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Effects of Peer Network Interactions on Adolescent Cannabis Use

John Moriarty & Kathryn Higgins

Abstract

**Purpose:** This study capitalises on three waves of longitudinal data from a cohort of 4351 secondary school pupils to examine the effects on individuals’ cannabis use uptake of both peer cannabis use and position within a peer network.

**Methodology:** Both cross-sectional and individual fixed effects models are used to estimate the effect on cannabis use of nominated friends’ cannabis use, of reciprocity and transitivity of nominations across the friendship cluster, and of interactions between these nominated friends. Post hoc analyses parsed the behaviour of reciprocating and non-reciprocating friends.

**Findings:** Cannabis use varied depending on the stability of friendship network and the degree of reciprocity and interconnectedness within the group. Behavioural influence was strong, but interaction effects were observed between the prevalence of cannabis use among friends, the structure of the friendship group and ego’s proximity to group members. These interactions demonstrate that behavioural influence is more salient in more cohesive groups. When reciprocating and non-reciprocating friends’ mean cannabis use were separated, influence from reciprocating friends was estimated at twice the magnitude of other friends.

**Originality and value:** While preventing of any one individual from using cannabis is likely to have a multiplier effect on classmates, the bonds and interactions between classmates will determine which classmates are affected by this multiplier and the salience of that effect.

**Keywords:** Peer Influence; Adolescent Cannabis Use; Social Network Analysis; Reciprocity; Interaction Effects
Introduction

Drug use is an interesting category of human behaviour for a variety of reasons. In spite of concerns about the risks to public health from certain drugs and resulting strict legal controls, many individuals succeed in obtaining, using and enjoying these substances. Individuals who are initiated into use of intoxicating and illicit substances usually undergo this initiation during their teenage years (van Ours & Williams, 2009). Lifetime experience of drug use prevalence among 11-15 year-olds in the United Kingdom has been estimated at 22%, with cannabis shown to be the most widely available and enduringly popular of these substances (Health and Social Care Information Centre, 2011; Miller & Plant, 2002). Persistent early adolescent cannabis use may have grave implications for long-term mental health and psychosocial outcomes (van Ours & Williams, 2009; Kuepper et al., 2011; Patton et al., 2002). Additionally, some authors have argued that some “soft” drugs, including cannabis, function as “gateways” into use of more expensive and addictive drugs later on (DuPont, 1985; Kandel & Jessor, 2002). Therefore, improved understanding of the circumstances and the intrinsically social context in which individuals decide to first experiment with cannabis could be immensely valuable, particularly if such an account lends itself to designing more effective interventions to prevent early initiation and minimise the harm inflicted on young people.

This paper describes an attempt to produce a model of early adolescents’ behavioural responsiveness to both peer network structure and the prevalence of cannabis use among their friends. It avails of a uniquely amenable dataset, containing multiple waves of data on both network structure and cannabis use behaviour, namely the Belfast Youth Development Study (BYDS). It provides evidence that, between ages 12 and 15, cannabis use was more likely among cohort members whose nominated friends represented a less cohesive unit and who were less central to their friendship cluster. Prevalence of cannabis among friends appears to exert a strong influence on participant cannabis use, though the salience of this influence depends on whether friendship is reciprocated by both parties.
The paper begins with a description of various strands of existing theoretical and empirical literature, highlighting the distinct disciplinary foci of the economic and health science literatures. Points of confluence between these perspectives are also identified.

**Literature**

A wide range of estimates and opinions are available as to the extent to which an individual’s drug use behaviour is influenced by the drug use behaviour of his or her peers and by the interactions which take place within the peer group. This variety stems, in part, from the separation which exists between the academic disciplines of those interested in this question, of which, Economics, Sociology, Psychology and Epidemiology make up a sub-set. While significant innovation has taken place over several decades to allow this question to be addressed more satisfactorily, progress has been neither linear nor cumulative. For example, consider two distinct areas of progress from the Health Sciences and Economics respectively.

**Social network parameters and structural peer effects**

The theories of Groupthink (Janis, 1972; 1982), and the Strength of Weak Ties (M. S. Granovetter, 1973; 1983) each show how focusing on friendship and the workings of small groups is fruitful in accounting for a given individual’s decision-making. The use of social network data allows for close examination of the parameters of the friendship network, distinguishing, for example, friends who reciprocate friendship nominations, from other friends (Krackhardt & Kilduff, 1999; Vaquera & Kao, 2008; Veenstra, Dijkstra, Steglich, & Van Zalk, 2013). By aggregating the nominations of various members of a clique or friendship cluster, a sociogram of the network can be drawn up and individuals assigned to positions relative to the “centre” of this cluster (e.g. Ennett & Bauman, 1993; Pearson & Michell, 2000). This assigned position is then used to predict likelihood of drug use behaviours.

