A Situational Understanding of Friendship Networks



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A thesis presented for the degree of
Doctor of Philosophy

Trinity Term 2014

To my family
for patiently supporting more than a decade of tertiary education.

Acknowledgements

I want to first and most of all thank my supervisor Tom Snijders, who invited me to his research group, taught me patiently, advised and inspired me, and without whom this thesis would never have been written. While numerous researchers gave me valuable comments and feedback, I would like to particularly mention in no specific order James Hollway, Johan Koskinen, Jon Mellon, Josh Lospinoso, Andras Vörös, Zsofia Boda, Paulina Preciado, Ruth Ripley, Christian Steglich, Garry Robins, Peter Hedström, Thomas Grund, Marijtje van Duijn, Maarten van Zalk, John Light, the Nuffield Network of Network Researchers, all members of the ECRP IV, the examiners of my transfer and confirmation, the anonymous reviewers from the journals Network Science and Social Networks, and the countless people that gave valuable comments at conference and seminar presentations that I attended.

I further owe thanks to Nuffield College and the Department of Sociology for their financial support of my studies over the last four years, and all funding bodies and responsible researchers that generously provided the data and methods I use in the thesis.

For personal support and advice I want to thank all those, who made this thesis possible and enjoyable by providing their time, patience, sofas, beds and guest rooms, dinners, lunches and breakfasts, sharing drinks and watching football, sacrificing sleep and work, and for being a great partner or friend.

Abstract

The structure of social networks, and people's position within these networks, are important predictors of many individual and group-level outcomes. One type of social networks that is regularly studied are the mutually interdependent relations of friends. This thesis focusses on friendship networks between adolescents in the context of schools.

Arguably the most important and consistently found regularities in adolescent friendship networks are i) the tendency of friendships to be mutual, called reciprocity; ii) their tendency to cluster in groups, known as transitivity; and iii) the tendency of friendships to be present between those that are similar to one another, called homophily. Various social theories originating in different disciplines have theoretically proposed and empirically found micro-mechanisms that explain the regular occurrence of these substructures in friendship networks. This thesis introduces a framework of how the relation between these different networks tendencies can be understood.

I propose that each of the three network evolution mechanisms can be connected to a type of social situation in which friends interact to form and maintain their friendships. Social situations that are dyadic and only involve two persons are connected to reciprocal friendships. Group-based social situations, on the other hand, are related to transitivity and homophily, where the groups are either defined socially or through common characteristics. Starting from this proposition, I suggest that when two adolescents share one forum for interaction with one another, i.e. they regularly meet within one of the social situations, meeting in additional other situations does not increase the likelihood of a friendship tie existing as much as could be expected from the sum of the effect of meeting in either situation. Consequently, I expect a negative interaction between the different network mechanisms.

After a series of empirical analyses that support the outlined reasoning, I use the developed perspective to investigate how the micro-mechanisms contribute differentially to the creation of newly formed friendships and to the maintenance of already existing friendships. Finally, I show how a situational understanding of friendship can be used to differentiate which friendships are most important for social influence and for peer pressure.

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Chapter 1

Introduction

Humans are inherently social; interpersonal relationships are a central aspect in the lives of many people. Individuals form all kinds of relationships with both positive and negative connotations. People co-operate, compete, advise, like, or dislike each other, have kin relations, supervise or examine one another, and many more. The content and structure of these relationships between individuals have a variety of consequences that are of interest to social scientists. Co-operation and competition are central themes in some fields of economics (e.g. Axelrod, 1984), inter-linkages between clans can be related to political power (Padgett and Ansell, 1993), while friendship and advice relations can be connected to a variety of individual outcomes, such as occupational success (Granovetter, 1973; Burt, 1992), health (Umberson et al., 2010; Schaefer et al., 2011), education (Sacerdote, 2011), and many more (a recent overview is given by DiMaggio and Garip, 2012). Studies on social capital (Coleman, 1988; Mouw, 2006) focus on relations between people and its diverse consequences. Or as phrased by Rivera et al. (2010):

> "Disciplines that once focused on individual attributes to explain behavior now see embeddedness in networks as a determinant of job attainment and advancement, creativity, obesity, mortality, neighborhood cohesion, political mobilization, state formation, markets, prices, digital ties, and the competitiveness of firms and states."

In case the detailed structure of relationships between individuals is of interest to a researcher, the relations between all members of a group can be visualised in what was

baptised a Sociogram (Moreno, 1934), but is now commonly known as a network. Mapping relations between people as networks allows the systematic analysis of individuals' positions in the network, the connection of network position to other characteristics, regularities in different types of human (or other) interaction, or discovering rules that guide the evolution of network relations from on time point to another.

One type of relations that is frequently analysed using a network approach are friendships. Friendships are a crucial part of peoples' lives and reasons to analyse them in network context are manifold, as expressed in the impressive but by no means exhaustive list in the previous quote. Although friendships are important in the lives of most people, they have a special role for adolescents. Adolescence is a period of reorientation from family to same age peers. Friendships play an increasingly important part in young peoples' lives, much more than in early childhood and later adult life; at these stages in life social ties of individuals to other family members are often more important (Steinberg and Morris, 2001; Smetana et al., 2006). Further, adolescence is a period of development of the self, when problem behaviour starts, first romantic experiences are made etc., and connected to this, a period where peer influence is very strong (*ibid.*). Therefore, the determinants and consequences of friendships and friendship changes might be of even more interest for adolescents than for adults or young children.

This thesis is concerned with the evolution of adolescent friendship networks. Given a potential set of alters to select from, which other is chosen to be a friend, and why? This question has been the subject of much research and I want to make a small contribution to this vast literature by empirically analysing configurations within complete adolescent friendship networks that have received little attention in the literature to date. Further, I want to build a conceptual framework that can explain the empirical regularities that I find for this type of configurations.

1.1 A Pot-pourri of Network Regularities and Friendship Network Theories

In a recent review focusing on change in social networks, Rivera et al. (2010) identify three types of mechanisms that explain dynamics of dyads: relational, proximity, and assortative mechanisms. Relational mechanisms refer to the importance of existing relationships within the network and highlight endogenous network effects, such as reciprocity or clustering. Dyads change on the basis of previous states of the networks in which they are embedded. Proximity mechanisms focus on actors' environments and put emphasis on social and spatial distance between individuals. Network ties form and are maintained in wider social contexts. And lastly, assortative mechanisms are concerned with exogenous and endogenous attributes of network nodes in dyads. Changes of network ties are studied from the perspective of joint characteristics of the actors who are involved.

In statistical analyses of complete adolescent friendship networks within school classes or cohorts, mainly relational and assortative mechanisms have been found to explain the presence of a tie between two people. Proximity mechanisms that focus on opportunities are often considered less important, as it is assumed that there are no opportunity constraints in these types of networks. In other words, it is often assumed that every pupil in a school cohort is aware of the existence of every other pupil in the same cohort[1]. Regarding relational mechanisms, a long tradition of network research suggests that friendships between two people tend to be mutual, and that friends tend to form groups. In line with these findings, statistical modelling of friendship dynamics finds that the two most important endogenous, or relational, network mechanisms are reciprocity and clustering, or transitivity (Snijders et al., 2010; Veenstra et al., 2013). Degree dynamics, which play an important role in other types of social networks, such as sexual contacts (Liljeros et al., 2001) or citation networks, reflecting the "Matthew effect" (Merton, 1968), are less important in offline friendship networks, as the continuing investment of time and resources in friendships inhibits actors from acquiring a

[1]This might or might not be a realistic assumption, which depends on the network delineation. If these are wide with larger cohorts sizes, proximity mechanisms come into play.

very high degree (Rivera et al., 2010).

The main mechanism that falls in the category of assortative mechanisms is homophily (McPherson et al., 2001). While for some types of relationships dissimilarity or complementarity of attributes is desired (e.g. co-operations or heterosexual relationships), in the context of friendship formation homophily takes the prime, if not only important role in this category of mechanisms. Homophily is the tendency of individuals to be connected to others that are similar to themselves in some designated respect and has been found in friendship networks for many achieved and ascribed characteristics.

A multitude of theories have been proposed that explain why reciprocity, transitivity and homophily are universal features of friendship networks. **Balance Theory** (Heider, 1946; Newcomb, 1961) delivers one of the most popular explanations for transitivity in friendship networks. It proposes that triadic configurations are only stable if they contain an odd number of positive ties. This can be rephrased to the more intuitive "a friend of a friend is my friend" and "an enemy of my friend is my enemy". A common explanation for reciprocation in friendships is based on **Social Exchange Theory** (Emerson, 1976; Rusbult and Buunk, 1993). It suggests that people invest in a friendship and and expect rewards. Both costs and returns can take the form of time committed, emotional support, advice, presents, etc. In case one of two friends finds that the balance between costs and returns is not satisfying or has a better alternative, the friendship may be broken. This makes it understandable why a friendship needs mutuality in investment. An example that explains why homophily is generally found in friendships is the **Similarity Attraction Theory** (Byrne, 1997; Hamm, 2000; Kossinets and Watts, 2009). Being friends with somebody similar is more rewarding, as common background and shared experiences related to that background simplifies communication, fosters trust and solidarity, and makes compatibility of views and opinions likely. This makes homophilous friendships more rewarding than heterophilous friendships[2].

[2]A more detailed treatment of the different theories and further approaches that explain reciprocity, transitivity, and homophily will be given in the thesis chapters where the mechanisms are in the focus of the respective studies.

1.2 Relation between Network Mechanisms and Research Agenda

Each of the presented theories has its merits and focuses on a different aspect of friendships between people. As a result, each theory can explain different regularities that are found in friendship networks. There are many more theories that focus on different, further aspects of friendships and can explain other or the same regularities in friendship, or more general, social networks. In this thesis I do not intend to question, challenge or test any of these theories. Further, I do not want to propose another theory that explains the same network regularities in a different way. Rather, this thesis is set out to deal with problems that have received little attention in current literature so far: What is the relation between different network mechanisms, especially in the context of adolescent friendship networks. In other words: How do different network evolution mechanisms interact? This question, which is my research agenda for this thesis, is one of the three big future research paths in the analysis of interpersonal relations as proposed in a large-scale review article by Rivera et al. (2010).

Specific research questions that arise from this larger field of study are, for example, What is the relation between homophily and reciprocity? Are friendships inside of transitive groups more likely to be reciprocated than friendships outside of transitive groups? Does homophily on multiple dimensions increase the likelihood of a tie compared to homophily on one dimension? I intend to analyse these questions empirically and develop a theoretical framework that can be applied to questions of this type. While interesting for the general understanding of friendship network evolution, the results of these studies might additionally have important consequences for research on segregation. Further, they show some seemingly unrelated, previous findings in the network literature to be spurious. Applying the developed framework to other empirical questions results in new insights to the differential predictors of creation and maintenance of friendships and integrates well with sociological and psychological approaches to social influence research.

1.2.1 Some Theoretical Notes in Advance

Before I begin, I would like to emphasise that over the course of this thesis I do not intend to develop a comprehensive theory of friendship network evolution. Further, many thoughts, concepts and ideas that I present and employ are not newly envisioned by me; rather they are assembled from other theories and approaches to result in a useful framework that can answer the questions I am interested in.

For the purpose of this thesis and in light of the research question addressed that all deal with the evolution of adolescent friendship networks in schools, a conceptual distinction between how different network evolution mechanisms work can be made that differs from the classification by Rivera et al. (2010). Network evolution mechanisms can either increase the likelihood of interaction between individuals, or lead to a more positive evaluation of interaction between individuals. The previously mentioned Balance Theory and Similarity Attraction Theory propose that interaction with certain others is more likely to be evaluated positively, if they are embedded in a group of friends or between similar people. Theories of social foci (Feld, 1981) and propinquity in transitive triads (Granovetter, 1973), on the contrary, suggest that interaction itself (and not the positive evaluation) between certain individuals becomes more likely, and through this channel lead to more friendships between people that are homophilous or members of a common friendship group.

The theoretical approach I use in this thesis for interactions between different network evolution mechanisms focuses on situations in which people interact with one another. Thus, it mainly uses opportunities for interaction between people as the primary explanation that underlies the formation of friendships. Cognitive considerations, such as the ones that underlie balance theory, are taken into account only peripherally. However, this does not mean that I think cognitive processes are not important for friendship network evolution. I leave them aside here, because I strive for a parsimonious model. A focus on times and compositions of social interactions between friends seems the most promising first approach to analyse interrelations between different network evolution mechanisms.

The principle idea that underlies the situational perspective is that different net-

work evolution mechanisms can be connected to different social situations in which the adolescents interact. Befriended adolescents that share other common friends are assumed meet and spend time in social cliques, in its colloquial meaning. Dyadic situations where two adolescents spend time vis-a-vis without others surrounding them are related to reciprocal friendships between the two involved parties. Finally, homophily along the lines of different dimensions is connected to group-based activities and situations that are typical for a certain demographic group.

The perspective I develop is presented side by side with empirical analyses to show at each step of the reasoning how it is falsifiable and that it is empirically supported. As such, each chapter uses concepts from, and logically builds on the previous chapters. In practice this means that there is not one theory chapter in the beginning that outlines the theoretical perspective and all empirical chapters to follow test different aspects of it. Rather, the overall picture is being developed in the course of the thesis.

Finally, homophily plays an important role in the course of this thesis and is analysed in most of the empirical chapters. However, I want to emphasise that I am only concerned with homophilous dimensions that are visible, i.e. ascribed characteristics. In the words of Lazarsfeld and Merton (1954), I am interested in *status homophily*. While *value homophily* is an interesting and much researched topic, too, it most likely does not fit very well in the theoretical framework that is developed in the course of this thesis. Additionally, *status homophily* on the dimensions of e.g. sex, ethnicity or social origin has important consequences for individuals' lives. In case we follow the liberal goal that a person's chances and perspectives in life should be unrelated to ascribed characteristics such as the mentioned ones, research on homophily on these dimensions is for Sociologists of more interest than homophily on dimensions such as musical taste, physical attractiveness, or a joint interest in a certain type of literature.

1.3 Outline of the Thesis

Chapter 2 and Chapter 3 introduce the **Data** and **Method** that are used in the thesis. The hypotheses in the substantive chapters are tested on four different longitudinal datasets of adolescent friendship networks within schools from the US, different parts

of the UK, and the Netherlands. The data spans ages from early to late adolescence and the networks are obtained employing different survey questions. These data are analysed using Stochastic Actor-Oriented Models (SAOMs). I explain the basic method, as well as some developed extensions in detail, including Goodness of Fit testing, analysing creation and maintenance of ties, analysis of multiple networks, co-evolution of networks and behaviour, and meta-analysis.

The first theoretical and empirical results are presented in Chapter 4, which analyses **Reciprocity, Transitivity, and the Mysterious Three-Cycle**. In this chapter I develop the general idea that different network evolution mechanisms can be related to different social situations, where reciprocal friendships are enacted in dyadic situations and transitively connected friendships in group-based situations, in which the group is defined socially. After relating the mechanisms to different situations, I propose that unreciprocated ties are more likely to exist within groups, as groups provide a forum for interaction between people and therefore stabilise one-sided friendships. Unreciprocated ties outside of transitive groups are unstable; therefore, the tendency towards reciprocation is higher outside of, compared to within groups. As a result, I hypothesise that the interaction between reciprocity and transitivity is negative, which is confirmed in the empirical analyses.

Chapter 5, **Homophilous Situations and One-Sided Friendship**, extends the developed perspective to homophily. Following the reasoning suggested by Scott Feld, I propose that homophily can be connected to group-based situations, as people that are similar choose similar free-time activities. However, I suggest that different dimensions of homophily are connected to different activities that adolescent friends undertake together, which I confirm empirically. Analogous to the reasoning in Chapter 4, I propose that unreciprocated friendships are unstable outside of group contexts, with the only difference to the previous chapter that the group is defined by common characteristics in this study. The resulting hypothesis that reciprocity and homophily in different dimensions interact negatively is confirmed in the empirical analyses.

Subsequently, I analyse **Multiple Homophily** in Chapter 6, i.e. I analyse the interaction between different dimensions of homophily. In this study, I emphasise and

develop the argument from the previous chapter that different dimensions of homophily are connected to different activities in which the adolescents form and maintain friendships. Within one activity, similarity or dissimilarity on other dimensions is not important for the formation and maintenance of friendships. In other words, if two adolescents have one forum to interact where they can cultivate their friendship, common membership in an activity that is connected to other dimensions of homophily does not increase the likelihood of being friends further. Operationalised in a testable hypothesis, the interaction between different dimensions of homophily is expected to be negative, which is confirmed in the empirical analyses.

Chapter 7 turns away from the the analysis of interactions between network evolution mechanisms. Here the perspective that different mechanisms can be connected to different social situations is used in order to analyse **The Peculiar Differences between Friendship Formation and Maintenance**. I argue that the exogenous network mechanism of homophily differs from the endogenous mechanisms reciprocity and transitivity with regards to how they foster the creation and the maintenance of friendships. Homophily operates mainly on the creation of ties, as it brings people together in social situations that are stratified by the relevant dimensions. Heterophilous friendships are also formed in social situations, however, there are less heterophilous situations than homophilous ones, which explains why more homophilous ties are created. Nevertheless, once either type of friendships are created, there is no reason to believe that homophilous ties are more stable than heterophilous ties from a purely situational perspective. Reciprocity and transitivity, on the other hand, lead to the creation of new dyadic or group-based situations that help maintaining a friendship compared to friendships that are not embedded in such a way. This reasoning is empirically confirmed.

Finally, in Chapter 8 I turn to the study of social influence from the situational perspective and analyse **Mechanism Specific Social Influence**. This chapter is mainly theoretical and tries to integrate different strands of influence research, which tend to either focus on friends, or group membership as sources of influence. I argue that adolescents are not influenced by all of their friends. Rather, on different issues

they are influenced by only a subset of their friends which is related to common membership in different groups and situations. This is because in different situations or contexts, different attitudes and behaviours are prescribed by a group norm. On these respective behaviours and attitudes, adolescents are only influenced by co-members of these situations. Co-members of the different situations are characterised by different relations between friends, i.e. being reciprocally tied, transitively tied or homophilous. Although the chapter is theoretical in nature, an illustration of an empirical analysis that is based on the outlined approach is given.

Chapter 9 concludes the thesis and outlines directions for future research.

Chapter 2

Data

The method that is used predominantly in this thesis, Stochastic Actor-Oriented Models (SAOMs), applies to longitudinal, complete network data. As such, the data I require is of this nature. However, let me first justify, why a complete, longitudinal network approach is most appropriate for the kind of research questions discussed in this thesis. While the importance of a longitudinal analysis will be discussed in Chapter 3, i.e. linking antecedents to consequences and analysing a process, I briefly present why a complete network approach is necessary.

In a complete network approach a bounded network is analysed, where all ties between the members of a closed group are known to the researcher (Marsden, 1990). Further, it is important that the members of the network have the majority of their ties under analysis within the specified boundaries (Laumann et al., 1989). There are two reasons why clear bounds of a network are important: First, in order to study whom an actor selects as a friend, it is important to know the set of options an actor can choose from. If girls are only friends with other girls in a school, it might be due to an active choice of same sex friends; however, it might also be the case that they visit a girls-school. If the latter is the case, then being only friends to other girls is due to the set of options available. Network boundaries clearly define the set of options an actor can choose from, and therefore allow controlling for opportunity structures (Steglich et al., 2010; Laumann et al., 1989).

Second, it is only possible to collect complete network data if the boundaries of a

network are defined. Complete data is important to properly account for the interdependence of ties. If only ties between a sample of individuals are being measured, it is not possible to fully account for endogenous network processes that guide network evolution. Transitive closure, for example, can only be analysed if it is known between which individuals two-paths exist. This is turn is dependent on obtaining complete data (for statistical network models e.g. Huisman and Steglich, 2008; Robins et al., 2004).

The condition that the vast majority of ties of networks members should be within the boundaries of the network follows from a similar logic. Ties within the network might depend on common, unmeasured friendships outside of the network. This bias resulting from measurement error grows more severe, the more relevant ties exist outside of the network boundary.

Generally, data on friendship networks that fulfils these conditions is not easy to find. Among adults, bounded networks with most friendship ties existing within the networks can often only be found in special contexts, such as monasteries (the "Sampson Data" as reported in White et al., 1976), or equally isolated communities (Johnson et al., 2003), where it is questionable how much the findings generalise to wider society. For adolescents, however, it is possible and practicable to find networks with natural boundaries. In many places, the primary social context in which adolescents form their friendships is their school. This is especially true if the choice of schools is predominantly driven by geographic proximity, i.e. if membership in the same school also entails living in the same neighbourhood. As a result the school offers a good context to study friendship dynamics between adolescents, as it provides a network boundary and adolescent friends often visit the same school.

2.1 Data requirements

The specific data requirements follow mainly from the previous reasoning, but also from methodological considerations that are outlined in Chapter 3. The first requirement is that the network data under analysis are large enough. As the power of a SAOM analysis increases with changes in network ties, being large enough depends on (i)

number of network participants, where 20 is usually the minimum, (ii) the number of waves, where more waves provide more information, and (iii) the amount of change in the network (each discussed in Snijders et al., 2010, p.49). The amount of information grows with the increase of each mentioned item, which allows more complicated models. However, there is a sensible middle-ground for each aspect: Analysing networks with too many actors (>500-1000) challenges the assumptions of the model that each actor is aware of every other actor in the network. A very large number of waves (>5) that are analysed could conflict with the assumption that the network evolution is time-homogeneous. Finally, the estimation of an SAOM gains power with network change, however, if turnover between two time-points is too large, data provide little information about the dynamic processes that connect two waves (only about their results)[1]. However, this will be discussed further in Chapter 3.

The second set of requirements concerns missing data of different kinds. First of all, the fraction of missing data should not be too high - following a rule of thumb, at most 25% of tie observations should be missing. A higher proportion of missing data results in similar conceptual problems as sampling network ties instead of recording complete network data, as outlined in the previous section (Huisman and Steglich, 2008). More missing data is likely to bias the estimates of endogenous network effects. The other kind of missing data arises from changing composition of the network over time, which should be kept to a minimum, too. While the SAOM and its implementation can deal with changing composition (Huisman and Snijders, 2003), individuals that enter the network between two observations contribute to missing data, as their network ties between the time of entry and the first observation in which they participate are unknown. A similar logic applies to individuals that leave the analysed network between two observations.

In the remainder of the chapter, I present four diverse datasets of adolescents in schools that I use throughout this thesis. Relevant descriptive statistics are presented in the appendix. Each network in the different datasets that is used in the empirical

[1] In the terminology of the model: if the two waves are too different, i.e. there is no stability between waves (Jaccard Indices < 0.3), it is difficult to find realistic chains of *mini-steps* that connect two observations.

analyses satisfies the criteria outlined above.

2.2 The Glasgow Data

The first dataset that is used extensively throughout the thesis was collected within the context of the *Teenage Friends and Lifestyle Study*[2] (Pearson and Michell, 2000). The data was gathered in Glasgow between 1995 and 1997; I will refer to this dataset as the *Glasgow Data*. As the only of the four datasets, the *Glasgow Data* consists only of one network in one school.

All 160 participants of the study were members of a school cohort (aged ~ 13 in the first wave) and were followed over a period of three years. Complete data is available for 129 adolescents, who participated in all three waves. Children were asked about demographic characteristics, lifestyle, and substance use patterns at the beginning of each calendar year. The demographic characteristics that I use in the thesis are the sex of adolescents and the amount of pocket money received from their parents. Substance use was measured for a series of items, most importantly for tobacco and alcohol. Drinking alcohol was recorded on a 5-point scale from never drank alcohol to drink alcohol more than once a week. Tobacco consumption was measured on a 3-point scale from not smoking at all to smoking regularly (more than once a week).

For lifestyle choices, the participants were asked to indicate whether they listened to any of 16 music styles suggested by the researcher or not. In an earlier study (Steglich et al., 2006), factor analysis shows that music tastes form 3 distinct clusters: Rock music, techno music and classical music. I only use rock and techno music, which consist of 4 items each: listening to rock music is measured listening to "indie", "rock", "grunge" and "heavy metal"; listening to techno music is measured by the items "chart", "dance", "techno", and "rave". One point was given for each of the four music styles a participant listened to, resulting in a range of each of the composite variables "rock music" and "techno music" from zero to four.

Furthermore, participants could nominate up to 6 persons in their year group as

[2]The Chief Scientist Office of the Scottish Home and Health Department funded the study under their Smoking Initiative (grant K/OPR/17/8). Data collection was executed by Lynn Michell and Patrick West of the Medical Research Council and Medical Sociology Unit, University of Glasgow.

close friends at each time point. This data was used to construct the directed friendship networks, which results in three waves of complete, directed friendships networks between the adolescents. Previous studies employing 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 exist between individuals who are similar on these attributes. Although pocket money similarity between friends is understood as status homophily, it is also possible that homophily on this dimension relates to opportunities to jointly engage in expensive activities and that only adolescents that have more money can do these things together.

Finally, the participants were asked to indicate what they do with each of their nominated friends. There were four options of which the adolescents could give multiple answers. The three activities that I use are "we do activities together", "we just hang about together", and "we are close, talk a lot, share secrets". For each of these activities directed networks were created that indicate what the respondents do with their friends at three time points, which allows analysing the longitudinal evolution of joint activities. Descriptive statistics of the data are presented in the appendix. The data is publicly available[3].

2.3 The ASSIST Data

Data for Wales and England comes from the *A Stop Smoking In Schools Trial* (ASSIST) study[4] (Campbell et al., 2008; Steglich et al., 2012). 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 demographic characteristics and substance use patterns. At the beginning of this three wave dataset, the adolescents were aged 12-13. While the dataset is part of a larger project that focussed, among others, on interventions to stop adolescents from smoking, I have access to data from 11 schools. The cohort sizes that were surveyed range from 80 to 236 pupil, amounting to a total of 1716 adolescents. The schools in the study were deliberately chosen from cities and towns of varying sizes

[3] `http://www.stats.ox.ac.uk/~snijders/siena/Glasgow_data.htm`, last accessed 30.06.2014

[4] The study was funded by the medical research council of the UK, project number ISRCTN55572965.

and varying levels of social deprivation, measured by the proportion of pupil that were entitled to free school meals.

As in the Glasgow data, the friendship networks were constructed by a name-generator, asking the pupil to nominate up to 6 friends within their cohort at each of the three time points. The two measured demographic variables that are used in this thesis are the respondents' sex and a measure of socio-economic status (SES) of the pupils' parents. The SES was measured by the "family affluence scale" (FAS), ranging from 0-6. The FAS was measured with three items: 1) does the respondent's family own one or more cars (responses coded 0-2), 2) did the family travel away from home one, two or more times over the last year (coded 0-3), and 3) does the respondent have an own bedroom (coded 0-1). Previous studies consistently found homophily along the lines of sex in the schools (Steglich et al., 2012), while in only some of the networks the adolescents chose their friends based on similarity of FAS. Descriptive statistics of the analysed network are presented in the appendix.

