Peer, school, and country variations in adolescents' health behaviour: A multilevel social network analysis of binary response variables in six European cities.

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Abstract

Adolescents often display similar health behaviour to their peers. Peer effects on health behaviour may be influenced by the school context, and by the country of residence. According to the complex contagion theory, these effects for risky health behaviour may be different from protective health behaviour. This paper combines social network analysis and multilevel analysis to estimate the relative share of variation of risky and protective health behaviours at different levels of the population structure: individuals, peer (friendship) networks, and schools. To achieve these aims, multiple membership models are applied to estimate variations in smoking, drinking, cannabis use, and physical activity at the individual, peer, and school levels, taking into account the differences between countries. The data come from a social network survey carried out in 50 schools in six medium-sized European cities. Networks of peers were found to have similar risky health behaviour when it comes to smoking, drinking, and cannabis use. This was not true, however, for positive health behaviour, i.e. physical activity. For smoking, drinking, and cannabis use, the peer network accounted for almost half of the total behaviour variance. In comparison, the school variance was quite small for all health behaviour. The results suggest that interventions are best carried out at the peer-network level, particularly for behaviour vulnerable to complex contagion, such as smoking and cannabis use.

Keywords: social network analysis; whole network design; multilevel analysis; health behaviour; adolescent health; international comparison;

Highlights:

- The peer network accounted for half of the variance for risky health behaviour.
- This was not true for physical activity, a protective health behaviour.
- School corresponds to a much smaller share of the overall variation for these behaviours.
- Future public health research on adolescents should emphasise peer-level components, particularly for risky behaviour.

Introduction

Adolescent health behaviour remains a public health concern. Several of these behaviours are associated with addiction, and may thus persist for many years until adulthood, bringing about long-term consequences (McCambridge et al., 2011). In addition, recent epigenetic studies suggest that some behaviour can be passed on to the next generation by turning on or off certain gene expressions (Godfrey et al., 2007). Finally, adolescents' health behaviour is socially patterned, and behaviour such as drinking alcohol and smoking is more frequent in adolescents from lower socio-economic backgrounds (Currie et al., 2012). This social patterning may thus fuel socio-economic inequality in health in adulthood.

Some health behaviours are particularly important during adolescence and, at the same time, are major concerns for public health authorities given their prevalence, or their potential for harm. These behaviours may include substance use such as drinking alcohol, smoking, or cannabis use; they may also include positive behaviours, such as physical activity. These health behaviours in adolescents are not easy targets as they are associated with a variety of social influences, with each behaviour having its own cluster of factors. From late childhood to early adulthood, adolescents undergo important changes in their socialisation as a consequence of the many individuals, groups, and institutions they engage with. In high-income countries, where adolescents spend most of their time at school, adolescents' health behaviours are strongly influenced by factors defined not only at the household level, but also at the school level, and at the friendship level (Cotterell, 2013; Rew, 2005). These micro-level factors are enmeshed in macro-level factors such as health policies and socio-structural determinants.

Over the last decade, several social network analyses of adolescent health behaviours have found that adolescents are more likely to use substances if their friends do so (hereafter, "peer effects"), for smoking (Ennett et al., 2006; Ennett et al., 2008; Fujimoto and Valente, 2012b; Go et al., 2010; Hoffman et al., 2007; Lorant et al., 2017), for drinking (Barnett et al., 2014; Ennett et al., 2006; Fujimoto and Valente, 2012b; Lorant et al., 2013; Osgood et al., 2014), and for illegal drug use (Ali et al., 2011; Ennett et al., 2006; Moriarty et al., 2016; Osgood et al., 2014). For smoking, a review of 40 prospective studies, including non-social network studies, evidenced, for all studies but one, a positive association between peer use at baseline, and adolescent smoking at follow-up (Simons-Morton and Farhat, 2010). A similar conclusion was reached, for drinking alcohol, by a review of 22 studies: exposure to peers' alcohol use was a consistent predictor for the adolescent's own alcohol use. For physical activity, a review found evidence that children or adolescents' own physical activity was associated with the physical activity of their friends in 30 out of 35 studies (Maturo and Cunningham, 2013).

According to this literature, peer effects are stronger with reciprocal and multiplex ties than they are with non-reciprocal ties (Daw et al., 2015; Fujimoto and Valente, 2012a; Mercken et al., 2007). The mechanisms driving these effects are complex, but include a combination of influence (alter influencing ego) and selection (ego selecting an alter) (Kobus, 2003). As far as smoking is concerned, empirical research supports the effects of both selection and influence (Huang et al., 2014; Kiuru et al., 2010; Mercken et al., 2009; Mercken et al., 2012; Wang et al., 2016), with two reviews concluding that peer selection provides much of the explanation of peer similarity for smoking (Seo and Huang, 2012; Simons-Morton and Farhat, 2010). The combination of selection and influence may, however, also be stage-specific, or behaviour-specific (Eisenberg et al., 2014; Long et al., 2017; Maxwell, 2002). There is evidence that influence has the edge on selection for smoking cessation (Go et al., 2010). For alcohol, both selection and influence processes have been evidenced (Knecht et al., 2011; Poulin et al., 2011) and a recent review of 22 longitudinal studies of high quality concluded that both peer influence and selection processes have effects on adolescent alcohol use, although the relative contribution of each process was not elucidated (Leung et al., 2014). Recent research points to the need to consider both processes in the coevolution of social ties and behaviour formation over time (Mercken et al., 2012; Wang et al., 2016). The theories underpinning these selection/influence mechanisms have been reviewed by others (Brechwald and Prinstein, 2011; Cotterell, 2013; Hoffman et al., 2006; Kobus, 2003; Umberson et al., 2010; Valente et al., 2004). Some theories locate the origin of social influence within the person, and focus on individual features that make some individuals more likely to be susceptible to influence and/or to be more influential (Hoffman et al., 2007). Other theories focus on the social dyadic processes that influence an adolescent's decision to engage in some health behaviours. The latter group, generally, consider influence to result from social learning, normative effects, and social identity processes. More recent works have sought to integrate these theories: in particular, the social cognition approach that emphasises how individuals process social information, and the social structure theory that focuses on the social structure of relationships (Friedkin and Johnsen, 2011).