This approach has yielded a variety of conclusions. Ennett and Bauman (1993) found that social isolates, those who report few ties and whose cluster membership is not acknowledged by their
peers, were more likely to take up smoking. Contrary findings have since suggested that the at-risk group reside between network centrality and isolation. “Liaisons” and “peripherals” are among the names given to individuals whose network position at the periphery of a single, or multiple clusters, i.e. where ties are with some but not all members of one or more groups. These individuals, who neither enjoy secure membership within one cluster, nor fall outside of all clusters in the network, have been identified as more likely to use both legal and illegal drugs (Abel, Plumridge, & Graham, 2002; Henry & Kobus, 2007). Being in a leadership\(^1\) or high status position in a cluster has also been suggested as a risk factor for substance use (Ennett et al., 2006; Lansford et al., 2009). Taking the evidence together, there seem to be risks associated with any network position, though Henry and Kobus offer a useful discussion of possible methodological sources of discrepancy (2007).

One problem which is addressed in this paper is that this approach to network analysis makes an overbearing assumption that a small number of latent categories of position exist. Given the idiosyncrasy of human relationships, it seems the introduction of arbitrary cut-offs between centrality, isolation and those in between may be too blunt of an approach. Given that the parameters of reciprocity and transitivity which underlie the assignment to network positions are surely continuous and fluid, network positioning will inevitably categorise two individuals who are close together on these distributions to distinct categories. By explicitly modelling these parameters on a continuous scale and allowing for curvature in their relationship with drug use outcomes, the current study seeks a more parsimonious iteration of this line of inquiry.

**Behavioural peer effects and endogenous interactions**

The fact that drugs are acquired and traded by vendors and consumers within a concealed and intrinsically social marketplace makes their use particularly relevant to an economic account of social interaction effects. Behavioural and Health Economists have chiefly concerned themselves

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\(^1\) This leadership construct is distinguished in a study of Lansford and colleagues (Lansford, Killeya-Jones, Miller, & Costanzo, 2009) from having a central and secure position within the network or cluster.
with a particular kind of peer effect, distinct from those described above: the effect on the drug use of one individual (ego) had by the drug use of alter, ego’s peer (also called “endogenous interactions”). However, several identification problems obstruct credible estimates of this effect (c.f. Manski 1993). Upward bias accrues from several sources. Peers are exposed to similar background factors which are also correlated with drug use. Individuals also respond to characteristics other than behaviours and select friends on the basis both of similarity of characteristics and of behaviour. Economists have responded to Manski’s challenges with concerted efforts towards finding appropriate data and developing appropriate statistical approaches to producing unbiased estimates.

This literature is dominated by cross-sectional studies which use mean group drug use at the level of the school, school grade or neighbourhood to estimate peer effects. In this context, the most credible models of the peer effect on a young person’s drug use employ either fixed effects at the school level (Gaviria & Raphael, 2001); fixed effects at the level of the neighbourhood (Case & Katz, 1991); or instrumental variables whereby peer drug use and ego’s drug use are estimated simultaneously. The latter method requires that the researchers identify a variable which predicts peer drug use but which can be validly omitted from the model for ego’s drug use. Examples include mean grademate background characteristics (Gaviria & Raphael, 2001) and neighbourhood-level socioeconomic indicators (Evans, Oates, & Schwab, 1992). Because these characteristics will often be functionally related to the peer status of ego and alter, their omission from the model for ego’s drug use is difficult to defend.

The reliance in the economics literature on assumed peer interactions and network ties within a common school or address owes in part to conventions of data collection. Information on friendships and ties were not, until recently, conventionally collected within economics (Manski, 2000). However, the availability of datasets such as the Add-Health (c.f. Clark & Lohéac, 2007) and ESPAD (c.f. McVicar, 2011) has enabled the location of peer effects using reference groups where
interactions are not wholly assumed, i.e. nominated friends. Furthermore, this has allowed for further innovation in the pursuit of valid instrumental variables, namely the characteristics of network members who are friends of ego’s friends but not nominated by ego herself (Bramoullé, Djebbari and Fortin, 2009). These can be validly omitted on the basis that ego do not interact directly with this group but that her friends are exposed to their characteristics.

**Confluence of interests**

Until recently, these distinct sub-disciplines pursued different questions as outlined. However, it is increasingly clear these questions cannot be considered wholly in isolation from one another. The questions can be viewed as complimentary: if the association between friends’ behaviour and ego’s is causal, the association should stronger where relationships are more intense and clusters more cohesive (Oetting & Beauvais, 1987; Vásquez, 2010). One reason for this is the two-versus one scenario raised by Kobus and Henry (2010). They argue (with due attribution to Simmel and Wolff, 1950), that a defining feature of tightly-knit clusters is the occurrence of triads, groups of three people where each has a friendship with the other two. This makes the individual more susceptible to influence, because they are placed in a two-versus-one situation. It follows that influence would be less salient if a person’s two drug-using friends had no relationship with one another, as the two-versus-one scenario would not arise. Similarly, it seems likely that the effect on drug use of network position relative to a friendship cluster will vary depending on the prevalence of drug use in the cluster.

Furthermore, there are affinities between the theoretical drivers of different disciplines. Consider, for example, the *Strength of Weak Ties* account of normative diffusion provided by Granovetter (1973; 1983). A person with a strong tie to a group, under Granovetter’s formulation, has consistent, emotionally intense and reciprocal relationships with other group members. A person with weak ties to the group (or multiple groups) either has less consistent or intense relationships with group members, or has consistent and intense relationships with only *some* group members. Granovetter
argues that weak ties are important agents within the network. Because they are not strongly
tached to a single group, they will likely move between groups, forming ties at the periphery in an
effort to gain full group acceptance and membership. In the process of moving between groups,
these individuals carry information about overall norms which would not transfer between groups if
all network members were firmly attached and embedded in one group.

