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*Multidimensional homophily in friendship networks**

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Abstract

Homophily—the tendency for individuals to associate with similar others—is one of the most persistent findings in social network analysis. Its importance is established along the lines of a multitude of sociologically relevant dimensions, e.g. sex, ethnicity and social class. Existing research, however, mostly focuses on one dimension at a time. But people are inherently multidimensional, have many attributes and are members of multiple groups. In this article, we explore such multidimensionality further in the context of network dynamics. Are friendship ties increasingly likely to emerge and persist when individuals have an increasing number of attributes in common? We analyze eleven friendship networks of adolescents, draw on stochastic actor-oriented network models and focus on the interaction of established homophily effects. Our results indicate that main effects for homophily on various dimensions are positive. At the same time, the interaction of these homophily effects is negative. There seems to be a diminishing effect for having more than one attribute in common. We conclude that studies of homophily and friendship formation need to address such multidimensionality further.

Keywords: *homophily, network evolution, stochastic actor-oriented models, adolescent networks*

1 Introduction

Already Georg Simmel emphasized the way in which individuals are involved in multiple dimensions of social life. Individuals occupy unique social positions through

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the combination of individual attributes and voluntary associations. And it is at the intersection of so-called "social circles" where identity is construed (Simmel, 1950: 135). Despite modern times being characterized by unprecedented opportunities to combine individuals' attributes and memberships, thus, situating individuals in a multidimensional social space (see also Blau & Schwartz, 1984) only little is known about how this multidimensionality affects network dynamics—the formation and dissolution of social relationships. Existing studies of network dynamics consider, for example, the importance of similarities between actors on various dimensions, such as age, education, or sex, for the likelihood that a network tie forms or dissolves between these actors. These dimensions are usually investigated separately, sometimes, controlling for one another. A substantive difference between individuals having one or more attributes in common, however, is rarely made. Studies of network structure do not investigate the qualitative difference that arises when individuals are similar on more than one attribute, i.e. the interaction of homophily on different dimensions.

Such interactions of homophily effects, however, are potentially important for understanding the emergence of integration or segregation in network contexts. A positive interaction effect (combined with positive homophily effects), i.e. people seek contact to those who are similar on as many dimensions as possible, would amplify clustering in disconnected, homogenous groups. Conversely, a negative interaction, i.e. decreasing returns for similarity on many dimensions, would lead to individuals seeking social contact to others who are similar in some, but not in all ways and allow heterogeneous groups to form.

This article aims to contribute filling the gap concerning multidimensional homophily in the literature. Drawing on panel data of friendship networks in eleven school classes and stochastic actor-oriented network models, we investigate the evolution of friendship relationships. Such a strategy allows us to investigate the interaction of homophily on different dimensions, while controlling for a large array of other relational and proximity based mechanisms.

Our findings indicate that in all school classes, across three different settings, individuals who have the same sex, ethnicity, family affluence and similar pocket money are more likely to become friends with each other than those who are not, which confirms previous findings of homophily. At the same time, perhaps counter-intuitively, the interaction of homophily effects is negative. For example, having the same sex and being of the same ethnicity makes a social relationship less likely to form than the combination of both effects would suggest.

These findings indicate that reducing individuals to single dimensions does not account for the complex nature of social relationships. Besides controlling for various homophily effects, we need to focus on the qualitative difference that arises at the intersection of attributes locating individuals at unique positions in social space. Such a perspective promises to advance our understanding of integration and segregation in network contexts.

The remainder of the article is structured as follows. First, theoretical considerations are presented. Next, the data and the methods are introduced. This is followed by a presentation of results, their discussion and some concluding remarks.

2 Theoretical considerations

2.1 Homophily

Homophily, defined as the "tendency for friendships to form between those who are alike in some designated respect" (Lazarsfeld & Merton, 1954: 23), is the most important covariate-based mechanism that guides network evolution. A large body of research confirms the prevalence of homophily in social networks. In over one hundred studies, it has been detected in one form or another (McPherson et al., 2001). For example, it has been shown along the lines of race and ethnicity (Goodreau et al., 2009; Quillian & Campbell, 2003; Blau, 1984; Marsden, 1987; Shrum et al., 1988), age (Fischer, 1977; Feld, 1982; Marsden, 1987), religion (Laumann, 1973; Verbrugge, 1977), education (Marsden, 1987; Louch, 2000), occupation (Laumann, 1973; Kalmijn 1998), sex (Smith-Loving & McPherson, 1993; Marsden, 1987), but also along the lines of values (Huston & Levinger, 1978) and behavior (Knecht et al., 2010; Cohen, 1977; Kandel, 1978; Alexander, 2001).

Although homophily shapes social networks in many ways, including but not limited to advice, marriage, support, exchange and co-membership, in this article we focus on homophily in friendship ties among adolescents. We do this for two reasons. First, adolescence is a period of re-orientation from family to same age peers. Friendship begins to play an important part in individuals' lives, much more than in childhood and later adult life (Steinberg & Morris, 2001). Second, in order to study homophilous friendship choices it is necessary to control for endogenous network processes, which requires a complete network approach, i.e. all friendship choices in a closed network need to be known. Schools classes proved to be an excellent setting for such kinds of studies meeting these requirements.[1]

Several arguments explain why homophily is so prevalent in friendships and how it comes about. For example, it has been suggested that it is rational for actors to form social relationships with similar others; actors are assumed to decide by themselves with whom they want to be friends. McPherson & Smith-Lovin (1987) refer to similarities based on such preferences as choice homophily. It is argued that similarity of attributes and experience simplifies the process of evaluating, communicating with, and even predicting the behavior of others (see also Festinger & Hutte, 1954; Hamm, 2000; Werner & Parmelee, 1979; Ibarra, 1992). The risks and costs that go along with the formation of new social relationships are lower for ties between similar actors. Having something in common (for example being of the same age, sharing a cultural background, speaking the same language or dialect) can make it easier to establish trust and solidarity between individuals, both characteristics of friendships. Furthermore, not only the formation, but also the maintenance of ties with similar counterparts may be less costly than maintenance of ties with dissimilar others (Felmlee et al., 1990; Leenders, 1996).

Another account suggests that similar people occupy positions in social space that are proximate to each other, and in consequence, similar people are more likely to meet (Blau, 1977; Feld, 1981, 1982). This perspective emphasizes that opportunities

[1] Of course, our study remains limited to friendship networks among adolescents. Further research could examine other settings as well.