But peer effects are also vulnerable to context: their magnitude depends on their prevalence at the school level (Go et al., 2012; Green Jr et al., 2013). There is also evidence that higher levels of school bonding or connectedness may help to lessen the effect of peer substance use (Marschall-Lévesque et al., 2014; Vogel et al., 2015). Similarly, the key role of popular individuals in spreading risky behaviour varies across schools (Tucker et al., 2014) and may also depend on the school's socio-economic context, such as the urbanisation and deprivation levels (Chuang et al., 2009; Pearson et al., 2006). For example, popular individuals were less likely to smoke in high-SES schools than in low-SES schools (Pearson et al., 2006). This indicates that the role of friends in adolescents' health behaviours should be considered within the context of their school (Valente et al., 2004). There are two reasons for this, one substantive and the other methodological.

From a substantive perspective, a large body of evidence from multilevel studies suggests that adolescents from the same schools display a similar risk of substance use (Bonell et al., 2013; Fletcher et al., 2008; Sellström and Bremberg, 2006). The prevalence of a behaviour at the school level may thus magnify or interact with the peer effect, as shown in other studies of substance use in adolescents (Clark and Loheac, 2007; Daw et al., 2015; Go et al., 2012). This could be due to school-level norm effects and/or to the health promotion activities of the schools. An alternative explanation is that the topology of friendship ties in schools matters: density and centralisation may affect how behaviour spreads in the school network (Ennett et al., 2006; Kreager et al., 2011; McGloin et al., 2014; Vogel et al., 2015).

From a methodological perspective, multilevel studies have shown that ignoring a level of the population in an analysis can bias the estimates of variation in behaviour for other levels that *are* included in a multilevel model (Tranmer and Steel, 2001). These findings suggest that network studies that ignore the school level may risk over-estimating the role of the network, as suggested by Manski (1995). Conversely, school multilevel studies that ignore the network of peers could in fact be capturing network similarity in the estimated variance components, particularly when the sampling design relies on classroom selection.

Adolescent health behaviour is embedded in a broader set of factors entrenched in the national context. Regarding substance use, adolescents respond to increases in taxes for both smoking (Carpenter and Cook, 2008) and drinking (Chaloupka et al., 2002), and to other health-protection legislative measures, such as bans on access to tobacco and places to smoke (Botello-Harbaum et al., 2009; Hublet et al., 2009). Thus, the school and friendship effects may need to be considered within a national context. For example, more stringent tobacco-control policies at the country level may lead to some schools implementing these regulations, resulting in increased differences between schools in smoking outcomes (Galán et al., 2012). However, the almost all social network studies of adolescents' health behaviour have been carried out in a single country, with the exception of the ESFA study, carried out in six European countries; on the whole, few cross-comparative social network studies have been carried out for more than two countries.

Adolescent health behaviour at the individual, peer, and school levels should all be considered together, and the country in which the school is located should be taken into account. From a policy perspective, such an approach would answer an important question, as interventions to promote adolescent health must target the appropriate level: different interventions may be needed, depending on whether the behaviour results from the school adopting policies to restrain substance use, or from social exchanges among friends.

Finally, each health behaviour may have a different share of variation at the various levels (individual, school, peers). The literature about peer effects is generally centred on one or two health behaviours, mainly smoking and drinking; but a few studies have broadened the spectrum to include illegal drug use and/or physical activity (Clark and Loheac, 2007; Daw et al., 2015; Eisenberg et al., 2014; Ennett et al., 2006; Henry and Kobus, 2007; Kobus and Henry, 2010; Lundborg, 2006; Maxwell, 2002; Osgood et al., 2014; Pearson et al., 2006; Tucker et al., 2011). Illegal drug use displayed higher peer effects than smoking or drinking alcohol (Ennett et al., 2006; Kobus and Henry, 2010; Maxwell, 2002; Osgood et al., 2014). However, behaviour associated with any substance use has stronger peer effects than other behaviours, such as watching TV or physical activity (Daw et al., 2015). The peer effects associated with smoking and drinking are generally of similar magnitude and sign, with, however, some exceptions (Kobus and Henry, 2010; Maxwell, 2002). A review comparing peer influence across behaviours concluded that unhealthy behaviours were more vulnerable to contagion processes (Brechwald and Prinstein, 2011). As argued by others, the social context of a health behaviour may bear on the magnitude of its peer effect (Maxwell, 2002). Different reasoning underpins this. From a biopsychosocial perspective, it has been argued that positive affective attraction to risky behaviours may fuel the peer influence (Romer and Hennessy, 2007). From a sociological perspective, the theory of complex contagion provides an interesting framework. According to this theory, social networks contribute to inequalities under four conditions: individuals are free to adopt a behaviour; adoption of behaviour is influenced by the network of peers; the network is homophilous in a feature associated with adoption; and, finally, the behaviour is complex and does not lend itself to simple contagion. Complex contagion occurs if the behaviour is less directly observable, if the behaviour is risky (i.e. for health), if the behaviour is perceived as illegitimate, and if the behaviour requires social support to be practised (Dimaggio and Garip, 2012). For example, if an adolescent adopts a less observable behaviour such as using cannabis as compared to smoking a cigarette outside the school premises, it is less likely that his/her behaviour will be noticed by all adolescents. Similarly, the more smoking is perceived as risky, the more the practice will need peers to reinforce the choice, and suppress the cognitive dissonance associated with the behaviour. Finally, cannabis consumption is more likely to be perceived as an illegitimate behaviour, requiring peer support to shift the norms. This theoretical framework is complementary with other frameworks for the role of norms and of social support in influencing a health behaviour. For norms, by sustaining beliefs about the behaviours that are approved in a referent group. For social support, by enabling the behaviour through emotional, tangible, or informational support.

This may explain why illegal drug use displays a stronger peer effect than other behaviours: as evidenced in the landmark study of marijuana smokers, social support helps marijuana smokers to learn how to engage in the practice and to access the product, helps to sustain alternative norms in relation to substance use, and helps to insulate users from anti-substance norms (Becker, 1963). Smoking is not an illegal behaviour, but smokers have recently been under increasing pressure due to strong tobacco control policies (Evans-Polce et al., 2015). We may thus expect smoking to display stronger peer effects than other behaviours perceived as more legitimate, as found in the large and more recent Prosper study in the US (Osgood et al., 2014). The legitimacy of a health behaviour, however, is obviously dependent on the national legal context for, say, drinking or smoking. One reason why peer effects have different magnitudes across behaviours and across different contexts is that different behaviours do not have the same perceived legitimacy in different countries (Valente, 2012).

This paper aims to break health behaviour prevalence down into the individual component, the peer social network component, and the school component, in order to identify the relative share of variation of each health behaviour, in the context of explanatory variables for individuals and countries. This cross-sectional study does not aim to test social influence. It aims to measure the strength of associations at different levels. We ask two research questions:

(1) To what extent does a particular health behaviour vary at the individual, peer, and school level?
(2) To what extent are more illegitimate behaviours associated with a stronger peer-network component?

This study advances knowledge in several ways. Firstly, an international social network study, involving 50 different schools in six European cities, is used. The multi-network and multi-setting design of this study gives a strong empirical basis to control for contextual effects in the analysis of health behaviour. Secondly, a range of health behaviours, including risky and protective health behaviour, is considered, providing very comprehensive information for health promotion in schools. Thirdly, by using the MMMC model (Browne et al., 2001), it is possible to assess the contribution of the peer level for each health behaviour in the context of school variations. Using this model, it is also possible to estimate country-specific school variation for the six countries in the dataset. Fourthly, the potential of the MMMC model to answer substantive research questions using school and network data that include categorical response variables is demonstrated. Multiple Membership Multiple Classification (MMMC) models were applied to network data with an interval response by Tranmer et al. (2014a). This paper aims to further develop and promote MMMC models for social network data with binary responses.

Methods

Data and variables

In 2013, a social network survey was carried out in 50 schools in six European cities: Namur (Belgium), Tampere (Finland), Hanover (Germany), Latina (Italy), Amersfoort (the Netherlands), and Coimbra (Portugal). The survey design is fully described elsewhere (Lorant et al., 2015). The survey targeted school grades in each city, corresponding to adolescents aged 14-16, and used a full network design (Knoke et al., 2008). In the ninth and tenth grades, all teenagers were invited to participate and complete a questionnaire about their health behaviour, social ties, and other socio-demographic information. The questionnaire and other supplementary materials are available on the SILNE (Smoking Inequalities Learning from Natural Experiments) website (http://silne.ensp.org/instruments_wp5/). The 50 schools selected had 13,870 students registered, of whom 11,015 participated (participation rate = 79.4%). The main reasons for non-participation were absence on the survey days (n=1,864; 16.9%) and unwillingness to participate (n=461, 4.2%).

Adolescents were asked to nominate up to five friends (also referred to as "alters") with the following name-generator taken from the Add Health design: "Who are your best and closest friends?". They were handed a directory that contained the names of every student enrolled in the two grades. A slightly different design was used in Tampere, because of different regulations in Finland (Lorant et al., 2015).

Four key "health behaviours" important for adolescents' health, and which have ramifications for their health in later life, were selected: smoking status, alcohol use, cannabis use, and physical activity. The adolescents' smoking behaviour was recorded with two questions: "Have you ever tried cigarette smoking, even just a few puffs?" (No/Yes). Those who answered "Yes" were also asked "How many cigarettes have you smoked in the last 30 days?". Adolescents were categorised as daily smokers when they reported smoking at least one cigarette per day in the last 30 days before the survey, and non-daily smokers if not. For alcohol, adolescents were asked, "Thinking back over the last 12 months, how often did you drink alcohol (more than just a sip)?". Adolescents reporting having drunk alcohol once a month or more in the last year were categorised as monthly alcohol users. Cannabis use was assessed with the question, "Thinking back over the last 12 months, how often did you use marijuana or cannabis?". Adolescents reporting using cannabis or marijuana once per month or more over the last year were classified as monthly users of cannabis. Physical activity was reported with the question, "On average, how many hours of hard physical activity do you do on each day of the week?". The total number of hours of strenuous physical activity from Monday to Sunday was then computed for each respondent. Adolescents with a total of more than seven hours per week were categorised as doing regular physical activity and coded 1, and 0 otherwise. This corresponds to the WHO recommendation for adolescents (World Health Organization, 2010).

The sociodemographic and socio-economic features of respondents may be associated with substance use, reinforcing norms or preferences more prevalent in some groups. For example, smoking has become less common in better-educated groups (Christakis and Fowler, 2008; Pampel, 2006), and drinking and substance use are lower in females (Eitle et al., 2009). Age, sex, low parental education, and deprivation were, therefore, all included in the analyses to control for school composition. Deprivation was computed as the number of lowest socio-economic categories an adolescent had in terms of father's and mother's employment status (unemployed), housing status (tenant), family affluence scale (FAS), McArthur scale of subjective social ranking (lower than the sixth decile) (Goodman, 1999), mother's education (lower secondary or less), and father's education (lower secondary or less) (Lorant et al., 2017). The FAS is computed on the number of cars, the number of holidays per year, the number of computers, and whether they have a bedroom of their own (Richter et al., 2009).

Variation in health behaviours across the peer network may also be dependent on structural features of ego in the network (Fujimoto and Valente, 2012b). Three measures of centrality are commonly used in health studies (Valente, 2010; Valente et al., 2004) to capture different aspects of social prestige: popularity, betweenness, and closeness. Popularity measures how much an adolescent is acknowledged by others as a friend, and is computed as the number of incoming friendship nominations (indegree); betweenness is the measure of how often an adolescent is on the shortest path between two other adolescents; closeness is the average geodesic distance of an adolescent from all other adolescents.

Statistical analysis

Multilevel models are popular in health studies as they help to account for variation in outcomes at both the individual and area levels in epidemiology (Merlo et al., 2006). Here, the multilevel model is extended to include a social network component via the Multiple Membership Multiple Classification (MMMC) model (Browne et al., 2001).

Four logistic MMMC models were fitted for each of the four binary health behaviour responses. One model included country dummies in the fixed part of the model, and the school variance component (Model 1). The second model added the peer-network variance component to the previous model (Model 2). The next two models included fixed effects and considered sociodemographic variables (Model 3) and added metrics of centrality (Model 4).

These models account for the structure of data collection (schools, countries) and the multiple memberships of individuals in friendship networks; although each individual belongs to one school and one city, individuals can also belong to several friendship dyads, which together comprise a peer network for each individual. Multiple Membership Multiple Classification (MMMC) models have recently been applied to such data structures (Lazega and Snijders 2015; Tranmer et al., 2014b). These models allow variation between (and thus similarity within) population classifications in responses for individuals to be assessed. Individuals in each country each belong to a specific school; they are networked through their membership of multiple dyads.

The logistic MMMC model used here for *n* individuals may be written as follows:

$$\text{logit}(\pi_i) = \boldsymbol{x}_i'\boldsymbol{\beta} + \mathrm{v}_k + \sum_{j \in net(i)}^{m} w_{i,j}\, u_j$$

$$i = 1, \dots, n\, ; net(i) \subset J \quad ; \ \ i \ \in k$$

$$\mathrm{v}_k \sim N(0, \sigma_{\mathrm{v}}^2);\ \mathrm{u}_j \sim N(0, \sigma_u^2)$$

Where, *i* indexes the individual, *j* indexes the alters of individual *i* within school *k* from the total set of dyads, *J*. π_i is the probability that individual *i* exhibits a particular health behaviour – either smoking, alcohol, cannabis, or physical activity. $\boldsymbol{x}_i'\boldsymbol{\beta}$ is a set of *p* covariates and their *p* coefficients in the fixed part of the model. v_k is a school-level random effect. $\sum_{j \in net(i)}^{m} w_{i,j}\, u_j$ is a weighted sum of random effects, where individual *i* is in network j with membership weight $w_{i,j}$. Membership weights $w_{i,j}$ sum to 1 for each individual *i*. This model does not include an individual random effect as it is in the logistic model framework. Compared with the linear model, the partitioning of the variance presents challenges for binary outcomes. The individual-level variance and higher level variance component estimates are not directly comparable, because the overall variance depends on the prevalence of the outcome (Merlo et al., 2006). Here, to compute the variance partition coefficients, the logistic threshold model is assumed, where the individual variance is $\pi^2/3$ = 3.29. The random effects are assumed to be uncorrelated between levels. Hence the variance components for each level σ_v^2, σ_u^2, and the assumed individual level variance component of 3.29 sum to the total variance of the log-odds for a health behaviour. In the results presented in Tables 2-5, network-level variance components are scaled by average membership weight, $\overline{w}$, to allow comparability with the components estimated at other levels.

Results

Table 1 describes the sample. The average age of the adolescents was 15.2. Regular physical activity and monthly drinking were more common than daily smoking and monthly cannabis use.

The results of the models are presented in Table 2 for daily smoking, Table 3 for alcohol consumption in the last month, Table 4 for cannabis use in the last month, and Table 5 for regular physical activity.

For daily smoking, including the peer network in Model 2 improved the model fit and was associated with a rise of the school variance component, compared with Model 1 (from 0.43 to 0.78), while the coefficient estimates of country dummies increased in absolute value. This change in these fixed effects, after adding the peer network component, may be due to typical friendship network structures in each country being different with respect to smoking (non-collapsibility of the country dummies). The Netherlands, Germany, and Finland had a lower rate of daily smoking than other countries. When both components are included, the variation for the peer-network component (16.34) is greater than for the school component (0.78). Model 3 adds fixed sociodemographic covariates, and fared worse in terms of model fit (DIC increases from 8004.19 to 8056.69). Daily smoking increased with age, the latter being the only significant fixed-effect sociodemographic covariate. Higher popularity and higher betweenness centrality, but not closeness centrality, were associated with more daily smoking (Model 4). Both the school variance component and the peer-network variance component decreased between Model 2 and Model 3, but did not decrease significantly between Model 3 and Model 4. This indicates that the sociodemographic make-up of the school accounts, in part, for these two variance components, but not for the structural position of ego.

For alcohol (Table 3) too, the peer-network variance component was larger than the school variance component (Model 2) and improved the model fit (DIC in Model 1: 12.442.72 *vs* DIC in Model 2: 10807.92). Finland, Germany, and the Netherlands displayed a lower risk of drinking than the other countries. Alcohol consumption increased with age and higher parental education, decreased with deprivation, and was lower among women (Model 3). Alcohol consumption increased in adolescents with higher popularity and higher betweenness centrality. As for smoking, the peer-network variance component was affected by the inclusion of sociodemographic and socio-economic covariates in Model 3, but less so by the inclusion of metrics of social prestige in Model 4.

For cannabis use in the last month (Table 4), the pattern was quite similar. The peer-network variance coefficient improved the model fit from 4655.33 to 4252.62, with a larger variance associated with the peer network than with the school (8.37 vs 0.57, Model 2). Again, Finland stood out as the country with the lowest rate. Adding sociodemographic correlates (Model 3) and centrality indices (Model 4) improved the model fit, but had little effect on the school variance and peer-network variance.

For physical activity, the school variance component and the peer-network component were both small (0.10 and 0.26, Model 2). The Netherlands had a higher frequency of physical activity than the other five countries. Physical activity decreased with age, among women, and with lower socio-economic status, and increased with centrality indicators.

Figure 1 depicts the relative share of variation, for peer networks and schools, as a percentage, across behaviours. As the total variance can be different across behaviours, total variance is provided in brackets for each model (∑=). For smoking, drinking, and cannabis use, the peer network had the greater percentage of variance (52% for smoking, 44% for drinking, 50% for cannabis, Model 4). Overall, the school variance was quite small, ranging from 2% for physical activity and drinking to 6% for smoking.

Discussion

Main findings

Networks of friends in schools were found to have similar risky health behaviour when it comes to smoking, drinking, and cannabis use. This was not true, however, for positive health behaviour, i.e. physical activity. The peer-network level had a larger relative share of the variation component for these risky health behaviours than the school level. Peer-network variation accounted for half of the variance for smoking and cannabis. For cannabis, country was also an important factor. School represented a relatively small share of the overall variation for all behaviours. Finally, the similarity of health behaviours between peers or between schools was not strongly affected by sociodemographic or socio-economic factors, or centrality.

Interpretation

The similarity of peers, i.e. the network levels, in these three substance uses (alcohol, smoking, and cannabis) has been evidenced in some European (Kiuru et al., 2010; Lundborg, 2006) and North American studies (Clark and Loheac, 2007; Ennett et al., 2006; Fujimoto and Valente, 2012a, b). The finding that peer-network variation is somewhat greater for smoking and cannabis than for drinking is also consistent with other studies (Fujimoto and Valente, 2012a; Kiuru et al., 2010), including the Add Health study (Clark and Loheac, 2007; Fujimoto and Valente, 2012a), but not with the early study by Ennett (Ennett et al., 2006). The stronger similarity of substance use than of positive behaviour such as physical activity is also consistent with two previous studies that considered a similar set of behaviours (Barnett et al., 2014; Long et al., 2017). Generally, these peer effects were quite robust after accounting for school compositional or selection effects, and controlling for other sociodemographic covariates (Clark and Loheac, 2007; Fujimoto and Valente, 2012a; Lundborg, 2006). The stronger peer similarity for smoking and cannabis than for drinking is possibly because smoking is a more rapidly developing form of addiction than drinking in that age group. As described elsewhere, on the basis of the SILNE and Health Behaviour of School-aged Children (HBSC) surveys data, one adolescent out of 20 is moderately to highly nicotine-dependent (Coban et al., 2018). Another possible explanation is that smoking and cannabis, compared to physical activity, are seen as more illegitimate behaviours: selling cigarettes or cannabis to adolescents is illegal. Smoking cigarettes or cannabis is largely de-normalised in Western countries. Finally, access to these products requires a social support network that facilitates access to non-official sources, as well as facilitating an alternative and more positive normative perspective on these behaviours.

The modest contribution of the school-level variance component compared with the peer-network variance, on the surface, appears to contradict the many multilevel studies of adolescent substance use at school (Bonell et al., 2013; Maes and Lievens, 2003; McVicar, 2011; Shackleton et al., 2016). A recent study, using the European School Survey Project for Alcohol and Other Drugs (ESPAD) data, had an average intra-class correlation (ICC) ranging from .14 to .21 for smoking and alcohol (Shackleton et al., 2016), at the school level, not accounting for the network level, a much higher value than in this analysis. The ICC is equivalent to the variance partition coefficient where linear multilevel models are applied. For the logistic multilevel models used here, the variance partition coefficients may be compared with those from the linear models, but these are not intra-class correlations as in the linear case. Differences in VPCs may arise from different sampling strategies: the ESPAD surveyed between one and two classrooms per school, whereas this study surveyed all classrooms in the particular grades. In a way, in the ESPAD study, the school variance component was more a classroom variance component, a level that is between the network (peer group) and the school at large. Thus, both studies suggest that the network is a key level for substance use behaviour in adolescents. For physical activity, too, the very low variance partition coefficient is consistent with other studies. The Add Health study (Daw et al., 2015) showed that network similarity was much smaller for exercise than for smoking and drinking, whereas a German study, using the HBSC data, found a low intra-class correlation of 2% for vigorous physical activity (Czerwinski et al., 2015).

Finally, both the peer-network and the school variance components were not significantly associated with compositional factors or social prestige. This was also confirmed by a study comparing behaviour similarity between different sociodemographic groups: broadly, similarity of behaviour between friends exhibited similar patterns between males and females, between racial groups, and between parental education groups (Daw et al., 2015).

<u>Limitations</u>

This study has two main limitations affecting, respectively, its internal and external validity. First, health behaviour was self-reported and it is likely that some behaviour was under-reported, particularly those behaviours that are more strongly patterned by social expectations (Hill et al., 1997; Lahaut et al., 2002). Smoking is increasingly de-normalised in countries and schools with lower smoking prevalence, drinking is strongly controlled and regulated in some countries, and prohibited in some religious groups. Cannabis consumption is prohibited and prosecuted in some European countries, while bans are strictly enforced in some schools. The extent to which this under-reporting affects the estimated variance components depends on the association between under-reporting and prevalence. Under-reporting might increase as prevalence decreases, because of stigmatisation or the risks attached to behaving in an unusual way. This bias was assessed by measuring the association between the percentage of missing values and behaviour prevalence at the school level. The correlation between the percentage of missing values and prevalence was small and non-significant (-0.06 for smoking, -0.04 for drinking, and 0.05 for cannabis). Also, this survey was initially designed to measure socio-economic inequalities in smoking; as a consequence, it collected more detailed information about smoking than about the other three behaviours considered here (cannabis use, drinking alcohol, and physical activity), and had no information available on other protective behaviours, such as nutrition or participation in socio-cultural activities. The wording of the physical activity question is different from the International Physical Activity Questionnaire (Rachele et al., 2012), and this may explain our higher proportion of moderate to vigorous physical activity as compared to the HBSC results (Kalman et al., 2015).

With respect to external validity, the estimate of the variance components could also be vulnerable to methodological features. First, in the SILNE sampling design, there were 50 schools in six cities, with variable numbers of schools per country (ranging from 6 to 13): this may impact on variance estimates of health behaviour. Also, as the schools were selected within one city, the average variance component at the school level may be underestimated, as the variance within a city is likely to be lower than the variance within a country. Finally, the intra-class coefficient, with binary outcomes, remains vulnerable to the prevalence of the outcome measured and will be at highest for a prevalence of 50% (Merlo et al., 2006). As a consequence, it could be that the size of the intra-class coefficients across the four types of health behaviour is also affected by the differences in prevalence between more frequent behaviour (physical activity and drinking alcohol) and less frequent behaviour (smoking and cannabis use).

Conclusions

Risky health behaviour among adolescents remains a matter of concern for educational and health authorities. The results of this study suggest that these risky behaviours are best addressed at the peer-network level. Peer-led interventions have become more popular over the last decade and are promising (Campbell et al., 2008), although the evidence remains limited (MacArthur et al., 2016). From a more theoretical perspective, peer-led interventions may fall into different categories (Valente, 2012), two of which are worth mentioning in relation to adolescent substance use: selecting key agents of change to be proponents of change in substance use; and focusing on the group level because substance use may be a group attribute, and an individual may resist change if his/her peers do not change at the same time.

From a public health perspective, the results of this study also suggest that other multilevel studies of adolescent health behaviour would benefit from the inclusion of a social network component. The MMMC model helps to take into account two important components frequently encountered in population health studies: (a) the clustering of individuals across entities (such as schools, households, companies, areas, etc.) and (b) the connectivity of individuals through their social networks (friendship, exchanges, and social support). The use of multilevel studies has given an impetus to public health studies that address clustered individuals. The use of MMMC models further contributes to progress by modelling the connections between individuals, a feature that population health studies have been reluctant to acknowledge.

Table 1. Sample description and substance use, SILNE international study of adolescent health behaviours, 2013.

Covariate	% or mean (sd)
City-Country	
Namur-Belgium	19.0
Tampere-Finland	13.6
Hanover-Germany	12.9
Latina-Italy	19.2
Amersfoort-The Netherlands	17.6
Coimbra-Portugal	17.7
Sociodemographics	
Age (y.)	15.2 (1.0)
Female (%)	51.9
Low parental education (%)	28.4
Deprivation index (score, 0-7)	1.3 (1.2)
Health behaviour	
Daily smoking (%)	14.7
Monthly cannabis use (%)	7.2
Monthly alcohol (%)	35.1
Regular physical activity (%)	41.9
Structural centrality metrics	
Popularity (no of in-degree)	3.4 (2.1)
Betweenness (%)	1.8 (2.8)
Closeness (average distance)	11.4 (4.6)

Table 2. MMMC model parameter estimates for daily smoking: SILNE international study of adolescent health 2013

	Model 1‡	Model 2‡	Model 3‡	Model 4‡
	Beta 95%CI	Beta 95%CI	Beta 95%CI	Beta 95%CI
Intercept	-1.18 *	-2.05 *	-2.17 *	-2.53 *
	[-1.63; -0.72]	[-2.78; -1.08]	[-2.80; -1.44]	[-3.27; -1.79]
Countries (ref = Belgium)				
Finland	-0.6	-0.94	-0.37	-0.36
	[-1.27; 0.07]	[-1.94; 0.02]	[-1.17; 0.40]	[-1.21; 0.50]
Germany	-0.77 *	-1.08 *	-0.58	-0.62
	[-1.40; -0.17]	[-1.96; -0.20]	[-1.33; 0.16]	[-1.42; 0.22]
Italy	0.3	0.54	0.7	0.69
	[-0.33; 0.95]	[-0.43; 1.50]	[-0.03; 1.49]	[-0.13; 1.55]
The Netherlands	-0.84 *	-1.14 *	-0.78	-0.83
	[-1.52; -0.16]	[-2.15; -0.20]	[-1.55; 0.05]	[-1.69; 0.03]
Portugal	-0.26	-0.36	-0.62	-0.65
	[-1.01; 0.41]	[-1.32; 0.64]	[-1.38; 0.28]	[-1.53; 0.24]
Random coefficients				
School variance	0.43 *	0.78 *	0.45 *	0.49 *
	[0.25; 0.70]	[0.37; 1.40]	[0.21; 0.84]	[0.22; 0.90]
Peer-network variance		16.34 *	12.13 *	14.08 *
		[0.32; 22.42]	[0.15; 15.47]	[3.37; 17.19]
Sociodemographics				
Age (year)			0.63 *	0.66 *
			[0.50; 0.74]	[0.54; 0.76]
Women (ref=men)			0.01	0
			[-0.17; 0.18]	[-0.18; 0.19]
Parental education (high versus low)			0.16	0.17
			[-0.05; 0.38]	[-0.05; 0.39]
Deprivation index (score, 1-7)			-0.02	-0.01
			[-0.11; 0.06]	[-0.10; 0.07]

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Table 2 *(continued)*

	Beta 95%CI	Beta 95%CI	Beta 95%CI	Beta 95%CI
Centrality				
Popularity (no of in-degree)				0.06 *
				[0.02; 0.10]
Closeness (distance)				0
				[-0.03; 0.03]
Betweenness (%)				3.83 *
				[0.79; 6.86]
Number of observations	10131	10131	10131	10131
DIC	9305.08	8004.19	8056.69	7853.19

‡ Model 1 includes a school variance component only; Model 2 includes both peer-network and school variance components; Model 3 adds sociodemographic variables to Model 2; Model 4 adds popularity, closeness, and betweenness to Model 3.

Table 3. MMMC model parameter estimates for monthly alcohol use: SILNE international study of adolescent health 2013

	Model 1‡	Model 2‡	Model 3‡	Model 4‡
	Beta 95%CI	Beta 95%CI	Beta 95%CI	Beta 95%CI
Intercept	-0.05 [-0.41; 0.29]	-0.09 [-0.58; 0.39]	0.1 [-0.31; 0.49]	-0.37 [-0.84; 0.09]
Countries (ref = Belgium)				
Finland	-1.63 * [-2.11; -1.14]	-2.68 * [-3.41; -1.99]	-1.98 * [-2.57; -1.35]	-1.98 * [-2.60; -1.22]
Germany	-0.98 * [-1.43; -0.54]	-1.64 * [-2.31; -0.98]	-0.94 * [-1.49; -0.39]	-0.92 * [-1.45; -0.38]
Italy	-0.29 [-0.75; 0.20]	-0.6 [-1.28; 0.10]	-0.28 [-0.81; 0.27]	-0.31 [-0.81; 0.22]
The Netherlands	-0.60 * [-1.06; -0.15]	-0.92 * [-1.61; -0.26]	-0.64 * [-1.18; -0.12]	-0.63 * [-1.19; -0.11]
Portugal	-0.3 [-0.80; 0.21]	-0.54 [-1.27; 0.14]	-0.78 * [-1.36; -0.20]	-0.78 * [-1.33; -0.23]
Random coefficients:				
School Variance	0.17 * [0.10; 0.28]	0.31 * [0.15; 0.56]	0.19 * [0.08; 0.36]	0.17 * [0.08; 0.33]
Peer-network variance		14.70 * [12.27; 17.56]	10.20 * [2.20; 12.45]	9.16 * [0.06; 11.60]
Sociodemographics:				
Age (years)			0.72 * [0.62; 0.80]	0.71 * [0.59; 0.80]
Women (ref = men)			-0.46 * [-0.62; -0.32]	-0.47 * [-0.63; -0.32]
Parental education (high versus low)			0.32 * [0.14; 0.50]	0.30 * [0.12; 0.49]
Deprivation index (score, 1-7)			-0.21 * [-0.28; -0.14]	-0.19 * [-0.27; -0.13]

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Table 3 *(continued)*

	Model 1	Model 2	Model 3	Model 4
Centrality:				
Popularity (no of in-degree)				0.06 *
				[0.03; 0.09]
Closeness (distance)				0.02
				[-0.01; 0.04]
Betweenness (%)				5.52 *
				[3.06; 7.99]
Num. obs.	10131	10131	10131	10131
DIC	12442.72	10807.92	10779.11	10888.82

‡ Model 1 includes a school variance component only; Model 2 includes both peer-network and school variance components; Model 3 adds sociodemographic variables to Model 2; Model 4 adds popularity, closeness, and betweenness to Model 3.

Table 4. MMMC model parameter estimates for cannabis use: SILNE international study of adolescent health 2013

	Model 1‡	Model 2‡	Model 3‡	Model 4‡
	Beta 95%CI	Beta 95%CI	Beta 95%CI	Beta 95%CI
Intercept	-1.95 * [-2.49; -1.44]	-2.76 * [-3.60; -1.81]	-2.73 * [-3.43; -1.85]	-3.37 * [-4.11; -2.65]
Countries: (ref = Belgium)				
Finland	-3.12 * [-4.13; -2.17]	-3.63 * [-4.88; -2.47]	-3.32 * [-4.44; -2.20]	-3.52 * [-4.63; -2.45]
Germany	-1.55 * [-2.30; -0.83]	-1.70 * [-2.59; -0.87]	-1.34 * [-2.16; -0.56]	-1.43 * [-2.29; -0.61]
Italy	-0.28 [-1.02; 0.44]	-0.19 [-0.96; 0.65]	0 [-0.73; 0.75]	-0.08 [-0.84; 0.67]
The Netherlands	-1.18 * [-1.93; -0.41]	-1.28 * [-2.18; -0.39]	-1.09 * [-1.86; -0.32]	-1.14 * [-1.98; -0.34]
Portugal	-0.97 * [-1.77; -0.17]	-1.10 * [-2.02; -0.19]	-1.46 * [-2.33; -0.62]	-1.53 * [-2.36; -0.70]
Random coefficients:				
School variance	0.48 * [0.24; 0.88]	0.57 * [0.26; 1.09]	0.40 * [0.15; 0.84]	0.38 * [0.13; 0.81]
Peer-network variance		8.37 * [0.07; 13.94]	10.61 * [0.21; 14.95]	12.31 * [4.94; 16.18]
Sociodemographic:				
Age (years)			0.68 * [0.54; 0.81]	0.71 * [0.57; 0.84]
Women (ref = men)			-0.97 * [-1.25; -0.64]	-1.02 * [-1.30; -0.74]
Parental education (high versus low)			-0.12 [-0.43; 0.18]	-0.13 [-0.44; 0.19]
Deprivation index (score, 1-7)			-0.02 [-0.13; 0.10]	-0.01 [-0.12; 0.11]

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Table 4 *(continued)*

	Model 1	Model 2	Model 3	Model 4
Centrality:				
Popularity (no of in-degree)				0.04
				[-0.02; 0.10]
Closeness (distance)				0.02
				[-0.01; 0.05]
Betweenness (%)				8.13 *
				[4.03; 12.28]
Num. obs.	10131	10131	10131	10131
DIC	4655.33	4252.62	3956.38	3832.48

‡ Model 1 includes a school variance component only; Model 2 includes both peer-network and school variance components; Model 3 adds sociodemographic variables to Model 2; Model 4 adds popularity, closeness, and betweenness to Model 3.

Table 5. MMMC model parameter estimates for regular physical activity: SILNE international study of adolescent health 2013

	Model 1‡	Model 2‡	Model 3‡	Model 4‡
	Beta 95%CI	Beta 95%CI	Beta 95%CI	Beta 95%CI
Intercept	-1.01	-1.02	-0.36 *	-0.31 *
Countries: (ref = Belgium)	[-1.29; -0.76]	[-1.30; -0.76]	[-0.62; -0.13]	[-0.61; -0.00]
Finland	0.98*	0.99*	0.89 *	0.96 *
	[0.64;1.34]	[0.63;1.38]	[0.56; 1.24]	[0.62; 1.33]
Germany	0.6*	0.61*	0.56 *	0.54 *
	[0.26;0.95]	[0.26;0.96]	[0.25; 0.89]	[0.23; 0.87]
Italy	0.28	0.27	0.26	0.22
	[-0.08;0.66]	[-0.10;0.64]	[-0.06; 0.58]	[-0.10; 0.54]
The Netherlands	1.69*	1.7*	1.71 *	1.70 *
	[1.33;2.06]	[1.34;2.09]	[1.34; 2.08]	[1.34; 2.08]
Portugal	0.34	0.33	0.37 *	0.32
	[-0.03;0.72]	[-0.04;0.74]	[0.02; 0.73]	[-0.01; 0.67]
Random coefficients:				
School variance	0.1*	0.1*	0.07 *	0.06 *
	[0.06;0.17]	[0.06;0.17]	[0.03; 0.12]	[0.03; 0.12]
Peer-network variance		0.26*	1.55 *	1.83 *
		[0.00;1.39]	[0.01; 2.88]	[0.02; 3.14]
Sociodemographics:				
Age (years)			-0.12 *	-0.11 *
			[-0.17; -0.06]	[-0.17; -0.05]
Women (ref = male)			-0.93 *	-0.94 *
			[-1.06; -0.79]	[-1.08; -0.80]
Parental education (high versus low)			0.24 *	0.24 *
			[0.10; 0.38]	[0.10; 0.39]
Deprivation index (score, 1-7)			-0.20 *	-0.19 *
			[-0.25; -0.15]	[-0.25; -0.14]

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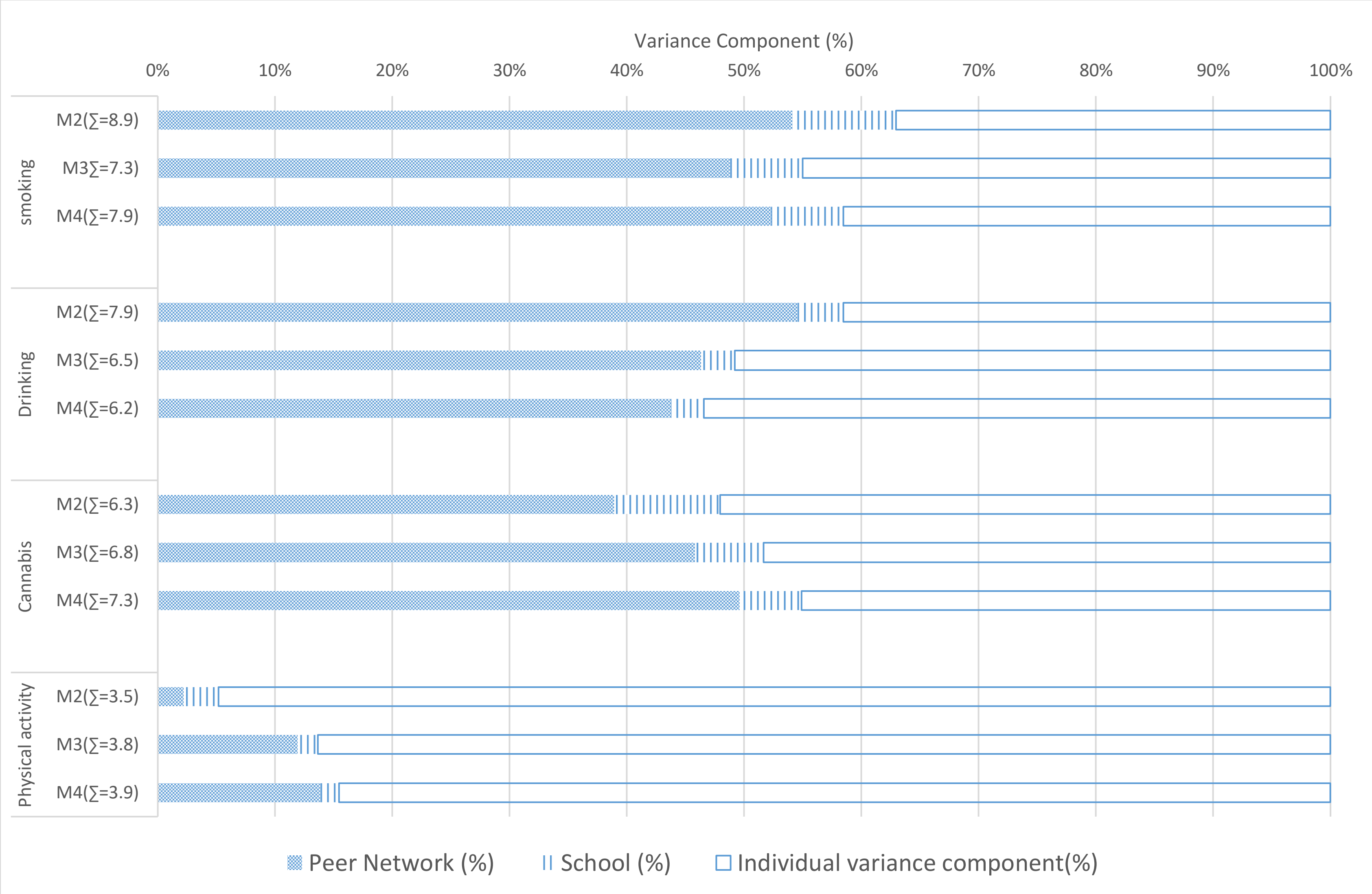
Table 5 *(continued)*

	Model 1	Model 2	Model 3	Model 4
Centrality:				
Popularity (no of in-degree)				0.04 *
				[0.02; 0.07]
Closeness (distance)				-0.02 *
				[-0.04; -0.01]
Betweenness (%)				3.37 *
				[1.49; 5.34]
Num. obs.	10131	10131	10131	10131
DIC	12896.07	12864.8	12388.44	12336.6

‡ Model 1 includes a school variance component only; Model 2 includes both peer-network and school variance components; Model 3 adds sociodemographic variables to Model 2; Model 4 adds popularity, closeness, and betweenness to Model 3.

Figure 1. Variance component in % of the total variance, per behaviour, SILNE international study of adolescent health 2013



Additional information:

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