Considering drug use, the corollary of this theory is that clusters which are internally cohesive to the
point of being exclusive, and, hence, have no weak ties and are without any drug using members to
begin with, will be protected and insulated from countervailing norms around drug use. This account
suggests drug use uptake may be most likely for those with a mix of strong and weak ties and that
there is curvature in the association between cluster interconnectedness and drug use. This mix of
strong and weak ties best describes the “liaisons” described as at risk by Henry and Kobus (2007). As
well as transmission of norms, this construct may relate to how drugs are physically obtained and
traded between individuals in a network. Here, the economic interest in drugs as tradable
commodity and as consumer good aligns with the application of this sociological construct. As well
as transmitters of norms, weak ties can also be constructed as facilitators of trade.

This hypothesis appears initially to be contradictory of the intensity hypothesis and of Peer Cluster
Theory (Oetting & Beauvais, 1987), which posit that individuals are more responsive to friends with
whom they share more intense bonds. In fact, the two are compatible and can be thought of as
complimentary. In essence, Grannovetter’s construct suggests how, on a group level, drug use can
initially penetrate the borders of a peer cluster. The intensity hypothesis then predicts how
individual cluster members will respond to drug use within their cluster, based on

Again, a line can be drawn between this account and theoretical writing in Economics. Becker’s
model of interaction effects (Becker, 1974) described how the normal utility formula for an
individual’s consumption of a given is augmented by the personal cost of being at a different level of
consumption to peers. Extending this analysis, the individual has more to lose from having their
behaviour differ from a reciprocating friend than they do from a non-reciprocating one: a closely-held friendship is potentially at stake if the individual does not conform.

Towards a parsimonious approach

Few empirical social network-oriented studies directly account for the effect of peers’ outcomes alongside network position, two exceptions being those of Ennett and colleagues (2007) and Kobus and Henry (2010). Ennett and colleagues found three measures of social proximity to cannabis, alcohol and cigarette use all to be significant predictors of ego’s own use, while also finding high social status and social isolation to predict use of alcohol and cannabis use. Kobus and Henry (2010) reported significant interaction effects between network position and peer influence. Peer effects for cigarette use were stronger for those in a central or isolated position, whereas the opposite was found for cannabis, for which peer effects were strongest for liaisons.

The ability to address the extents both of behavioural and relational peer effects hinges on the availability of data which describe ties within the network. The phase of innovation now underway and to which this study contributes is the integration of the different applications of these data such that greater understanding is reached, for example as to whether peer influence operates differently in different types of network or cluster, or whether individuals at the various network positions are differently susceptible to peer influence. However, perhaps the resource in most scant supply has been longitudinal data charting change in both cluster membership composition and behaviour across the cluster. Thus, many of the findings reviewed above are based on associations at a single point in time. The current study avails of one of the rare datasets containing such longitudinal information. Thus, its aim is twofold: to test the robustness of peer effects previously evidenced by cross-sectional studies; and to harness the aforementioned innovations in order to speak simultaneously to the importance both of peers’ behaviour and of peer group structure.
Hypotheses

This study retests the intensity hypothesis and the findings of Vasquez (2010), that the influence of peers increases in strength where peer interactions with the individual are more regular, intense and intimate. It is also hypothesised that a curvilinear relationship exists between drug use and indicators of network position and cluster density. Though network position is operationalised differently, this second hypothesis flows directly from the finding of Henry and Kobus (2007) that drug use uptake is most likely among those whose proximity to a friendship cluster lies between the extremes of network centrality and isolation. This second hypothesis also serves to test whether “weak ties” and cluster openness aid the transmission of norms (Granovetter, 1973; 1983), as well as the physical movement of drugs.

Methods

The current study avails of data from three consecutive waves of the Belfast Youth Development Study (BYDS). This is an ongoing survey-based longitudinal study of young people who attended one of 42 schools across Belfast and two nearby towns in Northern Ireland. Entry point to the current study is the second wave, collected in 2001/2002 when participants were aged between 12 and 13. Ethical approval for data collection was obtained from the Ethics Committee of the Queen’s University Belfast School of Sociology. Participants were fully informed of the nature and purpose of the study and their consent assumed by their agreement to complete the questionnaire. Participants’ parents could also withdraw consent for participation ahead of the data collection.

Cannabis use was measured within an array of self-report items pertaining to drug use experience in several categories. The outcome in the current study is a positive response to an item asking pupils if they had used cannabis in the previous 12 months. The dataset also contains an array of explanatory variables associated in the literature with intoxicant use, including sex, age, household structure, socioeconomic structure (using the proxy variable of number of cars in the household) and engagement with education.
Surveys in each wave included an identical field asking each pupil to name up to 10 individuals from their year group whom they considered friends or liked to spend time with. This allowed for cannabis use prevalence among identified friends to be calculated and also for the structure of the friendship cluster to be explored.