2.4 The DyNet Data

Data from the United States were collected as part of the *Dynamics in Networks* (DyNet) study[5] in middle schools in Oregon and California between fall 2008 and spring 2012 (Light et al., 2013). All members of the participating middle schools (usually grades 6-8) were interviewed four times each academic year. For this study a sub-sample of 6 schools in the first year of the data is used, so that 4 waves of data are available, collected within one school year. The networks contain between 117 and 192 pupil. In total, data of 932 adolescents is analysed.

Students were asked to complete electronic questionnaires concerning demographic characteristics and substance use patterns. In this thesis, the analysed demographic characteristics are the adolescents' sex and ethnicity. Ethnicity was measured using the question how they would "describe their ethnicity". The following choices were possible: White European American, Black African American, Latino-Hispanic, Asian American

[5]The study was supported by award number R01HD052887 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development with John M. Light as the Principal Investigator

or Pacific Islander, Native American (Indian), or Other. Multiple choices were possible. From this data, a dyadic Covariate was created, coded as 1 if two adolescents had at least one indicated ethnicity in common and 0 otherwise.

The networks were measured in a different way, compared to the *ASSIST Data* and *Glasgow Data*. Students were asked to select from a list of all participating individuals in their school the ones with whom they spent free time in the last month. Free time was defined as time where they could talk about whatever they want outside of school or organised activities. From within this group, individuals nominated their best friends. This approach to obtaining friendship networks focusses on joint free time together, i.e. only allows friendships that have a behavioural component, while the previous datasets focus only on perceptions of adolescents. This method of data collection resulted in a wider degree distribution compared to the previous studies.

In this data homophily can be found with respect to sex and ethnicity. It should be noted that two schools of this dataset were substantially different to the other schools. The average outdegree is considerably lower, and as many as 50% of pupil in some of the waves reported not to have a single friend in their school. This data was used nevertheless; however, potential differences to other schools might be due to these characteristics. The data was used in e.g. in Light et al. (2013), where a detailed treatment of the data can be found. Descriptive statistics are presented in the appendix.

2.5 The Dutch Data

The fourth dataset is taken from the *Dutch Social Behavior study* (Houtzager and Baerveldt, 1999). In the mid-1990s this two wave network dataset was collected in a total of 23 high schools, of which 19 took part in both waves. Data was collected on students in their 3rd year at wave 1 (most aged between 15 and 17) with classroom sizes varying from 31 to 91, amounting to a total of 990 pupils. Data collection was conducted by in-classroom questionnaires, where students gave information on some demographic and behavioural characteristics, of which only sex is used in this thesis. Further, two social network items were measured, that were jointly coded into a binary

friendship network for each classroom.

The two items that were asked are: 1. Emotional support received: "Which pupils help you when you are depressed, for example, after the end of a love affair or when you have a conflict with other people?" 2. Emotional support given: "Which pupils do you help when they are depressed, for example, after the end of a love affair or when they have a conflict with other people?". A directed tie between two adolescents was deemed present for each adolescent that was mentioned in at least one of the two questions. This is a stricter definition of friendship than the previous datasets and provides some variety for the method with which the networks were constructed. This is reflected in a lower average degree compared to the other datasets.

The dataset has been used in a number of network studies and is regarded as a thorough and high quality study of multiple comparable networks (e.g. Snijders and Baerveldt, 2003; Baerveldt et al., 2004). Further, it is publicly available[6]. Descriptive statistics are presented in the appendix.

2.6 Comparison of the datasets

The datasets vary considerably in the composition of pupils and the method that was used to obtain the data. The different ways to measure the networks lead to very different average degrees and degree distributions. Further, the different datasets take different approaches to friendship: While the *Glasgow data* and the *ASSIST data* rely on the definition of friends perceived by the adolescents and limit the maximum number of possible choices, the *DyNet data* focusses on the behavioural aspect of friendship. The *Dutch data* takes the most stringent approach to friendship, defining it as giving or receiving emotional support[7].

It should be noted here that the friendship networks that are used in this thesis are obtained from the perceptions of the pupil in the different datasets. Thus, they are not objective measures of friendship, but subjective perceptions of friendship. While this is common practise in the research on interpersonal friendship networks, it leads

[6] `http://www.stats.ox.ac.uk/~snijders/siena/BaerveldtData.html`, last accessed 30.06.2014

[7] stringent refers to the fact that this definition leads to the lowest average degree of all the analysed networks

to observing a relatively large number of unreciprocated friendship nominations, where i perceives j as a friend, but j does not perceive i as a friend. Over the course of this thesis and in line with conventions in the field, I will refer to such relationships as one-sided friendships, even though one-sidedness contradicts common understanding of the term friendship. A discussion on why we observe one-sided friendships very frequently can be found in Chapter 4.5.

For each of the datasets, a different set of variables was obtained. This means on one hand that the different datasets are not directly comparable. On the other hand, any regularities that are found in multiple datasets are unlikely to be artefacts the of a data collection method. While all datasets are collected in the "western world", there is some variance in the origin of the datasets. There are significant cultural and legal differences between the USA, the UK, and the Netherlands. This allows confidence that regular patterns across different datasets are not particular to a certain school or region.

In practice this means that, as the *Glasgow data* and the *ASSIST data* were collected in ethnically homogeneous schools, ethnicity was not recorded in the data collection and cannot be analyzed. The *DyNet data*, in which ethnicity was diverse and important for network evolution, on the other hand, did not record any measure of socio-economic status (SES). The SES in the *ASSIST data* was measured using the Family Affluence Scale (details in the following sections), while in the *Glasgow data* the pocket money the adolescents received was asked. In the *Dutch data* no covariate other than the sex of the adolescents was used.

Chapter 3

Methods

Since the dawn of social network research, numerous methods for the cross-sectional and longitudinal analysis of complete social networks have been proposed. They range from simple to very sophisticated description of networks and positions within these networks (for an overview Wasserman and Faust, 1994), over the statistical association of dyadic characteristics of networks nodes with tie strengths (QAP, Krackhardt, 1988; Dekker et al., 2007), and detailed analysis of particular micro-mechanisms, to the statistical analysis of different dependencies simultaneously within networks (for an overview see Snijders, 2011), for example Exponential Random Graph Models (Lusher et al., 2013). However, within the empirical analyses of this thesis I use Stochastic Actor-Oriented Models (SAOMs, Snijders, 2001, 2005; Steglich et al., 2010).

I focus on these models for a number of reasons. All empirical analyses in this thesis try to discover regularities that underlie the evolution of friendship networks. However, friendships do not form independently of the actors that are involved in the friendship; the individuals in the networks decide and choose to whom they want form, maintain and dissolve friendships. These decisions of the network members drive the evolution of network. As such, conceptually I want to model these choices. Next, network evolution is an inherently dynamic process. In order to link antecedents to consequences, a longitudinal approach is advantageous. Finally, numerous different network evolution mechanisms can be assumed to be at work simultaneously, such as reciprocity, transitivity or homophily. A statistical approach is necessary to model all

these tendencies and more at the same time, controlling for one another.

I use SAOMs throughout the empirical analyses of the thesis, as they satisfy all the criteria outlined above. While ERGMs would be a viable alternative in many ways for cross-sectional data, additional assumptions for an actor-, and process-oriented interpretation of the results are necessary. Finally, in many of the chapters I use additional capabilities of the SAOM that are only available in this method, such as the distinction between tie creation and maintenance or the co-evolution of networks and behaviour.

All analyses are conducted using the software RSiena (Ripley et al., 2014), the latest and recommended software that implements SAOMs.

3.1 The Stochastic Actor-Oriented Model

SAOMs are specifically designed to model the evolution of a network between multiple observed time-points. SAOMs explicitly take the perspective of the individuals in the modelling process, which are called actors; i.e. it directly attributes agency to the actors over their their outgoing network ties. The decision of the actors can be dependent on their own or other persons' position in the network, on their own or other persons' attributes, or on relational attributes between the actor and others in the network.

A SAOM models the stepwise evolution of a network of individuals between two or more discrete time-points. The evolution is modelled conditioned on the first observation. At the discrete time-points the ties between, and the attributes of the actors are observed. It is assumed that the change from the network at one observation moment to the network at the next observation moment happens in a series of discrete changes, each of which affects only one tie. These changes of only one tie are called a *mini-step*. An illustration of a series of *mini-steps* is given in figure 3.1. The changes from the first observation at t_1 at the top left to the observed network at t_2 at the bottom right are decomposed into changes of one tie variable at a time, where blue dotted lines refer to creation of new ties and red dotted lines to the deletion of existing ties. The glowing actors are the locus of control, thus, they decide to change the respective tie variable.

The process further assumes that tie changes depend only on the current state of

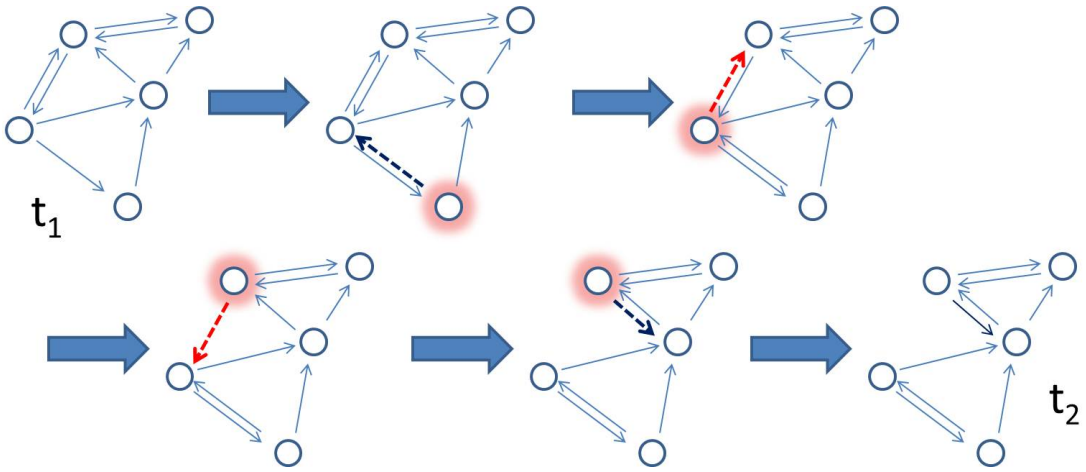


Figure 3.1: Example of a series of ministeps

the network and attributes of the actors in the network. This means that the actors neither have memory, e.g. form ties because this tie existed at some point in the past, nor do they act forward looking, i.e. no strategic or coordinated decisions are possible in this framework. In statistical terms, this implies we model a Markov process.

The fact that this model conditions on the first observation means that the process that guides network evolution from one time-point to another can be analysed without assuming that the system is in any kind of equilibrium state, which would be a very strong assumption in many cases (Snijders et al., 2010). However, this left-censoring also means that we enter the social world in a stage where a lot of social relations have already been created and broken off. Thus, it is not possible to account for the effect of the unobserved changes prior to the first measurement on the process after the first measurement. For example a violent dissolution of a friendship in the past will likely hinder the re-establishment of the same friendship in the future, thus past processes have an impact on future processes. As a way to deal with the implication of left-censoring of the data (and similarly the Markov assumption), covariates can be collected and included in the model specification that try to measure indicators of such past relations for example by collecting the duration of acquaintance between individuals, familial ties, common membership in groups, past conflicts etc..

As mentioned, the observations of the network are connected through a series of *mini-steps*. Each *mini-step* consists of two sub-processes. First, an actor in the network

is chosen to make a change in at most one tie, accounting for the state of the entire network and the attributes of all actors in the network. Which actor is stochastically chosen can depend on the position of the individual in the network, as well as her attributes. Who is chosen to make a change is modelled in the so-called *rate function*. In most contemporary empirical applications of SAOMs, as well as throughout this thesis with the exception of Chapter 7, actors are chosen at random to make a change (a period-wise constant *rate function*). Once an actor is chosen to make *a* change, she decides *which* change to make. Allowed changes are creating or breaking exactly one tie to any other actor in the network, or maintaining the current network state. Which of these options is chosen is modelled in the *objective function*.

The *objective function* is at the heart of the SAOM. Similar to generalised linear models, the *objective function* is a linear combination of different factors that influence an actor's decision to change ties, called effects:

$$f_i(\beta, x) = \sum_k \beta_k s_{ki}(x) \tag{3.1}$$

where $f_i(\beta, x)$ is the value of the objective function from the perspective of actor i, which depends on the statistical parameters β and the state of the network x. s_{ki} denotes the kth effect from the perspective of i. Examples for effects are the previously outlined micro-mechanisms, such as reciprocity or homophily. The different effects s_{ik} are weighted by their respective parameters β_k and summed to obtain the value of the *objective function* for the network resulting from one particular tie change. If the parameters β_k for the effects are positive, an actor is more likely to create or maintain a tie to an actor that contributes to a higher statistic of this effect.

In other words, in the second part of the *mini-step*, the actor changing a tie compares the outcome of the *objective function* for each network state that results from every possible tie change/non-change. The network state that results in the highest value of 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 likely. The probability to execute the particular tie change $i \rightsquigarrow j$, where i is the sender of a tie and j a potential recipient, is given by:

$$p_{i \rightsquigarrow j} = \frac{exp(f_i(\beta, x_{i \rightsquigarrow j}))}{\sum_k exp(f_i(\beta, x_{i \rightsquigarrow k}))} \tag{3.2}$$

where the denominator is the exponent of the outcome of the *objective function* for all potential tie changes, including no tie change of actor i. The realization of a tie change/non-change concludes a *mini-step*.

In an empirical analysis, the statistical parameters β_k are estimated from simulated series of *mini-steps* that connect the network observations at the different time points. The statistical parameters 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. However, it should be noted that this also means that parameter sizes are not comparable between models and different groups, as the unobserved heterogeneity affects all estimated parameters Mood (2010); Cramer (2003). Additionally, the interpretation of the coefficients and their translation to odds-ratios depends crucially on the specification of the model and can only be interpreted in light of the current model; thus, they should be interpreted carefully (*ibid.*).

For more details about the method, including different methods of parameter estimation, I refer to Snijders (2001, 2005). Non-technical introductions to the method are given by Steglich et al. (2006) and Snijders et al. (2010).

Technical details for all conducted empirical analyses in this thesis are as follows: Estimations were repeated with updated starting values until a convergence ratio of < 0.1 was reached. All presented models were estimated using Method of Moments. Whenever dictated by the data, a maximum value for outdegree was specified in the model.

3.1.1 Effects used in the Thesis

In each empirical analysis of the thesis, the focus lies on different micro-mechanisms that guide the evolution of the analysed friendship networks. As such, the effects of interest are different in each analysis. Nevertheless, the specification of all presented models is very similar. Although many effects that are included in all analyses are not related to the research question that is treated, they can be understood as controlling

for other tendencies that are known to be important predictors of friendship evolution and could bias the estimates of the parameters of interest. For example, it is known that both, a tendency towards transitivity and a tendency to create homophilous ties lead to the formation of groups in a network that have more within than between ties. Thus, if a researcher wants to analyse the extent to which people form homophlious ties, he has to control for the tendency towards transitivity, as otherwise the estimates would be biased (Goodreau et al., 2009).

Table 3.1 lists all single-network effects that are used throughout the thesis, including the mathematical formulation and a brief description of the effect[1]. The mathematical formula describes the network configuration that is modelled by the specific effect in terms of presence of ties and covariate values from the perspective of actor i. The statistical estimates that are connected to these configurations describe whether there is a general tendency of actors to predominantly form, or avoid these configurations. The detailed interpretation of each effect is discussed in the chapters where the effects are used. Interaction effects are specified as the multiplication of the part of the effect statistics $s_{ij}(x)$ that are independent of x_{ij} included in the interaction, multiplied by x_{ij}. All effects available in the current implementation of SAOMs are listed in Ripley et al. (2014).

The choice of effects that are used in this thesis is partly guided by theoretical considerations and partly by previous studies. Effects such as Reciprocity, Transitive Triplets, or Indegree Popularity are theoretically motivated for example by Social Exchange theory, Balance theory, or the Matthew effect, respectively. Other effects, such as Outdegree Popularity are not directly related to an existing theory and are included as they are needed to achieve a reasonable model fit to the data (see Section 3.4). While there is no canonical model specification, the set of effects used in this thesis are common in analyses using SAOMs for adolescents friendship networks.

[1] effects regarding the evolution of multiple networks and behavioural evolution are treated in their respective Sections 3.2 and 3.5

Effect Name and Mathematical Formula	**Effect Description: The tendency...**
Outdegree $s(x) = \sum_j x_{ij}$	...to form and maintain friendships. This can be viewed as an intercept.
Reciprocity $s(x) = \sum_j x_{ij}x_{ji}$	...to reciprocate friendships.
TransitiveTriplets $s(x) = \sum_{j,h} x_{ij}x_{ih}x_{jh}$	...to form and maintain ties to friends-of-friends.
Trans.Recip.Triplets $s(x) = \sum_{j,h} x_{ij}x_{ih}x_{jh}x_{hi}$	...to have reciprocated ties to friends-of-friends.
ThreeCycles $s(x) = \sum_{j,h} x_{ij}x_{hi}x_{jh}$	...to be tied to those who perceive ego as a friend-of-friend.
IndegreePopularity $s(x) = \sum_j x_{ij}x_{+j}$	...to attach to popular actors in the network.
OutdegreePopularity $s(x) = \sum_j x_{ij}x_{j+}$	...to be tied to those that nominate many others as friends.
OutdegreeActivity $s(x) = \sum_j x_{ij}x_{i+}$	...of those with a high outdegree to nominate more others as friends.
CovariateAlter $s(x) = \sum_j v_j x_{ij}$	...to befriend alters with a higher value of the Covariate.
CovariateEgo $s(x) = v_i \sum_j x_{ij}$	...of actors with a higher Covariate to nominate more friends.
SameCovariate $s(x) = \sum_j x_{ij} I\{v_i = v_j\}$	...of actors to befriend others of the same Covariate.
CovariateSimilarity $s(x) = \sum_j x_{ij} \frac{(1-\lvert v_i - v_j \rvert)}{max_{ij}\lvert v_i - v_j \rvert}$	...of actors to befriend others with similar Covariate values.
DyadicCovariate $s(x) = \sum_j x_{ij} w_{ij}$	...of actors to befriend others with higher values of the dyadic Covariate.

The used effects are denoted $s(x)$. A tie from actor i to actor j is called x_{ij}. The variables x_{+j} and x_{j+} refer to all incoming and outgoing ties of actor j, respectively. Variable v_i denotes the Covariate of actor i. The indicator function I equals 1 if the sender and recipient of a tie are of the same Covariate and 0 otherwise. The dyadic Covariate is denoted w_{ij}. All Covariates are centred, as well as the average similarity of Covariates in the Covariate Similarity effect.

Table 3.1: Network effects included in the analyses

3.1.2 Creation and Maintenance

In the standard specification for SAOMs, an actor evaluates a tie only dependent on its presence or absence from the personal network, e.g. not distinguishing between

a newly formed and an older, maintained friendship, given they are identical in their network position. However, in some contexts it is conceivable that certain effects mainly contribute to the formation of new friendships or to the maintenance of old friendships. For example, it might be the case that homophily mainly enables the formation of new ties, but does not stabilise existing friendships, or that reciprocity saves a friendship from being terminated (makes it enduring), but does not help establishing a friendship.

To allow distinguishing between effects that mainly contribute to the creation of ties and others that operate mainly on the termination of ties, an extension to the SAOM has been proposed (Snijders et al., 2010, Section 4.2). Within the *objective function*, effect statistics can be specified dependent on whether a tie was previously present or absent. Effects that only contribute to the *objective function* for newly formed ties are modelled in the *creation function*, while effects that only contribute to the *objective function* for ties that were present before the *mini-step* are modelled in the *maintenance function*. For models where creation and maintenance of ties are modelled separately, the *objective function* is the sum of the *creation function* and the *maintenance function*. However, the mathematical formulation of the effects is still equal to Table 3.1.

The distinction between creation and maintenance effects is employed in Chapter 7 of the thesis. Issues regarding model specification and parameter interpretation are presented there.

3.2 SAOM Multiple Networks

Within a closed group of individuals, multiple networks can exist interdependently of one another and be of interest to a researcher. For example, a study by Lomi et al. (2011) analysed the co-evolution of a friendship network and an advice networks between a group of students. The authors find that the students tend to ask their friends for advice, and that advice can often lead to friendship. This means that both, the friendship network and the advice network are understood best when analysing both networks interdependently. One feature of the SAOM is that it allows the interdependent modelling of multiple networks (Lomi et al., 2011; Snijders et al., 2013).

Modelling the evolution of multiple networks dependent on one another is concep-

tually not very difficult. The difference compared to the standard SAOM mainly lies in the first part of a *mini-step*: the selection which actor is chosen to make a tie change. For multiple networks, in the first part of a *mini-step* it is not only chosen which actor is allowed to make a tie change, it is also modelled in which network the tie is changed. Thus, a *rate-function* is estimated for each network; consequently, in the case of a period-wise constant *rate-function*, a basic rate parameter for each network and period is estimated, which decides which actor changes a tie in which network next.

The second part of the *mini-step* for multiple networks is conceptually identical to the estimation of one network. Each network has its own *objective function*, which might be dependent on the presence or absence of ties in the other modelled networks. This means that after the actor that will change a tie, and the network in which this change will take place is chosen, the actor decides which change to make, as outlined in Section 3.1. The difference to a basic SAOM is that the change in the network under consideration, the *dependent network*, can depend on the current state [2] of the other network, the *explanatory networks*, i.e. effects that depend on ties in other networks can be specified. The explanatory networks are regarded as dyadic covariates for the purpose of modelling at this *mini-step*. The simplest effect that can be included is the crossproduct of tie-variables between the two networks, which models whether a tie in the *explanatory network* leads to a tie in the *dependent network*. Using this approach, it can be distinguished whether a tie in network A leads to a tie in network B, and vice versa. A table of the cross-level network effects that are used can be found in Table 3.2. A detailed treatment for the modelling of multiple interdependent networks using SAOMs is given in Snijders et al. (2013).

In the Chapter 5 I employ this modelling approach, where I analyse what adolescents do with their friends. These activities form a series of networks, in which the participants nominate amongst their friends, with whom they do what. However, as they only nominate among their friends, these activity networks are embedded within their friendship networks. They can only nominate others that they have previously nominated as friends. To allow for this condition, the crossproduct effect from friendship to

[2] which cannot change at this point.

Effect Name and Mathematical Formula	**Effect Description: The tendency...**
Crossproduct $s(x) = \sum_j x_{ij} w_{ij}$	...to form a tie in network x following a tie in network w.
Reciprocated Crossproduct $s(x) = \sum_j x_{ij} w_{ji}$	...to form a tie in network x following an incoming tie in network w.

The effects are denoted $s(x)$. A tie in the network under consideration from actor i to actor j is called x_{ij}. A tie in the explanatory network from actor i to actor j is called w_{ij}

Table 3.2: Multiple Network effects included in the analyses

activities is not estimated, but fixed at a very high value, to exclude the possibility that the actors in the model nominate somebody that is not their friend. Further details to parameter interpretation and the modelling approach are given in Chapter 5.

3.3 SAOM Meta Analysis

Analysing the change of one network over time can show patterns and regularities in the evolution of this network. However, the analysis of a single network has to be considered a case study, where the dynamics of one particular group are studied. In order to generalize claims about the evolution of a certain type of networks, multiple, comparable networks should be analysed in a multilevel analysis framework. The procedure proposed by Snijders and Baerveldt (2003) can be followed to obtain mean population values of networks evolution effect estimates from a sample of comparable networks. Applying this meta-analysis framework allows claims about general tendencies in certain types of networks. This is crucial for the research questions I am interested in, as I want to establish general regularities of adolescent friendship evolution.

The proposed method assumes that the different networks from which the parameters are estimated are randomly drawn from a population of networks. It uses a two-step approach. In the first step, the identically specified model is estimated for each network. Using the parameter estimates from the different models, in the second step the mean population value for each included effect is estimated using a weighted least squares (WLS) estimator, originally proposed by Cochran (1954). Using this estimator assumes that the parameter estimates and the standard errors of the individual

networks are uncorrelated. This assumption is tested in the data analysis.

I employ the meta-analysis of different networks in the empirical chapters where I can use a larger number of networks that were obtained applying the same method. The meta-analysis is employed in order to show that the results generalise to this type of networks and are not a peculiarity of one analysed network. However, due to a low number of analysed networks or different networks not being comparable enough for this framework, it is not always possible to perform a meta-analysis. In these cases I present the results from multiple networks side by side and establish general patterns from regularities that are observed in all networks qualitatively.

3.4 SAOM Goodness of Fit

As opposed to many other statistical techniques, for network models such as Exponential Random Graph Models (ERGMs) or SAOMs no single number (such as R^2, AIC, etc.) has been developed and is in use that describes the goodness of fit (GOF) of a model specification[3]. However, testing whether a model is a good representation of data is a crucial part of statistical modelling. Lospinoso (2012) developed a method to assess GOF for SAOMs using auxiliary statistics of networks that are not explicitly modelled by the estimation procedure, such as degree distributions or the triad census, which was applied by Conaldi et al. (2012). The approach is similar to the work of Hunter et al. (2008) for ERGMs.

In this method, the parameters obtained from the estimation are used to simulate a large number of networks. The simulated networks are compared to the empirically observed network with regards to the auxiliary statistics. The results of the simulation and how they compare to the observed statistics are visualised using a violin plot (Hintze and Nelson, 1998) with the observed values superimposed. This allows determining whether the proposed model generates networks that are characterised by similar values for various statistics as the observed network. Common examples

[3]Snijders (2004) proposed a method for the explained variation in dynamic network models based on the entropy of the distribution of choices made by actors that described the fit of a model specification expressed in the single number $\hat{R}_H$. However, I am not aware of any application that uses this measure. Further, it is currently not implemented in RSiena.

for such auxiliary statistics are the degree distributions, or the average shortest path length. Further, for every statistic, or vector of statistics, a p-value is calculated that allows to conclude whether the current model represents the empirical data well with regards to the auxiliary statistics. This method is introduced in more detail in Lospinoso (2012) and Snijders and Steglich (2014).

