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Homophily and assimilation among sport-active adolescent substance users[1]

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We analyse the co-evolution of social networks and substance use behaviour of adolescents and address the problem of separating the effects of homophily and assimilation. Adolescents who prefer friends with the same substance-use behaviour exhibit the homophily principle. Adolescents who adapt their substance use behaviour to match that of their friends display the assimilation principle. We use the Siena software to illustrate the co-evolution of friendship networks, smoking, cannabis use and drinking among sport-active teenagers. Results indicate strong network selection effects occurring with a preference for same sex reciprocated relationships in closed networks. Assimilation occurs among cannabis and alcohol but not tobacco users. Homophily prevails among tobacco and alcohol users. Cannabis use influences smoking behavior positively (i.e., increasing cannabis increases smoking). Weaker effects include drinkers smoking more and cannabis users drinking more. Homophily and assimilation are not significant mechanisms with regard to sporting activity for any substance. There is, however, a significant reduction of sporting activity among smokers. Also, girls engaged in less sport than boys. Some recommendations for health promotion programmes are made.

1. INTRODUCTION

Smoking, drug-taking and alcohol use tend to be similar between friends (Brook et al. 1983, Doreian 1989). Two underlying dynamic principles which give rise to such similar behaviour have been debated for some time. One is the principle of homophily (McPherson, McPherson et al., 2001) whereby individuals interact more with similar than with dissimilar others. In the context of substance use, for example, this would mean that two actors with the same substance use behaviour pattern would be more likely to share a friendship tie. The other principle is that of assimilation (sometimes known as the principle of influence or contagion) whereby individuals adapt their behaviour to match that of their friends (Friedkin 1998).

In the literature some authors (Ennett and Bauman, 1994; Urberg, 1999) have argued that social processes, such as peer influence and selection, are more important determinants of substance use than

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are processes concerning emotional regulation. Hussong and Hicks (2003) examine the potential etiological models for adolescent substance use involving the peer context, affective experiences, and the interaction between these factors. Regarding sporting activities Moore and Werch (2005) conclude that those sports associated with increased substance use differed for males and females, and also for different types of substance use. They conclude that school-sponsored, male-dominated sports appeared to be associated with an increased substance use risk for males, whereas out-of-school, mixed-gender sports appeared to be for females. In general sport participation has been associated with lower use of cigarettes and marijuana (Baumert P.W. et al., 1998; Melnick M.J. et al., 2001), and increased use of alcohol (Rainey C.J et al., 1996; Winnail S.D. et al., 1997). Our current study broadly replicates these results, but investigates in more detail the co-evolutionary and causal links between sporting activity and network and substance use dynamics. We discuss some of the implications for health programs.

Recently co-evolutionary models taking into account both network and behavioural effects measured from panel data extracted from complete data sets in longitudinal studies have been the subject of rigorous analysis. This does, more than earlier analyses, justice to both the relational aspect of the network data, and to the dynamic nature of the entwined processes of peer influence and friendship selection. In particular stochastic actor-driven models (Snijders, 1996, 2001 ; Steglich et al., 2004) of network change have been analysed using the SIENA software (Snijders, Steglich, Schweinberger Huisman, 2005), which has recently been extended to account for the joint dynamics of networks and behaviour (Steglich, Snijders and Pearson (2004); Snijders, Steglich and Schweinberger (2005)).

The remainder of this paper is organised as follows: Section 2 states the questions and issues addressed in the paper. Section 3 outlines the Methodology employed to answer these questions. The section begins with a description of the theory employed in the analysis of the network and behaviour panel data and the way in which the SIENA program models this data and continues by describing the study design and actual sample data used. Section 4 outlines the results of the analysis carried out by SIENA. Section 5 concludes the paper.

2. QUESTIONS ADDRESSED

We address the following issues in our analysis and discussion:

1. To what degree can homophily and assimilation mechanisms account for the observed co-evolution of substance-use and friendship ties in our data?
2. Does the answer to the preceding question differ among the three substance-use behaviours of tobacco, cannabis and alcohol use?
3. What are the causal relationships between tobacco, alcohol and cannabis consumption? (We use cause in a weak sense here. So, for instance, cannabis use may act as a good predictor for subsequent smoking activity)
4. Questions 1 to 3, but now with sports behaviour as an additional dependent variable.
5. What are the implications for intervention programmes?

3. METHODS

3.1 Modelling of the Panel Data

To address the first question, which is about processes of the evolution of the social network, it is necessary to employ statistical models that represent this evolution in an adequate way. The modelling methods used in this paper are based on the idea that all possible network configurations (directed graphs) on a given set of actors, jointly with all possible configurations of their values of the behaviour variables (such as smoking and sporting behaviour) form the state space of a stochastic process. The modelling proceeds by observing the network dynamics after specifying parameters and estimating the transition probabilities between the states of the stochastic process. So, for instance, in the simplest of models we may wish to formulate the transition probability associated with a change from an isolated network position to the position of being in a dyadic relationship with another actor. This is illustrated in Figure 1 where a preference is expressed over time for a tie to another actor in the network and Figure 2 where a preference is expressed for reciprocated ties.