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for meeting and interacting with others are pivotal for social relationships. One cannot become friends with somebody if one never comes in contact with that person. Such a perspective has been developed by Feld (1981), who introduced the notion of focused choice. Foci, defined as "social, psychological, legal or physical objects around which joint activities are organized" (Feld, 1981: 1016), are seen as social structures which systematically constrain the formation and maintenance of social relationships. In Feld's (1982: 798) view, homophily is a likely outcome to the extent that "people draw their friends from foci, and foci bring homogeneous sets of people together."

While these two concepts are often presented as competing with each other, such a distinction is often less clear, especially in the context of friendship dynamics in schools. Adolescents in a school cohort most likely meet (and know) all other students in their cohort. Nevertheless, even within a school cohort there are social settings, such as organized activities, e.g. a soccer team, that provide opportunities and simplify the formation and maintenance of friendship ties. At the same time, adolescents actively choose which social activities they are part in. And these choices are often strongly influenced by what individuals perceive as stereotypical for somebody "like them"[2]. Often individuals do what they think is appropriate for somebody of their age, sex, ethnicity, or social class because similar other do these activities as well. Social Identity Theory (Hogg, 2006) extensively deals with how self-categorization into groups relates to engaging in activities that are perceived as stereotypical for a group-member. As a result, adolescents take part in certain activities, *because* they meet others that are similar to themselves through these activities. From this perspective, the mechanisms of preference and opportunity are amalgamated, as adolescents may prefer activities that create opportunities to meet similar others.

2.2 Multidimensional homophily

Despite consensus on the importance of homophily for social relationships as well as on the conceptualization of individuals as multidimensional beings, little is known about how both combine. Is there a qualitative difference in social relationships when individuals have more than one attribute in common? The literature is surprisingly silent on such multidimensional homophily. Feld (1982) implicitly acknowledges the multidimensionality of social life. According to him (1982: 798) "sets of people brought together by foci are [...] homogeneous in many respects." Therefore one can expect individuals to share more than one attribute with their friends. In another context, Blau (1977) as well as McPherson and Smith-Lovin (1987) focus on the correlation between individuals' attributes. When the correlation between attributes is high one will necessarily have to observe homophily across multiple attributes. In contrast, when the correlation between attributes is low, sharing a similar attribute

[2] This is strongly reflected in patterns of membership in sports teams of boys in different countries. While in many European Countries, most younger boys are members of Football (Soccer) teams, in parts of the USA most boys play Baseball while in e.g. New Zealand most boys play Rugby. It is unlikely that these patterns emerge because of differing preferences by countries, but that in different countries different activities are seen as stereotypical for young boys.

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with friends does not automatically mean that one shares other attributes with them as well.

Empirical studies treat multidimensional homophily to differing degree. For example Marsden (1987) analyzes homophily in discussion networks of Americans on different dimensions (sex, age, education, and ethnicity) using the 1985 General Social Survey not controlling for one another. Others study similarities between individuals on more than one attribute at the same time (Goodreau et al., 2009; Grund & Densley, 2012; Wimmer & Lewis, 2010; Preciado et al., 2012). Often, these studies apply multivariate designs in order to control for various homophily effects. But in the words of Schaefer (2010: 24), "while such research considers multiple dimensions simultaneously, thereby controlling for consolidation, models typically do not include interactions between dimensions. This implicitly assumes that interactions between homophily dimensions are independent or unimportant."

An exception is the study by Schaefer (2010). Using data from the 1985 General Social Survey, including information on socio-demographic characteristics (age, education, ethnicity, religion, sex) of the peers nominated by the respondents, Schaefer (2010) analyzed ego-networks and applied a set-theoretic approach to identify regularly occurring combinations of similarities between friends on multiple dimensions. Such multidimensional homophily was compared to a baseline model of the amount of multidimensional similarities between social contacts one would expect if ties in the network were assigned at random. The main finding of the analysis was that individuals form a significantly higher proportion of ties than expected to other individuals who are similar in at least three, but most often four or five socio-demographic dimensions. These findings, however, do not control for network dynamics or opportunity structures.

In spite of lacking theoretical and empirical research, there are good reasons to believe that the number of attributes one has in common with others matters. One can think of qualitative differences that arise through multidimensional similarities. For example, from a perspective that focusses on the returns of a tie it is reasonable to assume that individuals who are similar in more than one way are brought together even closer. If friendships between similar people are more rewarding, additional similarity could increase the value of a tie for an individual at the same effort and chances for a network tie to form between these individuals are elevated, more than what one would expect from the addition of separate dimensions of homophily alone. Similarities based on multiple grounds, e.g. cultural heritage, language, age, sex and so on, could develop stronger bonds between individuals. Taking a perspective that focusses on interaction and communication between people, multiple similarity might allow longer and deeper conversations that span multiple topics and allow relating different experiences to one another. In a similar fashion, network ties might be easier to maintain when individuals are similar in many respects.

At the same time, the opposite argument can be construed as well. Maybe there is a limit in how beneficial social relationships between similar others can be. A long tradition of research suggests that social network ties that bridge social settings and groups are beneficial because they provide access to a different set of individuals, with different thoughts, ideas, and knowledge and so on (Granovetter, 1973; Burt, 1992). In consequence, ties between individuals who are similar on many dimensions might be less beneficial.

Additionally, one can argue that similarities between individuals might generate opportunities for individuals to meet and become friends. However, such meeting opportunities do not necessarily have to translate into friendship ties. For example, individuals who do not like each other will not initiate a friendship tie simply because they meet more often. Therefore, multiple similarity will not make association between people more likely than similarity on one dimension.

Another perspective, originating in psychological research on identity (Tajfel, 1974; Tajfel & Turner, 1979; Turner, 1987; Hogg, 2006), suggests that within the context of one activity that is typical for adolescents with a certain attribute (e.g. boys), other dimensions are less salient and loose importance for the interaction between individuals. For example, when boys play soccer to meet other boys, similarity or dissimilarity on other dimensions might be less important; all that matters is similarity on the attribute that defines the activity. From this perspective, only one dimension at a time is salient for the formation of friendship ties, while others are pushed to the back. As a result, one could expect decreasing returns to similarity on multiple dimensions, as only one attribute at a time is considered—therefore, in any given context, adolescents are not more likely to choose others that are similar in multiple dimensions compared to others that are similar in only the dimension salient in the current context.