GoF testing is applied in the first empirical chapter of the thesis. The statistic used is the triad census (Holland and Leinhardt, 1976). The triad census counts the number of occurrences of each potential triadic configuration in a network. However, this will be discussed in more detail within the empirical chapter.

3.5 Co-evolution of Networks and Behaviour

The final extension of the SAOM I present is the possibility to analyse the co-evolution of networks and behaviour (Steglich et al., 2006, 2010). This extension is geared to analyse processes of social influence in networks. Example questions are, do individuals, organisations or states change their attitudes, behaviours, internal organisation, or practices in response to the others they are tied to? While these questions are highly relevant to the study of individual and collective behaviour, it is methodologically very difficult to distinguish influence from homophily; i.e. are actors connected because they are similar (selection), or are actors similar as a result of being connected (influence)? Numerous articles have dealt with the difficulties of distinguishing these two mechanisms, as the outcomes of both processes are identical: individuals are connected to others that are similar to themselves. Especially Shalizi and Thomas (2011) discuss this difficult task in detail. On a series of examples they show that what might look like social influence at first sight could also be the result of homophily (primary, on the observed characteristic; secondary, on a related, but different characteristic; or latent, on unobserved or unobservable characteristic) or external causation. Even asymmetry in relations or a temporal ordering in adopted behaviour is not certain to distinguish influence from selection and external causes (see also Lyons, 2011). Shalizi and Thomas (2011) argue that strong (parametric) assumptions are necessary to credibly distinguish selection and influence. The SAOM for the co-evolution of selection and influence makes

an attempt at modelling both processes, network and behavioural evolution, simultaneously and interdependently, and therefore models homophily controlling for influence and vice versa. However, as pointed out by Shalizi and Thomas (2011) this approach depends a set of assumptions (parametric and related to the absence of unobservable covariates that can affect selection and influence).

The data format of a behavioural variable that can be employed using the SAOM is ordinal with relatively few categories. The approach the SAOM takes is similar to the analysis of multiple networks (see Section 3.2). Different *rate functions* are specified for the evolution of the network and the evolution of the behaviour. This means that in the first part of a *mini-step* an actor is chosen to make a change in either the network (changing one tie) or in her behaviour.

Once an actor is chosen to make a change in either of the two dependent variables, a separate *objective function* models which change is executed. Changes in the network follow the same rules as outlined in Section 3.1, where the behaviour is fixed at the current, simulated value in the *mini-step* and can be used in the same way as a covariate to model e.g. homophily. In case an actor is chosen to make a change in her behaviour, a separate *objective function* models which change is executed. Potential changes an actor can make are (i) increase the level of the behavioural variable by one category, (ii) decrease the level by one category, or (iii) stay at the current level.

The *objective function* of the behavioural evolution is, equal to Equation 3.1 for the network evolution, a linear combination of factors that make higher values of the behaviour more or less likely.

$$f_i^z(\beta, x, z) = \sum_k \beta_k^z s_{ki}^z(x, z) \tag{3.3}$$

The *objective function* $f_i^z(\beta, x, z)$ equals the sum of statistical parameters β for the kth effect, multiplied by the respective statistics $s_i^z(x, z)$, where x is the state of the network from the perspective of actor i and z refers to the behaviour of the actors in the network. The outcome of the objective function for each of the three potential behaviours[4] is calculated and the highest value of the objective function is most likely

[4]increasing, decreasing, or staying at the same level; or, in case the current behaviour is at the

Effect Name and Mathematical Formula	**Effect Description: The tendency...**
LinearTendency $s^z(x,z) = z_i$	...to engage in higher levels of behaviour z.
QuadraticTendency $s^z(x,z) = z_i^2$	...to non-linearly engage in certain values of behaviour z.
EffectFromCovariate $s^z(x,z) = z_i v_i$	...to engage in behaviour z depending on higher levels of Covariate v.
AverageAlter $s^z(x,z) = z_i \frac{\sum_j x_{ij} z_j}{\sum_j x_{ij}}$	...to increasingly engage in behaviour z if more friends engage in this behaviour.
AverageReciprocatedAlter $s^z(x,z) = z_i \frac{\sum_j x_{ij} x_{ji} z_j}{\sum_j x_{ij} x_{ji}}$	...to increasingly engage in behaviour z if more reciprocated friends engage in this behaviour.
Av.Alt.SameCovariate $s^z(x,z) = z_i \frac{\sum_j x_{ij} z_j I\{v_i = v_j\}}{\sum_j x_{ij} I\{v_i = v_j\}}$	...to increasingly engage in behaviour z if more friends that have the same Covariate v engage in this behaviour.
Av.Alt.DifferentCovariate $s^z(x,z) = z_i \frac{\sum_j x_{ij} z_j I\{v_i \neq v_j\}}{\sum_j x_{ij} I\{v_i \neq v_j\}}$	...to increasingly engage in behaviour z if more friends that are different on Covariate v engage in this behaviour.

The effects that depend on the state of the network x and the behavioural variable z are denoted $s(x,z)$. The behaviour z of actor i is z_i. A tie in the network from actor i to actor j is called x_{ij}. Variable v_i denotes the Covariate of actor i. The indicator function I equals 1 if the sender and recipient of a tie are of the same Covariate and 0 otherwise for the Average Alter Same Covariate effect, and equals 0 if the sender and recipient of a tie are of the same Covariate and 1 otherwise for the Average Alter Different Covariate effect.

Table 3.3: Behavioural effects included in the analyses

to be chosen by the actor. The probabilities to choose either category can be calculated analogous to to Equation 3.2. A positive statistical parameter β for one effect means that an increased value in this statistic makes choosing a higher level of behaviour z more likely.

The statistical power of the behavioural evolution of an analysis that models the co-evolution of networks and behaviour depends on the amount of change in behaviour between two time-points. If N is the number of participants in a study, for the behavioural evolution there are N observations. This is considerably less than for the network evolution, where $N \times (N-1)$ observations are available, which equals the number of ties in a network. Consequently, there is a natural asymmetry in the statis-

lowest or highest possible level, two behaviours.

tical power for detecting selection and influence effects in a co-evolution study.

The effects that are used to model behavioural evolution are presented in Table 3.3. As previously, the detailed interpretation of the effects is given in the chapters where they are used. The co-evolution of a friendship network and adolescent behaviour is modelled in Chapter 8 of the thesis.

Chapter 4

Reciprocity, Transitivity, and the Mysterious Three-Cycle

Reciprocity and transitivity are the two most important structural mechanisms that underlie friendship network evolution. While on their own they are understood in great detail, the relation between them is rarely studied systematically in the context of adolescent friendship networks. Are friendships outside of social groups more or less likely to be reciprocated than friendships embedded in a group? On this empirical question I show how a situational understanding of friendship networks can help understanding the relation between different network evolution mechanisms. By relating reciprocity and transitivity to different social situations, dyadic and group-based, respectively, I develop the hypothesis that the tendency towards reciprocation of friendships within transitive groups will usually be lower than outside of transitive groups. This first chapter focusses on endogenous network mechanisms. In the following chapters the proposed logic is applied to exogenous network mechanisms, namely homophily.

In a meta-analysis of the *Dutch data* and the *ASSIST data*, the interaction between reciprocity and transitivity is analysed. Supporting the theoretical reasoning, the interaction is consistently negative. Further, modelling this interaction dramatically improves the goodness of fit of the SAOMs to empirical data. As a second result of

A slightly modified version of this chapter won the INSNA Best Student Paper Award 2014. It is currently being revised for publication at the journal *Social Networks*.

this chapter, the tendency against forming three-cycles in friendship networks, which was consistently found in previous studies, is shown to be spurious and a result of neglecting to control for the tendency against reciprocation in transitive groups. As the tendency against three-cycles was seen as an indicator that unreciprocated friendships indicate local hierarchy differences between individuals, this proposition has to be re-evaluated in the light of the findings of this study.

4.1 Introduction

As presented in the introduction of this thesis, the two most important relational network evolution mechanisms are mutuality and clustering (Rivera et al., 2010). Especially analyses using SAOMs allowed to firmly establish that their representations in a network, reciprocity and transitivity, are the main endogenous determinants of friendship network evolution in the context of school cohorts and classes (Snijders et al., 2010; Veenstra et al., 2013). This first substantive chapter approaches the interdependence of these endogenous friendship evolution mechanisms; as such it focusses on the interaction between reciprocity and triadic closure.

4.1.1 Reciprocity

Reciprocation describes the increased likelihood of an individual to send ties to those from whom she receives a tie. This dyadic relational mechanism is intuitively plausible and, for strong friendship ties, often understood as implicit in the definition of friendship (Newcomb, 1956). Some research defines friendship ties a priori as mutual (e.g. Krackhardt, 1992) and, therefore, models friendships as undirected. In statistical analysis of friendship digraphs, reciprocation is often the most powerful predictor of the existence of a tie.

The intuitions behind reciprocity are straightforward: First, similarity breeds connection (Lazarsfeld and Merton, 1954), and as similarity is a characteristic of a pair of individuals, it breeds connection in both directions. This similarity can be along the lines of any type of measurable (sex, social class, political attitudes etc.) and immeasurable (sense of humour etc.) attributes and attitudes. Further, Homans (1950)

states that time spent together makes people more likely to become friends, which works both ways. Finally, social exchange theory (Emerson, 1976) suggests that reciprocated friendships are more rewarding for an individual than unreciprocated ones, as the balance between costs and benefits of reciprocated friendships is more favourable. Investments and returns of relationships can take many forms, e.g. spending time with the other person, emotional support and commitment, material support, presents, or help performing tasks, such as moving. In case one party in a friendship feels she contributes more than she gets, a friendship is likely to be broken. Therefore, people seek to form and maintain mutual friendships where both partners make an effort.

4.1.2 Network Closure

The other persistent relational network mechanism in friendship dynamics is clustering. Clustering describes the pervasive and recurring tendency of people to form social groups where one's friends are connected to each other as well. The term "social group" that I use throughout this thesis is synonymous to what is colloquially known as an adolescent friendship clique. However, the term "clique" has quite a specific meaning in network terminology, thus I use "social group" instead. Being member of a common social group means that indirect connections between individuals, i.e. two unconnected actors that are tied to the same third party, tend to become direct connections over time. In directed friendship networks closure is generally represented by a transitive triplet (see Snijders et al., 2010). A transitive triplet between the three actors i, j and h, is commonly understood as a tie being present from i to j, from j to h and a tie being present from i to h (Figure 4.1a). There are many theoretical rationales that explain clustering in friendship networks.

One of the first approaches was given by Simmel (1950). He suggested that joint membership in a group leads to clustering in social networks. Further, if two people have a common acquaintance, they are more likely to meet and get to know each other (e.g. Granovetter, 1973), i.e. time constraints in individuals' social contacts lead to clustering in a network. Balance theory suggests that people seek balanced relationships in their lives (Heider, 1946; Newcomb, 1961). A triad is only balanced if the

number of positive ties is odd, therefore, open triads tend to either close, or lose a positive tie. A further mechanism that leads to clustering is the idea that ties between two unconnected individuals and the common third party are the result of homophily of some (latent) attribute. As a consequence, the two unconnected persons will have this attribute in common, too, which facilitates tie formation (Granovetter, 1973). Finally, an indirect connection can ease access to information about the potential interaction partner, therefore reducing the potentially involved risk of engaging in interaction (Granovetter, 1985; Coleman, 1988).

4.1.3 The relation of Reciprocity and Transitivity

While reciprocity and clustering in the development of friendship networks is widely analysed, little attention has been paid to the interplay of these two mechanisms. A question that arises is whether reciprocation is more or less likely within social groups, or transitive triads, as opposed to non-embedded friendships[1]. One reason might be that in large parts of theoretical work on triadic closure, friendships are understood as mutual, therefore rendering the question moot. However, since much statistical analysis of friendship dynamics focuses on directed friendship ties, this appears to be an important question. Further, a directional conception of friendship is theoretically important.

Some work on reciprocated ties within triads is done on so-called Simmelian ties (following Krackhardt, 1992). Simmelian ties are reciprocated ties where both partners are also mutually strongly connected to a common third party; for the case of a digraph this is represented by a complete triad with all six possible ties being present. This means that Simmelian ties do not *per se* deal with reciprocation in triads, only with the special case where all ties in a triad are reciprocated. Further, this line of work is mainly concerned with the consequences of this type of ties (Krackhardt, 1999; Tortoriello and Krackhardt, 2010), or their persistence (Krackhardt, 1998). The emergence of Simmelian ties is less part of this research, especially not the relationship of reciprocation within, compared to outside of these triads.

[1]The only statistical network study that models this interaction to my knowledge is Igarashi (2012). While modelled it in an analysis employing ERGMs, it was not discussed theoretically.

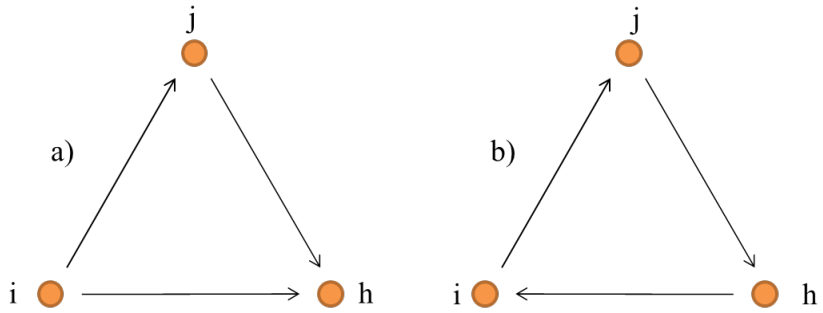


Figure 4.1: a) Transitive Triplet and b) Three-Cycle

Therefore, from a theoretical and empirical point of view, the question remains whether reciprocity is equally likely within compared to outside of transitive triplets and how the two mechanisms are interrelated. Since statistical methods for studying network dynamics are increasingly available and easy to use by now (Snijders, 2011), studying the interaction between the mechanisms of reciprocity and transitivity is facilitated from a statistical point of view. However, before I proceed to outline a theoretical approach that relates the two mechanisms in question, I will discuss a further relational network mechanism that seems somewhat disconnected to the research at hand. However, I intend to show later that it is closely related to the interplay of reciprocity and transitivity.

4.1.4 The Mysterious Three-Cycle

Ever since the increasing popularity of SAOMs, a further triadic configuration that guides network evolution has received growing attention, and is by now among the frequently used relational mechanisms modelled in analyses of friendship networks using this technique. The mechanism in question is the three-cycle. In a triad of actors i, j, and h, it describes the configuration where a tie from i to j, a tie from j to h, and a tie from h to i is present (Figure 4.1b). This configuration is similar to the transitive triplet, except that the direction of the tie from i to h is reversed. With surprising consistency, it has been found in many analyses of friendship networks that the effect that models whether actors choose to be in such a cyclic configuration is negative and both, highly significant and of substantive size (e.g. Snijders et al., 2010; Preciado et al.,

2012; Ellwardt et al., 2012; Giletta et al., 2012; Steglich et al., 2012; Cheadle et al., 2013; Veenstra et al., 2013; van Workum et al., 2013).

The, by now, canonical explanation for the negative three-cycle effect in friendship networks refers to a theoretical model proposed by Davis and Leinhardt (1970), and its further elaboration (Davis, 1970). It is proposed that the directionality of an unreciprocated tie is indicating a hierarchy difference between the sender and recipient, where the recipient of a tie occupies a higher position. A cyclic configuration in a network would imply a cyclic hierarchy, which is very unlikely, given the transitive nature of hierarchy. In their analysis of hundreds of networks, Davis and Leinhardt found that three-cycles were less often observed than random networks with the same density would suggest, which supports their theoretical model. However, given everything that is known about the structural interdependencies of ties within social networks by now, a contemporary study might not use a Bernoulli graph as a null hypothesis for this sort of question.

Nevertheless, after empirical analyses using dynamic network models consistently revealed that actors have a tendency against forming three-cycles, the Davis-Leinhardt model gained attention and popularity. The tendency against three-cycles in friendship networks is now commonly interpreted as an indication of the presence of local hierarchies (see previous list of references). This builds on the underlying assumption that the observed preference relations (friendships) are similar to dominance relations, where the directionality of a tie indicates hierarchy.

4.2 Theory and Hypothesis

In this section I develop and explain the fundamental assumption of a situational approach to friendship networks; namely that the relation between friendship evolution mechanisms can be understood with regards to the social situations that they represent. This is developed on the example of the differential importance of reciprocity within, compared to outside of transitive groups. As a second finding of this approach, I propose how failing to control for these tendencies in networks can lead to a spuriously found tendency against forming three-cycles.

4.2.1 A Situational Understanding

The theoretical reasoning that underlies the claim of differential importance of reciprocation within and outside of transitive triads, as well as all subsequent hypotheses that are tested throughout this thesis rests on a very simple assumption: Friendship ties are formed and maintained in social situations in which the involved parties spend time together. In other words, friendship ties that are observed in empirical studies are manifestations of individuals' choices to voluntarily spend time together. Although friendship is not a well-defined concept (e.g. Fischer, 1982; Van De Bunt et al., 1999), common understanding of friendship, as well as past research suggests that friends spend time together in social situations. Fischer (1982) finds in a study that analyses whom respondents of a survey consider as friends that "[friendship] ties tended primarily to be relations of sociability, ones in which people visited, went out together, discussed shared pastimes, participated in some organization together, and so on." (p.306). Carley and Krackhardt (1996) refer to friendship as an interaction-based relationship. In "Friendship as a social process", Lazarsfeld and Merton (1954) propose that friendship develops and is maintained through voluntary and rewarding contact with another individual. Therefore, I view the assumption that individuals voluntarily spend time in social situation with their friends as well grounded[2].

In a second step, I suggest that all persons involved in a social situation, have to agree to take part in this social activity. As they are explicitly voluntary, which is in line with the voluntary nature of friendships (e.g. Granovetter, 1973; Henderson and Argyle, 1984), this is by definition true. Using these two basic propositions, I develop why reciprocation is differentially important within as opposed to outside of social groups. A social group can be defined as a number of people that are densely connected to one another (although not everybody has to be friends with everybody else) and that undertake social activities together. In statistical network analysis, a social group is represented by the presence of transitive triplets.

[2]There are close friendships that do not necessarily involve people spending much time together, e.g. very old friendship ties. However, these are based on having spent time together at some point in the past, which still is the basis of the persisting friendship tie. Therefore, and because these types of friendships are unlikely within a school cohort, the argument to follow still holds.

4.2.2 Reciprocity in Transitive Triads

If we compare an asymmetrical, or one-sided friendship tie between two persons that are embedded in a social group to an asymmetrical friendship tie between people that are not embedded in a social group, we can argue that the non-embedded tie is less likely to be formed and/or to persist. Within social groups, many social activities are undertaken as a group together or by varying subsets of the group. Therefore, each member of the group will spend social time with every other member of this group. If spending time together is a necessary condition for friendship, this condition is fulfilled for any pair of actors that spend time with the same social group, which allows for friendships to form, both symmetric and asymmetric. Within a social group, or an adolescent clique (in its colloquial understanding) it is not difficult to conceive of friendships that are asymmetric. Affection between two people is not necessarily perfectly mutual, additionally, friendships can be based on appreciation or admiration. Especially in adolescent social groups, one-sided admiration can result in a one-sided friendship. However, even for one-sided friendships, both, the sender and the recipient of the tie still do spend time together - otherwise the basic condition for friendship is not fulfilled. Therefore, we can explain why we expect asymmetric friendships to exist within social groups, and to be stable.

Outside of social groups, however, unreciprocated friendships are much less likely. One-sided affection or appreciation is unlikely to create social situations in which the sender and the recipient of the friendship spend time together. This is because the recipient of the friendship has no (or much less) incentive to spend social time with the sender, as the affection or appreciation is not mutual. Therefore, asymmetric friendships outside of social groups create no social situations where the friendship can be maintained. However, because friendships require to spend social time together, a non-reciprocated friendship is much less likely to be created, or to persist outside of social groups.

Additionally, in a one-sided friendship outside a social group unilateral propositions for joint activity are likely to be made, but not honoured. Thus, the asymmetry of the one-sided friendship will become obvious to the sender. This will make a friendship

likely to be dissolved or prevent it from being established in the first place. For friendships inside social groups, asymmetry is less likely to be noticed and acknowledged by the sender of a friendship. This gives additional rationale to the proposition that one-sided friendships are unlikely to exist outside of social groups.

Nevertheless, reciprocated friendships can persist outside of social groups. If both partners of a friendship share affection or admiration of one another, they can spend social time together in situations that involve only the two of them. Mutual friends can create a dyadic forum in which they can interact and maintain their friendship.

Bringing these lines of argument together, I argue that unreciprocated friendships are more likely to exist within social groups, compared to asymmetric friendships outside of social groups. In summary, this means that reciprocation is less important within social groups compared to outside of social groups. This means two things: (i) if a tie is reciprocated, there is less a tendency towards transitive embedding compared to an unreciprocated tie, and (ii) if a tie is transitively embedded, there is less a tendency towards reciprocation compared to a tie that is not transitively embedded. Thus, in an empirical analysis of network dynamics, the tendency towards reciprocation should be lower within groups than outside of groups. The triadic substructures that could model this lowered tendency are displayed in Figure 4.2. They combine the common substructure used to model closure in networks, the transitive triplet, with reciprocation within this substructure. This leads to the first hypothesis:

Hypothesis 1: The tendency towards reciprocation within transitive triplets is lower than outside of transitive triplets.

4.2.3 The Spurious Three-Cycle

Using Figure 4.2, I now relate the concept of reciprocation in triads to the three-cycle. It can be seen that three of the triadic structures in Figure 4.2 (a, d, and e) contain at least one three-cycle. Following *Hypothesis 1*, in an empirical analysis the tendency towards reciprocation within triads should be negative. If, however, this tendency is not modelled, but instead the tendency towards forming three-cycles, the parameter that

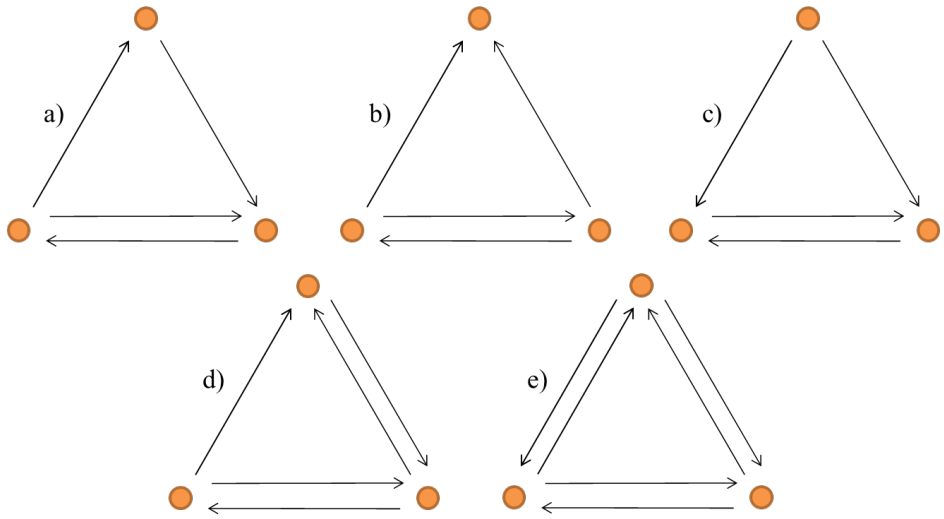


Figure 4.2: Triadic configurations with four or more ties

models the formation of three-cycles should pick up the effect of the omitted network structure. This means that, if *Hypothesis 1* is true, the found tendency against forming three-cycles could (at least partly) represent the tendency against reciprocation in triads. In other words, the observed negative tendency against forming three-cycles may be spurious. If this is the case, it casts serious doubts on the common interpretation that the tendency against forming three-cycles is indicative of the existence of local hierarchy in friendships. This leads to the second hypothesis tested in this article:

Hypothesis 2: When controlling for the tendency towards reciprocation in transitive triplets in an analysis of friendship network evolution, the tendency against forming three-cycles decreases or disappears compared to analyses in which the tendency towards reciprocation in triads is not modelled.

4.3 Analytic Strategy

In order to test the two hypotheses, I analyse all networks from the *ASSIST Data* and from the *Dutch Data*. Each individual network is analysed separately with two different model specifications and the estimated effect parameters for each dataset are combined

in a meta-analysis, as outlined in Section 3.3.

Two effects are needed to test the proposed hypotheses. These are the *Three Cycle* effect for *hypothesis 2* effect and the *Transitive Reciprocated Triplets* effect for both hypotheses. The latter effect was not discussed in the literature so far and was implemented in RSiena especially to model the tendency towards reciprocation in transitive triplets. The *Transitive Reciprocated Triplets* effect models whether actor i, the bottom left actor, in the network has a tendency towards or against forming a tie that results in structure a) in Figure 4.2. Thus, when included in a model jointly with the *Transitive Triplets* effect and the *Reciprocity* effect, it models whether an actor is differentially likely to reciprocate a tie within, compared to outside of a transitive triplet. Endogenous controls are *Reciprocity*, *Transitive Triplets*, and *Three Cycles*, the two degree related effects *Indegree Popularity* and *Outdegree Popularity* and *Ego-*, *Alter-*, and *Same Sex*, as Covariate based effects.

The further structures d) and e) of Figure 4.2 that combine transitivity and reciprocity include structure a) as a substructure multiple times. Structure c) in Figure 4.2 is of less interest to be directly modelled, as this structure is not transitive and reciprocated from the perspective of any of the three involved actors. The depicted triplet is only transitive for the top actor, however, the top actor has no reciprocated tie. The two bottom actors have a reciprocated tie to one another, but the triplet is not transitive for them (the top actor is not the friend of a friend).

Substructure b) in Figure 4.2 in principle is also an instantiation of *hypothesis 1*, however, in order to stay in line with conventions of effect specification in Siena it is not modelled. These conventions propose that in each effect only one substructure is modelled. Whether this omission biases the model is tested.

The proposed hypotheses are tested in a series of two models. The first model serves as a baseline with a standard model specification for adolescent friendship networks, which includes the three-cycle effect. In the second model, the *Transitive Reciprocated Triplets* is added. The findings are consistent with *Hypothesis 1* if the *Transitive Reciprocated Triplets* estimate in the second model is negative. *Hypothesis 2* is confirmed if the *Three Cycle* estimate in the second model has decreased substantively.

Finally, Goodness of Fit (GOF) of the two model specifications is tested. The statistic used for the test in this chapter is the triad census (Holland and Leinhardt, 1976), as this is directly related to the research questions addressed. The triad census counts the number of occurrences of each potential triadic configuration in a network. The numbers of reciprocated dyads, of transitive triplets, of 3-cycles, and of all triadic configurations presented in Figure 4.2 are linear combinations of the triad census. The GOF procedure is applied to each analysed network of the two datasets individually. As this raises issues of multiple testing, the resulting p-values are combined using the Bonferroni method for either dataset to test whether the proposed model specification is rejected. Details to this correction are given in the respective section.

4.4 Results

4.4.1 Parameter Estimates

The results of the SAOM meta-analyses are displayed in Table 4.1 for the *Dutch data* and Table 4.2 for the *ASSIST data*. The parameter estimates of interest in both analyses for the hypothesis are the *3-cycle* effect in model 1 and the *3-Cycle* and *Transitive Reciprocated Triplets* effect in model 2. While in the first model the *3-Cycle* parameter is negative, significant and of substantive size in both meta-analyses, in the second model the parameter is estimated positive and non-significant in the *Dutch data* and positive and significant in the *ASSIST data*. The newly included *Transitive Reciprocated Triplets* parameter is consistently estimated significantly negative and of twice the size as the previously modelled *3-Cycle* effect in each dataset. This suggests that the negative *3-Cycle* estimate that was found in model 1 was spurious.

In the *Dutch data*, the differences in parameter estimates between the results of model 1 and model 2 regarding the effects that are not directly related to the hypothesis are not statistically significant. This means that the other parameters are not biased by the omission of the *Transitive Reciprocated Triplets* effect. In the *ASSIST data*, not modelling the *Transitive Reciprocated Triplets* effect leads to a bias in the estimate of the *Reciprocity* and *Transitive Triplets* effect. This is not surprising, as the negatively

	Model 1			Model 2		
	estimate		s.e.	estimate		s.e.
Outdegree	-2.60	***	0.13	-2.63	***	0.14
Reciprocity	2.60	***	0.13	2.79	***	0.09
Transitive Triplets	0.94	***	0.07	1.06	***	0.07
3-Cycles	-0.41	**	0.13	0.21		0.14
Trans. Rec. Triplets				-0.79	***	0.08
Indegree - Popularity	0.02		0.02	0.01		0.03
Outdegree - Popularity	-0.26	***	0.05	-0.27	***	0.06
Sex Alter	-0.43	***	0.07	-0.45	***	0.07
Sex Ego	0.21		0.11	0.21		0.11
Same Sex	0.55	***	0.09	0.54	***	0.08

p-values: *** < 0.001; ** < 0.01; sex: 1=female

Table 4.1: Results of the three cycle meta-analysis for the Dutch data

estimated *Transitive Reciprocated Triplets* effect can be understood as the interaction between the two former effects. Omission of a negative interaction effect can often be associated with the main effects being estimated too low.

However, as the interpretation of the results does not differ qualitatively between the two models, I discuss these without distinguishing between them. For both datasets, the negative *Outdegree* parameter can be understood as an intercept with the interpretation that friendships are relatively sparse, as already seen in the description of the networks. However, ties are more likely to exist if they are *Reciprocated*, embedded in a *Transitive Triplet* or between *Same Sex* pupils. The parameter sizes for the reciprocity effect lie between 2.58 and 3.03. The objective function for a tie being embedded in an additional transitive triplet increases between 0.60 and 1.06. The parameter estimates for pupil being the same sex lie between 0.54 and 0.74. Pupil that send a lot of ties are less likely to be nominated as a friend, represented by the negative *Outdegree Popularity* parameter (estimates between -0.26 and -0.35). However, as mentioned in Section 3.1, differing parameter sizes in the two datasets and models do not allow the conclusion that the effects are differentially important in the different models, due to unobserved heterogeneity.

In the *Dutch data*, girls are less likely to be nominated as friends, seen in the negative *sex alter* parameter (estimates -0.43 and -0.45). This tendency cannot be observed

	Model 1			Model 2		
	estimate		s.e.	estimate		s.e.
Outdegree	-2.57	***	0.08	-2.55	***	0.08
Reciprocity	2.58	***	0.08	3.03	***	0.08
Transitive Triplets	0.60	***	0.02	0.74	***	0.03
3-Cycles	-0.35	***	0.04	0.30	***	0.04
Trans. Rec. Triplets				-0.71	***	0.04
Indegree - Popularity	0.06	***	0.004	0.06	***	0.004
Outdegree - Popularity	-0.30	***	0.01	-0.35	***	0.01
Sex Alter	0.01		0.04	-0.02		0.04
Sex Ego	0.01		0.03	-0.01		0.03
Same Sex	0.74	***	0.06	0.65	***	0.06

p-values: *** < 0.001; sex: 1=female

Table 4.2: Results of the three cycle meta-analysis for the ASSIST data

in the *ASSIST data*. On the other hand, in the *ASSIST Data* we can observe a small, but significant tendency towards preferential attachment (*Indegree Popularity*), which cannot be found in the *Dutch data*. In both datasets boys and girls are equally likely to send ties, although the parameter is bordering significance in the *Dutch data* indicating that girls might send more ties than boys, as modelled by the *sex ego* effect. The differences between the results of the two datasets might be attributed to the different contexts or the different method of collecting the data. However, the main determinants of friendship evolution are similar in the two networks (*Reciprocity, Transitive Triplets, Outdegree Popularity*, and *Sex Homophily*), especially concerning the parameter estimates relating to the tested hypotheses (*3-Cycles* and *Transitive Reciprocated Triplets*).

The assumption that parameter estimates and standard errors are uncorrelated underlying the WLS estimator for the meta-analysis is violated in some cases. In the *Dutch data*, the *Reciprocity*, *transitive triplets*, and *indegree popularity* estimates in both models, as well as *3-cycles* estimate in the first model show a p-value < 0.05 in a two-sided test. This means that the parameter estimates are likely to be biased. However, given the consistency of directionality and significance of the parameter estimates in each analysed network, the bias most likely relates to the exact size of the parameter, not to direction or significance. Further, most importantly the parameter estimates and

standard errors for *3-cycles* and *transitive reciprocated triplets* in the second model are uncorrelated. This means the parameter estimates most relevant to hypotheses testing are unbiased. In the *ASSIST data*, the parameter estimates and standard errors are uncorrelated in both models for all parameters, except the *same sex* estimate. This means that all structural effects that were modelled are not biased by the estimator used to obtain the population estimates.

The results were checked for robustness by modelling the tendency against reciprocation in triads by two different effects. The first was the *Dense Triads* effect, which models whether individuals have a tendency to be in triads with five or six ties, i.e. triads that are transitive and reciprocated. The second alternative effect was a so-called gratification effect that models in one effect whether individuals like to be in either substructure a) or b) in Figure 4.2. This is an effect that is not in line with the usual effect specification in Siena, as it combined two substructures in one effect; therefore, it was not used in the first place to test the hypothesis, even though it is a better operationalisation of it. When including either of the two effects instead of the used *Transitive Reciprocated Triplets* effect, the results led to the same conclusion regarding *hypothesis 1* and *hypothesis 2*.

4.4.2 Goodness of fit

Figure 4.3 and Figure 4.4 show examples of GOF tests for the first of the analysed networks in the *Dutch data* using the two separate models. The violin plots show the expected number of the different configurations in the triad census based on 3000 simulations of networks under the respectively proposed model. The superimposed point estimates show the empirically observed number of the respective configuration. Figure 4.3 shows that for model 1 especially the triadic configurations with one reciprocated and two unreciprocated ties fit poorly (configurations 120D and 120C). This is indicated by the point estimates (red dots) lying outside the confidence intervals of simulated networks (dotted lines). The overall p-value is 0.003, i.e. the proposed model is rejected even when using a very small level of significance. In other words, when simulating networks using the specification of the first model, the observed network is not represented

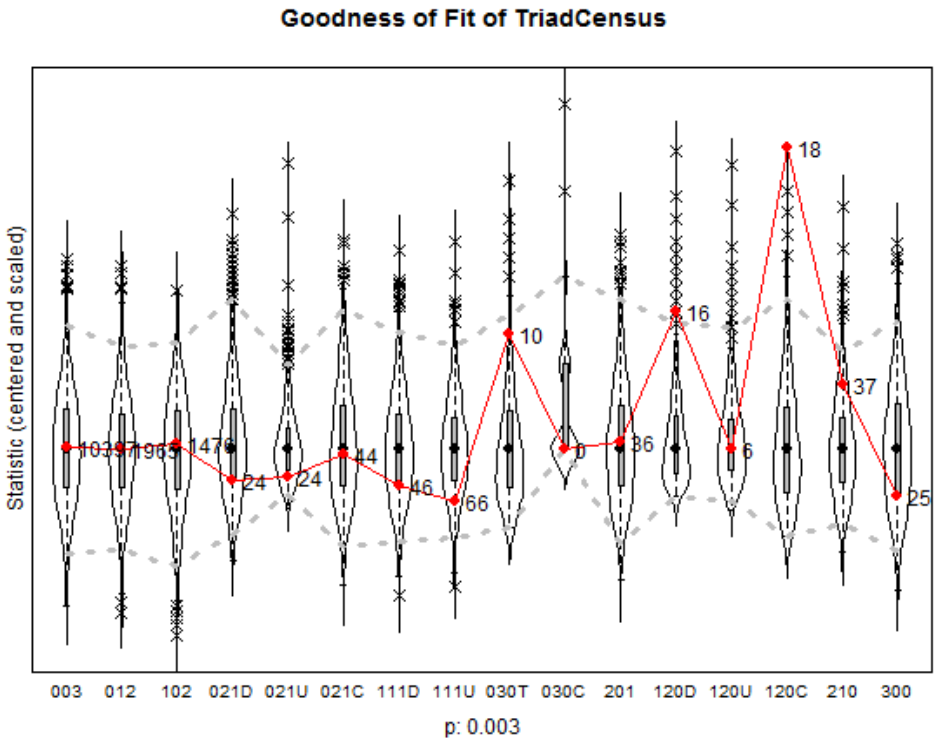


Figure 4.3: Triad Census GOF for Dutch Data Network 1 and Model 1.

well with regards to the triad census. Model 1 does not appropriately model decisions of actors which ties to form and keep embedded in triadic configurations. Figure 4.4 shows that the second model fits the empirical data better. The p-value for this model is considerably higher than the usual significance level of 0.05. This suggests that the second model fits the empirical data well.

Table 4.3 shows the p-values for the GOF test for each of the analysed networks in both datasets, indicating whether the model specifications fit the respective data well with regards to the triad census. For the *Dutch data* on the left-hand side of the table, in all but two cases (network 7 and network 13), model 2 outperforms model 1 in terms of GOF. Using the conservative Bonferroni correction for multiple testing of the same hypothesis, in order for a model to be rejected one of the p-values should be smaller than α / n, where α is the significance level (0.05 by convention) and n is the number of test, 19 in this case. This results in model rejection if a p-value < 0.003. For the first model, two p-values are < 0.003 (networks 5 and 11), which means that the hypothesis that model 1 provides good fit is rejected. The hypothesis that the second model fits

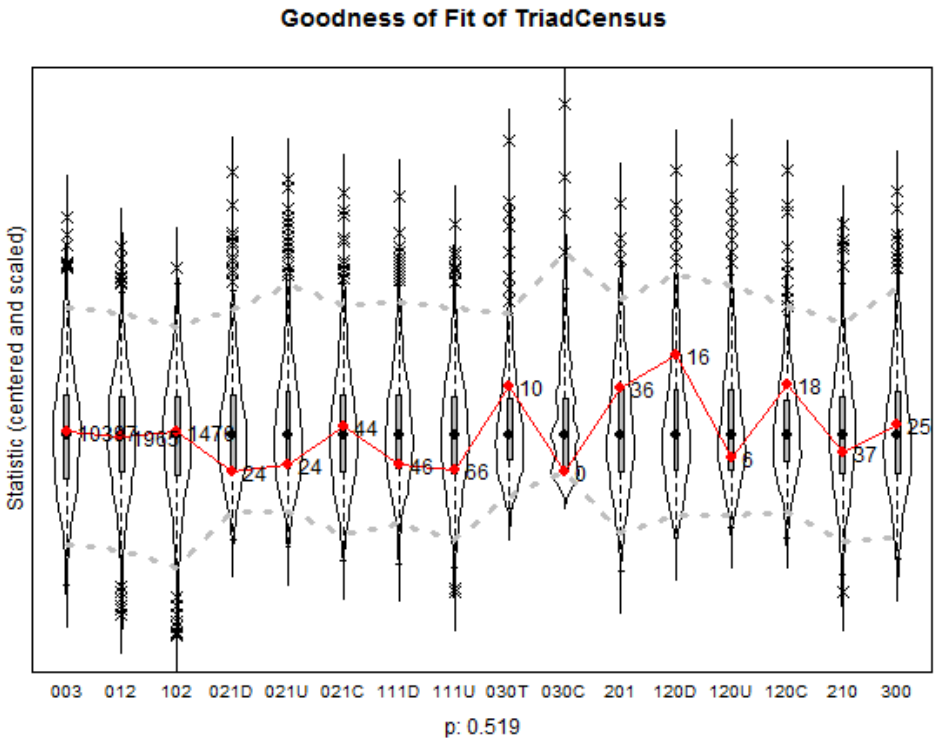


Figure 4.4: Triad Census GOF for Dutch data Network 1 and Model 2.

the data well is not rejected, as the lowest obtained p-value equals 0.005 (network 7).

On the right-hand side of Table 4.3 the p-values of the GOF tests for the *ASSIST data* are displayed. Here we see a different picture. While model 2 systematically exhibits a better fit than model 1, both proposed model specifications are consistently rejected. This suggests that the same model that provides a good fit for smaller networks cannot represent larger networks with more ties per actor well. This interpretation is supported by further investigation of the GOF results of the *Dutch data*. For the two largest networks (network 6 and network 11) the p-value whether the model specification is accepted is very low. Detailed examination of the GOF plots of the *ASSIST data* suggests that especially the configurations including one reciprocated and one unreciprocated tie are not represented well by this model specification.

4.5 Discussion and Study Conclusion

The present study analysed the relationship between reciprocity and transitivity in friendship networks. Although reciprocity and transitivity have been extensively stud-

	Dutch data		British data	
Network No.	Model 1	Model 2	Model 1	Model 2
1	**0.003**	0.519	**<0.001**	**0.001**
2	0.136	0.389	**<0.001**	**0.001**
3	0.258	0.261	**<0.001**	**<0.001**
4	**0.047**	0.499	**0.001**	**0.002**
5	**<0.001**	0.101	**<0.001**	**0.001**
6	**0.004**	**0.013**	**<0.001**	**0.002**
7	**0.006**	**0.005**	**<0.001**	**0.002**
8	0.415	0.935	**<0.001**	**<0.001**
9	0.500	0.594	**<0.001**	**0.001**
10	0.855	0.894	**<0.001**	**0.003**
11	**0.001**	**0.027**	**<0.001**	**0.006**
12	0.061	0.084		
13	0.111	0.103		
14	**0.007**	0.146		
15	0.310	0.325		
16	0.462	0.397		
17	0.651	0.922		
18	0.082	0.273		
19	**0.005**	0.067		

Bold: <0.05

Table 4.3: *p*-values for GOF triad census all analysed Networks

ied by themselves, they have not been related to one another using SAOMs[3]. Using a situational perspective that focusses on where and when ties are formed and maintained, I hypothesised that unreciprocated ties can exist within social groups, as represented by transitive triplets, while outside of social groups unreciprocated friendships do not have a forum for interaction, which is a prerequisite for a friendship. In a statistical model of friendship evolution, this should be represented by a tendency against reciprocation within transitive triplets. Further, as reciprocation within a transitive triplet contains a 3-cycle as a substructure, I hypothesised that the often observed tendency against forming 3-cycles in friendship networks is spurious and will not be observed, if the tendency against reciprocation in transitive triads is controlled for. The hypotheses were tested using SAOM meta-analyses of two datasets from different contexts using different methodology to obtain the friendship networks.

Hypothesis 1 is confirmed. The tendency towards reciprocation within transitive triplets is lower than outside of transitive triplets in each context. The other, comple-

[3]The *Transitive Reciprocated Triplets* effect was implemented especially for this study.

mentary interpretation of the same parameter is that once a potential tie is reciprocated, embeddedness in a transitive triad does not make the tie more likely to exist.

Hypothesis 2 is confirmed, too. After controlling for the tendency to reciprocate ties within transitive triplets, no tendency against forming three-cycles is found. This suggests that the negative three-cycle parameter, which is persistently found in analyses of friendship networks using SAOMs, is spurious and a result of a misspecified model.

Further, GOF testing of the two different models shows that including the tendency against reciprocation in transitive groups results in improved fit. For the *Dutch data*, the model that included only transitivity and 3-cycles as triadic configurations was rejected as fitting poorly; on the contrary, the model that additionally models reciprocity in transitive triplets was not rejected, based on the GOF testing regarding the triad census. For the *ASSIST data*, modelling the tendency against reciprocation in transitive triplets resulted in better fit, however, the proposed model specification was still consistently rejected. This suggests that for larger networks with more ties a more elaborate model specification is needed to achieve satisfactory fit with regards to the triad census.

The first main finding of the study at hand – embedding in a transitive group is more important for a one-sided tie than a reciprocal one – is in line with well-established theories in social network science. Both the sociological perspective that focuses on friends spending time together (Davis, 1963; Feld, 1981) and the psychological approach (Heider, 1958) can explain why friendships in triads are more stable than outside of them. While both approaches in principle are designed and formulated in such a way that they explain why transitive embedding leads to *reciprocated* friendships, either can equally be applied to one-sided friendships.

According to the former, spending time together is a condition for friendships. However, it is a *necessary* but not *sufficient* condition for friendships. Thus, even a one-sided tie fulfils this condition if a forum for interaction, such as a social group, exists. Equally, balance theory and social exchange theory can be used to explain why one-sided friendships are stabilised in transitive triads. As Carley and Krackhardt (1996) put it:

> Heider's formulation of inconsistency is not based on actual balance, but rather on people's perceptions of reciprocated liking, i.e. on non-symmetry. (...) balance exists if Person 1 thinks that Person 1 likes Person 2 and Person 1 thinks that Person 2 likes Person 1. (p. 4)

Thus, in the absence of mutual liking, a social group still provides a framework in which a one-sided friendship can exist. The group provides a rationale for Person 2 to be nice to Person 1, which leads to Person 1's perception of mutual liking.

The finding that reciprocity and transitivity interact negatively is supported by some studies (e.g. Igarashi, 2012; Lospinoso, 2012; Snijders and Steglich, 2014); however, these studies mainly include an effect that models reciprocity in transitive triads to improve the fit of their respective models and do not engage in a discussion of what these results mean.

The second finding of this article is that the tendency against forming three-cycles is spurious. This finding is more controversial, as it suggests that many past studies incorrectly interpreted the negative three-cycle parameter as an indicator of hierarchy in one-sided friendships. Do the findings of this article show that friendships are hierarchy-free, even if they are one-sided? Good arguments can be found for either position.

On the one hand, it is plausible that one-sided friendships lead to a power-difference between the sender and recipient of a friendship. The recipient can threaten the sender to withdraw, or promise to give approval to the sender under certain conditions, thus creating a clear hierarchy. Hallinan (1978) argues from a process-based perspective that a friendship offer, i.e. the first step to a friendships generally comes from a lower-status to a higher-status individual. Dijkstra et al. (2010) give an explanation why adolescents would strive for such asymmetric friendships, even though it implies a power imbalance. They argue and show empirically that being friends, even one-sided, with high-status individuals results in a higher status for oneself. They call this "basking in reflected glory". A further empirical study that explicitly models hierarchy difference between friends is carried out by Ball and Newman (2013). They find that they can infer a status ranking system from one-sided friendship nominations and that this ranking

correlates closely with other status-related characteristics of the participants, such as age and overall popularity. Thus, a wide array of work that does not base its finding on the negative three-cycle come to the same conclusion that one-sided friendships have a hierarchy imbalance.

On the other hand, many studies pose the exact opposite. If there is a clear hierarchy difference in a friendship, it tends to be of low quality, therefore unsatisfying and will most likely be terminated (Veniegas and Peplau, 1997). Additionally, high status adolescents tend to be mean to keep their high status position and are consequently less popular (Adler and Adler, 1995). Thus, one-sided friendships from low-status to high-status individuals are unlikely to exist in large numbers. Given the high proportion of one-sided friendships observed in empirical data (see Tables A.4 and **??**), in light of these elaborations it is improbable that all of them exist between adolescents of different hierarchy levels. Additionally, some work defines friendships as generally hierarchy-free, i.e. a relationship between equals (e.g. Allan, 1986). Finally, even the Article by Ball and Newman (2013) notes that under the proposed ranking model, most one-sided friendships are between individuals of equal status.

In light of the findings of this study and the literature on whether a one-sided friendship indicates a hierarchy-difference, a careful conclusion is that although some one-sided friendships might reflect a difference in hierarchy, it can hardly be stated a universal feature of them. Thus, if a sufficiently large proportion of one-sided friendships is non-hierarchical, then no tendency against three-cycle should be observed, as this requires all involved ties to reflect hierarchy on the same dimension.

Finally, if a one-sided friendship cannot be universally interpreted as an aspirational friendship from a lower to a higher ranking adolescent, what can be inferred from the information that a friendship is one-sided? One possibility is that these friendships are only one-sided in the observed data due to a differential understanding of the term "friendship" by different participants, echoing Fischer (1982). In other words, some individuals might have a lower threshold of intimacy for designating other as friends, thus, a perfectly symmetric relationship could be called a friendship by only

of the involved parties, resulting in observing an asymmetric friendship. Asymmetry of friendships would then only be a feature of the data, but not reflecting asymmetry of relations in the real world. This leads back to the basic idea (see Section **??**) that friendship is by definition mutual, otherwise it cannot be called a friendship:

> Wanting to be friends does not make you friends any more than wanting to be healthy makes you healthy. (Aristotle, *Eudemian Ethics*, in Annas, 1977)

Future research could focus on this broad question what can be inferred from observing a one-sided friendship.

4.6 The Bigger Picture

In this chapter I outlined the principal assumption of a situational understanding of friendship networks. Forming and maintaining a friendship requires spending time together. Time can be spent together in dyadic situations, i.e. two people like each other and decide to meet. This requires the friendship to be mutual, modelled as reciprocity. However, time can also be spent together in a social group, which is commonly represented by transitive closure. This will allow one-sided friendships. By relating both micro-tendencies, reciprocity and transitivity, to different social situations, dyadic and group-based, it is possible to relate the two mechanisms to each other. Reciprocity is a stronger determinant of ties outside of social groups compared to within social groups, which is confirmed in the empirical analyses.

Chapter 5

Homophilous Situations and One-Sided Friendship

The previous chapter related the two structural mechanisms of reciprocity and transitivity to one another. Reciprocity was understood as creating dyadic situations between two individuals that enable friendships, while transitivity was linked to group-based situations. In this chapter I elaborate on the relation between dyadic and group based situations, taking a further network evolution mechanisms into account that is group-based: Homophily. While transitive groups are defined by having common friends, homophilous groups are characterised by having similar attributes.

In the course of this chapter, I develop theoretically why I expect the same logic that applies to the interaction of reciprocity and transitivity to be appropriate to the interaction between reciprocity and homophily, too. This is empirically tested on a number of networks from the *Glasgow data*, the *DyNet data*, and the *ASSIST data*. To further strengthen the argument, I show empirically that different dimensions of homophily are indeed connected to adolescents doing different group-based activities together, while reciprocated friendships are primarily connected to dyadic activities. Finally, this study makes a small contributes to the discussion of the causes of homophily in adolescent friendship networks, a long standing issue in social network analysis.

5.1 Introduction

While the last chapter focussed exclusively on structural mechanisms, in this chapter the second class of important network mechanisms is introduced to the theoretical framework. Following Rivera et al. (2010) one of three types of network evolution principles relates to the complementarity of individual attributes of actors. The most important mechanisms of assortativity is without doubt homophily. This chapter analyses the interaction between reciprocity and homophily.

As discussed in the previous chapter, reciprocity is the tendency of friends to form mutual ties. Mutual friendships are generally understood as more rewarding than one-sided friendships (see Section 4.1.1) and can create their own situations to maintain a friendship (as elaborated in Section 4.2.2). As reciprocity has been discussed in the previous chapter, I immediately proceed to an introduction to homophily.

5.1.1 Homophily

Homophily, defined as the "tendency for friendships to form between those who are alike in some designated respect" (Lazarsfeld and Merton, 1954, p.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 and Campbell, 2003; Blau and Schwartz, 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-Lovin and McPherson, 1993; Marsden, 1987), but also along the lines of values (Huston and Levinger, 1978) and behavior (Knecht et al., 2010; Cohen, 1977; Kandel, 1978; Alexander et al., 2001). Apart from friendship, homophily shapes many different social networks, including but not limited to advice, marriage, support, exchange and co-membership in social groups.

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 and 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 Byrne, 1997; Festinger and Hutte, 1954; Hamm, 2000; Werner and 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, 1977b; Feld, 1981, 1982). This perspective emphasizes that opportunities 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, p.1016), are seen as social structures which systematically constrain the formation and maintenance of social relationships. In the view of (Feld, 1982, p.798), homophily is a likely outcome to the extent that "people draw their friends from foci, and foci bring homogeneous sets of people together".

5.1.2 The relation of Homophily and Reciprocity

As previously mentioned, the chapter at hand analyses the relation between homophily and reciprocity with the specific research question, how the two network evolution mechanisms interact. Similar to the previously discussed interaction between reciprocity and transitivity, this question has been, to my knowledge, under-researched,

especially in the context of complete adolescent friendship networks[1]. However, I argue that the interaction between these mechanisms is interesting for two reasons. First, it can be related to the overall structure of a network with regards to the amount of contact between different, homophilous groups; and second, it can shed some light on our understanding of homophily and reciprocity as network evolution mechanisms.

The interaction between homophily and reciprocity can have important consequences for the amount and quality of contact between groups characterised by different attributes. In case the interaction between the two mechanisms is negative, reciprocity can be understood as a tendency that mitigates homophily, and as such fosters contact between groups in which members otherwise prefer friendships to others in the same group. Homophily would operate more strongly on one-sided or unreciprocated friendships, while reciprocated friendships are not more likely to form and persist if they are homophilous. In this case, reciprocity can be understood as advancing integration between groups, as it diminishes the effect of homophily.

If the interaction between homophily and reciprocity were positive, the opposite argument could be made. In this case mainly the homophilous ties would tend to be reciprocated; and as reciprocated friendships are understood as closer and more rewarding, mainly the less intimate and more casual (unreciprocated) friendship would be formed and maintained between groups. From a positive interaction between homophily and reciprocity would follow that the combination of these parameters would not lead to more intimate ties between groups. Reciprocity would not stabilize heterophilous ties, but manifest friendships that are homophilous.

The interaction between homophily and reciprocity can further enhance the theoretical understanding of network evolution. In case the interaction is positive, homophily can be understood as moderating reciprocity, as I argue in the following, which can be taken as an argument that strengthens a preference perspective of homophily. As

[1]Exceptions are a study by Plickert et al. (2007) that analyses what type of exchange relations are more likely to be reciprocated dependent on monadic and dyadic characteristics of people and pairs. However, they study an adult population that exchanges goods and favours. As such it might not be very illuminating to apply their results to the dynamics of adolescent friendships. Two other studies focus (Burk *et al.*, 2007; Mercken *et al.*, 2010) interact reciprocity and homophily. However, here the dimension of homophily is delinquent behaviour and smoking behaviour, respectively, thus different from the ascribed characteristics that are in the focus of this thesis.

outlined earlier, reciprocated friendships can be perceived as a social exchange between people. There is a give and take of positive emotions, appreciation and advice in reciprocated friendships. The preference perspective on homophily suggests that homophilous friendships are more rewarding than heterophilous friendships, because of an improved understanding of, and communication with each other, both based on common experiences related to being similar. Mutual appreciation and giving of advice, both characteristics of reciprocated friendships, would be vastly facilitated by a common understanding of the world, as promoted by homophily. As such, we could understand why especially homophilous friendships would be reciprocated, while the social exchange that underlies reciprocity is less likely to be present in heterophilous friendships. Homophily would moderate the mechanisms that underlie reciprocity. Thus, a positive interaction could be interpreted as an indication that homophily is based on preference.

A negative interaction between homophily and reciprocity, on the other hand, would be more congruent with a situational view of homophily, as I will elaborate in the following section.

5.2 Theory and Hypothesis

In this part, I extend the previously developed situational understanding of network formation mechanisms to homophily on ascribed characteristics. Previously I argued that while reciprocity can be related to dyadic situation, transitive ties are maintained in group-based situations. In this chapter, I propose that homophily is equally related to group-based situations, however, to different ones than transitivity. As a result, I hypothesise that the interaction between reciprocity and homophily is negative, too.

5.2.1 Homophily and its Social Situations

From the work of Feld (1982) we know that people sort themselves into homogeneous groups and draw their social contacts from within these groups. This results in individuals being primarily connected to others that are like them in the dimensions that structure the groups they are members of. While Feld himself was able to show this

pattern, one of the studies that confirms his reasoning (McPherson and Smith-Lovin, 1987) shows that voluntary organisations are more homogeneous on the dimensions of education, occupation, sex, and age than the local population at large. In the same vein, a study by Kossinets and Watts (2006, 2009) found that students of a large university similar to one another in terms of gender, age, origin etc. choose to attend the same classes, therefore creating opportunities to interact mainly with others that are similar to themselves. This is a strong indicator that homophily can, at least in parts, be accounted for by opportunity structures.

However, contrary to this thesis, the studies by Feld and Smith-Lovin focus on an adult population. They looked at the homogeneity of work-places and membership in adults voluntary organisations. Applying the reasoning of focussed choice to closed settings, such as schools, and opportunity structures within these closed settings requires some further elaboration, as a strict opportunities argument does not hold here. A similar argument can be made for the study by Kossinets and Watts. In a large network with 10,000s of students the opportunities for meeting are limiting friendship choices much more strongly than in a school cohort.

Feld views his account of the sources of homophily as a competing explanation to the alternatively presented preference based view of homophily.

> "It is suggested that the neglect of structural factors has led to the overestimation of the extent to which people "prefer" to associate with similar others" (Feld 1982, p. 797).

A situational perspective of homophily, as developed for closed networks such as schools for adolescents, builds on Feld's theoretical elaborations. However, it needs to amalgamate the opportunity-based view with a preference approach to homophily.

While these two concepts are presented here as competing explanations for why homophily in friendship networks is observed, the conceptual distinction is less clear on a closer look, especially in the context of friendship evolution in schools. First of all, every adolescent in a school cohort has (most likely) met every other pupil in the same cohort. Therefore, meeting opportunities do not restrict friendship choices very much. Nevertheless, even within a school cohort there are social settings, such as joint courses

or organized activities, e.g. a football team, that facilitate the formation of friendships compared to forming friendships in the normal school day routine. Thus, activities that pupil in the school undertake jointly can be thought of as taking a similar role to meeting opportunities.

However, the adolescents actively choose which social activities they want to take part in and these choices are often strongly influenced by what they perceive as stereotypical for somebody "like them". This means they engage in activities they think of as appropriate for somebody of their age, sex, ethnicity, or social class, etc., because others that are similar in terms of age, sex, ethnicity or social class engage in these activities. As a result, to a degree they take part in certain activities, *because* they meet others that are similar to themselves in them. From this perspective, the mechanisms of preference and opportunity are amalgamated, as adolescents prefer activities that create opportunities to engage with similar others.

This perspective on homophily, focussing on the situations in which adolescents voluntarily meet and spend time together, will be used in the remainder of this thesis. It is very similar to the view of homophily proposed by Social Identity Theory or Self-Categorisation Theory (Tajfel, 1974; Tajfel and Turner, 1979; Turner, 1987; Hogg, 2006), which extensively deals with group membership (social identities) and how they relate to behavioural norms and engagement in activities.

Borrowing from this theory, I further propose that different dimensions of homophily are connected to different types of activities. This stems from the proposition that in different groups different norms and behaviours are prescribed.

> "From a social identity perspective, norms map the contours of groups and social identities and are cognitively represented as group prototypes that describe and prescribe identity-defining behavior" (Hogg 2006, p. 124).

Different group memberships prescribe engaging in certain behaviour[2]. For these group-based activities the similarities that define the group are salient, other dimensions are pushed into the background. To illustrate this with exaggerated stereotypes: Boys

[2]The case where membership in different groups produces competing norms regarding the same behaviour is dealt with in Krackhardt (1999)

play football with other boys[3] their age regardless of their social class and ethnicity, aristocrats meet other aristocrats at the horse races regardless of their sex and age etc.. As a consequence, different types of social situations are stratified by different dimensions, i.e. people participating are similar along the lines of some dimensions, but likely to be heterogeneous on other dimensions. I apply this reasoning directly to activities in which adolescents spend their free time together. Similarity in different dimensions leads to adolescents doing different activities together.

However, I further extend this hypothesis to the reasoning of the previous chapter. While homophily is related to group-based activities, I previously proposed that reciprocity is related to dyadic situations. Jointly they compose the third hypothesis:

Hypothesis 3a: Reciprocated friendships are related to a pair of adolescents spending time in dyadic interactions.
Hypothesis 3b: Homophilous friendships are related to adolescents spending time together in group-based interactions.
Hypothesis 3c: Different dimensions of homophily are related to different group-based activities.

5.2.2 Reciprocation in Homophilous Friendships

Based on a situational understanding of homophily and reciprocity, I now develop why reciprocity is less important as a stabilising force of friendships between people within homophilous groups as opposed to outside of homophilous groups.

The homophilous group provides a forum for interaction between the adolescents that are members of this group. Following Section 4.2.1, interaction, i.e. spending time together, is a necessary condition for friendship. Adolescents that are similar to each other are likely fulfil this prerequisite, e.g. two boys regularly spend time together because they play football in the same team. Spending time together in a group context that is independent of the connection between two people enables the formation of a

[3]It should be noted that the outlined reasoning does not imply that selection of activities is specific to boys. Boys playing football should be seen as an illustrating example; there are different stereotypical activities that girls engage in, thus the argument holds for either sex, and equally for either social strata etc.

friendship, both symmetrically and asymmetrically. This means that the group where they spend time together exists independently of whether they are friends or not, which explains why one-sided friendships within homophilous groups can be observed. Similar to friendships in transitive groups, it is not unlikely that not all feeling between two people are mutual and that one-sided admiration can lead to one-sided (perceived) friendship.

However, outside of these groups, a one-sided friendship is unlikely to exist, as there is no forum for interaction between two individuals. Friendships outside of groups (defined socially or through common characteristics) need to create situations of dyadic interaction, where the friendship can be cultivated. However, creating dyadic interactions outside of groups is only likely if a friendship is mutual, as both parties have to agree to engage in a dyadic social situation. Conversely, this is unlikely if a friendship is unreciprocated. In conclusion, one-sided ties are only likely in homophilous (or transitive) groups; and conversely, reciprocation is more important as a stabilising factor for a friendship outside of homophilous groups. This leads to the fourth hypothesis of the thesis:

Hypothesis 4: The tendency towards reciprocation within homophilous groups is lower than outside of homophilous groups.

5.3 Analytic Strategy

Due to data constraints *Hypotheses 3a-c* can only be tested using the Glasgow Data. For this data, I employ a multiple network SAOM, where friendships and activities with friends are modelled interdependently. The friendship model includes the same structural network, and covariate based effects as the empirical study in the previous chapter, namely *Reciprocity*, *Transitive Triplets*, *3-Cycles*, *Transitive Reciprocated Triplets*, the degree related effects *Indegree Popularity*, *Outdegree Popularity* and *Outdegree Activity*, the *Ego-*, and *Alter-* effects for Sex and Pocket Money, as well as the *Same Sex* and the *Pocket Money Similarity* Effects.

Additionally, and dependent on the friendship network, I estimate parameters for the dynamics of three networks that indicate which activities the adolescents do with

their friends. The three types of activities are "doing organised activities", "hanging about", and "sharing secrets", as introduced in the Data Section. The effects included in the evolution of the activity networks are the *Crossproduct* (called Friendship in the results table) of the two networks, which is fixed at a high value, in order to ensure that adolescents only choose among their friends which activities to do with each of them. Further, I include the *Reciprocated Crossproduct* (called incoming friendship) and the *Same Sex* and *Pocket Money Similarity* effects.

Hypothesis 3a is operationalised as follows: "Sharing Secrets" is understood as a dyadic interaction, one that is most likely happening between two people. I hypothesise that the *Reciprocated Crossproduct* effect is positive for this activity, as it connects reciprocated friendships to dyadic situations. The activities "Hanging about" and "Organised activities" are group based, following *Hypothesis 3b* I expect that they are connected to either of the homophily effects; according to *Hypothesis 3c* the two activities should be connected to the dimensions of homophily in different ways.

Hypothesis 4 is tested on a subset of networks from the *DyNet data*, the *ASSIST data*, and on the *Glasgow data*. The *Dutch data* could not be used, as the networks are too small to estimate differences between reciprocity within, as opposed to outside of homophilous groups[4].

The subset of the networks in the DyNet Data and the ASSIST Data was chosen as follows: In order to establish whether there is a significant interaction between homophily and reciprocity, which is not specific to any one dimension, full models according to the specification outlined below were estimated for all networks. Each model included homophily effects for sex and ethnicity in the case of the *DyNet data*, and sex and FAS in the case of the *ASSIST data*, and their respective interaction with reciprocity. Networks remained in the analysis, if both homophily effects were estimated positive and significant. Estimations in which only Sex homophily was estimated significant were excluded, to ensure a tractable number of networks for the analysis with relevant results on multiple dimensions[5]. Thus, I present the results of three networks

[4]This judgement is based on the fact that in almost all classrooms the homophily effect on Gender was not estimated significant any more when including an interaction with reciprocity.

[5]The networks in which only sex homophily was estimated significant showed a consistently negative pattern regarding their interaction with reciprocity.

from the DyNet data and one network from the ASSIST data, as well as the Glasgow data; a total of 5 networks with two homophily effects each.

Model specification is as follows: *Reciprocity*, *Transitive Triplets*, *Transitive Reciprocated Triplets*, *3-cycles*, the three degree related effects *Indegree Popularity*, *Outdegree Popularity*, and *Outdegree Activity*, the *Ego-*, and *Alter-* effects for Sex and FAS in the ASSIST Data, Sex in the DyNet Data[6], and Sex and Pocket Money in the Glasgow data, as well as the *Same Sex* and the *Same Ethnicity*, *Pocket Money Similarity*, and *FAS Similarity* Effects for the respective datasets.

Hypothesis 4 was tested using the interaction between the *Reciprocity* effect and each included homophily effect.

5.4 Results

5.4.1 Activity Analysis

Table 5.1 shows the results of the activity analysis conducted to test *Hypotheses 3a-c*. The parameter estimates of the co-evolving friendship network are not presented, as they follow the same model that is presented in Table 5.2, which will be discussed in the next section. For each Activity Network, the outdegree estimate is strongly negative, however, this is mainly due to the effect from Friendship being fixed at a high parameter value[7].

Table 5.1 a) shows the parameter estimates for the secret sharing network. Secret sharing was interpreted as an interaction that usually happens in dyadic situations between two people. Consistent with *Hypothesis 3a*, sharing secrets is related to reciprocated friendship, as indicated by the positive and significant Incoming Friendship parameter. This means that adolescents tend to share their secrets with those friends where the friendship is mutual. Being of the same sex, or receiving similar amounts of pocket money has no impact on sharing secrets between adolescents.

[6]It is not feasible to include ego- and alter-effects for each ethnicity. I tested whether the ego- and alter-effect of being white (the majority category) were significant or biased estimates of other parameters, and as this was not the case, I omitted them.

[7]Recall that this is necessary to account for the data structure in which the activity networks are nested in the friendship networks, i.e. activity ties are only possible between friends.

a) Secret Sharing Network

	estimate		s.e.
Outdegree	-5.98	***	0.35
Friendship	5.00		fixed
Incoming Friendship	0.87	*	0.36
Same Sex	0.00		0.32
Pocket Money Similarity	1.10		0.98

b) Organised Activities Network

	estimate		s.e.
Outdegree	-6.02	***	0.29
Friendship	5.00		fixed
Incoming Friendship	-0.48		0.26
Same Sex	0.94	***	0.24
Pocket Money Similarity	0.20		0.53

c) Hanging About Network

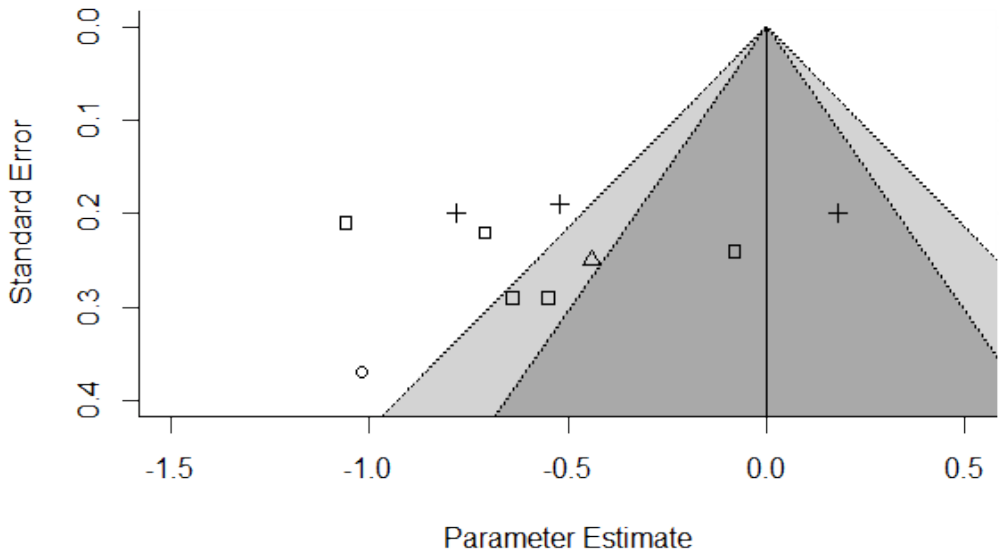
	estimate		s.e.
Outdegree	-4.84	***	0.19
Friendship	5.00		fixed
Incoming Friendship	-1.17	***	0.31
Same Sex	0.66	**	0.22
Pocket Money Similarity	1.01	*	0.49

p-values:***< 0.001;**< 0.01;*< 0.05

Table 5.1: Activity Analysis Glasgow Data

The parameter estimates for the organised activities network are presented in Table 5.1 b). Organised activities are understood as group-based activities, e.g. sports teams, extracurricular activities, etc.. A reciprocated friendship is, contrary to the secret sharing network, no predictor of doing activities together. This means adolescents are equally likely to do activities with one-sided, as well as mutual friends. The only significant parameter estimate in this network belongs to the Same Sex effect. This means that the adolescents mainly do organised activities with those friends that have the same sex as they do, which is in line with *Hypothesis 3b*. There is no indication that Pocket Money Similarity predicts doing organised activities together.

Finally, Table 5.1 c) shows the parameter estimates for the hanging about network. Hanging about was as well understood as a group-based activity; although differing opinions about this interpretation are possible, the analysis of this network supports this claim. The incoming friendship parameter is estimated significantly *negative*. This



squares: Same Sex; circle: Pocket Money Similarity; triangle: FAS Similarity; cross: Same Ethnicity; light grey area: p-value < 0.05; white area: p-value < 0.01; estimate of Pocket Money Similarity linearly transformed for presentation by factor 2.

Figure 5.1: Funnel Plot of Interactions Homophily × Reciprocity effects

means that situations in which a group of adolescents just hangs about is related to one-sided friendships. This will be dealt with in more detail in the discussion section. On the other hand, hanging about together is positively related to Same Sex friendships, as well as friendships between adolescents that receive similar amounts of pocket money. Although these results require some more discussion in Section 5.5, they are mostly in line with *Hypothesis 3b*; the group-based situation is not positively related to reciprocity, but to homophily along the lines of sex and pocket money. At least with regards to pocket money, this is a different dimension than the dimension that predicted the organised activities network, which confirms *Hypothesis 3c* at least partly.

5.4.2 Parameter Estimates Homophily × Reciprocity

For the analysis relating to *Hypothesis 4*, Tables 5.2 show the results of the estimation for the Glasgow and ASSIST data, and Table 5.3 presents the results for the different

	Glasgow Data			ASSIST Data		
	estimate		s.e.	estimate		s.e.
Rate Period 1	10.9	***	0.90	17.8	***	1.17
Rate Period 2	7.72	***	0.60	12.5	***	0.78
Outdegree	-2.08	***	0.22	-2.92	***	0.23
Reciprocity	3.18	***	0.30	3.52	***	0.20
Transitive Triplets	0.82	***	0.05	0.80	***	0.03
3-Cycles	0.24	*	0.10	0.14	*	0.06
Trans. Rec. Triplets	-0.64	***	0.09	-0.62	***	0.05
Indegree - Popularity	0.05	*	0.024	0.02		0.01
Outdegree - Popularity	-0.23	***	0.05	-0.14	***	0.04
Outdegree - Activity	-0.14	***	0.02	0.02		0.03
Sex Alter	-0.21		0.11	0.05		0.07
Sex Ego	0.06		0.14	-0.06		0.10
Same Sex	0.99	***	0.12	0.94	***	0.08
Pocket Money Alter	0.016	**	0.006			
Pocket Money Ego	-0.01		0.01			
P. Money Similarity	1.63	***	0.39			
FAS Alter				-0.04	*	0.02
FAS Ego				0.00		0.03
FAS Similarity				0.41	**	0.15
Same Sex × Recip.	-0.64	*	0.29	-1.06	***	0.21
P. Money Sim. × Recip.	-2.04	**	0.74			
FAS Sim. × Recip.				-0.44	*	0.26

p-values:*< 0.05;**< 0.01;***< 0.001

p-values for hypothesis testing one-sided

Table 5.2: Homophily × Reciprocity Results Glasgow data and the ASSIST data school 63

networks in the DyNet Data.

The *Reciprocity* parameter is positive and highly significant in each of the analysed networks. The estimate ranges from 2.17 to 3.52 of forming a reciprocated, as opposed to a non-reciprocated tie in a (hypothetical) mini-step. While these effects sizes are extreme and larger than what is usually observed in comparative analyses, one has to bear in mind that they are, as opposed to other analyses, compensated by the negative interactions with transitivity and homophily. The estimate of the *Same Sex* effect in the different networks ranges from 0.49 to 0.99. The *Pocket Money Similarity* effect in

	School 4			School 6			School 13		
	estimate		s.e.	estimate		s.e.	estimate		s.e.
Rate Period 1	22.7	***	2.43	17.1	***	1.42	12.5	***	1.08
Rate Period 2	24.1	***	2.96	19.2	***	1.53	9.08	***	0.77
Rate Period 3	40.1	***	7.51	13.4	***	0.91	7.22	***	0.68
Outdegree	-2.90	***	0.07	-2.89	***	0.08	-3.25	***	0.10
Reciprocity	2.17	***	0.17	2.42	***	0.21	2.49	***	0.23
Transitive Triplets	0.38	***	0.03	0.67	***	0.04	0.80	***	0.06
3-Cycles	0.01		0.05	0.06		0.11	0.09		0.14
Trans. Rec. Triplets	-0.39	***	0.09	-0.51	***	0.11	-0.59	***	0.15
Indegree - Popularity	0.03	**	0.01	0.02	*	0.01	0.01		0.02
Outdegree - Popularity	-0.05	***	0.01	-0.09	***	0.01	-0.11	***	0.02
Outdegree - Activity	0.010	***	0.001	-0.00		0.00	0.016	***	0.004
Sex Alter	-0.16	**	0.05	0.12	*	0.05	0.06		0.06
Sex Ego	-0.21	***	0.06	-0.38	***	0.06	-0.33	***	0.07
Same Sex	0.59	***	0.05	0.70	***	0.06	0.49	***	0.07
Same Ethnicity	0.23	***	0.06	0.14	*	0.06	0.56	***	0.07
Same Sex × Reciprocity	-0.55	***	0.29	-0.71	***	0.22	-0.08		0.24
Same Ethnicity × Reciprocity	-0.52	**	0.19	0.18		0.20	-0.78	***	0.20

p-values:*< 0.05;**< 0.01;***< 0.001; p-values for hypothesis testing one-sided

Table 5.3: Homophily × Reciprocity Results DyNet data

	Different Sex	Same Sex
Unreciprocated	0.00	0.99
Reciprocated	3.18	3.53

Table 5.4: Crosstabulation Sex Homophily and Reciprocation for Glasgow data

the Glasgow data is estimated at 1.63, and the *FAS similarity* effect at 0.41. In the DyNet data, the same ethnicity parameter ranges from 0.14 to 0.56.

Out of the ten estimated interaction effects between a homophily effect and reciprocity, eight were estimated negative and significant. Further, the parameter sizes of the interactions are comparable to the size of the main homophily estimates in the same network. This means that the interaction effect is not only significant, but also of substantial size. In other words, a tie that is reciprocated and homophilous does not have a significantly higher contribution to the objective function than a tie that is only reciprocated. An overview of the effect sizes and standard errors of the interactions can be seen in Figure 5.1. Parameter estimates are plotted against their standard errors to get an overview of the parameters of interest in all models. The grey area in the funnel plot contains the non-significant estimates, the light grey area the estimates with a p-value < 0.05, and the white area the estimates with $p < 0.01$. With eight out of ten estimates being negative and significant, I view *Hypothesis 4* as generally confirmed.

To facilitate interpretation of the interactions, Table 5.4 shows the cross-tabulation of the change in the values of the objective function for same sex vs. different sex and reciprocated vs. unreciprocated friendships on the example of the Glasgow data. When an actor considers forming/keeping an unreciprocated friendship in a mini-step, being of the same sex adds 0.99 to the objective function compared to a friendship to a peer of different sex. When comparing two peers that have a reciprocated tie to ego, being of the same sex only increases the objective function by 0.35 (3.53 - 3.18). In fact, this difference is not statistically significant. Consequently, everything else being equal, the negative interaction means that a reciprocated tie to a same sex peer is not more likely than a reciprocated tie to a different sex peer, i.e. homophily mainly contributes to one-sided friendships but loses its effect for reciprocated friendships.

Regarding the results that are not used for hypothesis testing, I find the following

patterns. In line with previous studies on the evolution of friendship networks between adolescents and Chapter 4 of this thesis, friendships are stabilised if they are reciprocated or embedded within a transitive triad. As explained in the previous chapter, there is a tendency against reciprocation within transitive triads (*Transitive Reciprocated Triplets*). In the Glasgow data and the ASSIST data, the *3-Cycle* effect is estimated positive, while in the DyNet data it is non-significant in all three networks. Parameter estimates for *Indegree Popularity* and *Outdegree Activity* are inconsistent across the different networks. The *Outdegree Popularity* parameter is consistently estimated negative; a finding that replicates earlier studies. However, there is no established explanation for this phenomenon yet.

With regards to covariates, there is no clear tendency of either boys or girls being more popular (*Sex Alter*). While non-significant in the Glasgow and ASSIST data, in the DyNet data, girls tend to nominate more friends than boys. Additionally, adolescents in the Glasgow data are more popular if they receive more pocket money, while adolescents with a higher FAS in the ASSIST data are less popular. As this was the selection criterion for being included in the study, the homophily effects for sex in all datasets, ethnicity, pocket money, and FAS in the respective datasets are estimated positive and significant.

5.5 Discussion and Study Conclusion

In this chapter I analysed the relationship between homophily and reciprocity. The interaction between these two mechanisms was so far understudied. Extending the logic of the previous chapter, I proposed that homophilous friendships are connected to, and enacted in group-based situations. Following research on Social Identity Theory originating in the area of Social Psychology, I further argued that different dimensions of homophily are connected to different social situations that are perceived as stereotypical for a group defined by a certain socio-demographic dimension. As homophily is connected to adolescents spending time together in group-based situations, it can stabilise and enable reciprocated, but also one-sided friendships between two adolescents, as the necessary condition for a friendship, spending time together, is fulfilled. Outside

of these homophilous groups, a one-sided friendship is less likely to exist, as the pair does not have a forum for interaction and spending time together. Creating dyadic situations is only likely if the friendship is mutual. As a result, I expect reciprocity to be less prevalent within, as opposed to outside of homophilous groups.

In *Hypothesis 3a-c*, I tested whether different social situations can be related to different network evolution mechanisms. Especially, I analysed whether dyadic situations are connected to reciprocated friendships and whether different group-based situations are associated with homophily on different dimensions. Due to data availability, I could only test this hypothesis on the Glasgow data. I found that secret sharing, a dyadic interaction, is linked to reciprocation and that undertaking organised activities is connected to gender homophily. These two results are completely in line with *Hypotheses 3a* and *b*. The third analysed activity, "hanging about", was positively connected to sex homophily and pocket money similarity, but negatively related to reciprocity. While this does not contradict the specified hypotheses directly and gives some evidence for *Hypothesis 3c*, it requires further discussion.

The positive homophily estimates can be easily explained – adolescents hang about with same age peers that receive similar amounts of pocket money[8]. These places to hang about could be, dependent on the wider context, youth clubs, somebody's home, shopping malls etc.. My interpretation of the negative reciprocity parameter is that these situations are perceived differently by different adolescents. While for some these occasions are just places to pass some time, their main source of friends is in other situations (e.g. organised activities or dyadic interactions). Even if these friends are also members of the "hanging about" situations, they might be unlikely to give this as an answer in the survey. The exact wording is "we just hang about together; we don't do much". Therefore, friends that do other things together are unlikely to be nominated here. Further, doing other things together indicates a more intimate friendship, which makes reciprocation of a friendship more likely. As a result, only the less intimate, and thus one-sided friendships are likely to be nominated in this category. Regardless of whether this interpretation of the negative incoming friendship parameter is shared, the

[8]Recall that in previous studies pocket money was linked to social status of the parents.

parameter shows that group-based situations stabilise and enable one-sided friendships, as this group situation can be empirically linked to one-sided friendships via the negative Incoming Friendship parameter. This finding is in line with *Hypothesis 4*.

Hypothesis 4 was confirmed in eight out of ten cases for 4 different dimensions of homophily. The interaction between homophily and reciprocity is generally negative. The underlying argument that proposes the situational logic in that homophily is connected to group-based interactions and reciprocity is enacted in dyadic situations is strengthened by the analysis associated with *Hypotheses 3a-c*. Further, additional persuasion of the theoretical model is taken from the same pattern holding for another group-based mechanisms – transitivity, as shown in Chapter 4.

The negative interaction between homophily and reciprocity can be viewed as counteracting segregation within school contexts. As discussed previously, reciprocated friendships are equally likely between similar and dissimilar peers. Homophily mainly operates on one-sided, less intimate friendships. As such, segregation and intergroup conflict might be less likely for groups where this negative relation holds.

Further, I conclude that homophily does not amplify reciprocity, as could be presumed by a preference based understanding of homophily. Rather, this analysis is in line with a situational understanding of homophily, which is much closer to an opportunity based approach to homophily. However, it also takes the active choices of adolescents for social situations into account.

5.6 The Bigger Picture

In the previous Chapter, I outlined the basic idea of a situational understanding of friendship networks and illustrated it on the example of reciprocity and transitivity. This chapter expanded the logic to homophily, a further, major determinant of friendship ties between adolescents. Just as reciprocity and transitivity are enacted in different social situations, homophily is connected to a further type of social situations; situations that are stereotypical for a particular strata. As a result, the same logic that applies to the interaction between transitivity and reciprocity also applies to the interaction between homophily and reciprocity. Reciprocity is generally a stronger

determinant of friendships outside of groups compared to within groups.

Chapter 6

Multiple Homophily

In the previous two substantive chapters of this thesis, I related the dyadic network evolution mechanism of reciprocity to the group-based mechanisms network closure and homophily. I argued that each mechanism is related to different social situations and each one is a stronger predictors of tie formation in the absence of the other. In the last chapter, I further showed on the Glasgow data that different activities can be connected to different configurations. In this chapter, I try to discover whether this situational logic also applies to the relation between different group-based mechanisms, namely the interaction between different dimensions of homophily.

I argue that activities connected to different dimensions of homophily each provide a forum for interaction between adolescents. Within these activities, similarities along the lines of other dimensions are not important and do not further increase the probability of creating a tie. As a result, I hypothesise that there is a diminishing effect for having more than one attribute in common. This hypothesis is tested using the Glasgow data and a subset of the DyNet data and ASSIST data by analysing the interaction between different dimensions of homophily. The findings generally support the hypothesis, as the majority of the analysed networks exhibit a negative and significant interaction estimate.

A slightly modified version of this chapter is accepted for publication in the journal *Network Science* with Thomas Grund as a Co-Author. I, Per Block, am the first Author of this paper and did the majority of the theoretical and empirical work.

6.1 Introduction

Already Georg Simmel emphasized the way in which individuals are involved in multiple dimensions of social life. Individuals occupy unique social positions through the combination of individual attributes and voluntary associations. It is at the intersection of so-called "social circles" where identity is construed (Simmel, 1950, p.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 and Schwartz, 1984) only little is known about how this multidimensionality affects network dynamics – the formation and dissolution of social relationships and particularly friendships.

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 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.

6.1.1 Consequences of Multi-dimensional Homophily

Such interactions of homophily effects, however, are potentially important for understanding the emergence of integration or segregation in network contexts. The reasoning underlying this claim is very similar to the argument brought forward by Peter Blau (Blau, 1977a; Blau and Schwartz, 1984). Blau as well as McPherson and Smith-Lovin (1987) focus on the combination of homophily and the correlation between individuals' attributes. When the correlation between attributes is high (e.g. correlation of ethnicity and income) one will necessarily have to observe homophily across multiple attributes (e.g. less contact between people of different ethnicity and disparate income). In contrast, when the correlation between attributes is low, sharing a similar attribute with friends does not automatically mean that one shares other attributes with them,

as well. Similarly, interaction between different dimensions of homophily could lead to more or less segregation.

If this interaction is strongly positive, i.e. people seek contact to those that are similar to themselves in as many dimensions as possible, we would expect people to cluster in groups that are very homogenous in all the dimensions that exhibit homophily. If, on the other hand, different dimensions would interact negatively, i.e. decreasing returns to similarity, it would point towards individuals seeking social contact to others that are similar in only some way, not in as many ways as possible. Thus, negative interaction between different dimensions of homophily would foster heterophilous ties; if similarity on one dimension is sufficient for the formations of a connection, it enables the connection to be heterophilous on all other dimensions. Therefore, the interaction between different dimensions of homophily can be a predictor of the integration of different social groups.

6.1.2 Past Work on Multi-dimensional Homophily

Despite consensus on the importance of homophily for social relationships as well as on the conceptualisation 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, p.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.

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 and Densley, 2012; Wimmer and 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, p.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 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. Further, contrary to this thesis, which is focussed on adolescent networks, Schaefer's findings concern an adult population.

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 (see Chapter 5.1.1), 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. However, it is questionable how much this reasoning can be applied to the friendship between adolescents.

Finally, a perspective that focusses on social situations connected to different dimensions of homophily leads to expecting decreasing returns to multiple homophily, too. This will be elaborated in the following section.

6.2 Theory and Hypothesis

Due to its importance for the reasoning to follow, I recount and elaborate some of the core arguments of a situational understanding of homophily.

Since the research by Feld (1981, 1982) and subsequent studies (e.g. McPherson and Smith-Lovin, 1987), it is known that people predominantly spend time in social foci that are comprised of people that are similar to themselves. Workplaces, educational institutions, voluntary organisations, etc. are stratified by a multitude of socio-demographic dimensions. As individuals only choose their social contacts among the people that they know and are aware of, and they mainly meet similar people within social foci, as a consequence people are mainly friends with similar others; according to this position homophily is at least partly a consequence of focussed choice.

However, these opportunities to form friendship ties to similar others within social foci are the result of an active choice for social foci. Individuals, especially adolescents, choose to engage in certain activities because they perceive them as appropriate for somebody "like them". This can be illustrated by patterns of young boys membership in sports teams 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 (in the little league) 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. People choose their activities or social foci, because others that are similar to themselves choose these social foci as well. This means they preferentially choose activities that bring them in contact with similar others. As such speaking of a simple opportunities arguments shows only one half of the story. Bridging this argument to research in the field of social psychology and in particular SIT once more, peoples' choices for social foci is guided by their self-categorisation.

Following this strand of research, different dimensions of social life are connected to different stereotypical activities and behaviours. While some activities are gendered, others are typical for a certain ethnicity, or social class (Hogg 2006). However, in a reasonably well integrated society, activities are often only stratified by one or two socio-demographic dimensions and mixed in other dimensions. It is only within very segregated societies that one dimension stratifies all social activities, e.g. in the Apartheid system there were no social activities that were not segregated by ethnicity. The societies under analysis in this thesis exhibit no such extreme segregation in any way. Rather, many activities are stratified by only one or few dimensions.

Now a combination of two arguments allows to predict how different dimensions of homophily interact. First, I resort to the argument of the previous two chapters. Comparing individuals that are heterophilous on all dimensions to ones that are homophilous on at least one dimension, the homophilous ones are likely to have a forum for interaction in which their friendship can be formed and maintained. This enables a friendship between two adolescents to exist. For individuals that are homophilous on one dimension similarity on further dimensions is not as crucial for the formation and maintenance of a friendship as they already have a forum for interacting with one another by similarity in one dimension. Consequently, the first dimension of homophily is most important, additional dimensions are less important - there are decreasing returns to multiple homophily from a situational perspective.

While the first argument focusses on the social situations in which people meet and spend their time, the second argument elaborates on a deeper level why within a situations that is stratified by one dimension, similarity on another dimension does not make tie formation more likely either. To this end, it engages more directly with the reasoning of SIT. This perspective on homophily 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 lose importance for the interaction between individuals. For example, when boys play football to meet other boys, similarity or dissimilarity on other dimensions is 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.

Resulting from these two lines of argument, I expect decreasing returns to similarity on multiple dimensions, as different dimensions of homophily lead to people spending time in different social situations together; further, only one attribute at a time is considered within these social situations – 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. This results in the fifth hypothesis of the thesis.

Hypothesis 5: The interaction between different dimension of homophily that are connected to different sets of activities is negative.

6.3 Analytic Strategy

Hypothesis 5 is tested using the Glasgow data, and a subset of the ASSIST and DyNet data. Due to similar issues as in the previous chapter, the Dutch data could not be used. The subset of networks in the ASSIST data and the DyNet data was chosen analogous to the previous empirical chapter as follows: A full model including all structural control effects and the relevant homophily effects, as well as the interaction between different dimensions of homophily were estimated. All networks that did not exhibit two dimensions of homophily were excluded from the analysis, as analysing

the interaction between different dimensions of homophily only makes sense if multiple dimensions of homophily can be detected. After this selection criterion, four networks from the ASSIST data and six networks from the DyNet data remained in the analysis. With the Glasgow data this amounts to a total of eleven networks that were analysed to test the hypothesis.

For the Glasgow data *Hypothesis 5* was tested on the interacion between the *Same Sex* effect and the *Pocket Money Similarity* effect. In the ASSIST data the interaction between the *Same Sex* and and *FAS Similarity* effect was modelled, while in the DyNet data the hypothesis was tested with the interaction between the *Same Sex* and *Same Ethnicity* effect. The models were specified as follows: *Reciprocity*, *Transitive Triplets*, *Transitive Reciprocated Triplets*, *Three-cycles*, the three degree related effects *Indegree Popularity*, *Outdegree Popularity*, and *Outdegree Activity*, the *Ego-* and *Alter-* effects for Sex and FAS in the ASSIST Data, Sex in the DyNet Data[1], and Sex and Pocket Money in the Glasgow data, as well as the *Same Sex* and the *Same Ethnicity*, *Pocket Money Similarity*, and *FAS Similarity* Effects for the respective datasets were included. For School 3 of the DyNet data a model with less structural controls had to be specified due to convergence and collinearity problems.

6.4 Results

The results of the analyses are presented in Tables 6.1 to 6.4. In all datasets, ties are more likely to form between individuals who have the same sex. Effect sizes vary between 0.41 and 0.89. 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 0.45 and 1.10). Lastly, individuals in the DyNet data are more likely to become friends with others who have the same ethnicity (effect size between 0.13 and 1.03).

The main focus in this chapter rests on the interaction of these homophily effects. I study whether the positive effect of having the same sex changes when actors are similar

[1] As in the analysis of the previous chapter, *Ego-*, and *Alter-*effects for ethnicity were omitted.

	Glasgow Data			ASSIST School 22		
	estimate		s.e.	estimate		s.e.
Rate Period 1	11.1	***	0.90	11.2	***	1.08
Rate Period 2	7.77	***	0.62	9.63	***	0.89
Outdegree	-1.94	***	0.23	-1.46	***	0.23
Reciprocity	2.57	***	0.13	2.60	***	0.12
Transitive Triplets	0.84	***	0.05	0.79	***	0.04
3-Cycles	0.25	*	0.10	0.12		0.11
Trans. Rec. Triplets	-0.67	***	0.09	-0.54	***	0.08
Indegree - Popularity	0.05	*	0.023	0.06	**	0.02
Outdegree - Popularity	-0.23	***	0.06	-0.30	***	0.06
Outdegree - Activity	-0.15	***	0.02	-0.18	***	0.02
Sex Alter	-0.16		0.09	-0.07		0.09
Sex Ego	0.00		0.12	-0.01		0.12
Same Sex	0.89	***	0.10	0.82	***	0.10
Pocket Money Alter	0.013	*	0.006			
Pocket Money Ego	-0.00		0.01			
P. Money Similarity	2.66	**	0.97			
FAS Alter				0.04		0.02
FAS Ego				0.02		0.03
FAS Similarity				1.01	*	0.54
P. Money Sim. · Same Sex.	-1.86	*	0.98			
FAS Sim. · Same Sex.				-0.92	*	0.55

p-values:*< 0.05;**< 0.01;***< 0.001

p-values for hypothesis testing one-sided

Table 6.1: Multiple Homophily Results Glasgow Data and ASSIST School 22

on other attributes as well. The results indicate an overwhelmingly clear tendency concerning such interaction effects. In nine out of eleven schools that were analysed, the interaction is negative and significant or borderline 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. As such, I view *Hypothesis 5* as generally confirmed.

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

In Table 6.5 I show a detailed example how these effects alter the likelihood for individuals to become friends in School 6 in the DyNet data. I 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 the objective function increases by 0.62. Similarly, the objective function increases by 0.44 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 the objective function increases by 0.73 compared to the scenario where individuals are different on both dimensions.

I can now study the relative increases in the objective function for different scenarios. For example, the score of the objective function increases by 0.29(= 0.73–0.44) for having the same sex amongst those individuals who already have the same ethnicity. This much less than the 0.62 that apply when ethnicity is different. Conversely, the additional effect for sharing the same ethnicity when two individuals already have the same sex is 0.11(= 0.73–0.62) and only marginally increases the chance for a tie to emerge; this is dramatically less compared to when sex is different (0.44). This overall pattern holds for most networks in this study. When two individuals have the same sex, additional similarity on another attribute hardly increases the likelihood for the formation of a friendship tie.

	ASSIST School 35			**ASSIST School 63**			**ASSIST School 71**		
	estimate		s.e.	estimate		s.e.	estimate		s.e.
Rate Period 1	14.6	***	1.21	17.2	***	1.16	12.9	***	1.36
Rate Period 2	13.0	***	1.00	11.7	***	0.71	17.4	***	1.97
Outdegree	-1.21	***	0.23	-0.56		0.31	-1.46	***	0.25
Reciprocity	2.65	***	0.10	2.60	***	0.08	2.41	***	0.14
Transitive Triplets	0.69	***	0.04	0.79	***	0.03	0.76	***	0.05
3-Cycles	0.14		0.08	0.16	*	0.08	-0.26	*	0.11
Trans. Rec. Triplets	-0.57	***	0.07	-0.65	***	0.05	-0.32	***	0.09
Indegree - Popularity	0.04	*	0.02	0.04	*	0.02	0.04		0.02
Outdegree - Popularity	-0.16	***	0.04	-0.19	**	0.07	-0.14	*	0.06
Outdegree - Activity	-0.15	***	0.02	-0.26	***	0.03	-0.17	***	0.03
Sex Alter	-0.22	**	0.07	0.05	*	0.06	0.10		0.09
Sex Ego	-0.04		0.09	-0.14		0.10	-0.01		0.11
Same Sex	0.41	***	0.07	0.77	***	0.07	0.58	***	0.09
FAS Alter	-0.00		0.02	-0.01		0.02	-0.00		0.03
FAS Ego	0.02		0.03	0.04		0.03	0.03		0.04
FAS Similarity	0.45	*	0.25	0.88	**	0.35	0.76	*	0.42
Same Sex · FAS Similarity	-0.25		0.28	-0.72	*	0.36	-0.71		0.46

p-values:*< 0.05;**< 0.01;***< 0.001; p-values related to hypothesis testing one-sided

Table 6.2: Multiple Homophily Results ASSIST Schools 35, 63, 71

	DyNet School 1			**DyNet School 2**			**DyNet School 3**		
	estimate		s.e.	estimate		s.e.	estimate		s.e.
Rate Period 1	23.1	***	3.28	12.4	***	0.80	8.05	***	0.87
Rate Period 2	13.2	***	1.07	23.1	***	1.78	4.46	***	0.54
Rate Period 3	17.2	***	1.81	14.7	***	0.94	3.26	***	0.38
Outdegree	-2.75	***	0.09	-2.81	***	0.06	-3.54	***	0.15
Reciprocity	1.83	***	0.11	1.99	***	0.08	1.71	***	0.18
Transitive Triplets	0.29	***	0.04	0.55	***	0.02	0.67	***	0.13
3-Cycles	0.36	***	0.08	0.06		0.05	-0.60	*	0.29
Trans. Rec. Triplets	-0.38	***	0.06	-0.53	***	0.06			
Indegree - Popularity	0.07	***	0.01	0.03	***	0.01	0.03		0.03
Outdegree - Popularity	-0.14	***	0.02	-0.09	***	0.01			
Outdegree - Activity	0.02	***	0.003	0.01	***	0.002			
Sex Alter	0.07		0.05	0.05		0.04	-0.21	*	0.10
Sex Ego	-0.22	***	0.06	-0.02		0.04	0.40	**	0.13
Same Sex	0.66	***	0.05	0.48	***	0.04	0.73	***	0.12
Same Ethnicity	0.19	*	0.09	0.13	*	0.07	1.03	***	0.26
Same Sex · Same Ethnicity	-0.15		0.09	-0.15	*	0.08	-0.81	**	0.28

p-values:*< 0.05;**< 0.01;***< 0.001; p-values for hypothesis testing one-sided

Table 6.3: Multiple Homophily Results DyNet Schools 1, 2, 3

	DyNet School 4			**DyNet School 6**			**DyNet School 13**		
	estimate		s.e.	estimate		s.e.	estimate		s.e.
Rate Period 1	23.6	***	2.53	17.2	***	1.45	12.5	***	1.08
Rate Period 2	24.8	***	3.16	19.4	***	1.52	9.15	***	0.82
Rate Period 3	40.5	***	8.11	13.5	***	0.89	7.21	***	0.68
Outdegree	-2.94	***	0.08	-2.83	***	0.07	-3.19	***	0.09
Reciprocity	1.60	***	0.09	1.85	***	0.10	2.22	***	0.13
Transitive Triplets	0.33	***	0.03	0.67	***	0.04	0.78	***	0.06
3-Cycles	-0.11		0.06	0.07		0.10	0.07		0.15
Trans. Rec. Triplets	-0.21	**	0.08	-0.52	***	0.11	-0.55	***	0.16
Indegree - Popularity	0.04	***	0.01	0.02	*	0.01	0.01		0.02
Outdegree - Popularity	-0.04	***	0.01	-0.09	***	0.01	-0.10	***	0.02
Outdegree - Activity	0.01	***	0.001	-0.00		0.00	0.016	***	0.004
Sex Alter	-0.13	**	0.05	0.10	*	0.05	0.06		0.10
Sex Ego	-0.24	***	0.05	-0.36	***	0.06	-0.33	***	0.07
Same Sex	0.59	***	0.05	0.62	***	0.05	0.46	***	0.06
Same Ethnicity	0.54	***	0.14	0.44	***	0.11	0.30	**	0.11
Same Sex · Same Ethnicity	-0.52	***	0.16	-0.33	**	0.12	0.11		0.13

p-values:*< 0.05;**< 0.01;***< 0.001; p-values for hypothesis testing one-sided

Table 6.4: Multiple Homophily Results DyNet Schools 4, 6, 13

	Different Sex	Same Sex
Diff. Ethnicity	0.00	0.62
Same Ethnicity	0.44	0.73

Table 6.5: Crosstabulation Sex Homophily and Ethnic Homophily DyNet School 6

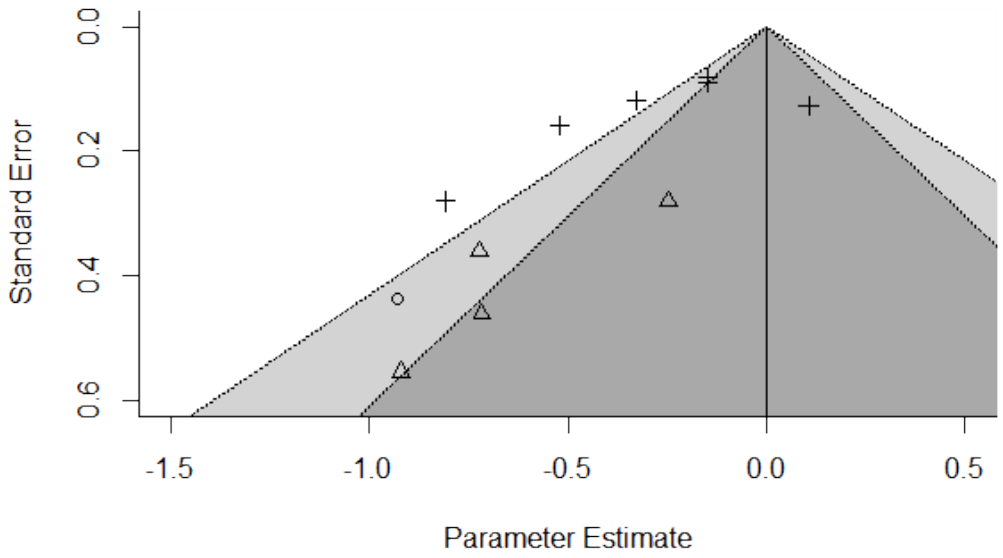
Similar to Chapter 5, an overview of all estimates and standard errors of the interactions can be found in a funnel plot in Figure 6.1. Two of the eleven estimated parameters are clearly non-significant, while five parameters are clearly significant. Four parameters are borderline-significant at the 0.05 level. However, as the standard errors are derived from simulations the significance values are not precise. The reason for having such a large number of borderline significant estimates is relatively simple. The significance levels of the estimated interactions are generally a little lower than the significance level of the main homophily effect that is not sex. For there were a number of schools in which the main homophily estimates were not very strong and just significant, it is not surprising that the interactions are just below significance. That there were so many schools with just significant homophily estimates (and therefore borderline significant interactions) is a result of the selection criteria of networks as outlined in Section 6.3. However, as the tendency of the interactions is clearly negative and mostly significant or close to significant, I view *Hypothesis 5* as confirmed.

The estimates of the parameters that are not related to hypothesis testing are in line with the findings of the previous chapters. Therefore, I will not discuss them further.

6.5 Discussion and Study 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.



Parameter Estimates of interaction of Same Sex with: circle: Pocket Money Similarity; triangle: FAS Similarity; cross: Same Ethnicity; light grey area: p-value < 0.05; white area: p-value < 0.01; estimate of Pocket Money Similarity linearly transformed for presentation by factor 2.

Figure 6.1: Funnel Plot of Interactions between Homophily effects

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 interaction between homophily effects significant?

I 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.

If this study stood by itself, 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. However, I find this perspective not very convincing in the context of adolescent friendships, as I doubt that for adolescent friendships access to new information etc. is an important characteristic.

A purely opportunity based perspective could emphasise 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.

However, the explanation for the observed findings that I prefer relates to the situational understanding of homophily, as developed in Section 6.2 and expressed in *Hypothesis 5*. As soon as people are homophilous on one dimension, this can create situations in which a friendship can be enacted. Therefore, being homophilous on one dimension compared to none is more important than every additional dimension of homophily, as a a forum for interaction in already created. Within a social situation, I argue that not all of individuals' attributes are salient and matter when social relationships are formed. Individuals behave and focus on similarities related to current situations, while similarities or dissimilarities that are not related to the current situation are pushed into the background. Within certain situations, adolescents focus on similarity in specific domains, while dissimilarity in others are less important. For example, within a situation where boys play football with other boys, similarity or dissimilarity on ethnicity or social status is less relevant, as this does not play a role for the interaction within this situation. As such, only similarity on one dimension at a time is important, which explains the negative interaction between different dimensions of homophily.

It certainly can be argued that this chapter standing by itself does not allow to make credible claims about which of the alternative explanations for the decreasing returns to homophily should be preferred. However, in conjunction with the previous chapters, I believe that a perspective that focusses on the situations in which ties are formed and maintained is a good approach to the interaction between different network evolution mechanisms. In my opinion the theoretical reasoning brought forward in the theory section gains persuasiveness in light of the findings in the previous empirical chapters. However, as before I do not actually observe the social situations in which people interact. Consequently, the suggested explanation should be confirmed in future research in which this kind of data is available.

Even if the reader does not follow my theoretical argument in this chapter or the previous ones, this article shows nevertheless 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 and whether a tie is reciprocated or not. Or in other words: similarity on a particular dimension makes some ties more likely, but not all.

6.6 The Bigger Picture

The first two substantive chapters of this thesis analysed the interaction between the dyadic network evolution mechanism reciprocity and the two group-based mechanisms transitivity and homophily. The logic for both chapters was very similar: reciprocity is less important as stabilising a friendship tie within a group (social or demographic), as the group provides a forum for interaction. A further result of Chapter 5 was that different dimensions of homophily are connected to different social activities. The chapter at hand extends the situational logic of homophily to the interaction between different dimensions of homophily. While interesting in itself, it also is a test for the previously developed framework. The guiding idea that in different situations only similarity in one dimension is important was tested by its implications and the formulated hypothesis was confirmed.

This chapter concludes the series of empirical studies that analyse the interaction

between different network evolution mechanisms. As one more study of interactions is possible, but will not be undertaken, this means that the series of analyses remains incomplete, as the interaction between transitivity and homophily along the lines of different dimensions has not been analysed yet. This would be the fourth and last logical step in this series. However, the next section details why I have not included this in my thesis.

6.7 The Relation of Transitivity and Homophily

The theoretical reasoning underlying the previous chapters could be applied directly to the interaction between homophily and transitivity. Transitivity and homophily each create social situations in which individuals interact; therefore, for individuals that are transitively connected, being homophilous should not be as important and vice versa, as a forum for interaction already exists either way. E.g. it is easy to befriend somebody of the same or opposite sex if that adolescent is part of a common social group. However, if two people are not transitively connected, a different forum for interaction is necessary, which could be based on homophilous situations. In short, a situational perspective suggests that homophily is more important for people that are not transitively connected, i.e. a negative interaction between homophily and transitivity can be expected. While this sounds relatively simple, there are a number of problems connected to this research question that are discussed in the following. Overall, these issues prompt me to believe that this study is well beyond the scope of one thesis chapter.

I see two sets of problems, one set connected to conceptual/data availability issues and one set connected to problems with empirical analyses. Conceptually, it is questionable whether situations of social groups and homophilous groups can be separated as e.g. dyadic and group-based situations were. Or in other words, do social, transitive groups sometimes form within larger demographic groups? If this were the case, some situations in which people interact in groups would be transitive as well as homophilous. In a larger sports-team of twenty or more people, for example, social groups might form within the boundaries of the sports-team. Thus, in the homophilous team, social sub-groups form that provide the frame for more close social interaction.

Within this team, transitive closure might be more likely than transitive closure to a third party that is not part of the team but indirectly connected to an individual via a team-member. I.e. social groups within a team might be exclusive to team members. In consequence, for some situations a positive interaction between homophily and transitivity can be expected, as situations are likely to be stratified by demographic and social characteristics. This means that mechanisms that lead to positive and negative interactions could both be expected and potentially both be present.

This reasoning might become clearer when comparing it to the interaction between reciprocity and homophily. The previously developed argument proposes that a reciprocated friendship can create its own forum for interaction and is therefore self-sufficient. In other words, it does not need embedding in a group for tie stabilisation and common membership in a group is of less importance. For the overlap between different groups it is not clear to me whether the same argument can be made. If a social group forms within the realms of a homophilous group and this results in the members of this social group to engage in group-based activities, does the demographic similarity lose importance the way it does in a reciprocated friendship enacted in a dyadic situation? The situation here is much less clear to my mind.

Disentangling when a positive or a negative interaction can be expected is in principle possible. However, this would require detailed knowledge of which dimensions of homophily are connected to which social situations. If this information were available, a more detailed and direct analysis would be possible, i.e. the interaction between a social setting and transitivity could be modelled directly, such as the interaction between common membership in a sports-club and transitivity. However, in order to model this statistically, a richer dataset than I possess with detailed information on social situations would be necessary. Further, to form hypotheses on when a positive and when a negative interaction can be expected, qualitative information on the nature of the social situations is necessary, which I do not have either.

Overall, this conceptual difficulty points towards a limitation of the presented approach in its current form. As presented in this thesis, the social situations in which people are assumed to interact are taken as given, their emergence and selection of peo-

ple into these situations is only discussed peripherally. However, for the understanding of the interaction between transitivity and homophily, this is an important question; treating this is necessary for understanding the mentioned interaction.

The second set of concerns is related to empirical problems. In particular, how can the hypotheses be translated into effects that can be modelled in SAOMs? The case in which a positive interaction can be expected, all members of the triad should be similar to each other, while in case of the negative interaction, only the source and the target of the transitive triad should be similar, whereas the mediator is less important. This means that both configurations would have to modelled. As these effects are not yet implemented, they would have to be programmed first.

Further, when modelling such a complicated configuration, best practises require to model all smaller configurations that the more complex structure is composed of[2]. For the case that we want to model a transitive triad where all members are of, e.g., the same gender, the following controls would have to be included: Are boys more likely than girls to be at the sending end of a transitive triad, are boys more likely than girls to be mediating triads, are boys more likely than girls to be at the receiving end of a transitive triad, is transitive closure more likely between people of the same sex (regardless of the sex of a mediator), is transitive closure more likely if the sender and mediator are of the same sex (regardless of the sex of a receiver), is transitive closure more likely if the mediator and the recipient are of the same sex (regardless of the sex of a sender) and finally the effect of interest: Do transitive triads mainly form when all members are of the same sex. This means that an additional five transitivity effects have to be programmed and included in a model for each dimension of homophily of interest. I personally think that this will result in large difficulties for interpretation (taking all lower level effects into account) and would lead to very large collinearity between the different effects.

Overall these considerations convince me that studying the interaction between homophily and transitivity is a large project, and beyond one chapter in this thesis. Therefore, I do not approach this question here.

[2]This practise has its analogue in other types of regression. When including an interaction between different variables in a model, all main effects the interaction is composed of should be included as well.

Chapter 7

The Peculiar Differences between Friendship Formation and Maintenance

The preceding chapter concluded the series of analyses that concern the interaction between the most important network evolution mechanisms: reciprocity, transitivity and homophily. The approach that was employed throughout the chapters focussed on the different social situations that are connected to the different mechanisms. The hypotheses developed using this perspective were, with some exceptions in Chapters 5 and 6, confirmed. In this and the following Chapter, I take the developed perspective and apply it to two research questions that do not deal with the interaction between different network evolution mechanisms. First, I use it to research the differing predictors of the creation and dissolution of friendships, and in the final empirical chapter I apply it to influence processes in friendship networks.

In the study at hand I propose that endogenous (e.g. reciprocity, transitivity) and exogenous (e.g. homophily) network evolution mechanisms differ in their pattern of enabling the formation and maintenance of friendships. I propose that the difference lies in the relation of tie formation to social situation. Friendships that create reciprocated or transitive friendships enable new social situations (dyadic or group-based) through their formation. Homophilous friendships, on the other hand, are consequences of

already existing social situations. As a result, endogenous mechanisms contribute to the long-term maintenance of existing friendships compared to friendships that are not relationally embedded, while exogenous mechanisms have no impact on the duration of a friendship. The hypothesis is tested using the *ASSIST data* and generally confirmed.

7.1 Introduction

Only the fewest social relationships people are involved in last their entire lives from birth to death. Most relationships undergo at least one or more often two or multiple transitions between presence and absence. Most relationships are formed at some point, persist for a while and end at some later point (and might potentially be re-established and re-broken and so on). As a consequence, multiple different transitions exist, where a tie changes from being absent to present (formation) and from being present to absent (termination). Although in their outcome (presence or absence of a tie) the two transitions are just the opposite of one another, the processes underlying these transitions might be very different for at least some types of relationships.

Probably the most intuitive example to illustrate this phenomenon is the different reasons for formation and termination of a romantic relationship. Reasons for breakups can be differences in values or long-term goals that developed over time, lost trust, etc., however beginning relationships depend mainly on physical and psychological attractiveness[1]. In other words, the predictors for the end of a relationship are not the same as the predictors for the beginning of a relationship with opposite signs. This is not surprising, as most couples find each other attractive in the beginning and other dimensions decide which relationships are successful in the long run (e.g. Felmlee et al., 1990; Berscheid, 1994). A further, intuitively plausible example relates to academic collaboration. Very famous and esteemed scientists get a lot of offers to collaborate, i.e. academic achievement is related to forming new ties (known as the Matthew effect, c.f. Merton, 1968). However, at the same time the abundance of collaboration oppor-

[1] If process underlying the beginning a relationship would be the opposite of terminating a relationship, common reasons for starting a relationship would be values and long-term goals converging, sudden gained trust etc.. While these processes might happen in the course of a relationship, it is difficult to argue that they are the reasons to begin one.

tunities for distinguished academics might also lead to short-lived collaborations. This means that the same predictor, being famous, is connected to formation of new, but also the termination of existing ties in opposing ways. Following this hypothetical argument, being famous does not lead to having more or less ties, i.e. there is no impact on the outcome, but there is an impact on the process[2]. While friendship relations are in many ways not comparable to romantic relations or scientific collaborations, I argue that it is not unlikely that formation and termination of friendships have distinct causes.

While the differing predictors of friendship formation and dissolution have not been studied systematically in a network context, I believe that it is an interesting topic worth researching. If we only study determinants of friendship ties with regard to presence or absence, we might miss important predictors that only work on either one of the two transition processes. By distinguishing between creation and maintenance of friendship ties, we allow the formulation of more elaborate and complete theories about the evolution of friendships (Veenstra and Dijkstra, 2011), e.g. whether achieved and ascribed characteristics play a role in different parts of friendship evolution (van Duijn et al., 2003).

Further, all reasoning that applies to why we study the evolution of friendships in the first place can also motivate why we should study the difference between friendship creation and maintenance. One of the motivations to study friendship evolution in networks are the consequences: Not having friends makes you sad, having the right friends makes you healthy, having the wrong friends makes you start to smoke or go to university, etc.. If we are interested in why people are in particular network positions, we should test for and acknowledge that creation and termination processes might differ from one another. A good example might be the study by Schaefer et al. (2011), who analysed why depressed adolescents have few friends and mainly other depressed adolescents. There might be interesting differences in the creation and withdrawal of friendship to depressed adolescents. Being depressed might make it more difficult to

[2]i.e. it increases the likelihood of a tie turning present among all ties that are absent (makes creation more likely). At the same time it increases the likelihood of a tie turning absent among the ties that are present (makes termination more likely)

approach a person to form a new friendship, which would explain why less friendships are created. At the same time, friendships to depressed adolescents might not be very rewarding and therefore could be more likely to be terminated.

Another study which comes to mind is the effect of the big five personality traits on network position. Following the logic offered in Selfhout et al. (2010) who employed SAOMs to analyse differential attractiveness and activity based on personality, more elaborate hypotheses should be possible that distinguish between creation and maintenance of friendships. In their study they find that extroversion leads to people having more friends, i.e. a positive ego-effect estimate, which is explained by extrovert people searching more social contact. Looking at this argument closer, a more elaborate hypothesis would be that extravert individuals *form* more new ties, but there is no reason to believe that they *keep* their friendships any longer. Another finding was that agreeable individuals are found to be more attractive as friends, as expressed by a positive alter-effect estimate. The reasoning the authors propose is that agreeable individuals have better conflict resolution strategies. However, this would mean that ties to agreeable individuals are less likely to be *broken*, but not more likely to be *created*, as conflict resolution only becomes important if a relationship is already present.

7.1.1 Past work on creation and maintenance

Within the realm of the analysis of friendships taking an explicit network perspective, differences between creation and dissolution of ties have rarely been studied empirically or were treated in theories about friendship network evolution. The few empirical studies I am aware that distinguish between creation and dissolution of friendships within a network paradigm are Cheadle et al. (2013), Ojanen et al. (2013), van Workum et al. (2013), Sijtsema et al. (2013), and Van Zalk et al. (2010), most of which were published in a special issue on network dynamics in the *Journal of Research on Adolescence* and, as illustrations of methodological capabilities, Snijders et al. (2010) and Krivitsky and Handcock (2014).

Cheadle et al. (2013) research how alcohol consumption leads to differential creation and maintenance of ties, focussing on the (party) contexts in which alcohol is consumed.

Van Zalk et al. (2010) find that similarity in levels of depression protect a friendship from being dissolved, while Sijtsema et al. (2013) show that similarity of adolescents in being victimized can lead to relationships being more, or less stable depending on the group the pupil are embedded in. Ojanen et al. (2013) study the impact of agentic and communal goals on network evolution and find that in one of their networks, agentic goals predict de-selection as a friend. Finally, van Workum et al. (2013) find that dissimilarity in happiness predict instability of a friendship over time, confirming the theoretical reasoning brought forward in Buunk and Ybema (2003).

However, all these empirical studies have in common that they focus on one particular covariate. The empirical and theoretical goal of each study is to establish how one attribute affects network evolution for creation and maintenance, with the reasoning being specifically geared to the attitude or attribute in question. Other studies, such as Aboud et al. (2003), analyse the stability of inter-ethnic friendships in adolescents based on similarity attraction theory (Byrne, 1997); however, they only analyse the dyad and disregard other network processes. Further, they do not model creation and maintenance of friendships, but only the predictors of friendship dissolution. Empirical research that distinguishes between the differential effect of inherent network mechanisms, such as reciprocity or transitivity, on creation and dissolution of ties is lacking to this moment.

Theoretical work on friendship with an explicit network approach tends to focus on configurations that are more likely to exist, regardless of the previous state they were in. Balance theory (Heider, 1946; Newcomb, 1961), for example, states that people prefer to be in balanced states in triadic configurations (i.e. have an odd number of positive ties). However, the theory stays silent on whether this tendency is stronger for cases in which a balanced state is present or for cases that are unbalanced. In other words, are ties within balanced states (such as the complete triad) especially stable and ties are unlikely to be broken, or is there a strong force towards closing an open two-path and achieving balance, while it is less important for maintenance of ties. As balance theory focusses on the comparison of states and not processes, it makes the implicit assumption that balance in triads is equally important for the creation and

maintenance of ties.

The theory of focussed choice by Feld (1981, 1982) can be equally applied to the creation and the maintenance of ties. Social foci can enable the creation of new ties, by providing meeting opportunities, but also help stabilising friendships as foci provide regular forums for interaction that keep friendships alive. Although he acknowledges the different processes, by stating that

> "foci as social structures which systematically constrain choices to form and maintain relationships" Feld (1982),

he does not elaborate on potentially different importance of social foci for either process.

Finally, similarity attraction theories (Byrne, 1997) propose that ties between similar individuals are more rewarding than between dissimilar people (see Chapters 5 and 6). This does not allow conclusions about differential importance of similarity for creation and maintenance. Do individuals strategically choose to form friendships to similar others, as they expect a higher reward, or do they maintain friendships to similar other because those ties are more rewarding? Both explanations are plausible, however, they draw from a different underlying understanding of friendship selection processes, where one is strategic and forward looking and the other is based on experience and backward looking. This is an interesting parallel to decision models in other areas of Social Sciences, where, based on the school of thought, processes of decision making are assumed to be either strategic/forward-looking or learned/backward-looking (Macy and Flache, 2009).

Friendship research that does not focus on networks is richer with regards to the specific predictors of friendship termination. However, naturally it also does not focus on the role of specific network configurations on friendship stability. In research on close relationships (Felmlee and Sprecher, 2000; Clark and Lemay, 2010), a field that can be most closely related to social psychology, predictors of the dissolution of close relationships have been studied to some extent. However, even though research on close relationships in principle covers many different types of relationships, empirical studies of relationship termination generally are concerned with the breakup of heterosexual romantic relationships. For these cases diverse predictors for breakups of couples have

been found, such as the presence of attractive alternatives, social support and commitment, interdependence between partners and time spent together (Rusbult and Van Lange, 2003; Berscheid, 1994; Wieselquist et al., 1999), but also concepts more familiar to network researchers such as homophily between partners (Felmlee et al., 1990) and social embeddedness of a couple in a group (Felmlee, 2001). Interdependence theory (Rusbult and Buunk, 1993; Rusbult and Van Lange, 2003), which focusses on close relationship, deals with some predictors of relationship maintenance that are presented as applicable to friendships. Mainly non-returnable investments in a relationship prevent its ending. These can be for example joint hobbies or exchanged gifts, which would be lost without return after the relationship ends, however, it might also be common friends. However, the end of a friendship that makes it necessary to break all common contacts is a rather extreme ending and probably the exception rather than the norm. As such this theory is not very helpful for research on adolescent friendships.

The only study that particularly focuses on the dissolution of friendship in adolescents that I am aware of from this psychological perspective is an MA thesis (Owens 2003). However, this study focusses on predictors that are not the main interest of network researchers. It finds that the predictors of friendship dissolution among adolescents is the duration of friendships and approval of a friends personal characteristics.

Interestingly enough, the only substantive studies I am aware of are listed in the beginning of this section, which all have in common that they only concerns creation and maintenance related to particular attitudes and attributes, but not specific network configurations. Further, and I am not aware of theories that concern the different mechanisms that underlie friendship formation and friendship maintenance from a network perspective. Nevertheless, at least two methods (Snijders et al., 2010; Krivitsky and Handcock, 2014) have been developed that allow to analyse whether a mechanism contributes to friendship creation or dissolution[3]. In conclusion, it seems that scholars in different fields are aware that there might be interesting differences in processes underlying creation and maintenance of friendships in social networks, but this awareness has not led to substantive or theoretical studies yet that have been published in the

[3]These papers also do not refer to any theoretical or empirical work that drives the development of these methods.

literature related to friendship networks[4].

7.2 Theory and Hypothesis

In this section I approach the question how different network evolution mechanisms might contribute to the creation and maintenance of friendship ties to differing degrees, employing a situational perspective. Once more, I focus on transitivity, reciprocity, and homophily, as they are the most important predictors of friendship network evolution.

The situational perspective proposes that reciprocity is connected to people spending time together in dyadic social situations and transitively connected friends spend time together in group-based situations, where the group is defined socially through the ties between the members of the group. Homophilous friends also interact in group-based situations, however, the groups in these situations are defined by a common characteristic that makes individuals take part in this group activity.

At this point I want to emphasise again that I am only concerned with homophilous dimensions that are visible and connected to stereotypical behaviour in the mind of the people under study, i.e. ascribed characteristics. Although researching how homophily for dimensions that are not directly visible (such as deviant behaviour or private opinions) is related to creation and maintenance of friendships is very interesting, it is not the topic of this thesis chapter[5]. A discussion of visibility of characteristics and its relation to homophily can be found in van Duijn et al. (2003).

In the context of this chapter, I differentiate between endogenous network mechanisms, in this case transitivity and reciprocity, and exogenous network mechanisms, here homophily. For endogenous mechanisms the adolescents have control over whether they want to be in a certain configuration with an alter in the network, i.e. they can create and break transitive and reciprocated ties; over exogenous mechanisms, on the other hand, individuals have no control. This means that they cannot decide to whom they want to be homophilous, as they cannot change their ascribed characteristics or

[4]One potential reason for this might be a publication bias, i.e. work on this subject did not produce interesting results and was therefore never published.

[5]I would hypothesise that these kinds of characteristics, if at all, contribute to the maintenance of a friendship, as only people that already are friends should even be aware of them.

those of the other members in the network. This distinction is of crucial importance for the argument to follow.

7.2.1 Situations as antecedents and consequences of ties

While endogenous and exogenous mechanisms are equally related to social situations in which friendships are enacted, the causal relationship (within the logic of the model) between mechanisms and situations is distinct. Network configurations arising from endogenous network mechanisms are under the control of an individual, i.e. she can decide whether she wants to reciprocate a tie or not, or whether she wants to close a two-path or leave it open. In other words, an actor can always decide to create or break a network configuration that is connected to these endogenous mechanisms, given the necessary ties by other actors are present. With the creation or termination of a tie that is part of a transitive triad or a reciprocated dyad, the potential for a social situation that is connected to the mechanisms also is created or deleted. For example, before the reciprocated tie was formed, and after one or both parts break the reciprocated tie, they do not spend time in dyadic situations. Only when a reciprocated tie exist, is a dyadic situation possible, which means that the formation of a reciprocated friendship precedes the dyadic situations. The situation is a *consequence* of the tie formation. The same logic holds for transitive ties. Only when a transitive triplet is closed can it be related to group-based situations.

Exogenous mechanisms, in this case homophily, follow a different logic. The fact that two individuals are similar to one another is unrelated to whether they share a tie or not. Further, the situations that I connect to homophily – doing activities in a group, such as boys playing football – also exist regardless of friendship ties between the members. The social situations that are connected to homophily are the place where the adolescents meet and potentially make friends. As such, the situations connected to homophily are *antecedents* of tie formation.

This differential logic of situations being antecedents or consequences of ties can be related to how endogenous and exogenous mechanisms relate to creation and maintenance of ties. The theoretical reasoning brought forward in Sections 4.1.1 and 4.1.2

about Reciprocity and Transitivity can explain why people primarily form their new friendships to alters from whom they receive a tie or to those they are indirectly connected to. E.g. a one-sided friendship can be seen as an invitation for reciprocating a tie in the future. Or an indirect connection can make it easier to get to know a person, which can lead to the closing of a two-path. This explains why individuals primarily form ties that are socially embedded, although they also create non-embedded (e.g. only homophilous) friendships.

Once new embedded ties are created, they can lead to new social situations for interaction between people, such as spending time in a dyad or in a social group together. Non-embedded friendships, on the contrary, are unlikely to lead to new situations in which a friendship is enacted. As I proposed in Chapter 4.2.1 social situations are where friendships are cultivated. The dyadic and group-based situations that are connected to reciprocity and transitivity can only unfold their effect on friendship after it is formed, as they do not exist prior to the creation of the friendship. In consequence, these situation contribute primarily to the maintenance of ties. The reasoning brought forward leads to the following hypothesis:

Hypothesis 6: The endogenous network evolution mechanisms Reciprocity and Transitivity make both the creation and the maintenance of friendships more likely compared to non-embedded friendships.

For homophily the picture is different. Homophily brings people together in situations that are connected to the dimension of similarity. These situations enable people to meet similar others. Resulting from this focussed choice, people mainly find friends amongst others that are similar to themselves and they form more homophilous friendships. Nevertheless, we know that people also create (some) heterophilous friendships. Both, homophilous and heterophilous ties have a basis for the tie creation, i.e. some forum for interaction, although for heterophilous ties these interactions are not based in activities that are connected to homophilous dimensions[6]. The formation of either

[6]If argued most precisely, it is likely that even activities that are not connected to dimensions that generally exhibit homophily are connected to some sort of similarity. In a hypothetical case of a school

type of homophilous or heterophilous friendship in itself does not lead to new situations for interaction being created, as opposed to endogenous network mechanisms. As the basis for homophilous and heterophilous ties remains unchanged by the formation of the tie, from this purely situational perspective there is no reason to suspect that a homophilous tie is more stable compared to a heterophilous one. In consequence, we can hypothesise with regards to creation and maintenance of homophilous ties:

Hypothesis 7: Homophily makes the formation of ties more likely compared to heterophilous ties; however, it has no effect on the likelihood that a tie is maintained.

7.3 Analytic Strategy

In order to test Hypotheses 6 and 7, I use SAOMs where each modelled effect is included twice, once for creation and once for termination of ties. However, as this has not been done in the literature before, parameter interpretation and model specification require some additional explanation before I proceed to outlining the analytical strategy.

7.3.1 Modelling Creation and Maintenance in SAOMs

Although the main interest of this chapter lies in the differential effects of transitivity, reciprocity and homophily on creation and maintenance of ties, all included effects that operate on the objective function of the SAOM were included in both variants, as creation and endowment effects. The reason for this can be illustrated as follows:

Presume that the processes that underlie friendship formation and friendship maintenance are distinct with regards to the effects A, B, and X. If effect X is included only as the evaluation effect, the implicit assumption that underlies this modelling decision is that the parameters for creation and maintenance are identical (and identical to the

cohort that exhibits homophily on the ascribed dimensions of ethnicity and sex, many ties can be formed and maintained in situations that are related to stereotypical activities for one ethnicity or sex. Other activities, e.g. acting classes that are neither connected to a particular ethnicity or sex can provide situations where heterophilous ties are formed and maintained. However, these heterophilous situations are only heterophilous with regards to the ascribed characteristics sex and ethnicity, but not with regards to every attitude, such as enjoying acting. Therefore, heterophilous friendships in the context of this study means friendships that are dissimilar with regards to the dimensions that structure interaction between different, ascribed groups. It does not mean friendships where the involved parties have absolutely nothing in common.

evaluation parameter). However, in the example this assumption is violated for effect X; if nevertheless effect X is only included in the evaluation function in a model specification, this can bias the estimate of the creation and maintenance parameters of effects A and B. The reason for this is that when modelling creation and maintenance of A and B separately, in either process it is not controlled adequately for effect X, as the parameter of effect X in each function is not the true creation or maintenance parameter, but the different evaluation parameter. An example of this phenomenon is shown in Table 7.1[7]. For illustration purposes, I analysed one school of the ASSIST Data in three consecutive models to show the effect of model misspecification on parameter estimates.

The same sex effect is included distinguishing between creation and maintenance for all three model specifications. The reciprocity effect is included as an evaluation effect in model 1 and separated into creation and maintenance in models 2 and 3, while the transitive ties effect is separated to creation and maintenance only in model 3. It can be seen that the estimates for creation and maintenance of the same sex effect are influenced by the specification of the other two effects. For both, creation and maintenance, the parameter estimates are substantively different between model 1 and model 3 where the difference between the parameter estimates is more than two standard errors. While difference in parameters does not necessarily indicate bias, due to unobserved heterogeneity, a reversal in parameter sign clearly indicates that the omission of the creation and maintenance effects for the other two effects has a strong impact on the conclusion we draw. For this reason, it is advisable to distinguish all or none of the included effects into creation and maintenance.

As each effect in an analysis that focusses on the difference in creation and endowment has to be included in the two variants, creation and endowment, the model specification is quite different from the previous analyses. Distinguishing between creation and endowment requires a lot of information, and the combination of data and model that I use does not have enough power that would allow including each effect modelled in the previous chapters. Further, there might be asymmetries in statistical

[7]This very simple model specification is for illustration purposes only

	Model 1		Model 2		Model 3	
	est	s.e.	est	s.e.	est	s.e.
Rate Period 1	11.7 ***	0.83	10.7 ***	0.93	9.38 ***	0.65
Rate Period 2	9.52 ***	0.81	8.87 ***	0.57	8.01 ***	0.48
Outdegree	-3.35 ***	0.09	-3.37 ***	0.09	-3.41 ***	0.09
Recip. eval	1.99 ***	0.07				
Recip. create			3.19 ***	0.20	3.13 ***	0.22
Recip. endow			0.94 ***	0.25	1.11 ***	0.23
Trans. Ties eval	1.28 ***	0.07	1.25 ***	0.07		
Trans. Ties create					2.12 ***	0.16
Trans. Ties endow					0.34	0.24
Same Sex create	1.49 ***	0.19	1.25 ***	0.17	1.05 ***	0.17
Same Sex endow	-0.32	0.25	0.04	0.24	0.29	0.24

p-values:*< 0.05;**< 0.01;***< 0.001

Table 7.1: Example of misspecification bias for creation and maintenance

power for detecting creation and maintenance effects. However, there is little work in the current literature that systematically examines this asymmetry; nevertheless, the interpretation of the results should keep in mind that they might exist. Details on which effects are included will be given in the next section.

Another difference to the previous models is that it is not feasible to include effects that depend only on ego (covariate or network based) in both variants for the majority of the data that I use. The resulting collinearities are so high that I encountered problems with model convergence. There are two potential options to overcome this problem. First, to include them as evaluation effects that equally operate on the creation and maintenance of ties, and second, to model these effects in the rate-function instead. The advantage of the first option is that all effects are in the objective function instead of the rate function; the disadvantage is related to potential specification bias as outlined earlier. The alternative is to model whether actors with certain characteristics are more active with regards to their amount of change, as opposed to their activity with regards to number of outgoing ties. In this case the effect is included in the rate function. The advantage is that the misspecification bias is avoided; the disadvantage that the interpretation of the effect is a little different. I chose the second alternative, as I perceive the potential bias from misspecification as more severe than the differing

interpretation of a rate effect.

Finally, I want to discuss parameter interpretation, especially the comparability of parameter sizes between the creation and endowment parameters. Although their mathematical interpretation, as expressed in odds-ratios, is comparable between the different models, a larger parameter estimate in, say, the creation function than in the endowment function does not warrant the interpretation that an effect is *sociologically* more important for creation than endowment. Parameter interpretation has to consider that the set of potential alters that an ego can form a tie to is vastly different from the set of alters to which ego can break a tie (the risk set) in terms of size and characteristics. The risk set for maintenance is composed of the outcome of the choices for creation, i.e. preferences for certain types of friendships are already expressed in the friendship creation step. As a result, the alters that are in the endowment risk set are more embedded and more homophilous with respect to ego than the entire network. Taking this into account, it would be very surprising if the parameters for creation and endowment would be identical or even of similar size. Take the following example to illustrate this:

Consider an individual that sends 6 ties and receives 6 ties from others, of which she reciprocates three. In a network of 100 individuals, a reciprocation *creation* parameter of 3.48 could be translated to the individual having a probability of forming a new tie to somebody from whom she receives a tie of 50% and probability of forming an unreciprocated tie of 50%. In the long run, a reciprocation creation parameter of 3.48 for a network of this size, degree and reciprocation rate would lead to 50% of newly formed ties being reciprocated and 50% being unreciprocated. However, if the *maintenance* parameter for reciprocated ties for the same example network would also be 3.48, it would result in a probability of breaking one of the three unreciprocated ties the hypothetical individual has with 97%, compared to a probability of 3% for breaking one of the three reciprocated friendships. The identical parameter in creation and endowment would lead to very different distributions of choices in the different decision processes, as the risk sets are not comparable. Additionally, the creation parameter is dependent on the size of the network. In case of the example at the

beginning of the paragraph in a network of 200 individuals, the creation parameter would have to be substantively higher (4.18) to achieve a probability of 50% to form a reciprocated tie.

This example illustrates how the differing sizes and compositions of the risk sets lead to very different expected parameter sizes for creation and endowment. Especially for endogenous effects, such as Reciprocity and Transitivity for which the statistics are zero in most cases[8], the creation parameters can be expected to be much larger than e.g. the respective maintenance parameters or exogenous network effects. In consequence, assertions such as "the reciprocation creation parameter is larger than reciprocation maintenance parameter - therefore, reciprocation is more important for creation than maintenance" should not be made, due to differing risk sets and different decisions being modelled. If a researcher wants to make this comparison, it should be clear that it only refers to the mathematical comparison of odds-ratios, not whether an effect is more important for creation and maintenance sociologically.

7.3.2 Modelling Approach

As outlined before, the distinction of creation and maintenance requires a lot of information, as a result I employed a meta-analysis of comparable datasets to get reliable parameter estimates; this means that I did not use the Glasgow data in the analysis. The Dutch data could not be used due to small class-room sizes and even small models leading to convergence problems and very large standard errors (>5) when including creation and maintenance effects. I am hesitant to use meta-analysis on the DyNet data, as the schools vary a lot in terms of size, composition, average degree, number of isolates etc.. As such, estimating the mean parameter for such a small, but yet diverse set of schools might not be very meaningful. What is needed for a meta-analysis is either a larger sample or a more homogeneous set of schools. As a result, I test *Hypothesis 6* and *7* on the *ASSIST data*.

Due to the large demands on the data, the model specification is rather minimal: Apart form the *Outdegree* I include the structural effects *Reciprocity*, *Transitive Ties*,

[8]They are zero, as adolescents are neither transitively tied nor receive an incoming tie from most others in the network.

Indegree Popularity as creation and endowment effects, as well as the effect of *Outdegree on Rate*, to model activity dependent on the number of outgoing ties. I had the choice to model clustering or transitivity using either the *Transitive Triplets* effect or the *Transitive Ties* effect. I chose the latter one, as it resulted in better model fit. I further include the *Same Sex* and the *Sex Alter* effects for creation and maintenance, and further the effect of *Sex on Rate* instead of the Sex Ego effect. I did not include FAS in the analysis, as it only is a determinant of network evolution in four out of the eleven schools.

Of the eleven schools that I analysed, I excluded three from the meta-analysis. I did this because in these three schools the model specification led to very large standard errors (> 5) and because the estimated parameters were very different from the estimates of the other schools, both in terms of size and direction. The combination of unusually large effect sizes, large standard errors and diverging results for these schools makes these schools unsuitable for the inclusion in a meta-analysis, as they significantly differ from the other ones.

Hypothesis 6 is tested using the *Reciprocity* and *Transitive Ties* creation and maintenance parameter estimates. *Hypothesis 7* is tested using the *Same Sex* creation and maintenance estimates.

7.4 Results

The results of the SAOM meta analysis of the eight schools in the ASSIST data are presented in Table 7.2. Parameter estimates and standard errors for each network of the most interesting parameters are presented in the funnel plots in Figures 7.1 and 7.2.

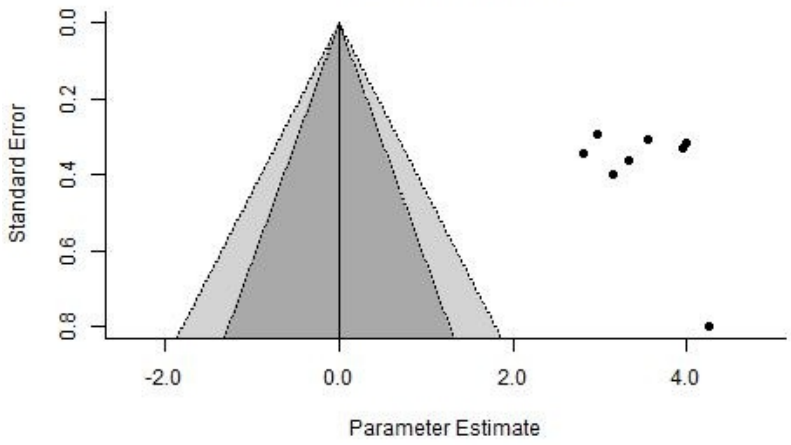
The parameter estimates of each network for *Reciprocity* and *Transitive Ties* creation are shown in Figures 7.1a and 7.1c. Every estimate of either parameter is highly significant, and the size of the estimates is about twice as high as the estimated Evaluation parameters in the analyses in the previous chapters, which is not surprising, given the elaborations on parameter interpretation in Section 7.3.1. Naturally, the estimates of the meta-analysis in Table 7.2 for both effects are equally large and significant (effect

sizes: Reciprocity 3.44; Transitivity 2.25). For the *Reciprocity* parameter, this can be interpreted as follows: In a school cohort of 158 adolescents with an average degree of 4.6 and a reciprocation rate of 63% (these values are taken from a School in the *ASSIST data*), when an average actor creates a tie, it will be reciprocated in 26% of choices and non-reciprocated 74% of times[9]. The endowment estimates of Reciprocity and Transitivity for each network are shown in Figures 7.1b and 7.1c. While most of the parameter estimates are significant, estimate sizes are generally lower than the same evaluation parameters in earlier chapters (Reciprocity 0.86; Transitivity 0.82). For the same example cohort, when an actor decided to break a tie, this will be a non-reciprocated tie in 64% of the cases and a reciprocated one in only 36% of cases[10]. As outlined earlier, this difference in parameter sizes between creation and maintenance could be expected. However, the meta-analysis gives a very clear picture that the mean parameter estimates are positive. These estimates show that the adolescents under analysis tend to preferably form and maintain ties to others that they are indirectly connected to and that they receive a tie from; therefore, I view *Hypothesis 6* as confirmed.

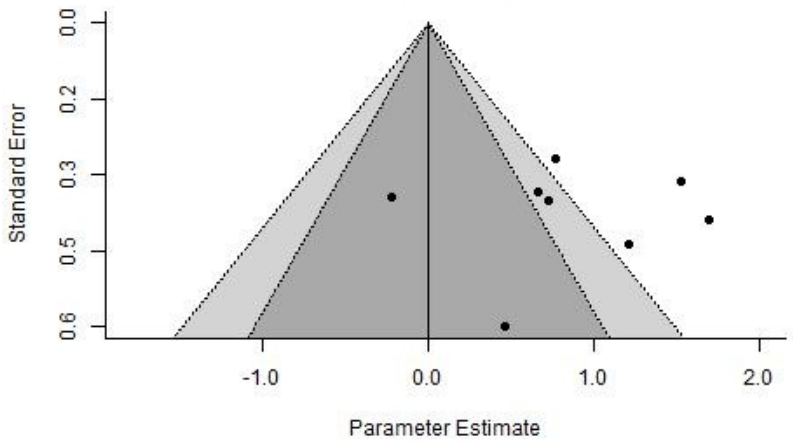
Figures 7.2a and 7.2b display the parameter estimates and standard errors of each analysed network for the Same Sex Creation and Endowment effects. All but two parameters for the Same Sex Creation effect are estimated significant and all are positive. This is reflected in the meta-analysis in Table 7.2, where the overall mean estimate is positive with a value of 0.77 and highly significant. In a gender homogeneous cohort, the interpretation is that adolescents on average form gender homophilous ties in 68% of choices. The story for the Same Sex Endowment estimates is quite different, as seen in Figure 7.2b. The majority of estimates are non-significant and positive as well as negative. Consequently, the mean estimate of the Same Sex Endowment effect from the meta-analysis is non-significant, although positive with a value of 0.25. The interpretation is the following: in a school cohort with 88% gender homophilous friendships,

[9]These are of course hypothetical values that would apply if the individuals an adolescent receives ties from would be identical to the individuals that do not send ties to an adolescent with regards to the effect statistics included in the model. This, of course, is unlikely; therefore, the values of 26% and 74% should be seen as a rough guide to what could be expected in a hypothetical mini-step.

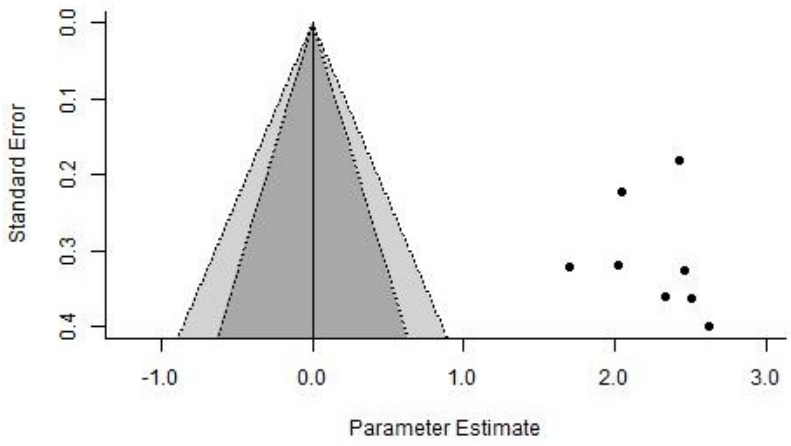
[10]see previous footnote.



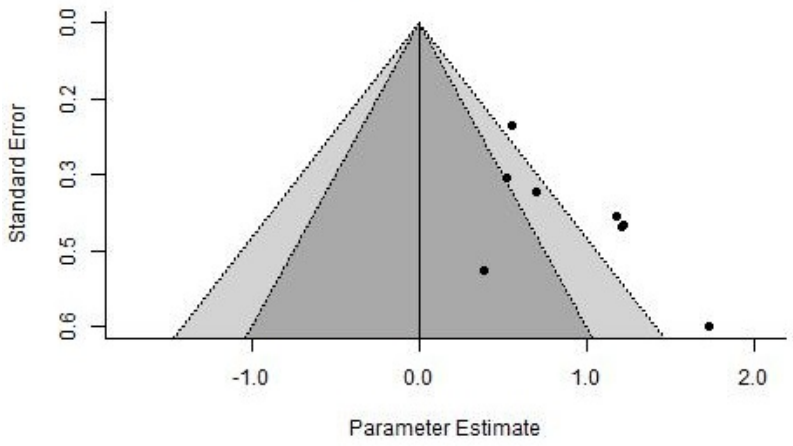
(a) Reciprocity Creation



(b) Reciprocity Endowment

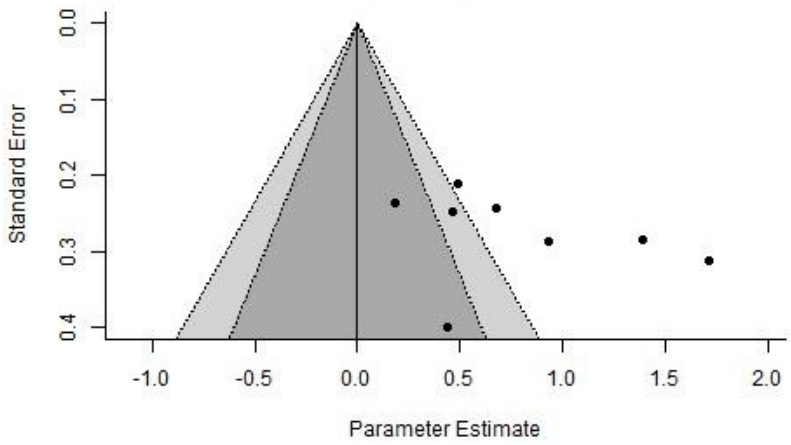


(c) Transitive Ties Creation

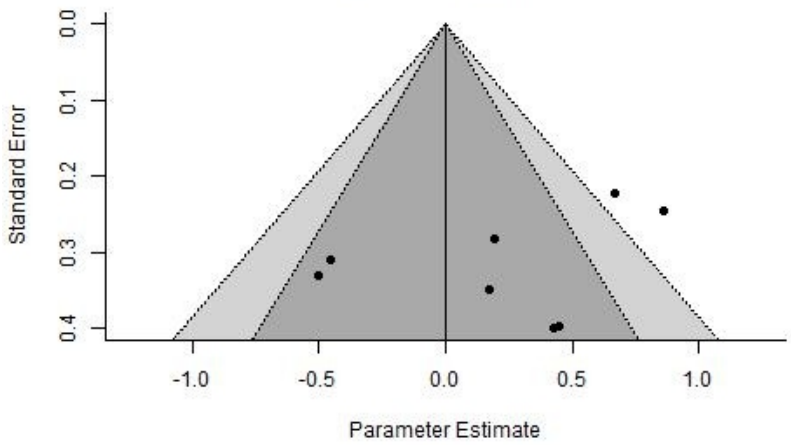


(d) Transitive Ties Endowment

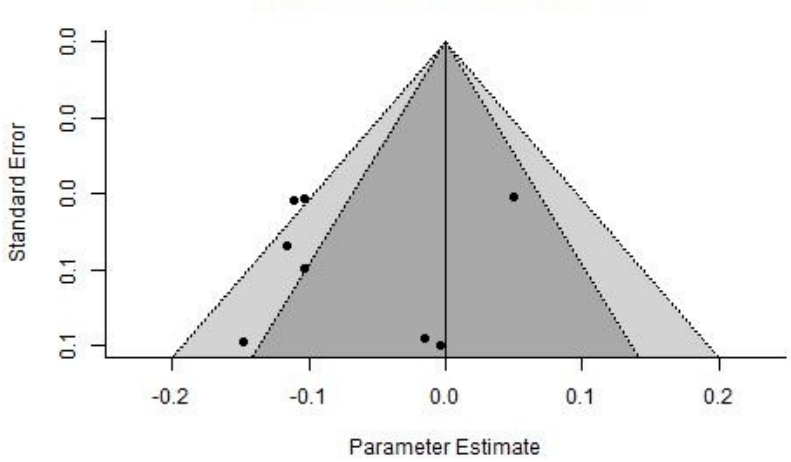
Figure 7.1: Funnel Plots of parameter estimates for Reciprocity and Transitive Ties Creation and Endowment



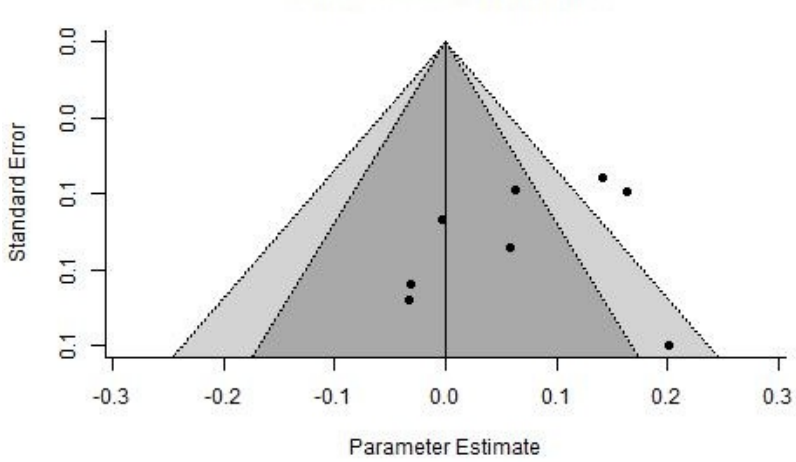
(a) Same Sex Creation



(b) Same Sex Endowment



(c) Indegree Popularity Creation



(d) Indegree Popularity Endowment

Figure 7.2: Funnel Plots of parameter estimates for Same Sex and Indegree Popularity Creation and Endowment

Global Parameters

	estimate		s.e.
Rate Period 1	2.62	***	0.49
Rate Period 2	2.36	***	0.35
Outdegree on Rate	0.28	***	0.04
Sex on Rate	-0.05		0.04
Outdegree	-3.14	***	0.07

Creation Parameters

	estimate		s.e.
Reciprocity	3.44	***	0.17
Transitive Ties	2.25	***	0.10
Indegree Popularity	-0.068	*	0.025
Sex Alter	-0.02		0.05
Same Sex	0.77	**	0.18

Endowment Parameters

	estimate		s.e.
Reciprocity	0.86	***	0.22
Transitive Ties	0.82	***	0.14
Indegree Popularity	0.076	*	0.030
Sex Alter	-0.01		0.07
Same Sex	0.25		0.18

p-values:***< 0.001;**< 0.01;*< 0.05

Table 7.2: Results Creation and Endowment Analysis ASSIST data

this means that in 85% of choices when a tie is broken it will be a same sex tie. Only in 15% of choices will a heterophilous tie be broken. This means that the pupil under analysis preferably form ties to similar others, however, there is no statistically significant indication that homophilous ties are less likely to be broken than heterophilous friendships; thus, I view *Hypothesis 7* as confirmed, too.

Further interesting results from the analyses concern the effect of *Outdegree on Rate* and *Indegree Popularity*. The effect of *Outdegree on Rate* is estimated positive, which is intuitively plausible. Individuals with more friends have a higher rate of change, i.e. are more active in changing their friendship network. A surprising result is that the estimates of the meta-analysis for *Indegree Popularity* Creation and Endowment and both significant but in opposite directions. In the analyses of the different networks, the Creation parameters are mostly estimated negative (see Figure 7.2c); the meta-analysis accordingly estimates a significantly negative parameter at -0.068. On the other hand,

although mostly non-significant in the analyses of each network (see Figure 7.2d) the meta-analysis estimates a positive parameter for the *Indegree Popularity* Endowment effect. This means that the adolescents tend to avoid forming friendships to highly popular alters, but once these ties exist, they tend to be more stable than ties to less popular peers.

7.5 Discussion and Study Conclusion

The evolution of adolescent friendship networks has received plenty of attention in the literature, especially with the rise of statistical network models. However, little attention has been paid to whether the most important network evolution mechanisms – reciprocity, transitivity and homophily – operate mainly on the creation or on the maintenance of friendships. Research in other fields, especially on romantic relationships, suggests that the principles that guide tie formation and tie dissolution are not identical; further, it is intuitively plausible that at different stages in an evolving friendship, different factors are important. Additionally, I argue that analysing the formation and dissolution process separately can yield interesting insights and advance our understanding of why people are friends with one another.

Departing from a situational perspective, I argue that endogenous network mechanisms contribute to the creation and maintenance of ties, while exogenous mechanisms operate only on the creation of new ties. The underlying rationale proposes that the formation of reciprocally or transitively embedded friendships creates new fora for interaction. These new situations stabilise the friendships. Friendships that are formed in situations based on homophily, on the other hand, have no additional stabilising effect on friendships. I suggest that this is observed, because friendships formed and maintained in homophilous situations (in different dimensions) are in principle no different compared to friendships formed in other situations that are not stratified by a (measured) dimension of social life. The resulting *Hypothesis 6* and *Hypothesis 7* were generally confirmed in an analysis of the ASSIST data that distinguishes between the creation and maintenance of friendships.

Before concluding, I would like to discuss the limitations of the study at hand. I

see two shortcomings that future work should address: First, the only dimension of homophily under analysis is sex. It would be interesting to see whether the observed pattern also holds for other dimensions of homophily, such as social status, ethnicity etc.. However, I do not have the data to do these analyses. Although the FAS measure in the ASSIST dataset is a proxy for social status, it is only a significant predictor of network evolution in three schools – too little for a meta-analysis. There is information and some homophily in the DyNet data on ethnicity. However, due to reasons outlined in Section 7.3 and the weaknesses that I discussed in the Data Chapter 2 I decided not to use the data.

The second limitation is closely related to the ones discussed in Chapters 5 and 6. While the theoretical approach attributes social situations to different dimensions of homophily, I do not actually observe these situations. If the data I use would provide information on the actual situations between adolescents, e.g. the clubs, teams and societies adolescents are member of, I could analyse whether co-membership fosters friendship creation but not maintenance. This would be a direct test of the theoretical perspective.

As in previous chapters, the theoretical approach is primarily concerned with situations in which friendships are enacted and little with its cognitive foundations. This means that this perspective shall not be seen as competing with theoretical accounts such as balance theory or similarity attraction theory, but rather as complementing it.

Finally, I would like to come back to the findings regarding the parameter estimates of the Indegree Popularity effects. It is in itself interesting that the estimates for creation and maintenance are significant but in opposing directions. While I can only speculate about the potential reasons for this, *ad hoc* I can see two potential types of explanations. One explanation might be that an adolescent's indegree is a proxy for two different characteristic, where one is related negatively to creation of ties and the other positively to the maintenance of ties. The second possible type of explanation is that the same underlying concept leads to differing effects on creation and maintenance. A purely speculative mechanism is that very popular individuals take a lot of time for their friends and are very nice to them (they are "good friends"). As a result, adolescents who

are friends with popular alters will keep their tie to them, as friendship to these alters is very rewarding. On the other hand, it might be more difficult to become friends with these popular individuals, because they spend so much time with the current friends that it is unlikely that a new person will interact with her enough to establish a new friendship. This way the same characteristic can lead to opposite predictions. However, more research is needed to establish this finding and to explain it properly.

Taking the limitations of this study into account, I believe this is a first step to analysing systematically how different friendships evolution mechanisms contribute differentially to the creation and maintenance of friendships. I found that there are indeed important differences between the processes underlying creation and maintenance of friendships and proposed an explanation that is in line with the empirical findings. However, further research is necessary to establish whether these patterns hold in other networks, and for other dimensions of homophily. Further, the theoretical reasoning should be tested on data that contains information on situations in which people spend time.

Finally, as this chapter is the first to look at systematic differences between creation and maintenance employing SAOMs, it makes a methodological contribution by providing guidelines for model specification and parameter interpretation in these kinds of analyses.

7.6 The Bigger Picture

In Chapter 4 to Chapter 6 I outlined a theoretical framework of friendship network evolution to understand how the different and most important network evolution mechanisms are related to one another. I chose a perspective that focusses on interaction between adolescents as the basis of friendships and the social situations in which these interactions take place. After I could show that this approach leads to a series of hypotheses regarding the interaction between different mechanisms that were generally confirmed in the preceding empirical chapters, in this chapter I assessed whether it can also be applied to other aspects of adolescent friendship network evolution. I found that a situational perspective can yield insights into the differences between creation

and endowment of endogenous and exogenous evolution mechanisms. However, this study can only be seen as a first step; future work should address whether these finding generalise to other data sets and dimensions of homophily, as well as whether the situational understanding of homophily is warranted.

Chapter 8

Mechanism Specific Social Influence

The last substantive chapter of this thesis applies the perspective that focusses on situations in which people interact to the area of social influence research. Especially in the context of adolescent friendship networks and health related behaviour, social influence research has received considerable attention, lately for example with a special issue in the *Journal of Research on Adolescence* (Veenstra et al., 2013) or treated in recent articles in the *Annual review of Sociology* and *Psychology* (Umberson et al., 2010; Dishion and Tipsord, 2011; DiMaggio and Garip, 2012) - but also outside of academic network research. Much reasoning within this chapter is not new; social psychological ideas about influence are combined with a network perspective in order to investigate influence in real network contexts. These different concepts can neatly be integrated in a situational approach. However, a comprehensive treatment of this topic including a proper empirical application is beyond the scope of a thesis chapter. As such, I do not claim to give a complete overview of the influence literature here, and this chapter shall be understood as providing the groundwork for future research in terms of theoretical approach and empirical application. However, the empirical analysis in this chapter is for the purpose of illustration only.

While past research using a network-influence framework has shown that adolescents are influenced by their friends, in this chapter I argue that they might be influenced

by only a sub-group of them, where the subgroup varies depending on the issue that is subject to social influence. Just as friendships are formed and maintained in social situations, social influence takes place in social situations; and influence on different issues is exerted in different situations. By whom adolescents are influenced depends on who is a co-member of the relevant situations, which are characterised by different network configurations (e.g. homophily, reciprocity, transitivity).

8.1 Introduction

The experimental research on peer influence dates back at least to 1924 when Allport showed that individuals gave less extreme judgements on various issues in the presence of other people - he interpreted this as conformity. The classical experiments on social influence of Sherif (1936) and Asch (1956) are widely known, also outside the field of social psychology and the academic community (e.g. in the popular science writings by Paul Watzlawick). Sherif (1936) used the optical illusion that a stationary spot of light on a white wall in the dark appears to be moving to the observers, known as the auto-kinetic effect, to show influence between participants in his experiment. Participants were affected by fellow observers in their estimation of the distance the spot travelled, and this estimate, adjusted by personal influence, persisted in later repetitions of the experiment with the same participants, even if they judged without the others present.

Asch (1956) showed in his experiments that people even are influenced in their behaviour by their peers knowing that they are wrong. Participants in his experiment conformed to the judgement of the other imposing participants when judging the similarity or dissimilarity of the length of lines. In this experiment, all but one participant were part of the experimenter's team and made obviously wrong judgements, to which the participant conformed publicly, even though he held a different private opinion.

Later experiments on influence, and theories that explain how and why social influence spreads are numerous and have developed considerably since the first social influence experiments. Turner (1991) as well as Friedkin and Johnsen (2011) give an overview of the different strands of social influence research focussing on different issues. These build mainly on experiments, following the research tradition of social

psychology.

One approach that I want to pay special attention to, as some of my propositions in Section 8.2 of are grounded here, is Self-Categorisation Theory (SCT), an elaboration of Social Identity Theory (SIT) (Tajfel, 1974; Tajfel and Turner, 1979; