level risk factors for mental health outcomes vary across different neighbourhood contexts. The most consistent finding has been that risk of schizophrenia associated with ethnic minority status varies according to the proportion of ethnic minority individuals within a neighbourhood (Boydell et al., 2001, Kirkbride et al., 2007, Veling et al., 2008), and we recently showed that this effect might not be specific to ethnic background, but to other characteristics that might mark individuals out as different from others in their surrounding environment, including markers of deprivation and social fragmentation (Zammit et al., 2010). These findings resonate with work of Durkheim and others that implicate lack of social cohesion as a risk factor for suicide and other adverse mental health outcomes (De Silva et al., 2005, Durkheim, 1951, Kawachi and Kennedy, 1997, McKenzie et al., 2002), and we therefore wished to extend this work to examine whether individual-level risk factors for suicide also varied by neighbourhood context.

We are aware of only three studies that have used multilevel data to examine such cross-level interactions for suicide. One study reported that ethnic minority status was associated with increased suicide risk in areas with small minority populations, but with decreased risk in areas with large minority populations (Neeleman and Wessely, 1999), similar to the findings for schizophrenia. In another study there was no evidence of interaction between individual and area measures of socio-economic status on suicide (Martikainen et al., 2004), whilst in the third study evidence for interactions was inconsistent across the subgroups examined (Agerbo et al., 2007). Again, these studies examined the effects of area around the time of suicide. Whether the effect
of individual characteristics on suicide risk is moderated by the context in which people grow up has not been previously investigated.

The aims of this study therefore were to: i) estimate the overall relative importance of individual-level and higher-level area (school, municipality and county) factors during childhood on suicide, ii) examine whether area-level characteristics during childhood are associated with risk of suicide, independently of individual characteristics, and iii) examine whether individual effects on suicide risk vary according to the context in which individuals grow up.

Based on the literature to date, we hypothesised that neighbourhood-level variation would account for only a small proportion of variance in suicide risk (as it does for other mental health outcomes), that growing up in adverse (particularly deprived and socially fragmented) neighbourhoods would increase suicide risk independently of individual-level markers of childhood adversity (though much of the association between neighbourhood characteristics and suicide would be explained by these individual-level characteristics), and, that any characteristics that mark individuals out as different from others in their surrounding environment as they grow up would increase suicide risk.
METHOD

Study population

The study population consists of all individuals born in Sweden in 1972 and 1977 (cohorts selected as school register data were available) and resident there at age 16 \( (N=213,395) \). Record linkages were performed using unique person identification numbers. Data were linked (up to 31^{st} December 2003) to the National Cause-of-Death Register, the Multi-Generation Register, the Swedish National School Register, and the Swedish National Patient Register, and to census records (1980 and 1985; child age 8), and occupation and income registers (1985 and 1990; child age 13) at Statistics Sweden. Of those not having died by suicide prior to the end of follow-up, 1,422 individuals had emigrated, whilst 912 had died of other causes. A further 6,738 had missing data on school or municipality at age 16 and were also excluded, leaving a sample of 204,323 individuals.

Measures

Suicide: Deaths from suicide and, as is convention, from undetermined causes (Allebeck et al., 1991, Linsley et al., 2001) according to the Swedish version of ICD-8 (ICD-9 from 1987-1996, ICD-10 from 1997) were included within our definition of suicide outcome. ICD codes for suicide were E950-959 (ICD-8 & ICD-9) and X60-X84 (ICD-10), whilst codes for deaths of undetermined intent were E980-989 (ICD-8 & ICD-9) and Y10-Y34 (ICD-10). Of the 204,323 subjects, there were 314 (0.15\%, 95\%CI 0.14 to 0.17\%) with a suicide outcome (225 definite suicides and 89 deaths of undetermined intent).
**Exposures**: Data were structured at the following ascending hierarchical levels; individuals \((N = 204,323)\), school year-groups at age 16 \((N = 2,106)\), schools \((N = 1,264)\), municipalities \((N = 286)\), and counties \((N = 24)\). Fixed-effects were examined at individual (individual-level), school year-group (school-level), and municipality (municipality-level) levels. The median number of individuals in the school year-groups was 103 (range 1 to 260), and in the municipalities was 416 (range 71 to 10,113).

*Individual-level* variables included sex, family history of suicide (in either biological parent), being foreign-born \((0, 1 \text{ or } 2 \text{ biological parents born abroad})\), changing municipalities between age 8 and 16, parental socio-economic position (SEP) at age 8 (unemployed/blue collar/white collar/company owner; highest of rearing parents), parental receipt of welfare benefit at age 13, family income (total of income, welfare benefits and disability pensions for rearing parents) at age 13, single-parent household at age 8, parental education \(<9 \text{ years}/9-10 \text{ years}/\text{secondary school/higher education}; \text{highest of rearing parents})\), school grade achieved at age 16 (continuous score between 1 (lowest) and 6 (highest)), and having received a diagnosis of any psychotic disorder prior to end of follow-up.

*School-level* variables were derived by aggregating data from individuals in schools that had at least ten children registered in a particular year-group. School-level variables included foreign-born average (proportion of children with one or both parents born abroad; median \(= 0.15, 90\% \text{ range } 0.03 \text{ to } 0.65\)), social fragmentation average (proportion of children who migrated into
Sweden, moved into a different municipality between ages 8 and 16, or were raised in single-parent households; median = 0.23, 90% range 0.08 to 0.46), deprivation average (proportion of children with parents unemployed, receiving welfare benefits, or in lowest 10% of income; median = 0.15, 90% range 0.05 to 0.30), low grade average (proportion of children scoring in lowest 10% of grade score; median = 0.10, 90% range 0.02 to 0.18), and males (proportion of children who were male; median = 0.51, range 0.29 to 1).

Municipality-level data included measures of urbanicity (residence in a city (Stockholm, Gothenburg, and Malmo); town (>20,000 inhabitants in 1980); or rural area (≤20,000 inhabitants) at age 16), population density, and markers of deprivation (derived by summing z-scores for mean income, proportion unemployed and proportion on benefits) and social fragmentation (derived by summing z-scores for proportion of people migrating in/out of the municipality, voting in municipality elections, married, and living in single-person households).

Statistical analysis

Multilevel models were fitted using the MLwiN software (Rasbash et al., 2009) via the runmlwin (Leckie and Charlton, 2011) command in Stata. Null, random-effects models were fitted first, and then individual-, school-, and municipality-level covariates subsequently added to the models. Birth year was included in all models. As outcomes were binary we used multilevel logistic regression. To calculate variance partition coefficients (VPC) for higher-level random effects in binary response multilevel models it is common practice to appeal to the latent
response formulation of the multilevel logistic model (Goldstein, 2010), in which case a VPC is calculated in terms of an individual’s propensity to die by suicide. In this case the person-level variance is standardised to the standardised logistic variance of $\pi^2/3 \approx 3.29$. For example, in a 3-level model, where we denote the unexplained variance at level-2 as $v_2$, and at level-3 as $v_3$, the proportion of the total unexplained variance at level $j$ is estimated as $v_j/(v_2 + v_3 + 3.29)$.

All models were fitted using Markov Chain Monte-Carlo (MCMC) methods (Browne, 2009). Models were run for a burn-in of 10,000 iterations followed by 100,000 monitoring iterations. The mean and standard deviation of each parameter chain give the parameter point estimate and standard error, while the 2.5\textsuperscript{th} and 97.5\textsuperscript{th} quantiles give the 95\% interval estimates. Effects for school-level variables are reported per 10\% increase in proportion, whilst those for municipality-level variables are per standard deviation increase. Statistical significance of fixed effect estimates, including cross-level interactions, was tested by deriving Z ratios and comparing against a standard Normal distribution.

Missing data for any of the exposure variables or covariates was present in less than 5\% of the sample ($N$ with complete case data = 187,316). Sensitivity analyses were conducted by comparing model results to those based on a complete data set where the missing values were replaced with plausible values derived from the observed data by single random imputation.
Cross-level interactions: We examined interactions between individual-level and school-level characteristics as we hypothesised that school-level measures would most strongly characterise the environment within which the children grew up. To do this, we created the following variables:

a) individual-level deprivation (summed score of parental unemployment (yes/no), welfare benefits (yes/no), and family income in lowest 10th percentile (yes/no); score range 0 to 3)

b) individual-level social fragmentation (summed score of single-parent family (yes/no), immigrated during childhood (yes/no), and moved into a different municipality between age 8 and 16 (yes/no); score range 0 to 3)

We aimed to examine the following interactions:

a) Individual foreign-born × school-level foreign-born average

b) Individual social fragmentation × school-level social fragmentation average

c) Individual deprivation × school-level deprivation average

d) Individual grade × school-level grade average
RESULTS

*Higher-level variation*

The risk of suicide amongst individuals born in municipalities in the lowest risk quartile was 0.6 per 10,000 (95% CI 0.1 to 1.7), and was 34 per 10,000 (95% CI 29 to 39) in the highest quartile. However both the null and full models only 3% of the estimated proportion of variation in suicide risk was at higher (non-individual) levels (Table 1). The confidence intervals indicate that, even at its upper-most limit, less than 15% of the variance in suicide risk is explained by higher-level variation, and that almost all variation is due to individual-level variation.

*Individual-level characteristics*

Most individual-level variables apart from parental education were associated with risk of suicide (Tables 2 & 3). When adjusted for other individual level characteristics, having a history of a psychotic disorder was the strongest risk factor for suicide (OR=22.8, 95%CI 16.4 to 31.2). Other individual characteristics associated with increased risk were male sex, having a low school grade, family history of suicide, and having foreign-born parents.

School grade score and diagnosis of psychosis were not included in the adjusted models as these could potentially mediate associations between other risk factors and suicide. Although having a higher family income at birth was strongly associated ($P=0.003$) with reduced risk of suicide in the model adjusting for background characteristics (Table 3), this association was substantially
attenuated when further adjusting for grade score, such that there was now only weak evidence
for association between family income and suicide (OR=0.80, 95%CI 0.62, 1.01; \( P=0.065 \)).
Adjustment for grade score or diagnosis of psychosis did not change the adjusted estimates for
any other individual- or school-level variables in Table 3.

Higher-level characteristics
Most school-level characteristics showed some evidence for association with suicide in the
unadjusted analyses (Table 2), though school-level social fragmentation and school-level grade
average only weakly so, whilst school-level income inequality showed no evidence of
association. These associations were eliminated after adjusting for individual-level
characteristics, with the exception of the association between the proportion of male pupils in the
school and suicide, where the association strengthened markedly, particularly after adjusting for
individual gender. This association persisted when we restricted the analysis to schools where the
proportion of males fell within 3 SDs of the mean (33.6% to 65.8%, \( p=0.001 \)). Individuals in the
10% of schools with the most males (range 57.4 to 100%) had approximately half the odds of
suicide (adjusted OR=0.56, 95%CI 0.34, 0.92; \( P=0.023 \)) compared to those in the 10% of
schools with the least males (range 28.6% to 45.0%). There was no evidence to support a non-
linear effect for the proportion of males at a school-level (\( P \)-value for quadratic term = 0.868).

None of the municipality-level characteristics were associated with suicide in the null model or
after adjusting for individual-level factors (Table 3). The risk of suicide was similar in cities
(0.15%), towns (0.16%) and rural areas (0.14%). There was a similar level of variation in risk of suicide across rural areas (suicide risk range 0 to 1.2%, IQR 0.00% to 0.26%) as there was across areas within cities (range 0 to 0.54%, IQR 0.06% to 0.23%).

Study of cross-level interactions

There was weak statistical evidence of cross-level interactions between a) being foreign-born × school foreign-born average (OR=0.91, 95% CI 0.82, 1.00; P=0.057), and b) deprivation × school deprivation on risk of suicide (OR=0.81, 95% CI 0.64, 1.03; P=0.087), and interaction estimates were unchanged after adjustment (Supplementary Table S1). Both interactions were qualitative in nature; in other words, risk of suicide associated with the presence of the individual-level characteristic changed in an opposite direction compared to individuals without that characteristic as the context changed. For example, individuals who were foreign-born were at a high risk of suicide if they were part of a school group with very few others who were foreign-born, and this risk decreased if their school group consisted of a large proportion of foreign-born individuals (Fig 1). However, an opposite pattern of risks was observed for individuals whose parents were both born in Sweden. A similar pattern of interaction (Fig 2) was observed for deprivation. Differences from baseline groups for these interactions were significant primarily within the lower halves of the school-level averages (Supplementary Figures S1-S2), with greater uncertainty around estimates at the higher ends of the school-level averages as these were based on relatively small proportions of the sample.
There was no evidence of cross-level interactions between a) social fragmentation $\times$ school social fragmentation ($P=0.734$), or b) grade $\times$ school grade average ($P=0.420$). As a result of the finding of an association between school-level male average and suicide we also examined for an interaction between individual sex $\times$ school-level male average, though this was not an a priori aim. The reduced risk of suicide associated with an increasing proportion of male pupils in the school was similar for males (OR=0.72, 95% CI 0.54, 0.96) and females (OR=0.62, 95% CI 0.38, 1.00; interaction $P=0.804$).

The patterns of interaction remained very similar when we used different methods of coding individual and school level variables (for example using deciles or grouping using different cut-offs), and when we excluded undetermined deaths from our outcome. This suggests that these interactions are robust to variation in the manner in which data were defined, though the statistical evidence for interaction remained relatively weak across these sensitivity analyses. Evidence for interactions in the adjusted models was slightly stronger using the imputed data sample ($P=0.047$ for ethnicity and $P=0.032$ for deprivation).

Psychotic disorder as a mediator for interactions observed

Estimates of interaction were partly attenuated when excluding individuals who developed a psychotic disorder, which might have mediated the associations with suicide (foreign-born $\times$ school foreign-born average OR=0.94, 95%CI 0.83, 1.06; deprivation $\times$ school deprivation
OR=0.84, 95%CI 0.65, 1.08), although the number of suicides in these restricted analyses was reduced (n = 245).
DISCUSSION

Area effects

This is the first cohort study examining the effect of area characteristics during childhood on suicide risk. We observed very little variation (approximately 3%) in incidence of suicide at higher (non-individual) levels. The relative importance of higher-level and individual-level factors on suicide risk has not been previously reported, but is in keeping with findings for other mental health disorders. For example, although a substantial amount of variation in incidence of depression has been observed at a household level (Chandola et al., 2003, Thomas et al., 2007), which could reflect shared psychosocial and environmental, as well as, to a lesser extent, genetic influences, the proportion of variance for depression at neighbourhood levels has consistently been reported as being <5% (Duncan et al., 1995, Fone et al., 2007, Skapinakis et al., 2005, Thomas et al., 2007, Wainwright and Surtees, 2004, Weich et al., 2003), and was approximately 2% for psychosis in a previous study using this dataset (Zammit et al., 2010). We were unable to model household-level effects, and these therefore become subsumed within the individual-level estimates of variation in incidence of suicide.

We found no evidence that municipality-level measures during childhood were associated with suicide risk in young adults. However, municipality measures reflect an average across large geographical areas, and a single municipality could encompass within it a number of smaller neighbourhoods with low levels of deprivation or social fragmentation, as well as neighbourhoods with high levels of these characteristics. We used school-level data to capture
the smaller area variation as these measures potentially encompass both peer-group influences and small neighbourhood characteristics during childhood given that school attendance was based on catchment areas relating to place of residence.

A number of school-level measures were associated with suicide risk. Higher levels of deprivation and of ethnic minorities were both associated with increased risk, though were attenuated by approximately 50% after adjusting for individual-level characteristics. We also found that suicide risk was higher for individuals who attended schools with a higher proportion of females, and this applied equally to males and females. It is possible that the social environment within schools differs as the relative proportions of male and female pupils change. However, although this appears to be a robust finding within our data, this was not an \textit{a priori} hypothesis, and might be a chance finding. Future studies examining this hypothesis are needed to resolve this uncertainty.

Although ours is the first study that has examined both compositional and contextual effects during childhood on risk of suicide, other studies have explored these effects measured in adulthood and found little evidence for important contextual effects once compositional effects were accounted for (Agerbo \textit{et al}., 2007, O'Reilly \textit{et al}., 2008). For example, in a large Danish nested case-control study, an association between suicide and the proportion of people living alone at a municipality-level was attenuated by over 50% after controlling for individual-level characteristics, whilst associations with municipality-level unemployment and lower income
were eliminated completely (Agerbo et al., 2007). Similarly in a record-linkage study based in Northern Ireland associations between suicide and area-level measures of deprivation and social fragmentation were eliminated after adjusting for individual and household characteristics (O'Reilly et al., 2008). Although our study suggests that most neighborhood characteristics during childhood do not have a long-term impact on suicide risk, the association with the proportion of school peers who are female warrants further study.

**Individual effects**

We observed a number of individual characteristics that were associated with suicide, as consistently reported in the literature (Li et al., 2011, Yoshimasu et al., 2008). Having a diagnosis of a psychotic disorder was very strongly associated with increased suicide risk, conferring a greater than twenty-fold risk on suicide; one in five suicides, but less than 1 in 100 cohort members had a history of psychosis. Poorer performance academically in school grades at age 16 was also strongly associated with increased suicide risk. The association between lower family income during childhood and risk of suicide was substantially attenuated after adjusting for performance in school exams, indicating that performance on school grade exams might mediate the association between family income and suicide.

**Cross-level interactions**

Although the proportion of variance explained at higher levels within the study was very low it is still possible for higher-level effects to be important in the context of cross-level interactions. We
found some, albeit weak, evidence that the relative risk between individual characteristics and risk of suicide differed according to the context where individuals were raised (school-level characteristics). Having foreign-born parents increased suicide risk for individuals brought up in areas where they were in a relative minority, but protected against suicide in areas where larger proportions of the population had foreign-born parents. We found some evidence of a similar interaction for deprivation, whereby risk of suicide associated with coming from a deprived family changed as the neighbourhood context changed, but in an opposite direction compared to those coming from more affluent families.

A similar interaction between ethnicity and neighbourhood ethnic density at the time of suicide has been previously reported (Neeleman and Wessely, 1999), and our results suggest this may be a long-term effect starting during childhood. Our results also suggest that this effect might not be specific to ethnicity, but to other characteristics that mark individuals out as being different from people living around them. This is consistent with a study showing that associations for a number of individual characteristic on suicide varied across case-control studies with a wide range of contextual settings during adulthood (Crawford et al., 2010).

Similar interactions for psychosis have been previously described within this dataset (Zammit et al., 2010). The interaction estimates for suicide however were only partly attenuated when excluding individuals with a history of a psychotic disorder, suggesting that these interactions might also have effects on suicide that are not mediated through development of psychosis.
Strengths and limitations

One of the strengths of this study is that it is based on a large cohort of individuals, with data on a number of important exposures measured during childhood and adolescence, many years prior to the outcome of suicide. This is in contrast to almost all other studies of neighbourhood-level exposures to date, and allows us to exclude effects of selection into neighbourhoods as a consequence of mental health or social problems as an explanation for our findings.

However, we did not have data on all potentially important factors that could confound or explain the associations observed. It is not possible therefore to exclude the possibility that the associations observed in our study are due to residual confounding. Furthermore, area-level measures of deprivation, and particularly social fragmentation, are difficult to measure.

Routinely collected administrative data frequently used to measure constructs of social cohesion and fragmentation include data on the proportion of people married, voting, renting privately, and living in single-person households, as well as levels of residential stability and population turnover (Congdon, 1996). Such data were available at municipality-level, whilst our school-level measure was based on the proportion of children immigrating, moving area, or brought up in single-parent households. These measures are likely to capture the construct of social fragmentation to some extent, although ideally we would have liked to survey the schools to obtain a more direct measure of social cohesion within the schools or small neighbourhoods the children were raised in, as well as more detailed measures of deprivation.
It is also unclear to what extent our individual-level measures of social fragmentation and deprivation reflect disrupted social relationships or economic hardship during childhood. Such direct measures are possible (Kirkbride et al., 2008) but unfortunately are not available in large studies such as ours that rely on administrative data. Furthermore, there are clearly difficulties in determining what size ‘neighbourhoods’ are or how they should be defined. Ideally neighbourhoods would be defined such that contextual characteristics within each neighbourhood are homogeneous, but of course in reality research data usually relies on administrative information (for example schools, or municipalities) to define levels.

However, although misclassification of data may be particularly likely for our higher-level measures, especially of social fragmentation, this is likely to be non-differential. Furthermore, suicide and most of the exposures examined were more common in individuals excluded due to missing data, and this, as with non-differential misclassification, may have resulted in estimates being underestimated. Decisions about recording deaths as suicide may have been influenced by neighbourhood effects, but such bias is less likely for neighbourhood measures during childhood. Finally, although this was a large study, the rarity of suicide limited the extent to which contextual effects, and particularly cross-level interactions, could be examined.

**Implications**

If the cross-level interactions we observe are robustly replicated they lend support to the belief that contextual effects during childhood can influence suicide risk in young adults. Circumstances whereby individuals fail to fit in with others in their immediate environment
during childhood can lead to a decreased sense of connectedness (Durkheim, 1951) and to increased levels of stress, perhaps through discrimination, hostility or isolation, in keeping with the model of social defeat (Selten and Cantor-Graae, 2005). For example, victimisation has important effects on psychological adjustment and is one of the most consistently identified risk factors for suicidal ideation and self-harm in early life (Winsper et al., 2012). Furthermore, mechanisms linking repeated stressors with long-term biological changes associated with development of psychosis have been described (Kapur, 2003, Laruelle, 2000), and it is possible that these or other such effects also influence suicidal behaviour.

If these qualitative interactions are replicated in other studies, they have potentially important implications for understanding more about social policy. Integration of individuals within communities is clearly important to minimise risks associated with social isolation (Durkheim, 1951), and because segregation at local levels may undermine social cohesion in society as a whole (Kawachi and Kennedy, 1997). Our findings suggest that attending a school or growing up in a neighbourhood where at least some others are of a similar ethnic and socio-demographic background can potentially buffer suicide risk in vulnerable individuals.
Authorship: This is to confirm that all authors have contributed substantially towards the design of the study, the analysis and interpretation of the data, and drafting the manuscript. All authors have approved the final version. S. Zammit had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Acknowledgements: We would like to thank Jan-Eric Gustafsson for allowing us data access, and Sofia Lofving and Henrik Dal for their kind help with data preparation. Glyn Lewis and David Gunnell are NIHR Senior Investigators.

Declaration: None of the authors have any conflicts of interest in relation to this work.
REFERENCES


Table 1: Variance partition co-efficients\(^a\) and 95% confidence intervals\(^b\) (95% CI) at each level

<table>
<thead>
<tr>
<th>Level</th>
<th>Null Model(^a)</th>
<th>Full Model(^d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>County</td>
<td>0.29% (0.02% to 1.42%)</td>
<td>0.32% (0.03% to 1.65%)</td>
</tr>
<tr>
<td>Municipality</td>
<td>0.47% (0.03% to 2.57%)</td>
<td>0.47% (0.03% to 2.63%)</td>
</tr>
<tr>
<td>School</td>
<td>1.53% (0.03% to 6.81%)</td>
<td>1.00% (0.03% to 3.63%)</td>
</tr>
<tr>
<td>School-year</td>
<td>0.68% (0.03% to 2.09%)</td>
<td>1.12% (0.02% to 5.96%)</td>
</tr>
<tr>
<td>Total higher levels</td>
<td>2.97% (0.11% to 12.89%)</td>
<td>2.91% (0.11% to 13.87%)</td>
</tr>
<tr>
<td>Individual level</td>
<td>97.03% (87.11% to 99.89%)</td>
<td>97.09% (86.13% to 99.89%)</td>
</tr>
</tbody>
</table>

\(^a\) MCMC 100,000 iterations; \(^b\) 95% confidence intervals are calculated as the 2.5\(^{th}\) and 97.5\(^{th}\) percentiles of the MCMC chain for each VPC statistic; \(^c\) model including birth-year; \(^d\) model including all individual, school-year and municipality level variables
Table 2: Proportion of suicide cases and non-cases exposed to individual-level characteristics

<table>
<thead>
<tr>
<th></th>
<th>Suicide</th>
<th>Non-case</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex</td>
<td>232 (73.9%)</td>
<td>104525 (51.2%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Family history of suicide</td>
<td>14 (4.5%)</td>
<td>2438 (1.2%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Foreign-born</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 parents</td>
<td>220 (71.7%)</td>
<td>165817 (82.4%)</td>
<td>-</td>
</tr>
<tr>
<td>1 parent</td>
<td>41 (13.4%)</td>
<td>19237 (9.6%)</td>
<td>-</td>
</tr>
<tr>
<td>2 parents</td>
<td>46 (15.0%)</td>
<td>16172 (8.0%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Single parent family</td>
<td>49 (16.3%)</td>
<td>24974 (12.6%)</td>
<td>0.050</td>
</tr>
<tr>
<td>Parent SEP:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployed</td>
<td>15 (5.0%)</td>
<td>7014 (3.6%)</td>
<td>-</td>
</tr>
<tr>
<td>Low</td>
<td>118 (39.6%)</td>
<td>66461 (34.2%)</td>
<td>-</td>
</tr>
<tr>
<td>Mid</td>
<td>134 (45%)</td>
<td>99240 (51.0%)</td>
<td>-</td>
</tr>
<tr>
<td>High</td>
<td>31 (10.4%)</td>
<td>21746 (11.2%)</td>
<td>0.021</td>
</tr>
<tr>
<td>Parent education:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;9 years</td>
<td>32 (13.1%)</td>
<td>21040 (11.5%)</td>
<td>-</td>
</tr>
<tr>
<td>9-10 years</td>
<td>36 (14.7%)</td>
<td>24367 (13.3%)</td>
<td>-</td>
</tr>
<tr>
<td>Secondary</td>
<td>102 (41.6%)</td>
<td>74951 (41.0%)</td>
<td>-</td>
</tr>
<tr>
<td>Higher</td>
<td>75 (30.6%)</td>
<td>62354 (34.1%)</td>
<td>0.261</td>
</tr>
<tr>
<td>Parent on benefits</td>
<td>24 (8.2%)</td>
<td>11397 (5.8%)</td>
<td>0.077</td>
</tr>
<tr>
<td>Parent income lowest 10%</td>
<td>47 (16.0%)</td>
<td>19275 (9.8%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lowest school grade</td>
<td>31 (10.2%)</td>
<td>7451 (3.7%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Moved municipality</td>
<td>48 (16.0%)</td>
<td>21663 (10.9%)</td>
<td>0.005</td>
</tr>
<tr>
<td>Psychosis diagnosis</td>
<td>58 (18.5%)</td>
<td>1862 (0.9%)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*for categorical variables p-value is from omnibus test for variable
**Table 3: Multilevel model results (OR & 95% CI) for association between suicide and individual-level, school-level, and municipality-level variables**

<table>
<thead>
<tr>
<th></th>
<th>Crude&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Adjusted&lt;sup&gt;b&lt;/sup&gt;</th>
<th>p-value&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Individual</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2.78 (2.11, 3.66)</td>
<td>2.82 (2.11, 3.71)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Family history</td>
<td>2.99 (1.54, 5.82)</td>
<td>2.55 (1.14, 4.57)</td>
<td>0.013</td>
</tr>
<tr>
<td>Foreign-born 0 parents</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1 parent</td>
<td>1.60 (1.12, 2.29)</td>
<td>1.49 (1.00, 2.08)</td>
<td></td>
</tr>
<tr>
<td>2 parents</td>
<td>2.49 (1.73, 3.59)</td>
<td>2.26 (1.50, 3.22)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Single parent</td>
<td>1.54 (1.11, 2.13)</td>
<td>1.09 (0.73, 1.53)</td>
<td>0.725</td>
</tr>
<tr>
<td>Parent SEP&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployed</td>
<td>1.77 (1.01, 3.07)</td>
<td>1.04 (0.53, 1.78)</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>1.30 (1.00, 1.68)</td>
<td>1.04 (0.78, 1.37)</td>
<td></td>
</tr>
<tr>
<td>Mid</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.02 (0.68, 1.54)</td>
<td>0.92 (0.58, 1.36)</td>
<td>0.865</td>
</tr>
<tr>
<td>Parent on benefits</td>
<td>1.52 (0.95, 2.42)</td>
<td>1.03 (0.60, 1.60)</td>
<td>0.939</td>
</tr>
<tr>
<td>Family income&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.64 (0.51, 0.79)</td>
<td>0.70 (0.54, 0.88)</td>
<td>0.003</td>
</tr>
<tr>
<td>School grade&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.56 (0.50, 0.63)</td>
<td>0.66 (0.58, 0.75)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Moved municipality</td>
<td>1.38 (0.97, 1.95)</td>
<td>1.26 (0.86, 1.75)</td>
<td>0.237</td>
</tr>
<tr>
<td>Psychosis diagnosis</td>
<td>27.2 (19.9, 37.1)</td>
<td>22.8 (16.4, 31.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>School</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social fragmentation&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.07 (0.98, 1.17)</td>
<td>1.03 (0.93, 1.13)</td>
<td>0.589</td>
</tr>
<tr>
<td>Foreign-born&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.15 (1.05, 1.26)</td>
<td>1.06 (0.95, 1.16)</td>
<td>0.280</td>
</tr>
<tr>
<td>Deprivation&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.25 (1.07, 1.46)</td>
<td>1.12 (0.95, 1.32)</td>
<td>0.165</td>
</tr>
<tr>
<td>Income Inequality&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.80 (0.59, 1.09)</td>
<td>0.81 (0.59, 1.03)</td>
<td>0.147</td>
</tr>
<tr>
<td>Male&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.77 (0.60, 0.98)</td>
<td>0.70 (0.55, 0.89)</td>
<td>0.005</td>
</tr>
<tr>
<td>Low grade&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1.24 (0.96, 1.59)</td>
<td>1.00 (0.77, 1.30)</td>
<td>0.993</td>
</tr>
<tr>
<td><strong>Municipality</strong></td>
<td>Urbanicity&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Rural</td>
<td>1</td>
</tr>
<tr>
<td>Rural</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Town</td>
<td>1.10 (0.80, 1.51)</td>
<td>1.08 (0.77, 1.54)</td>
<td></td>
</tr>
<tr>
<td>City</td>
<td>1.13 (0.79, 1.62)</td>
<td>1.06 (0.73, 1.54)</td>
<td>0.829</td>
</tr>
<tr>
<td></td>
<td>Unadjusted</td>
<td>Adjusted</td>
<td>p-value</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------</td>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>Population density</td>
<td>1.05 (0.94, 1.18)</td>
<td>1.03 (0.92, 1.16)</td>
<td>0.569</td>
</tr>
<tr>
<td>Social fragmentation</td>
<td>1.08 (0.97, 1.22)</td>
<td>1.04 (0.92, 1.17)</td>
<td>0.542</td>
</tr>
<tr>
<td>Deprivation</td>
<td>0.98 (0.88, 1.11)</td>
<td>0.97 (0.86, 1.10)</td>
<td>0.591</td>
</tr>
</tbody>
</table>

---

*a* including birth-year, and variance components at school, municipality, and county levels

*b* adjusted for birth-year, sex, family history, ethnicity, single parent status, parental SEP, parental benefits, parental income and moving municipality, and includes variance components at school, municipality, and county levels

*c* p-value is overall p-value for categorical variable

*d* Per standard deviation

*e* Per 10% increase

*f* Per 10% increase in proportion with grade <10th percentile; in Model 1 also adjusted for individual-level grade
Figure 1: Cross-level interaction between foreign-born status and school-level foreign-born average.

Figure 1: For non-foreign-born individuals, risk of suicide increases as the proportion of foreign-born individuals within the school increases. However, for foreign-born individuals, risk of suicide decreases as the proportion of foreign-born individuals within the school increases.
Figure 2: Cross-level interaction between deprivation score and school-level deprivation average.

Figure 2: For individuals with low deprivation, risk of suicide *increases* as deprivation within the school increases. However, for individuals with high deprivation, risk of suicide *decreases* as deprivation within the school increases.
**Supplementary Table S1:** Main effects and cross-level interactions between individual-level (L1) and school-level (L2) variables for suicide

<table>
<thead>
<tr>
<th>Individual-level variable (L1)</th>
<th>School-level variable (L2)a</th>
<th>Effect of L1 OR (95% CI)</th>
<th>Effect of L2 OR (95% CI)</th>
<th>Interaction effect OR (95% CI)b</th>
<th>Interaction p-valueb</th>
<th>Interaction effect OR (95% CI)c</th>
<th>Interaction p-valuec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreign-bornd</td>
<td>Foreign-born</td>
<td>1.85 (1.38, 2.48)</td>
<td>1.23 (1.01, 1.49)</td>
<td>0.91 (0.82, 1.00)</td>
<td>0.057</td>
<td>0.91 (0.81, 1.01)</td>
<td>0.084</td>
</tr>
<tr>
<td>Social fragmentationb</td>
<td>Social fragmentation</td>
<td>1.49 (0.98, 2.27)</td>
<td>1.07 (0.94, 1.22)</td>
<td>0.97 (0.85, 1.11)</td>
<td>0.645</td>
<td>1.02 (0.89, 1.18)</td>
<td>0.734</td>
</tr>
<tr>
<td>Deprivationb</td>
<td>Deprivation</td>
<td>1.90 (1.14, 3.16)</td>
<td>1.30 (1.10, 1.53)</td>
<td>0.81 (0.64, 1.03)</td>
<td>0.087</td>
<td>0.81 (0.63, 1.02)</td>
<td>0.080</td>
</tr>
<tr>
<td>Gradef</td>
<td>Low grade</td>
<td>0.59 (0.51, 0.69)</td>
<td>0.99 (0.76, 1.28)</td>
<td>0.97 (0.78, 1.21)</td>
<td>0.808</td>
<td>0.91 (0.73, 1.14)</td>
<td>0.420</td>
</tr>
<tr>
<td>Male</td>
<td>Male</td>
<td>2.00 (0.16, 25.41)</td>
<td>0.67 (0.43, 1.03)</td>
<td>1.07 (0.64, 1.76)</td>
<td>0.859</td>
<td>1.07 (0.62, 1.83)</td>
<td>0.804</td>
</tr>
</tbody>
</table>

a Per 10% increase; b Models include individual and school level variables and their interaction term, birth-year, and variance components at school, municipality, and county levels; c Additionally adjusted for all individual-level variables; d Per parent foreign-born; e Per score of 1; f Per sd
Supplementary Figures

Figure S1: Difference (& 95% CI) from baseline group (both parents born in Sweden) in risk of suicide in relation to school-level average foreign-born

Differences from baseline group for ethnicity were significant primarily within the lower half of the school-level average, with greater uncertainty around estimates at the higher end of the school-level average as these were based on relatively small proportions of the sample.
Figure S2: Difference (& 95% CI) from baseline group (0 markers of deprivation) in risk of suicide in relation to school-level average deprivation

Differences from baseline group for deprivation were significant primarily within the lower half of the school-level average, with greater uncertainty around estimates at the higher end of the school-level average as these were based on relatively small proportions of the sample.