The samples used in the current study are restricted to those with valid responses on the aforementioned cannabis question and to individuals who name at least two friends, as this is required to obtain valid transitivity scores. Wave 3 cross-sectional results are based on a sample of 4,206 participants. Longitudinal analysis is conducted on two available panels: those satisfying the above criteria in at least two of waves 2, 3 and 4 (N = 4213), and those satisfying the criteria in all three waves (N = 2707).

**Parameters of network and cluster structure**

*Reciprocity*

This is the rate at which ego’s nominated friends nominate them reciprocally. This was calculated by counting the number of friends who nominated ego in return, and dividing this number by the total number of friends who also responded in the same wave.

*Transitivity and Convergence*

Whereas the reciprocity index reflects the extent to which ego’s friendship is accepted by her cluster of friends, transitivity and convergence reflect the extent of interconnectedness among the group ego has identified as her friends. The specific role of these two indices is to reflect whether the friends identified *function as a group of friends*, or comprise separate friendships or subgroups.

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2 As no substantial differences were found between the two panels, results from the larger unbalanced panel are reported here exclusively.
Transitivity refers to the existence of friendship triads involving ego and is calculated as the proportion of ego’s friends’ nominations which are given to another of ego’s friends, using the following formula:

(A.)

\[
\sum \left( \frac{1(\text{nom}_1 + \text{nom}_2 + \cdots + \text{nom}_n - \text{nom}_\text{Ego})}{\text{N}_f - 1} \right) + \left( \frac{2(\text{nom}_1 + \text{nom}_2 + \cdots + \text{nom}_n - \text{nom}_\text{Ego})}{\text{2N}_f - 1} \right) + \cdots + \left( \frac{\text{fn}(\text{nom}_1 + \text{nom}_2 + \cdots + \text{nom}_n - \text{nom}_\text{Ego})}{\text{fnN}_f - 1} \right)
\]

\*f = friend; nom = nominated (yes/no)

In descriptive terms, the denominator is the total number of friends nominated by ego who also completed the survey. The numerator is the sum of the proportions of ego’s friends’ friends who are also among ego's friends, minus the number of times ego herself is nominated by a friend.

Though transitivity is the key indicator of cluster structure used in the ensuing models, it is possible that cluster density and cohesion cannot be wholly captured by this index alone. At either end of its distribution, the transitivity index independently gives a clear picture of the connectivity of ego’s friends. If all nominations concur, then all cluster members will have a high score close to 1, which would clearly represent a dense and cohesive cluster with definite boundaries. If none of ego’s friends nominate one another and the score is close to zero, his friends do not function as a cluster at all. However, if half of nominations are concurred with, this index does not indicate whether every friend is nominating half of ego’s list without reciprocation, or if half of ego’s friends are reciprocally nominating one another. Though the latter scenario is intuitively more likely, in order to test whether peer effects differ in these scenarios.

(B.)

\[
\frac{2\sum (\text{nom}_1 + \text{nom}_2 + \cdots + \text{nom}_n - \text{nom}_\text{Ego})}{\sum (\text{nom}_1 + \text{nom}_2 + \cdots + \text{nom}_n + \text{nom}_1 + \text{nom}_2 + \cdots + \text{nom}_n)}
\]
The convergence index is, in effect, the intra-cluster reciprocity among ego’s friends. It is calculated using the numerator, number of instances when one of ego’s friends reciprocates a nomination from another of ego’s friends. This is divided by the number of times one of ego’s friends nominates another. When entered into a model alongside transitivity, convergence adjusts for the potentially distinct structures represented by a score of in the middle of the transitivity distribution. Entered together into the model, the two indices jointly capture the existence of a friendship cluster and the degree of openness or exclusivity of that cluster.

**Turnover**

In models which use multiple waves, this index is used to take account of the role of homophilic selection processes. It reflects the proportion of a person’s friends who were not nominated as friends in the previous year.

**Indegrees**

This index is adapted from the SIENA platform (Ripley & Snijders, 2010). In the current study, the term refers to the number of individuals outside of ego’s nominated cluster who nominate ego. It serves as a further surrogate for popularity and possible network interactions and ties beyond the immediate boundaries of friends.

**Empirical Modelling**

This paper focuses both on main effect estimates of the associations between cannabis use likelihood and the various predictors outlined above, including friends’ cannabis use and network parameters; and on interactions between those predictor variables within reduced-form models of responsiveness to peer interactions and behaviour. Models specifications are first explored in a cross-sectional Ordinary Least Squares regression, using data from wave 3 of BYDS. The model adjusts for correlated effects using dummy variables representing the school the individual attended. In addition to the aforementioned network parameters, the square of each term is also
included in multiple iterations of the model, allowing for a test of whether a curvilinear relationship exists between these indices and likelihood of cannabis use.

In order to minimise any upward bias in estimates owing to reverse causality (whereby ego’s behaviour is influencing friends’ behaviour and/or the shape of her network), models are re-tested using a fixed effects model, constructed using waves 2 through 4 of BYDS. This model effectively expresses change in the cannabis use outcome as a function of change in the predictors. Explanatory variables included in the model are restricted to those which can vary within the period of the study, such as household structure. Stable characteristics such as gender can be validly omitted, assuming the effects of these characteristics are fixed, i.e., already captured in the baseline value of the individual’s behaviour.

Results

Main effects

Cluster parameters

Indices pertaining to cluster structure and ego’s proximity to the cluster are shown to be associated with likelihood of cannabis use, though the magnitude and sign of these effects vary depending on the specification of the model. In the cross-sectional model, greater reciprocity from nominated friends appears to be positively associated with greater likelihood of cannabis use (Table 1). However, this is only significant when either friends’ cannabis use or transitivity of nominations are also in the model, suggesting multiple interaction effects. This suggestion is born out where interaction terms are included in the models described in Table 2 and Table 3 and are further discussed further.

Transitivity is negatively associated with likelihood of cannabis use in all models, again suggesting that the more agreement there is among an individual’s friends on the membership composition of a group or cluster, the less likely that the individual has used cannabis. Cannabis users are found to
identify with more open, diffuse, less interconnected and cohesive groups. However, the fixed effects estimator puts the magnitude of this effect much lower than the cross-sectional model, with the coefficient dropping from -0.14 in Table 1 to -0.47 in Table 3. This suggests a simultaneity bias whereby ego’s cannabis use may be influenced by the structure of her network, but may also influence the type of friendship networks which she joins, with the suggestion that friendship cohesion may be a lower priority for cannabis users than for non-users.

No independent effect of convergence is found in any model; hence we only report the relevant coefficients in Tables 1. This suggests that, while the possibility exists that equivalent transitivity scores may represent differently shaped clusters, this variation is not sufficiently high as to affect the coefficient for transitivity. Additionally, no curvilinear effect is apparent for either the transitivity or convergence indices, suggesting no evidence for the idea conveyed in hypothesis 2 that “weak ties” are required for pro-cannabis norms to be diffused to members of a cluster, or for trade and experimentation with cannabis to take place.

In all models, coefficients for indegrees were small, positive and statistically significant. In OLS models, coefficients were all ~0.015 (SD = 0.005), suggesting that receiving an additional 10% of nominations from outside named friends is associated with 1.5% additional likelihood of cannabis use. This coefficient diminishes to 0.05 (SD = 0.02) in fixed effects models, suggesting some of the cross-sectional coefficient may be biased by reverse causality, whereby cannabis use affects popularity rather than vice versa.

(INSERT TABLE 1 ABOUT HERE)

Friendship “turnover”

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3 No curvilinear effects were suggested by the inclusion into the model the square of any of the cluster parameters. Results are not shown in the interest of conserving space, but are available on request.
Lower continuity in friendship nomination is strongly associated with greater likelihood of cannabis use (Table 3). This supports the idea of drug use taking place against a backdrop of network instability. As discussed in the context of transitivity, social churn may be a condition which exposes an individual to more behavioural possibilities and normative influences.

**Friends’ cannabis use**

The main effect for friends’ cannabis use is estimated at a range of values in tables 1-3. In all cases, the effect is positive, indicating that, as shown throughout the literature, ego is more likely to have used cannabis where a greater proportion of ego’s friends have used cannabis. The magnitude of coefficients are lower in fixed effects models (~0.35; Table 3) than in cross-sectional models (~0.6; Tables 1 & 2), suggesting that fixed effects models are successful in removing some of the simultaneity bias which causes cross-sectional associations.

**Interaction effects**

There is some evidence of an interaction effect between reciprocity and transitivity, born out in both cross-sectional models (Tables 2) and fixed effects (Table 3). This indicates that the negative association between less transitivity and greater likelihood of cannabis use partly captures an association between reciprocity and cannabis use.

In the case of reciprocity, strong interactions with both transitivity and friends’ cannabis use are key to understanding how it effects cannabis use, as reciprocity coefficients are non-significant where those variables are omitted. Taken together, the results indicate that the association between reciprocity and an individual’s cannabis use probably captures influence from those reciprocating friends. Furthermore, the interaction terms in Tables 2 and 3 suggest that the peer effect of friends’ cannabis use is greater where friends have reciprocated ego’s nomination, supporting the intensity hypothesis.
There is little clear evidence of an interaction effect between cannabis use prevalence and transitivity of nominations among ego’s nominated friends. Where significant interaction coefficients appear in cross-sectional models (Table 2), they suggest that cannabis use prevalence is more salient at lower levels of transitivity, so long as the \textit{reciprocity X friends’ cannabis prevalence} interaction is already adjusted for. Results were inconclusive as to the existence of a three-way interaction between reciprocity, transitivity and peer behaviour, though the positive sign on this interaction term in the cross-sectional model suggests that friends’ use is more influential where both reciprocity and transitivity are high.

\textbf{(INSERT TABLE 2 ABOUT HERE)}

Clear also is the evidence for a positive interaction effect between friendship turnover and cannabis prevalence among friends. Furthermore, the addition of this interaction term causes a diminution in the strength of the effects of all of the above predictors. This indicates that new friends who are cannabis users have a significant influence on behaviour, and that the influence of friends’ cannabis use overall depends on the proportion of friends who are new to ego’s friends and use cannabis.

\textbf{(INSERT TABLE 3 ABOUT HERE)}

\textbf{Post-hoc analysis: Discrete influence from reciprocating and non-reciprocating friends}

The strong interaction effect of \textit{reciprocity X friends’ cannabis use} suggests that behavioural influence is not necessarily weighted equally across ego’s friends. To explore this more fully, effects were modelled from mutually exclusive groups of school peers, using discrete prevalence indices, along the lines suggested with respect to discrete modelling of friends and non-friends in Moriarty, McVicar and Higgins (2012). This approach is used to assess the relative influence of mean cannabis use among friends who reciprocate ego’s friendship nomination versus mean cannabis use among those who do not.
Initially, the wave 3 cross-sectional OLS model is augmented such that two separate terms representing the effect of each group’s cannabis use prevalence. This model is then retested using the fixed effects approach using longitudinal values for both groups’ cannabis use prevalence in waves 2, 3 and 4.

Table 4 suggests that both groups appear quite influential where the average behaviour of either group is entered as a stand-alone predictor. However, when both terms are entered together, there is a diminution in the size of the coefficient for non-reciprocating friends’ cannabis use. When the individual fixed effects estimator is used, the coefficient for reciprocating friends’ cannabis use falls to circa 0.24. The fact that this estimate of the effect of reciprocating friends’ behaviour is at over twice the magnitude of that of non-reciprocating friends is further support for the intensity hypothesis: friends at greater proximity and with whom more intense relationship exist exert a greater influence. However, it is also noteworthy that the behaviour of non-reciprocating friends remains statistically significant in all models. What is more, the two coefficients in this model sum to a value which resembles the overall effect estimated for friends’ use using fixed effects in Table 3. This suggests that, while reciprocating friends are the dominant influence within the friendship cluster, the behaviour of non-reciprocating friends also makes up a valid component of the peer effect from friends’ use.

(INSERT TABLE 4 ABOUT HERE)

**Discussion**

This paper underlines the value of integrating various approaches and outlooks on social networks and friendship clusters when considering the influence of peers on drug use behaviours and decisions. This represents an early attempt, using highly amenable data, to account simultaneously for behavioural and structural peer effects. The availability of longitudinal data covering key developmental period of adolescence renders the estimates presented highly plausible estimates of the underlying causal effect. The novelty of these results is increased by the inclusion of post hoc
analyses in which discrete behavioural influence of reciprocating and non-reciprocating friends are modelled separately within each model, a novel strategy for examining the intensity hypothesis.

Results suggest that network position and cluster structure have some direct effect on behaviour, though the actual behaviour of friends appears, from interaction effect models, to be the main driver of peer effects. Negative associations were found between cannabis use and both reciprocity from nominated friends and transitivity of nominations to cluster members. This suggests that being more embedded within a social group and experiencing greater group cohesion at the cluster level are protective factors against drug use during the age period observed. No curvilinear effects were apparent from the inclusion into the model of a squared terms for any of the cluster parameters. Therefore these findings more closely corroborate the risk to social isolates posited by Ennett and Bauman (1993), rather than the risk identified by Henry and Kobus (2007) to those positioned between isolation and centrality. Note however that participants in the latter study were 16 years old and thus older than participants in both the current study and that of Ennett and Bauman. Henry and Kobus accept in their discussion that the risk to peripherals may develop in later adolescence. While those residing “in between” group attachment and total isolation may be at greater risk in later adolescence, the results presented here suggest that those peripheral to clusters or in clusters with little internal cohesion were most likely to use cannabis.

The interactive effects of friends’ cannabis use and transitivity of nominations illustrates most clearly the complex dynamic between structural and behavioural effects. The main effect for transitivity on cannabis use is negative, suggesting cannabis use is less likely where friends nominate on another more often. This relationship between cannabis use and lower transitivity coheres strongly with Grannovetter’s *Strength of Weak Ties* (1973). Clusters with higher transitivity of nominations are those which have fewer weak ties and are therefore more “closed”. Participants whose clusters had lower transitivity may be exposed to a wider sphere of influences across the overall network and may have more means of obtaining information about drug use and supply. However, the
interaction between transitivity and friends’ mean cannabis use suggests that friends’ cannabis use is more influential and salient for ego when ego’s friends form a tightly-knit cohesive cluster. Therefore the main effect of cluster structure needs to be distinguished from the interaction effect. Drug use prevalence being equal, greater cohesion is protective against drug use. However, if drug use is more prevalent within the group, then greater cohesion makes members more likely to follow suit.

Estimates of the relative behavioural influence of reciprocating and non-reciprocating friends lends further support to the intensity hypothesis, that influence is greater where friendships are more intense. The behaviour of a reciprocating friend is more observable to ego because they spend a greater amount of time together. Also, through the discourse within friendship, ego will come to know about their reciprocating friends’ behaviours better than through discourses with a grademate whom they admire from afar. Ego has more to lose from having their behaviour differ from a reciprocating friend than they do from a non-reciprocating one, as a closely-held friendship is potentially at stake if ego does not conform. If ego’s drug use does differ from their friend’s, there is more scope to purposely influence ego to change their behaviour if the friendship is reciprocal. However, this result also demonstrates some influence from friends who do not reciprocate. Whereas the former effect may represent one type of direct peer influence, the latter may represent a more aspirational mechanism whereby individuals try to “attain” friendships through mimicry of admired others.

Another significant contribution of the longitudinal dimension of this research that it enables comment on the extent to which of homophilic selection augments peer effect estimates. Because individuals befriend others with similar traits and interests, an association between ego’s behaviour and friends’ behaviour may represent the combined effects of peers influencing behaviour and of individuals selecting drug using peers as friends. In the longitudinal model, the “Turnover X Cannabis Use” interaction term reflected the proportion of friends who were newly nominated and had used
cannabis in the previous year. Other authors have suggested that selection of cannabis using peers accounts for approximately half of the association between ego’s behaviour and peer behaviour (Kirke, 2006; Kiuru, Burk, Laursen, Salmela-Aro, & Nurmi, 2010). If this were to hold in the current model, the peer effect would be moderated to a much greater degree by the inclusion of this parameter. It is clear from both interaction models that the behaviour of new friends has a significant effect, but that overall friends’ cannabis prevalence continues to be a significant factor.

Additionally, the independent effect on cannabis use of “turnover”, or the proportion of new friends named is of importance. This showed cannabis use to be more likely in more volatile network groups. This should be considered alongside main effect for transitivity. There is mounting evidence that being in an insecure position at the margins of friendship clusters, or having friends who do not share cohesive bonds with another are risk factors for the onset of drug use, as attested by Ennet (2006); Henry and Kobus (2007) and the current study. These marginal individuals may use drugs to impress and court new friends, or as a reaction to stress or rejection. Alternatively, their befriending may be linked to supply and the need to make new contacts. This finding gives additional support to Granovetter’s Strength of Weak Ties (1973).

This study shares a limitation with much of the literature, which is that only a selected subset of peers is observed. Missing from the data is any representation of the type of ties ego has outside of the school grade boundary, and behaviour in those alternative peer reference groups. Furthermore, there is no way of verifying how friendship nominations map onto day-to-day interactions with peers. Even if self-reported friendship intensity were available, it would be very difficult to model alongside peer behaviour without creating further problems of endogeneity.

Adding further depth to social network-based research and further testing its validity are challenges for future research. One promising avenue is the use of Ecological Momentary Assessment (EMA; Shiffman, Stone, & Hufford, 2008)). This method requires participants to report on phenomena such as health, mood, behaviours and, in this instance, social interactions, in real time using devices such
as electronic diaries. By incorporating this technique into a follow-up study alongside a replication of the survey-based nomination field, researchers could obtain two important pieces of evidence: how often is there actual interaction between ego and each of their nominated friends (and, by extension, how does this day-to-day intensity moderate their influence on ego’s behaviour); secondly, what proportion of social interaction is with individuals outside of the boundaries of school.
References


Clark, A. E., & Lohéac, Y. (2007). "It wasn't me, it was them!" social influence in risky behaviour by adolescents. *Journal of Health Economics, 26*, 763-764-784. doi:10.1016/j.jhealeco.2006.11.005


Table 1: Friends’ cannabis use, reciprocity, transitivity & convergence as independent predictors of cannabis use

<table>
<thead>
<tr>
<th>Peer Effect (Friends’ mean)</th>
<th>Reciprocity</th>
<th>Transitivity</th>
<th>Convergence</th>
<th>Nobs</th>
<th>R-squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>0.030</td>
<td>-</td>
<td>-</td>
<td>4206</td>
<td>0.166</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-0.087***</td>
<td>-</td>
<td>4206</td>
<td>0.168</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.052</td>
<td>4206</td>
<td>0.167</td>
</tr>
<tr>
<td>-</td>
<td>0.087***</td>
<td>-0.129***</td>
<td>-0.019</td>
<td>4206</td>
<td>0.169</td>
</tr>
<tr>
<td>0.579***</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4206</td>
<td>0.240</td>
</tr>
<tr>
<td>0.572***</td>
<td>0.057***</td>
<td>-</td>
<td>-</td>
<td>4206</td>
<td>0.243</td>
</tr>
<tr>
<td>0.567***</td>
<td>-</td>
<td>-0.062***</td>
<td>-0.020</td>
<td>4206</td>
<td>0.242</td>
</tr>
<tr>
<td>0.567***</td>
<td>-</td>
<td>-</td>
<td>-0.020</td>
<td>4206</td>
<td>0.241</td>
</tr>
<tr>
<td>0.567***</td>
<td>0.126***</td>
<td>-0.140***</td>
<td>0.005</td>
<td>4206</td>
<td>0.245</td>
</tr>
</tbody>
</table>