3 Data

We draw on friendship networks from three different sources: secondary schools in Scotland (the Glasgow data), England and Wales (the ASSIST data), and from middle schools in the United States (the DyNet data). In total, we use network data from eleven schools to investigate the interaction of homophily effects. For all eleven schools, repeated observations of the networks are available.

The three datasets vary considerably in composition of students, variables collected and in the method how the data was obtained. But this also means that any regularities we might find across datasets are unlikely to be artifacts of a specific data collection strategy or particular to a certain region or school.

Data from Glasgow were collected within the context of the *Teenage Friends and Lifestyle Study* (Pearson & Mitchell, 2000). All participants were members of one school cohort (aged 12–13) and were followed over a period of three years. Children were asked about demographic characteristics, lifestyle, and substance use patterns at the beginning of each academic year between 1995 and 1997. Furthermore, participants could nominate up to 6 persons in their year group as close friends. Previous studies using this data found strong homophily effects along the lines of sex and pocket money (e.g. Steglich et al., 2010). Friendship ties are more likely to evolve and persist between individuals who are similar on these attributes. Pocket money homophily is often interpreted as an approximation for the similarity in social status of parents (see appendix in Table A1 for descriptive statistics).

Data for Wales and England comes from the *A Stop Smoking In Schools Trial* (ASSIST) study. In a number of secondary schools, all members of a cohort were administered questionnaires once a year between 2002 and 2004, in which they indicated various demographic characteristics and substance use patterns. Similar to the Glasgow data, they were asked to nominate up to 6 friends within their

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cohort. Homophily effects have been found along the lines of sex and a so-called 'family affluence scale' (FAS). The FAS was measured with three items: 1) does the respondent's family own one or more cars, 2) did the family travel away from home one, two or more times over the last year, and 3) does the respondent have an own bedroom. A more detailed description of the data can be found in Steglich et al. (2012) (see appendix in Table A2 for descriptive statistics).

Lastly, data for the United States was collected in the *Dynamics in Networks* (DyNet) study. Data were collected in middle schools in the Unites States in Oregon and California between fall 2008 and spring 2012. All members of the participating middle schools (usually grades 6–8) were interviewed four times each academic year. For this study only the first year of the data is used. Students were asked to fill out a questionnaire concerning various demographic characteristics. Furthermore, they were asked to select on a list of all participating individuals in their school the ones they spend their free time with. Individuals nominated their best friends from this subgroup. In this data, homophily effects can be found with respect to sex and ethnicity. Table A3 in the appendix gives descriptive statistics.

One guiding principle for the selection of relevant attribute dimensions in this study is to remain focused on exogenous attributes that cannot be altered by individuals so easily. In contrast, endogenous attributes (e.g. political opinion, fashion taste), would introduce the additional issue of having to distinguish between effects driven by selection, influence, or influence specific to certain dimensions of social life.

Based on previous research that detected homophily along various dimensions in the three datasets, we decided to apply the following strategy: First, we examined all available attributes of individuals in each dataset and tested whether there is a significant homophily effect or not. Next, we chose to include the sex of students as a relevant dimension for our analyses as it was significant in all three datasets. Lastly, for each dataset we selected one additional attribute dimension on which homophily was found. There were no other attribute dimensions (besides sex) that were available (with a significant homophily effect) in all three datasets. The other, homophilous dimensions for the different datasets were pocket money (Glasgow data), FAS (ASSIST data) and ethnicity (DyNet data). All three variables have been found to matter for friendship dynamics in their respective setting. Sex, ethnicity and social status are generally the strongest exogenous predictors (apart from religion) of homophilous tie formation (McPherson et al., 2001).

4 Method

In order to investigate the role of individuals having one or more attributes in common for the dynamics of social relationships we draw on stochastic actor-oriented network models (SAOM's). These models were introduced by Snijders (2001; Snijders et al., 2010) and are implemented in RSiena (Ripley et al., 2014). At the core of these models are tie changes between network panel waves. Some relationships are formed and others disappear in time. These relational changes can be considered to be the outcome of the structural position of the actors within the network (as in the case of forming a tie to somebody because he/she is the friend of a friend), characteristics of the actor (e.g., some actors might be more or less

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attractive because of an attribute they possess), or characteristics of pairs of actors (for example, when two actors form a tie because they share a certain attribute). SAOM's have now been widely used for the study of network dynamics (van Duijn et al., 2003; van de Bunt et al., 2005; de Nooy, 2002; Schaefer et al., 2011) and the co-evolution of networks and actor behavior (Checkley & Steglich, 2007; Burk et al., 2007; Pearson et al., 2006; Steglich et al., 2010; Lewis et al., 2012).

SOAMs apply to longitudinal, complete, and directed network data and model change of network ties. Although networks are measured at discrete points in time, SAOMs model a continuing underlying process where many tie changes occur sequentially. Chains of such tie changes connect the networks that are observed at discrete points in time. Each individual change of one tie in the network is called a *mini-step*. A *mini-step* is modeled through two sub-processes. The first one selects the actor who is allowed to make a tie change. This is modeled through the *rate function*. In the current case we use a period-wise constant *rate function*, i.e. we assume no difference in the rate of change between actors. In the second step, the selected actor evaluates all potential changes in her personal network. To this end, the actor considers how each tie change (creation or deletion of a tie, as well as keeping the current state) would affect her personal network with regards to parameters specified by the researcher. The desirability of each potential outcome for the focal actor is modeled in the *objective function*. The *objective function* stands at the core of the SAOMs. It combines different factors that influence an actor's decision to change/leave ties, called effects. Examples for effects are reciprocity or homophily. If the parameters for those effects are positive, an actor is more likely to create or maintain a tie to an actor that also has an incoming tie to herself, or who is similar to herself, respectively. In other words, in the second step the actor compares the outcome of the objective function for each network state that results from every possible tie change/non-change. The network state with the highest value in the objective function is the most likely one to be selected by the actor, the network state with the lowest value in the objective function is least. The realization of a tie change/non-change concludes a *mini-step*[3].

Parameters that attach relative importance to different effects are estimated from the series of mini-steps that connect the empirical network observations. Ultimately, they can be interpreted in the same way as parameters from a multinomial logistic regression as they influence the relative likelihood of a mini-step to be realized. For more details about the method, including different methods of parameter estimation, we refer to Snijders (2001, 2005). Non-technical introductions to the method are given by Steglich et al. (2006) and Snijders et al. (2010).

As mentioned before, the network dynamics are assumed to be driven by the tendencies of actors to change network ties which are modeled by effects. The structural effects we include in our analyses should be seen as important controls and have been selected on the basis of results from previous studies using similar data and SAOM's (Steglich et al., 2010) and theoretical considerations based on past experience with these models:

[3] The mathematical formulation of the model can be found in the appendix.

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- *Outdegree*, which can be understood in a similar fashion as an intercept in regression analyses and determines the average degree.
- *Reciprocity*, the tendency of actors to reciprocate ties to each other.
- *Transitive triplets*, which technically counts the number of cases in which an actor is connected to another one through a direct and an indirect tie. Therefore, it models the tendency of actors to be connected to friends-of-friends, known as transitivity.
- *3-Cycles*, describing situations in which a friend-of-a-friend nominates the focal actor as a friend, in contrast to the transitivity effect, where a friend-of-a-friend is nominated by the focal actor as friend. The 3-Cycles effect is generally interpreted as indicating the presence or absence of local hierarchies.
- *Indegree-popularity and Outdegree Activity,* which control for dispersion in indegree and outdegree. Indegree popularity models the Matthews effect: is somebody that already has a lot of incoming ties more popular as a target for further friendship nominations. Outdegree activity models whether actors that nominate a lot of alters are likely to nominate even more.

In all analyses, and for all datasets, we include effects for the sex of ego and alter (which refers to the tendencies to send and attract ties depending on sex). In addition, in the analysis of the Glasgow data we further control for the ego- and alter-effect with respect to the amount of available pocket money. In the ASSIST data the ego- and alter-effect of family affluence are included. As the DyNet data includes six different ethnicities (White, Black, Latin, Asian, Native, and Other) it is not feasible to include ego- and alter-effects for each ethnicity. The ego- and alter-effects for being white were tested, as this was the majority category in all networks. However, they were not significant and therefore excluded from the analysis.

Of most concern, in the context of this article, are dyadic effects indicating the similarity between actors. Such effects capture the idea that ties might be more or less likely to form between individuals who are similar with respect to a certain attribute. In all analyses, we include an effect for having the same sex. The statistic (meaning the value of the independent variable) for the effect included in the analysis is 1 when the sender and recipient of the tie are of the same sex and 0 when they are of different sex[4]. In addition, in the analysis of the Glasgow data an effect for similarity concerning the amount of pocket money is included. Analyses using the ASSIST data include an effect that captures the similarity of actors in FAS (family affluence scale). The two relevant statistics are 1 when sender and recipient of a tie have exactly the same pocket money, or FAS respectively; and they are 0 when individuals are most different on these attributes, with a continuing scale of similarity in between extremes. In the analyses using the DyNet data a dyadic effect is modeled, which captures whether actors have the same ethnicity. To this end a dyadic covariate is created that has the value of 1 when the sender and recipient have at least one ethnicity in common and 0 otherwise. A dyadic covariate instead of using a "same ethnicity" effect is necessary, as multiple nominations for ethnicity were possible.[5]

[4] As opposed to the ego times alter effect, which is often used to test homophily in statistical social network analysis and is equal to 1 only if sender and recipient are of the sex coded as 1 in the data.

[5] All statistics in this paragraph are subsequently centered.

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In line with the general aim of our paper, we include the interaction of the homophily effects in the analyses. Concerning the Glasgow data, we model an interaction effect, which captures whether the same sex effect is more or less pronounced when actors receive similar amounts of pocket money. When it comes to the ASSIST data, we include an interaction of sex and FAS similarity. The statistic for both interaction effects is calculated as the product of the statistic for the same sex effect and the statistic for the pocket money similarity, or the FAS similarity effect respectively. This means the relevant statistic for the interaction effect is 0 when both sender and recipient of a tie are of different sex and/or at the opposite end of the pocket money (or the FAS scale, respectively). In contrast, the statistic for the interaction effect only takes a non-zero value when individuals are somewhat similar on FAS/pocket money and are of the same sex. Regarding the DyNet data, the interaction effect we study is the statistic for the same sex effect multiplied by the dyadic covariate for same ethnicity. This means that the effect statistic takes the value 0 in all cases, except when sender and recipient of a tie are of the same sex and mentioned at least one common ethnicity.

We decided to use SAOMs, as they are well suited to study different mechanisms that drive network change simultaneously. As the dynamic of a network is modeled, i.e. it is conditioned on the first observation of the network, no assumptions that the network is in some state of equilibrium has to be made. And finally, the multinomial nature of the model directly takes opportunity structures in the network into account. This means that homophily estimates are net of the distribution of attributes in the network.

5 Results

The results of our analyses are presented in Tables 1–3. In all datasets, ties are more likely to form between individuals who have the same sex. Effect sizes vary between 0.44 and 0.95 (these numbers correspond to an increase in odds for the formation and maintenance of a sex homophilous tie between 1.55 and 2.59, compared to sex-heterophilous ties). Furthermore, in the Glasgow data, students nominate more friends who receive similar amounts of pocket money. In the ASSIST data, significant homophily along the lines of family affluence (FAS) is observed. Students with similar FAS are more likely to form friendship ties (effect size between 0.46 and 1.08, odds increase between 1.58 and 2.94). Lastly, individuals in the DyNet data are more likely to become friends with others who have the same ethnicity (effect size between 0.14 and 1.03, odds increase between 1.15 and 2.80).

Our main focus in this paper rests on the interaction of these homophily effects. We study whether the positive effect of having the same sex changes when actors are similar on other attributes as well. Our results indicate an overwhelmingly clear tendency concerning such interaction effects. In nine out of eleven schools that were analyzed, the interaction is negative and significant. The magnitude of the interactions lies between two thirds and one times the homophily effect that is not related to sex. Hence, the interaction effects are not only significant but also of substantive magnitude.

For example in the DyNet Data, we find a clear tendency for individuals to choose somebody as a friend who is either of the same sex or ethnicity, over somebody

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Table 1. *Results glasgow data.*

	estimate	*s.e.*	*p-val*
Rate parameter Period 1	**11.30**	(0.93)	<0.001
Rate parameter Period 2	**7.77**	(0.58)	<0.001
Outdegree	**−2.21**	(0.20)	<0.001
Reciprocity	**2.16**	(0.11)	<0.001
Transitive triplets	0.72	(0.04)	<0.001
3-Cycles	**−0.44**	(0.08)	<0.001
Indegree popularity	**−0.03**	(0.02)	0.021
Outdegree activity	**−0.15**	(0.02)	<0.001
Sex alter	**−0.15**	(0.09)	0.055
Sex ego	0.02	(0.13)	0.443
Same sex	**0.95**	(0.11)	<0.001
Pocket money alter	**0.020**	(0.005)	<0.001
Pocket money ego	0.00	(0.01)	0.390
Pocket money similarity	**2.68**	(0.88)	0.001
Same sex · Pocket money similarity	**−1.90**	(0.92)	0.019

Parameters for SAOM estimation of Glasgow data; p-values for one-sided tests.

who is different on both. However, having the same ethnicity matters significantly less for forming a friendship relationship between two individuals, when both have the same sex compared to a scenario where both have opposing sexes. Similarly, when an adolescent chooses friends amongst others who have the same ethnicity, being of the same sex is less important than when friends are chosen amongst others who have a different ethnicity. In the Glasgow data, the picture looks similar: For same-sex friendships, pocket money similarity is not very important, however, for cross-sex friendships pocket money similarity becomes a strong predictor. The same pattern holds the other way around as well: adolescents who get similar amounts of pocket money tend to become friends regardless of whether they share the same sex. Only when they receive very different amounts of pocket money, having the same sex seems important for friendship choice. In the ASSIST data, a similar pattern for the interaction between sex and FAS is observed as well.

In Table 4 we show a detailed example how these effects alter the likelihood for individuals to become friends in School 1 in the DyNet data. We derive the changes in the objective function of the SAOM depending on similarity on sex and ethnicity. Having different ethnicity and different sex is the baseline scenario. When two individuals have the same sex, but different ethnicity a friendship tie becomes $e^{0.65} = 1.92$ times more likely. Similarly, a friendship tie becomes $e^{0.51} = 1.67$ more likely when two individuals have the same ethnicity (but different sexes) compared to the baseline scenario. Lastly, when two individuals have the same sex and the same ethnicity a friendship tie is $e^{0.71} = 2.03$ times more likely than in the comparison scenario where individuals are different on both dimensions.

We can now study the relative increases in the objective function for different scenarios. For example, the score of the objective function increases by 0.20 (= 0.71 – 0.51) for having the same sex amongst those individuals who already have the same ethnicity. This means that having the same sex makes a friendship tie among individuals who share the same ethnicity only $e^{0.20} = 1.22$ times more likely (which

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Table 2. *Results ASISST data.*

	School 22			School 35		
	estimate	*s.e.*	*p-val*	*estimate*	*s.e.*	*p-val*
Rate Parameter 1	**11.37**	(1.09)	<0.001	**15.09**	(1.29)	<0.001
Rate Parameter 2	**9.85**	(0.90)	<0.001	**13.68**	(1.11)	<0.001
Outdegree	**−1.99**	(0.21)	<0.001	**−1.17**	(0.21)	<0.001
Reciprocity	**2.20**	(0.11)	<0.001	**2.24**	(0.09)	<0.001
Transitive triplets	**0.72**	(0.04)	<0.001	**0.60**	(0.03)	<0.001
3-Cycles	**−0.54**	(0.07)	<0.001	**−0.46**	(0.07)	<0.001
Indegree popularity	**−0.04**	(0.02)	0.027	−0.01	(0.01)	0.157
Outdegree activity	**−0.18**	(0.02)	<0.001	**−0.18**	(0.02)	<0.001
Sex alter	−0.01	(0.11)	0.478	**0.25**	(0.06)	<0.001
Sex ego	−0.02	(0.14)	0.443	0.07	(0.09)	0.214
Same sex	**0.92**	(0.10)	<0.001	**0.44**	(0.06)	<0.001
FAS alter	0.02	(0.03)	0.188	−0.02	(0.02)	0.210
FAS ego	0.02	(0.03)	0.296	0.03	(0.03)	0.114
FAS similarity	**1.08**	(0.50)	0.015	**0.46**	(0.23)	0.026
Same sex · FAS similarity	**−0.92**	(0.52)	0.038	−0.23	(0.26)	0.191
	School 63			**School 71**		
	estimate	*s.e.*	*p-val*	*estimate*	*s.e.*	*p-val*
Rate Parameter 1	**17.52**	(1.18)	<0.001	**12.52**	(1.31)	<0.001
Rate Parameter 2	**12.22**	(0.81)	<0.001	**16.69**	(1.81)	<0.001
Outdegree	**−1.17**	(0.21)	<0.001	**−1.67**	(0.19)	<0.001
Reciprocity	**2.23**	(0.08)	<0.001	**2.21**	(0.13)	<0.001
Transitive triplets	**0.67**	(0.03)	<0.001	**0.72**	(0.04)	<0.001
3-Cycles	**−0.51**	(0.06)	<0.001	**−0.62**	(0.08)	<0.001
Indegree popularity	−0.02	(0.01)	0.051	−0.01	(0.02)	0.274
Outdegree abtivity	**−0.24**	(0.02)	<0.001	**−0.17**	(0.02)	<0.001
Sex alter	0.09	(0.07)	0.099	0.12	(0.09)	0.091
Sex ego	−0.11	(0.10)	0.117	0.13	(0.12)	0.139
Same sex	**0.87**	(0.06)	<0.001	**0.60**	(0.09)	<0.001
FAS alter	−0.02	(0.02)	0.146	0.00	(0.03)	0.472
FAS ego	0.04	(0.03)	0.098	0.03	(0.04)	0.231
FAS similarity	**0.88**	(0.34)	0.005	**0.77**	(0.36)	0.016
Same sex · FAS similarity	**−0.77**	(0.34)	0.011	**−0.65**	(0.39)	0.048

Parameters for SAOM estimation of ASSIST data; p-values for one-sided tests.

is much less than the 1.92 that apply when ethnicity is ignored). Conversely, the additional effect for sharing the same ethnicity when two individuals already have the same sex is 0.06 (= 0.71 – 0.65) and only marginally increases the chance for a tie to emerge ($e^{0.06} = 1.06$ times more likely); this is dramatically less compared to when sex is ignored (here it a tie was 1.67 times more likely). This overall pattern holds for most networks in our study. When two individuals have the same sex, additional similarity on another attribute hardly increases the likelihood for the formation of a friendship tie.

One intriguing question is whether one dimension takes primacy over the other. Is it that one homophily effect moderates the other one or that both decrease in salience

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Table 3. *Results DyNet data.*

	School 1			School 2			School 3		
	estimate	*s.e.*	*p-val*	*estimate*	*s.e.*	*p-val*	*estimate*	*s.e.*	*p-val*
Rate Period 1	**24.25**	(4.34)	<0.001	**11.83**	(0.74)	<0.001	**8.91**	(1.06)	<0.001
Rate Period 2	**13.00**	(1.01)	<0.001	**21.38**	(1.60)	<0.001	**4.95**	(0.63)	<0.001
Rate Period 3	**16.89**	(1.66)	<0.001	**14.02**	(0.86)	<0.001	**3.54**	(0.42)	<0.001
Outdegree	**−2.94**	(0.07)	<0.001	**−2.83**	(0.06)	<0.001	**−3.54**	(0.15)	<0.001
Reciprocity	**1.24**	(0.09)	<0.001	**1.61**	(0.08)	<0.001	**1.71**	(0.18)	<0.001
Transitive triplets	**0.21**	(0.02)	<0.001	**0.49**	(0.02)	<0.001	**0.67**	(0.13)	<0.001
3-Cycles	**−0.20**	(0.04)	<0.001	**−0.59**	(0.05)	<0.001	**−0.60**	(0.29)	0.018
Indegree popularity	**0.04**	(0.01)	<0.001	−0.01	(0.01)	0.127	**0.03**	(0.03)	0.177
Outdegree activity	**0.02**	(0.00)	<0.001	0.01	(0.00)	<0.001			
Sex alter	**0.25**	(0.05)	<0.001	0.14	(0.07)	0.030	−0.21	(0.10)	0.018
Sex ego	**−0.23**	(0.06)	<0.001	−0.03	(0.04)	0.260	**0.40**	(0.13)	0.001
Same sex	**0.73**	(0.05)	<0.001	**0.51**	(0.04)	<0.001	**0.73**	(0.12)	<0.001
Same ethnicity	**0.16**	(0.09)	0.031	**0.14**	(0.07)	0.030	**1.03**	(0.26)	<0.001
Same sex · Same ethnicity	**−0.17**	(0.10)	0.047	**−0.14**	(0.08)	0.038	**−0.81**	(0.28)	0.002

Parameters for SAOM estimation of DyNet data; p-values for one-sided tests.

Table 3. *Continued.*

	School 4			School 6			School 13		
	estimate	*s.e.*	*p-val*	*estimate*	*s.e.*	*p-val*	*estimate*	*s.e.*	*p-val*
Rate Period 1	**22.05**	(2.15)	<0.001	**16.13**	(1.23)	<0.001	**12.33**	(1.03)	<0.001
Rate Period 2	**23.69**	(2.79)	<0.001	**18.37**	(1.46)	<0.001	**9.05**	(0.77)	<0.001
Rate Period 3	**35.38**	(5.42)	<0.001	**13.28**	(0.86)	<0.001	**7.09**	(0.70)	<0.001
Outdegree	**−2.95**	(0.07)	<0.001	**−8.88**	(0.07)	<0.001	**−3.18**	(0.09)	<0.001
Reciprocity	**1.42**	(0.09)	<0.001	**1.48**	(0.09)	<0.001	**1.93**	(0.11)	<0.001
Transitive triplets	**0.31**	(0.02)	<0.001	**0.58**	(0.04)	<0.001	**0.73**	(0.05)	<0.001
3-Cycles	**−0.42**	(0.05)	<0.001	**−0.58**	(0.08)	<0.001	**−0.61**	(0.12)	<0.001
Indegree popularity	**0.02**	(0.01)	0.001	**−0.03**	(0.01)	0.003	−0.05	(0.02)	0.005
Outdegree activity	**0.01**	(0.00)	<0.001	**−0.04**	(0.00)	<0.001	0.01	(0.00)	<0.001
Sex alter	**−0.17**	(0.05)	<0.001	**0.10**	(0.06)	0.039	0.06	(0.07)	0.219
Sex ego	**−0.17**	(0.05)	0.001	**−0.36**	(0.06)	<0.001	**−0.35**	(0.07)	<0.001
Same Sex	**0.65**	(0.05)	<0.001	**0.72**	(0.13)	<0.001	**0.48**	(0.06)	<0.001
Same ethnicity	**0.51**	(0.14)	<0.001	**0.56**	(0.12)	<0.001	**0.32**	(0.10)	0.001
Same sex · Same ethnicity	**−0.45**	(0.16)	0.002	**−0.41**	(0.13)	0.001	0.15	(0.12)	0.109

Parameters for SAOM estimation of DyNet data; p-values for one-sided tests.

Table 4. *Crosstabulation School 1 DyNet data.*

	Opposite Sex	Same Sex
Different Ethn.	0	0.65
Same Ethn.	0.51	0.71

at the same time? In other words, do adolescents think of the two dimensions as equally important, or do they first consider similarity on one dimension and then, if there is no similarity, they consider the second? As the interaction effect represents the combination of two similarity effects, we cannot parcel this out in a quantitative way. From a modeling point of view, having the same ethnicity given the same sex is statistically identical to having the same sex, given the same ethnicity. Different research designs, for example, a qualitative study could help to answer this puzzle more.

Concerning the other effects included in the study, echoing the empirical SAOM literature, effects for reciprocity and transitive ties are positive and significant. We find evidence that friendship ties are more likely to evolve and persist between individuals who reciprocate friendship and who have a friend in common. Our estimates for the reciprocity effect lie between 1.24 and 2.24 (increase in odds between 3.46 and 9.39); estimates for the transitive triplet effects are between 0.20 and 0.71 (increase in odds between 1.22 and 2.03 for each tie to be present when it is part of an additional transitive triplet). The 3-Cycle effect is usually interpreted as an indicator of local hierarchies. In our analyses we find a negative effect (except in the Glasgow data) which suggests the presence of local hierarchies (Davis, 1970). The parameter estimates for indegree popularity and outdegree are mostly negative, but in most cases of small relative size.

Concerning the individual covariates included in the analyses, there is no general trend in activity and attractiveness depending on sex. The ego- and alter effects included for family affluence (ASSIST data) are also not significant. However, there is a clear effect concerning pocket money in the Glasgow data. Children who receive more pocket money are more attractive as friends.

6 Discussion and conclusion

Although most scholars agree that social life is inherently multidimensional, homophily research has not explicitly addressed such multidimensionality. Previous research finds clear evidence for homophily—the tendency for individuals to form social relationships with similar others—regarding different socio-demographic characteristics, such as age, ethnicity, or sex. Yet, we know only little about multidimensional homophily.

Scholars use multivariate designs where more than one homophily effect is studied at the same time. Such a strategy explicitly accounts for the fact that correlation (positive or negative) between attributes leads to perceived homogeneity along multiple variables. The question that remained unanswered so far is: What are the substantive implications that follow for the formation and dissolution of social relationships when individuals have more than one attribute in common? Is the

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interaction between homophily effects significant? We use the well-studied and substantially important setting of adolescent friendships in school cohorts as a starting point to establish regularities in the interaction between different dimensions of homophily.

Our study investigates longitudinal friendship data from eleven schools in four different countries. A longitudinal approach is useful, as it allows controlling for many factors that drive the formation and dissolution of social relationships. Individuals possess many different attributes and reducing them to only one attribute at a time does not account for the complexities of social life. We find a clear pattern pointing towards a more general regularity concerning the interaction of homophily effects in friendship networks. The interaction of positive homophily effects are negative and overwhelmingly significant. When individuals have more than one attribute in common, a social relationship between these individuals is not as likely to evolve and be maintained as the combination of the separate homophily effects would suggest. Additional studies could confirm (or reject) this empirical regularity in other settings.

Several possible explanations could account for this. A straightforward explanation for such a negative effect could be that there is an upper limit in how beneficial social relationships with similar others can be. Several studies proposed that social relationships are especially useful when they provide access to a different set of individuals, with different thoughts, ideas, and knowledge (Granovetter, 1973; Burt, 1995). Sharing more than one attribute with others can create redundancies, which could eventually explain the negative interaction effect we do observe.

Another perspective puts emphasis on multidimensional homophily creating multiple opportunities for individuals to meet. Seeing each other more often does not necessarily increase the chances for individuals to become friends. When individuals do not like each other when they meet in one setting, they are unlikely to like each other when they meet elsewhere. Therefore, while similarity on more than one attribute might increase opportunities to meet, this does not have to translate into friendship relationships being formed.

There is also a situational understanding of homophily based on social identity theory (Tajfel & Turner, 1979; Hogg, 2006). Not all of individuals' attributes might be salient and matter when social relationships are formed. Individuals behave and focus on norms and themes related to current situations, while norms and themes associated with other situations are pushed back (Tajfel, 1974; Turner, 1987; Lindenberg, 2009). Within certain situations, adolescents might focus on similarity in specific domains, while dissimilarity in others are less important. Such a mechanism could also explain the negative interaction between different dimensions of homophily.

Disentangling various motives for homophilious friendship selection is difficult and requires further work. Already, decomposing the origins of one-dimensional homophily from each other seems impossible with most current designs. Most often, many aspects matter at the same time. And of course, context- and attribute-specific explanations can be construed as well. For example, it might be that adolescents prefer their friends to be similar to themselves or that individuals take part in activities through which they meet others who are similar. In the context of multidimensional homophily this becomes even more complicated as the

underlying one-dimensional homophily effects might have different origins to begin with. Nevertheless, this article shows that an overly simplified view of homophily is inaccurate. People, or at least adolescents, do not always prefer similar others as friends - it is highly dependent on similarity on other dimensions. Or in other words: similarity makes some ties more likely, but not all.

Of course, this study also has its limitations. We only test the interaction of homophily effects on a limited set of attribute dimensions. Our guiding principle in this context was to remain focused on exogeneous attributes that cannot be altered by individuals so easily. Dimensions that are under more direct control of individuals (e.g. political opinion, fashion taste), would introduce the additional issue of having to distinguish between effects driven by selection, influence, or influence specific to certain dimensions of social life.[6] Considering such endogenous attributes (also in other settings) could be useful in future studies, but it would also require specific designs because individuals can change their attributes as well. Sex, ethnicity and social status are generally the strongest exogenous predictors (apart from religion) of homophilous tie formation (McPherson et al., 2001) and, hence, a reasonable choice for the purpose of our study. One may question whether the pattern we observe can also be detected for other attribute dimensions. Further research could address this more.

Finally, it remains to conclude that future research should address the multi-dimensionality of social life further and study what it means in terms of social network outcomes, regarding additional social settings and additional social dimensions. More research is needed to clarify the mechanisms that bring about the negative interaction effect we detect.

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[6] I.e. a confounder of the interaction between homophily on e.g. political opinion and occupation would have to control for, apart from the main influence effects, whether people of the same opinion influence each other their occupational choices and whether people with the same occupation influence each other on their political opinion, which poses a whole lot of empirical problems.

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Appendix

Descriptive statistics of the analyzed datasets.

Table A1. *Descriptives Glasgow data.*

N	160
indegree wave 1 (mean, min, max)	3.66, 0, 12
indegree wave 2 (mean, min, max)	3.23, 0, 11
indegree wave 3 (mean, min, max)	3.11, 0, 10
Age in first wave	12–13
% Girls	52.5
Moran's I for sex (waves 1, 2, 3)	0.77, 0.84, 0.79
Pocket money wave 1 (avg (min - max)) £	8.8 (0–40)
Pocket money wave 2 (avg (min - max)) £	11.1 (0–50)
Moran's I for pocket money (waves 1, 2, 3)	0.11, 0.14, 0.11
% Missing Periods 1, 2	5, 4
Jaccard Index Periods 1, 2	0.28, 0.31
Correlation sex, Pocket money	0.05

Mathematical details of SAOMs:

The *rate function* models the differences in speed of network change between actors. It is defined as

$$\lambda_i(x) = \sum_k \rho_k r_{ik}(x)$$

where r_{ik} are statistics of i's neighborhood in x, which are weighted by model parameters ρ_k. These weights express whether an actor changes her network more frequently ($\rho_k > 0$) or less frequently ($\rho_k < 0$).

The objective function models which network change an actor decides to realize. It is defined as

$$f_i(x) = \sum_k \beta_k s_{ik}(x)$$

where s_{ik} are statistics that describe characteristics of i's network, attributes of i, or dyadic attributes shared between i and j. β_k are weights that express whether a tie yielding a higher statistic is more ($\beta_k > 0$) or less ($\beta_k < 0$) likely. Actor i compares the outcome of the objective function for making a tie change to all other members in the network and decides which tie to change accordingly. The probability to realize a specific tie change is given by

$$p_{ij}(\beta, x) = \frac{exp(f_i(\beta, x(i \rightsquigarrow j)))}{\sum_{h=1}^{n} exp(f_i(\beta, x(i \rightsquigarrow h)))}$$

where p_{ij} is the probability of i to change the way she is tied to j. The numerator in the fraction is the exponent of the objective function of i for changing the tie to j ($i \rightsquigarrow j$). The denominator is the sum over the exponent of all possible tie changes of i plus the option not to make any change to i's network as a normalizing constant. This is the multinomial logit expression.

The statistics s_{ik} of the used structural effects, where $x_{ij} = 1$ indicates the presence of a tie from i to j, and $x_{ij} = 0$ indicates the absence of that tie, are as follows:

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Table A2. *Descriptives ASISST data.*

	School 22	**School 35**	**School 63**	**School 71**
N	149	158	236	102
indegree wave 1 (mean, min, max)	3.49, 0, 10	4.58, 0, 17	4.63, 0, 11	3.77, 0, 13
indegree wave 2 (mean, min, max)	3.97, 0, 12	4.82, 0, 16	4.94, 0, 11	4.37, 0, 14
indegree wave 3 (mean, min, max)	3.38, 0, 9	4.46, 0, 15	4.20, 0, 12	3.98, 0, 10
Age in first wave	12–13	12–13	12–13	12–13
% Girls	51	53.8	52.1	44.1
Moran's I sex (waves 1, 2, 3)	0.89, 0.89, 0.87	0.88, 0.81, 0.73	0.84, 0.85, 0.85	0.79, 0.76, 0.76
FAS (avg (min-max))	3.9 (0–6)	4.1 (1–6)	4.2 (0–6)	3.8 (1–6)
Moran's I FAS (waves 1, 2, 3)	0.02, 0.02, 0.02	0.03, 0.13, 0.12	0.03, 0.08, 0.13	0.08, 0.00, 0.03
% Missing Periods 1, 2	1, 4	1, 4	0, 5	8, 5
Jaccard Index Periods 1, 2	0.38, 0.38	0.37, 0.35	0.33, 0.37	0.32, 0.30
Correlation sex, FAS	0.08	0.02	−0.11	−0.06

Table A3. *Descriptives DyNet data.*

	School 1	School 2	School 3	School 4	School 6	School 13
N	117	184	129	122	192	188
Indegree wave 1 (mean, min, max)	3.1, 0, 15	4.5, 0, 14	3.1, 0, 9	4.69, 0, 17	3.63, 0, 11	2.89, 0, 10
Indegree wave 2 (mean, min, max)	4.9, 0, 17	4.4, 0, 12	2.1, 0, 6	4.30, 0, 15	3.30, 0, 11	2.46, 0, 10
Indegree wave 3 (mean, min, max)	3.58, 0, 15	5.1, 0, 15	1.9, 0, 6	4.70, 0, 14	4.66, 0, 14	1.93, 0, 7
Indegree wave 4 (mean, min, max)	4.61, 0, 14	4.2, 0, 14	2.1, 0, 5	3.73, 0, 12	3.48, 0, 14	1.91, 0, 8
Age	12–13	12–15	12–18	12–15	13–14	14–15
% Girls	47.9	54.9	50	52.5	50.5	51.1
Moran's I for sex (waves 1, 2)	0.78, 0.67	0.72, 0.62	0.35, 0.38	0.76, 0.67	0.65, 0.65	0.69, 0.64
Moran's I for sex (waves 3, 4)	0.71, 0.70	0.62, 0.59	0.36, 0.26	0.65, 0.64	0.62, 0.59	0.64, 0.56
% White	61.5	78.3	79.8	81.1	83.3	51.1
% Latin	11.1	13.0	3.1	2.5	12.5	41.5
% Native	14.5	11.4	9.3	17.2	8.9	9.0
% Other	26.5	15.8	19.4	23.8	14.6	13.3
% Missing Periods 1, 2, 3	18, 24, 29	16, 18, 23	22, 21, 21	18, 23, 15	33, 31, 22	21, 21, 28
Jaccard Index Periods 1, 2, 3	0.25, 0.28, 0.25	0.35, 0.29, 0.33	0.20, 0.26, 0.33	0.26, 0.27, 0.20	0.25, 0.23, 0.31	0.26, 0.27, 0.30
Coorelation sex, White	−0.06	0.03	−0.03	−0.02	0.01	−0.05

Outdegree / Density:

$$s_i(x) = \sum_j x_{ij}$$

Reciprocity:

$$s_i(x) = \sum_j x_{ij}x_{ji}$$

Transitive Triplets:

$$s_i(x) = \sum_{j,h} x_{ij}x_{ih}x_{hj}$$

Three-Cycles:

$$s_i(x) = \sum_{j,h} x_{ij}x_{jh}x_{hi}$$

Indegree Popularity:

$$s_i(x) = \sum_{j,h} x_{ij}x_{hj}$$

Oudegree Activity:

$$s_i(x) = \sum_{j,h} x_{ij}x_{ih}$$

The covariate dependent effects are defined as follows:

Dyadic Covariate (used for being of the same ethnicity in the DyNet data):

$$s_i(x) = \sum_j x_{ij}\left(w_{ij} - \bar{w}\right)$$

where ω_{ij} is the value of the dyadic covariate between i and j, and $\bar{\omega}$ is the mean value of the covariate.

Ego Covariate:

$$s_i(x) = v_i \sum_j x_{ij}$$

where v_i is the value of the covariate for i.

Alter Covariate:

$$s_i(x) = \sum_j x_{ij}v_j$$

Same Covariate:

$$s_i(x) = \sum_j x_{ij}I\{v_i = v_j\}$$

where the indicator function $I\{v_i = v_j\}$ is one if the condition is fulfilled and 0 otherwise.

Covariate Similarity:

$$s_i(x) = \sum_j x_{ij}\left(sim^v_{i,j} - \widehat{sim^v}\right)$$

where $sim^v_{i,j}$ is the normalized similarity on covariate v between i and j, and $\widehat{sim^v}$ is the mean of all similarity scores.

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