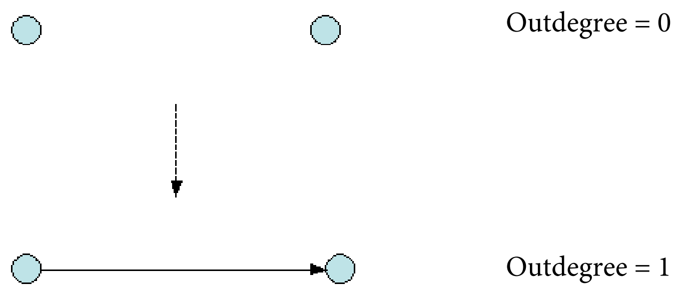

Figure 1. Network transition indicating a preference for a tie to another

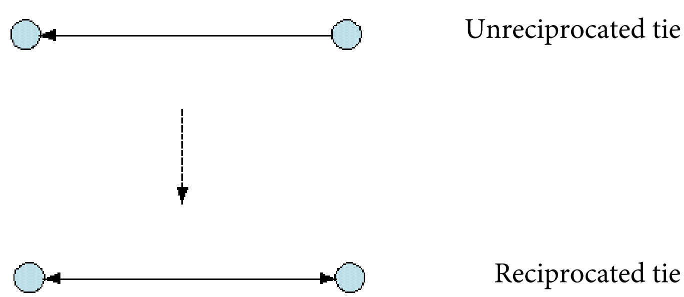

Figure 2. Network transition indicating a preference for reciprocated ties

There are, in fact, for just two actors, four possible dyadic configurations depending on the way in which the relationship is expressed. As we increase the number of network actors the number of possible network configurations rises exponentially, thus dramatically increasing the size of the state space. The modelling of these changes from one network configuration to another is carried out by formulating transition probabilities from one state to another. These probabilities are then used to simulate realisations of the process. The outcomes of such realisations are compared with the actual results observed in the panel data to identify the best fitting model parameters as explained in Snijders (2001).

Another possible formulation for a change in network configuration over time is the transition probability associated with a change from having a close link with another actor to that of having an indirect tie (i.e. link at distance two or more away). This is illustrated in Figure 3 where a preference is expressed over time for keeping others at social distance two (or more) and thus avoiding many direct links with other individuals. A negative coefficient associated with this parameter would therefore indicate the opposite tendency and a desire for network closure.

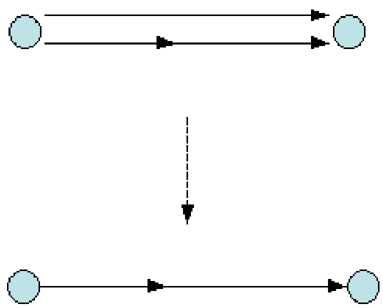

Figure 3. Network transition indicating a preference for keeping others at social distance two

The model for the joint evolution of the friendship network and the various behavioural variables, described in more detail in Snijders (2001) and Steglich, Snijders and Pearson (2004), is based on the following principles. First, the evolution of network and behavior proceeds in steps of small changes, unobserved, between the panel observations. The small changes consist of either a change in one relational variable between two pupils, or a change in one behavioural variable of one pupil. Second, these changes are made in dependence upon the current network-behavioural configuration, but – given this dependence – without coordination between the pupils. This means, e.g., that a friendship group cannot suddenly spring into being, but can only grow as the result of the gradual coalescence of friendship ties. Third, the changes are considered as resulting from a limited goal pursuit process, the goal being the local improvement of the evaluation by the pupils of their network position and their behaviour. The network position is evaluated also in view of the behaviour of self and of one's friends; the behaviour is evaluated also in view of the behaviour of friends. The precise specification of the model according to these principles is given in the above references. To give a plausible but also parsimonious representation of the network-behaviour co-evolution, the assessment of the network position is based on a limited list of aspects. Each of these aspects has a weight in the overall assessment; these weights are parameters of which the estimates, based on the observed data, are given in the tables below. The following aspects are considered:

- Out-degree, which is the term used in social network analysis for the number of friendship choices made by the pupil (Figure 1).
- Reciprocity, the number of reciprocated choices for the pupil (Figure 2).
- Indirect ties, the number of 'friends of friends' of the pupil who are not his or her direct friends. The general tendency in networks of positive affect towards network closure, also called transitivity of choices, implies that friends of friends will tend to become friends, so that the number of indirect ties will be lower than expected under random patterns of ties. Thus, a negative weight for the number of indirect ties will reflect a positive tendency toward network closure (Figure 3).
- Homophily for the variables under consideration (gender, smoking, behavior etc.) expressing the preference for friends with the same value on this variable (Figure 4).
- The value of a variable under consideration for the 'sender' of a friendship tie ('ego').
- The value of a variable under consideration for the 'receiver' of a friendship tie ('alter').

The last three of this list make it clear that any single individual variable, e.g., smoking behaviour, is assumed to potentially have three types of effect on friendship choices, and thereby on the network dynamics. A positive homophily effect would mean that pupils prefer friendships with others having a similar smoking behaviour, which will drive the dynamics to friendship groups being preferentially homogeneous in smoking behaviour (although in actual practice this homogeneity will be not at all perfect, due to other influences that also operate on the friendship process); a positive 'ego' effect would mean that those with a higher value on smoking behaviour attach a higher value to friendships, and thus will tend to increase their number of friends more strongly over time; and a positive 'alter' effect would mean that those who smoke more are more attractive as friends, and therefore will tend to receive more friendship nominations. Although a variable such as smoking behaviour, due to its changing nature over time, operates differently on the network dynamics than a variable such as gender which is constant over time, the representation of their impact on the network evolution, indicated by the homophily, ego, and alter effects, is the same.

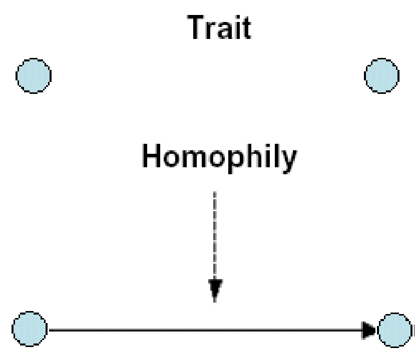

Figure 4. Network transition indicating a preference for ties to similar others (Homophily)

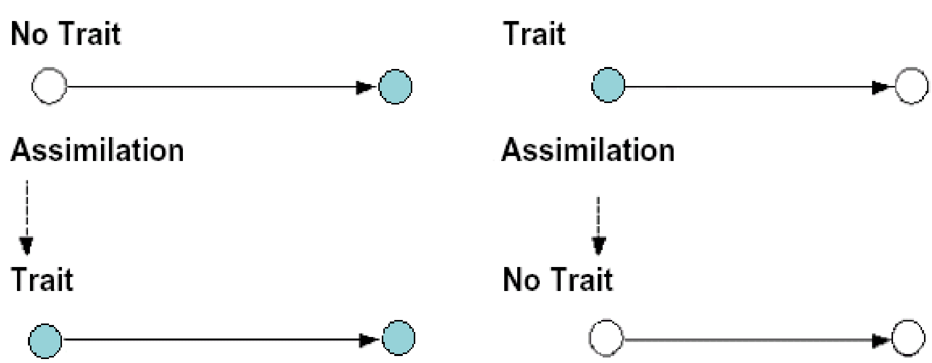

Figure 5. Behavioural transition indicating assimilation to friends(Assimilation)

The modelling process is given greater scope by the addition of the behavioural variables, which in this paper include the substance-use and sporting behaviours. The assessment by the individuals of their behaviour, e.g., smoking, and hence the direction of the dynamics of this behaviour, is based on the following list of aspects.

- The basic tendency to perform this behaviour, or to have a high value on it. A higher tendency parameter will lead to a more positive trend in the average of this behaviour. Since it is assumed that there are also random influences operating on the dynamical process, a zero weight for the tendency effect would imply that the average behaviour is not necessarily constant, but will tend toward the middle value in its range and stabilize there. Hence, e.g., to maintain the behaviour at a low stable level, it is necessary that the weight of the tendency effect is negative.

- The assimilation to the average value of one's friends on this particular behavioural variable (trait) (Figure 5).
- Other individual variables (traits), which can themselves be changing (e.g., representing the effect of sporting behaviour on smoking behaviour) or non-changing (e.g., the effect of gender on smoking behaviour).

Fitting the statistical model produces not only the weights for these effects, but also the rate of change. Due to the definition of the model (cf. Snijders, 2001; Steglich et al., 2004), the rate of change is not identical to the average number of observed changes between successive panel waves, but will be slightly higher, representing that there can be unobserved up-and-down changes cancelling each other, and also that the individuals may have had opportunities to change their network ties or their behaviour but chose not to do so. Such non-utilized opportunities for change are considered in the model definition also to contribute to the rate of change.

In this paper we will pay particular attention to the mechanisms of homophily and assimilation. Figure 4 illustrates homophily (McPherson et al., 2001) occurring in the network model. According to this principle individuals tend to form relationships with others, who have similar rather than dissimilar behavioural characteristics or traits. Figure 5, on the other hand, illustrates assimilation whereby individuals undergo a behavioural transition to match the trait of their already existing friends (Friedkin, 1998). More generally, we will use the mechanisms illustrated in Figures 1-5 to analyse the panel data and record the results in Tables 2-4.

The SIENA program (Snijders et al., 2005) is used to analyse the panel data. This program estimates the parameters in the model sketched above. The parameters can be tested by testing the t-ratios (parameter estimate divided by standard error) in the standard normal distribution (Snijders, 2001). The results enable us to test the way in which sporting activity and substance use evolve for different substances, and also the hypotheses that increased sporting activity leads to decreased substance use or that increased substance use leads to decreased sporting activity over time. We do not in this paper address the way in which sporting activity and substance use evolve for different sporting activities; although data on differing types of sporting activities were gathered (the main out of school sporting activity for 13 year old boys at that time was football, while for girls it was dancing). We concentrate here on observing and identifying the dynamic interaction between sporting activity (defined in general) and substance use for particular substances.

3.2 Study design and sample data

The social network data were collected in the Teenage Friends and Lifestyle Study (Michell and West 1996, Pearson and Michell 2000, Pearson and West 2003). Friendship network data and substance use were recorded for a cohort of pupils in the West of Scotland. The panel data were recorded over a three year period starting in 1995, when the pupils were aged 13, and ending in 1997. A total of 160 pupils took part in the study, 129 of whom were present at all three measurement points. The friendship networks were formed by allowing the pupils to name up to twelve best friends.

Pupils were also asked about substance use and adolescent behaviour associated with, for instance, lifestyle, sporting behaviour and tobacco, alcohol and cannabis consumption. The question on sporting activity asked if the pupil regularly took part in any sport, or go training for sport, out of school (e.g. football, gymnastics, skating, mountain biking). The school was representative of others in the region in terms of social class composition (Pearson and West 2003).

The behavioural variables were coded as follows:

Smoking: 1(non), 2(occasional) and 3(Regular i.e. more than once per week)

Cannabis: 1(non), 2(tried once), 3(occasional) and 4(Regular)

Alcohol: 1(non), 2(once or twice a year), 3(once a month), 4(once a week) and 5(more than once a week)

Sport: 1(not regular) and 2(regular)

The data set investigated in this paper has been analysed in other publications. Other analyses using NEGOPY (Richards, 1989) were carried out by Michell and Amos (1997), Pearson and Michell (2000) and Pearson and West (2003). The cohesiveness and influence of larger groups and the investigation of sociograms was of special interest in these papers (at present SIENA does not analyse large cohesive groups). In particular the second of these publications has detailed sociograms for the complete data set at the first two time points. Pearson and West used a Markov process to model transitions between network and behavioural states and identify sojourn times in these states. Steglich, Snijders and Pearson (2004) extended SIENA to model processes of selection and influence among adolescent smokers and alcohol-users. Steglich, Snijders and West (2006) illustrated the analysis of the co-evolution of adolescents' friendship networks, taste in music and alcohol consumption. In this publication we extend the earlier work of Steglich, Snijders and Pearson (2004) by including three substance-use traits as well as sporting activity to explore the mechanisms of homophily and assimilation.

4. RESULTS

Table 1 summarises each of the behavioural and sporting activity traits at each age by gender. Gender and age appear to play an important role in the determination of these traits, with a general pattern of increased substance use and decreased sporting activity among older females. We investigate these tendencies in the context of co-evolving network and behavioural mechanisms.

4.1 Results on network evolution: selection of friends

Estimation of a reference model was carried out containing only network information on selection of friends together with gender. The results for outdegree, reciprocity, number of actors at distance 2, gender homophily, gender ego and gender alter are shown in Table 3 ('Network'), where the significant results are shown in italics. Hence a negative outdegree effect (Figure 1 and Table 2; 'Network: outdegree) indicates that friendship with other pupils is unlikely and unstable unless there is some additional property added to the desired friendship such as reciprocity (Figure 2 and Table 2; 'Network: reciprocity'). Other desirable properties are possible. One such is the benefit of having mainly direct ties in a friendship network. This would result in a strong preference against having school friends at social distance 2 (Figure 3 and Table 2; 'Network: distance-2').

Another desirable property which adds to the value of a friendship is being of the same gender. (Figure 4 and Table 2; 'Network: gender: homophily'). There is strong gender homophily in friendship selection. Girls significantly prefer to have more friendship ties than boys, and are significantly less attractive as friends. (Table 2; 'Network: gender: ego and alter').

Male

Trait/Age	Age 13	Age 14	Age 15	Total
Occasional and Regular Smoking	6 (8.2%)	10 (13.7%)	14 (19.2%)	16.0%
Occasional and Regular Cannabis	8 (11%)	12 (16.5%)	26 (35.6%)	21.0%
Alcohol (once or more per week)	8 (10.9%)	14 (19.1%)	27(36.9%)	20.0%
Regular Sport (Any Sport)	64 (87.7%)	60 (82.2%)	56 (76.7%)	82.2%

Female

Trait/Age	Age 13	Age 14	Age 15	Total
Occasional and Regular Smoking	14 (25%)	19 (33.9%)	22 (39.3%)	22.0%
Occasional and Regular Cannabis	8 (14.3%)	10 (17.9%)	19 (33.9%)	22.0%
Alcohol (once or more per week)	18 (32.2%)	20 (35.7%)	26(46.4%)	38.1%
Regular Sport (Any Sport)	39 (69.6%)	33 (58.9%)	19 (33.9%)	54.1%

Male and Female

Trait/Age	Age 13	Age 14	Age 15	Total
Occasional and Regular Smoking	20 (15.6%)	29 (22.5%)	36 (28%)	22%
Occasional and Regular Cannabis	16 (12.5%)	22 (17.1%)	45 (34.9%)	21.4%
Alcohol (once or more per week)	26 (20.2%)	34 (26.3%)	53(41.1%)	29.2%
Regular Sport (Any Sport)	103 (79.8%)	93 (72.1%)	75 (58.1%)	70%

Table 1. Numbers and Percentages of Pupils with Traits at each Age

Network Evolution

Model	Parameter	Estimate	St. Error	p-value	Interpretation
Network	outdegree	-1.89	0.057	<0.001	*Costly friendship ties*
	reciprocity	2.34	0.084	<0.001	*Prefer reciprocation*
	distance-2	-1.12	0.063	<0.001	*Prefer network closure*
	gender homophily	0.77	0.093	<0.001	*Prefer same sex friends*
	ego	0.18	0.091	0.04	*Girls prefer more friends*
	alter	-0.25	0.100	0.01	*Girl less attractive as friend*
	rate period 1	12.62	1.061		Rate of network change (1)
	rate period 2	9.49	0.805		Rate of network change (2)

Table 2. SIENA estimation results for the model. Effects labelled in italics indicate significance at $\alpha = 0.05$ (two-sided)

If we extend our study to include the behavioural effects of smoking, cannabis and alcohol use some of these effects display reduced significance levels. For instance, girls do not significantly prefer to have more friendship ties than boys, nor are they significantly less attractive as friends. (Table 3; 'Network: gender: ego and alter'). Furthermore this is also displayed in an earlier study (Steglich et al., 2004) using the same data set, but without cannabis use, where some significance was identified with regard to the ego and alter effects of gender. We will discuss this finding in the conclusion. The rates of network change are high during both time periods one and two (Table 3; 'Network: rate period 1: rate period 2'). This means that the average number of occasions per time period which each actor gets for applying a small change to his network neighbourhood (i.e., erasing an existing tie or creating a new one) is high, indicating a highly active dynamic evolution in the formation of friendship ties.

4.2 Results of the behaviour-related effects on network evolution

The results about the behaviour-based selection of friends are also summarised in Table 3. The first significant result is that smokers name more friends than non-smokers (Table 3; 'Network: smoking: ego'). It is also the case that smokers are less attractive as friends than non-smokers (Table 3; 'Network: smoking: alter'), although this is of borderline significance. There are no significant ($p<0.05$) network effects associated with cannabis use, although there is a marginal cannabis-ego effect ($p<0.1$), indicating that cannabis users do appear to name fewer friends than non-users (Table 3; 'Network: cannabis: ego'). The alcohol-based selection effect is the strongest behaviour-based effect. Adolescents appear to prefer friends with the same drinking behaviour (Table 3; 'Network: alcohol: homophily').

4.2.1 Smoking

The low smoking tendency (-3.36) shows that pupils in general have a preference not to smoke. Gender acts as a borderline significant effect on smoking (Table 3; 'Smoking: gender'), suggesting that girls have a higher preference for smoking than boys. Cannabis has a highly significant behavioural effect on smoking (Table 3; 'Smoking: cannabis'), cannabis users being far more likely to smoke than non-users.

4.2.2 Cannabis

The negative tendency of cannabis (Table 3; 'Cannabis: tendency') is a weak effect indicating that pupils in general have a tendency not to use cannabis. The most significant effect is a positive influence effect of friends on cannabis use (Table 3; 'Cannabis; assimilation). A non cannabis user with a friend who uses cannabis (or a cannabis user who has non-user friends) is more likely to assimilate (change) his behaviour to match that of his friends. There is a mild, but not significant, gender effect on cannabis use (Table 3; 'Cannabis; gender'), suggesting that contrary to the smoking effect, girls may have a stronger dislike for cannabis than boys. Cannabis use changes slowly at first, but more rapidly later (Table 3; 'Cannabis: rate period 1: rate period 2').

4.2.3 Alcohol

Alcohol use seems more popular than either smoking or cannabis use (Table 3; 'Alcohol: tendency'). The most significant effect is a positive influence effect of friends on alcohol use ($p < 0.001$). A non-drinker who has drinking friends (or a drinker who has non-drinking friends) is more likely to assimilate (change) his behaviour to match that of the friends. Gender, smoking and cannabis use do not appear to significantly affect alcohol use. The rate parameters indicate that changes on the alcohol dimension increase over time, which means that alcohol dynamics speed up.

4.3 Sporting Activity

We repeated our analysis including the sporting behaviour of the pupils as an additional dependent variable. The results for the two dependent variables smoking and sports behaviour are shown in Table 4a. The network effects show homophily occurring in the cases of gender and smoking (without alcohol and cannabis) behaviour, but very weak negative effects for sporting behaviour. Pupils seem to prefer friends with different sporting behaviours. Sporting pupils also name fewer friends. Neither do the behavioural effects show assimilation occurring among sporting pupils. The main effect appears to be the causal relationship between smoking and sporting activity (in addition to the effect of gender on sporting activity). Smoking reduces sporting activity and girls engage in less sports activity.

The analysis was repeated for cannabis and alcohol use (Tables 4b and 4c) but the effects were not significant. The analysis was extended for sporting activity and all substance uses as dependent variables and the results (not displayed), were very similar to Table 3 and 4a, b and c.

Finally, we observe an interesting gender effect from Table 3 that girls smoke more (p=0.05), which vanishes in Table 4a (p=0.23) after controlling for sport. This occurs because of the combined effects of girls sporting less and smokers engaging in less sporting activity.

5. CONCLUSIONS

The first question we address is the degree to which influence/homophily and selection/assimilation mechanisms account for the observed co-evolution of substance-use and friendship ties in our data. The answer is that we observe both mechanisms occurring in the data set. There are strong selection effects occurring in the choice of friendship ties. Preference for same sex reciprocated relationships in closed networks predominates. There is quite strong assimilation and influence and also a degree of homophily and selection associated with some of the substance use behaviour.

The second question relates to the difference between the three substance-use behaviours. If we regard these substance use behaviours as dimensions, then assimilation occurs on only two dimensions (cannabis and alcohol) and not on the third (smoking), (Table 3; 'Alcohol: assimilation' and 'Cannabis: assimilation'). Pupils are therefore more likely to assimilate their behaviour to match that of their friends with regard to drinking and cannabis use, but not with regard to smoking behaviour.

Selection, on the other hand is most noticeable among drinkers (Table 3; 'Network: alcohol homophily') and smokers (Table 3; 'Network: smoking: ego and alter'). Drinkers prefer friends with the same drinking behaviour. Smokers name more friends but are less attractive as friends.

The third question concerns the causal relationships between tobacco, alcohol and cannabis consumption. There is an effect of cannabis use on smoking behaviour. Cannabis users smoke more tobacco. This is not perhaps a very surprising result, since much cannabis is smoked together with tobacco. There are also weak effects of other substances on each other (drinkers smoke more and cannabis users drink more). There is a mild gender effect on smoking and cannabis use (girls smoke more but use less cannabis).

The fourth question introduces the dependent behavioural variable 'sporting activity'. Tables 4a, 4b, 4c all show that homophily and assimilation are not significant mechanisms with regard to sporting activity for any of the substances. What is apparent, however, is that there is a significant causal relationship between substance use and sporting activity which results in a significant reduction of sporting activity among smokers and a mild (less significant) reduction among cannabis users. The results of alcohol consumption are inconclusive, but seem to indicate an increase (not significant) among sports activists. We also found that sporting activity was highly gendered, with girls engaging in less sport than boys. The apparent increased smoking levels among girls could be partly accounted for by their reduced sporting activity, since sports active pupils smoke less.

The fifth question relates to the implications for health intervention programmes. The programmes need to address the likely effect of any intervention by taking into account the different ways that friendship networks, substance use and sporting activity co-evolve.

Insights into these patterns of co-evolution can help, first, to focus interventions on certain groups or developmental phases; second, to pinpoint particularly adverse links in the processes leading to substance abuse and attempt to break or weaken them. As an example of focussing interventions on certain groups or developmental phases we note that friendships appear to be less stable among the younger children, who are also most vulnerable to increasing smoking rates. The fact that smokers name more friends, while appear less attractive as friends suggests a simple message targeting younger pupils. The message 'Choosing to smoke won't win you friends' needs to be emphasised, especially among young and vulnerable pupils. As an example of pinpointing particularly adverse links in the processes leading to substance abuse we propose that peer group based programmes would be better targeted at the substance uses of drinking and cannabis, since assimilation is strongest among these users (Table 3). Accordingly an example of this type of intervention is promoting the message 'Don't be coerced by peers into drinking and cannabis use' as more appropriate for drinking and cannabis. Programmes would also benefit by addressing gender issues. Girls are more likely to smoke (Table 3) and prefer more friends (Table 2). The message 'Choosing to smoke won't win you friends' could be particularly apt for them. The fact that girls network more strongly than boys (Table 2) may also indicate an ability to exercise greater influence, but this effect becomes weaker when the substance use behaviours are taken into account (Table 3).

If we consider only the network effects girls appear to be more socially active than boys, since they prefer to have more friendship ties (Table 2). They are also less attractive as friends (Table 2). These effects are not significant, however, when we include the co-evolutionary behavioural effects (Table 3; 'Network: gender: ego and alter'). In the current analysis we may be tempted to attribute this to the gender-specific effect of smoking. Table 3 indicates that girls smoke more than boys ($p = 0.053$), a result which is corroborated elsewhere (Pearson et al., 2005). The table also indicates that smokers name more friends and are less attractive as friends. We might therefore suppose that girls prefer more friendship ties and are less attractive as friends largely because of their smoking tendency. However, an earlier study (Steglich et al., 2004) using the same data set, but without cannabis use, did find some significance with regard to the ego and alter effects of gender, as well as similar gender-specific results for smoking. In our current analysis this gender-specific ego and alter effect is better explained by seemingly gender-specific cannabis consumption patterns. There is a marginally significant negative cannabis-ego effect (Table 3; $p = 0.096 < 0.1$) indicating that cannabis users do appear to name fewer friends than non users. Girls also appear to consume less cannabis. Although this is not a significant result in this study (Table 3; $p = 0.12$), the result is significant in a larger study carried out in the West coast of Scotland (Pearson et al., 2005). We might therefore conclude that the earlier result (that girls appear to be more socially active) can now be explained by their lower cannabis consumption and the marginally significant negative cannabis-ego effect.

The cannabis-ego effect whereby cannabis users tend to name fewer friends also implies that cannabis use tends to make people less socially active. This could tie in with the frequent portrayal of drug-takers as being lethargic. It also ties in with the level of sports activity of cannabis users, which is marginally lower (Table 4b; $p = 0.08$). When we take into account all the behavioural effects this direct effect disappears (not shown), and is replaced with the combination of two effects. Firstly that cannabis users smoke more (Table 3, $p < 0.01$) and secondly that smokers sport less (Table 4a, $p = 0.01$). We might therefore target our intervention program more efficiently at anti-smoking than anti-cannabis use when attempting to increase sports involvement. We may also wish to exploit the higher assimilation effect of cannabis compared with smoking. Initially this could mean separating the activities of smoking and cannabis use by encouraging cannabis users not to smoke their cannabis in order that they might become more involved and improve their performance in sport.

Other interesting effects appear in Tables 3 and 4a, b and c. These are that the strongest homophily, as well as the strongest assimilation, effects associated with substance use are the effects of alcohol. Drinkers prefer the same drinking behaviour friends, as well as exercising a strong influence on the drinking behaviour of their friends. The effects are not surprising when we consider the social dimensions of alcohol use. The challenge for health intervention programs is to reduce drinking choice opportunities among adolescents in order to control the homophily effect. The assimilation effect requires more careful control of the environment in which drinking occurs among adolescents. Drinking often occurs outside of the school environment and so the importance of out of school networks should be taken into consideration (Dolcini, Harper, Watson, Catania and Ellen, 2005).

Co-evolution of Network and Substance Use

Model	Parameter	Estimate	St. Error	*p*-value	Interpretation
Network	*outdegree*	-1.98	0.22	<0.001	*Costly friendship ties*
	reciprocity	2.29	0.11	<0.001	*Prefer reciprocation*
	distance-2	-1.08	0.07	<0.001	*Prefer network closure*
	gender homophily	0.78	0.11	<0.001	*Prefer same sex friends*
	ego	0.12	0.12	0.32	Girls prefer more friends
	alter	-0.17	0.13	0.19	Girls less attractive as friend
	smoking homophily	0.42	0.34	0.22	Prefer same smoke friends
	ego	0.28	0.13	0.03	*Smokers name more friends*
	alter	-0.25	0.13	0.05	*Smokers less attractive*
	cannabis homophily	0.18	0.51	0.72	Prefer same hash friends
	ego	-0.15	0.09	0.10	Hashers name less friends
	alter	0.09	0.10	0.37	Hashers more attractive
	alcohol homophily	0.96	0.38	0.01	*Prefer same drink friends*
	ego	-0.04	0.04	0.32	Drinkers name less friends
	alter	0.06	0.05	0.23	Drinkers more attractive
	rate period 1	12.72	1.49		Rate of network change (1)
	rate period 2	9.65	1.33		Rate of network change (2)
Smoking	tendency	-3.36	1.19	0.004	*Low smoking tendency*
	assimilation	0.39	0.37	0.29	Some smoking influence
	gender	0.91	0.47	0.05	Girls smoke more
	cannabis	1.09	0.38	<0.01	*Hashers smoke more*
	alcohol	0.33	0.25	0.19	Drinkers smoke more
	rate period 1	2.01	0.87		Rate of smoking change (1)
	rate period 2	1.31	0.35		Rate of smoking change (2)
Cannabis	tendency	-1.02	0.93	0.27	Low hashing tendency
	assimilation	3.54	1.43	0.01	*High hash influence*
	gender	-0.99	0.64	0.12	Girls hash less
	smoking	0.60	0.47	0.20	Smokers hash more
	alcohol	0.42	0.41	0.31	Drinkers hash more
	rate period 1	0.61	0.17		Rate of hash change (1)
	rate period 2	1.53	0.40		Rate of hash change (2)
Alcohol	tendency	0.25	0.30	0.41	High drinking tendency
	assimilation	1.63	0.43	<0.001	*High drinking influence*
	gender	0.23	0.22	0.30	Girls drink more
	smoking	-0.50	0.44	0.26	Smokers drink less
	cannabis	0.51	0.37	0.17	Hashers drink more
	rate period 1	1.67	0.31		Rate of drinking change (1)
	rate period 2	2.33	0.47		Rate of drinking change (2)

Table 3. SIENA estimation results for the model. Effects labelled in italics indicate significance at $\alpha = 0.05$ (two-sided)

Co-evolution of Network, Smoking and Sport Activity

Model	Parameter	Estimate	St. Error	*p*-value	Interpretation
Network	*outdegree*	-1.64	0.38	<0.001	*Costly friendship ties*
	reciprocity	2.31	0.10	<0.001	*Prefer reciprocation*
	distance-2	-1.11	0.07	<0.001	*Prefer network closure*
	gender homophily	0.80	0.12	<0.001	*Prefer same sex friends*
	ego	0.12	0.12	0.32	Girls prefer more friends
	alter	-0.20	0.14	0.16	Girls less attractive as friend
	smoking homophily	0.57	0.22	0.01	*Prefer same smoke friends*
	ego	0.12	0.08	0.13	Smokers name more friends
	alter	-0.14	0.07	0.05	Smokers less attractive
	sport homophily	-0.17	0.17	0.31	Prefer different sport friends
	ego	-0.15	0.11	0.16	Sports name less friends
	alter	-0.01	0.14	0.96	Sports neutral attractive
	rate period 1	12.55	1.48		Rate of network change (1)
	rate period 2	9.56	0.98		Rate of network change (2)
Smoking	tendency	0.18	1.19	0.88	Low smoking tendency
	assimilation	0.63	0.38	0.10	High smoking influence
	gender	0.52	0.43	0.23	Girls smoke more
	sport	-0.05	0.67	0.94	Sports smoke less
	rate period 1	0.88	0.27		Rate of smoking change (1)
	rate period 2	0.88	0.21		Rate of smoking change (2)
Sport	*tendency*	2.12	0.80	0.01	*High sports tendency*
	assimilation	-0.05	0.20	0.81	Low sports influence
	gender	-1.73	0.52	<0.001	*Girls sport less*
	smoke	-1.20	0.49	0.01	*Smokers sport less*
	rate period 1	0.88	0.22		Rate of sport change (1)
	rate period 2	1.03	0.29		Rate of sport change (2)

Table 4a. SIENA estimation results for the model. Effects labelled in italics indicate significance at $\alpha = 0.05$ (two-sided)

Co-evolution of Network, Cannabis and Sport Activity

Model	Parameter	Estimate	St. Error	*p*-value	Interpretation
Network	*outdegree*	-1.58	0.71	0.03	*Costly friendship ties*
	reciprocity	2.30	0.11	<0.001	*Prefer reciprocation*
	distance-2	-1.10	0.08	<0.001	*Prefer network closure*
	gender homophily	0.81	0.11	<0.001	*Prefer same sex friends*
	ego	0.11	0.12	0.34	Girls prefer more friends
	alter	-0.27	0.17	0.12	Girls less attractive as friend
	cannabis homophily	0.81	0.48	0.09	Prefer same hash friends
	ego	-0.05	0.05	0.28	Hashers name more friends
	alter	-0.02	0.07	0.80	Hashers less attractive
	sport homophily	-0.11	0.21	0.60	Prefer different sport friends
	ego	-0.18	0.15	0.26	Sports name less friends
	alter	0.03	0.20	0.87	Sports neutral attractive
	rate period 1	12.61	1.73		Rate of network change (1)
	rate period 2	9.78	1.40		Rate of network change (2)
Cannabis	tendency	-0.89	1.84	0.63	Low cannabis tendency
	assimilation	3.37	2.06	0.10	High cannabis influence
	gender	-0.24	0.47	0.61	Girls hash less
	sport	1.21	1.56	0.44	Sports hash less
	rate period 1	0.53	0.15		Rate of cannabis change (1)
	rate period 2	1.37	0.39		Rate of cannabis change (2)
Sport	tendency	1.32	0.73	0.07	High sports tendency
	assimilation	0.05	0.21	0.81	Low sports influence
	gender	-1.91	0.51	<0.001	*Girls sport less*
	cannabis	-0.64	0.37	0.08	Hashers sport less
	rate period 1	0.85	0.24		Rate of sport change (1)
	rate period 2	0.94	0.25		Rate of sport change (2)

Table 4b. SIENA estimation results for the model. Effects labelled in italics indicate significance at $\alpha = 0.05$ (two-sided)

Co-evolution of Network, Alcohol and Sport Activity

Model	Parameter	Estimate	St. Error	*p*-value	Interpretation
Network	*outdegree*	-1.55	0.44	<0.001	*Costly friendship ties*
	reciprocity	2.32	0.11	<0.001	*Prefer reciprocation*
	distance-2	-1.10	0.07	<0.001	*Prefer network closure*
	gender homophily	0.81	0.10	<0.001	*Prefer same sex friends*
	ego	0.15	0.11	0.17	Girls prefer more friends
	alter	-0.22	0.12	0.06	Girls less attractive as friend
	alcohol homophily	1.14	0.32	<0.001	*Prefer same drink friends*
	ego	-0.06	0.03	0.06	Drinkers name more friends
	alter	-0.01	0.03	0.86	Drinkers less attractive
	sport homophily	-0.09	0.22	0.67	Prefer different sport friends
	ego	-0.17	0.13	0.19	Sports name less friends
	alter	0.04	0.14	0.76	Sports neutral attractive
	rate period 1	12.57	1.29		Rate of network change (1)
	rate period 2	9.49	1.22		Rate of network change (2)
Alcohol	tendency	0.19	0.54	0.73	Low alcohol tendency
	assimilation	1.44	0.31	<0.001	*High alcohol influence*
	gender	0.03	0.17	0.86	Girls drink more
	sport	0.10	0.35	0.77	Sports drink more
	rate period 1	0.82	0.22		Rate of drinking change (1)
	rate period 2	0.96	0.27		Rate of drinking change (2)
Sport	tendency	0.68	0.67	0.32	High sports tendency
	assimilation	0.06	0.23	0.79	Low sports influence
	gender	-1.66	0.52	0.001	*Girls sport less*
	alcohol	-0.15	0.23	0.51	Drinkers sport less
	rate period 1	0.85	0.24		Rate of sport change (1)
	rate period 2	0.94	0.25		Rate of sport change (2)

Table 4c. SIENA estimation results for the model. Effects labelled in italics indicate significance at $\alpha = 0.05$ (two-sided)

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