*** p < 0.01; ** p < 0.05; * p < 0.1
<table>
<thead>
<tr>
<th>Behavioural effect: friends' mean cannabis use</th>
<th>Reciprocity</th>
<th>Transitivity</th>
<th>Reciprocity * Transitivity</th>
<th>Reciprocity * Friends' Cannab</th>
<th>Transitivity * Friends' Cannab</th>
<th>Reciprocity * Transitivity * Friends' Cannab</th>
<th>Nobs</th>
<th>R-squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.571 *** (0.045)</td>
<td>0.024</td>
<td>-0.256 ***</td>
<td>0.193 *</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4206</td>
<td>0.246</td>
</tr>
<tr>
<td>0.580 *** (0.040)</td>
<td>0.105 ***</td>
<td>-0.117 ***</td>
<td>0.316 ***</td>
<td>-0.020</td>
<td>0.042</td>
<td>-</td>
<td>4206</td>
<td>0.247</td>
</tr>
<tr>
<td>0.458 *** (0.069)</td>
<td>0.003</td>
<td>-0.200 *</td>
<td>0.318 ***</td>
<td>-0.182 *</td>
<td>0.048</td>
<td>-</td>
<td>4206</td>
<td>0.249</td>
</tr>
<tr>
<td>0.450 *** (0.069)</td>
<td>-0.080</td>
<td>-0.209 **</td>
<td>0.196 *</td>
<td>0.318 ***</td>
<td>-0.182 *</td>
<td>-</td>
<td>4206</td>
<td>0.249</td>
</tr>
<tr>
<td>0.594 *** (0.029)</td>
<td>-0.006</td>
<td>-0.082</td>
<td>0.028</td>
<td>0.097</td>
<td>-0.543 **</td>
<td>0.498</td>
<td>4206</td>
<td>0.250</td>
</tr>
</tbody>
</table>

*** p < 0.01; ** p < 0.05; * p < 0.1
### Table 3: Fixed Effects (Balanced Panel) : Mean cannabis use X network parameters

<table>
<thead>
<tr>
<th>Behavioural effect: friends’ mean cannabis use</th>
<th>Reciprocity</th>
<th>Transitivity</th>
<th>Friendship Turnover</th>
<th>Reciprocity * Trans</th>
<th>Reciprocity * Friends’ Cannabis</th>
<th>Transitivity * Friends’ Cannabis</th>
<th>Reciprocity * Transitivity * Friends’ Cannabis</th>
<th>Turnover * Friends’ Cannabis</th>
<th>N Obs (People)</th>
<th>R-squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.463*** (0.022)</td>
<td>0.035 (0.022)</td>
<td>-0.047* (0.026)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10472 (4213)</td>
<td>0.210</td>
</tr>
<tr>
<td>0.373*** (0.023)</td>
<td>0.029 (0.021)</td>
<td>-0.029 (0.026)</td>
<td>0.160*** (0.013)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10472 (4213)</td>
<td>0.204</td>
</tr>
<tr>
<td>0.211*** (0.048)</td>
<td>-0.036 (0.025)</td>
<td>-0.031 (0.026)</td>
<td>0.163*** (0.013)</td>
<td>-</td>
<td>0.238*** (0.062)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10472 (4213)</td>
<td>0.203</td>
</tr>
<tr>
<td>0.180** (0.084)</td>
<td>-0.087** (0.037)</td>
<td>-0.114** (0.053)</td>
<td>0.111*** (0.016)</td>
<td>-</td>
<td>0.161 (0.114)</td>
<td>-0.148 (0.167)</td>
<td>-</td>
<td>-</td>
<td>10472 (4213)</td>
<td>0.201</td>
</tr>
<tr>
<td>0.105* (0.059)</td>
<td>-0.114*** (0.037)</td>
<td>-0.156*** (0.052)</td>
<td>0.111*** (0.016)</td>
<td>-</td>
<td>0.271*** (0.072)</td>
<td>0.022 (0.083)</td>
<td>-</td>
<td>0.197** * (0.053)</td>
<td>10472 (4213)</td>
<td>0.201</td>
</tr>
<tr>
<td>0.180** (0.084)</td>
<td>-0.087** (0.037)</td>
<td>-0.114** (0.053)</td>
<td>0.111*** (0.016)</td>
<td>0.105** (0.052)</td>
<td>0.161 (0.114)</td>
<td>-0.148 (0.167)</td>
<td>0.226 (0.194)</td>
<td>0.197** * (0.053)</td>
<td>10472 (4213)</td>
<td>0.201</td>
</tr>
</tbody>
</table>

*** p < 0.01; ** p < 0.05; * p < 0.1
<table>
<thead>
<tr>
<th></th>
<th>Reciprocating friends’ cannabis use, coefficient (robust standard error)</th>
<th>Non-reciprocating friends’ cannabis use, coefficient (robust standard error)</th>
<th>Nobs</th>
<th>R-squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLS, school dummies:</td>
<td>0.417*** (0.025)</td>
<td>-</td>
<td>4206</td>
<td>0.226</td>
</tr>
<tr>
<td>Reciprocating only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OLS, school dummies:</td>
<td></td>
<td>0.138*** (0.027)</td>
<td>4206</td>
<td>0.166</td>
</tr>
<tr>
<td>Non-reciprocating only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OLS, school dummies:</td>
<td>0.404*** (0.026)</td>
<td>0.081*** (0.022)</td>
<td>4206</td>
<td>0.235</td>
</tr>
<tr>
<td>2 groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed Effects: 2 groups</td>
<td>0.230*** (0.022)</td>
<td>0.086*** (0.014)</td>
<td>9876 (3881)</td>
<td>0.170</td>
</tr>
</tbody>
</table>

*** p < 0.01; ** p < 0.05; * p < 0.01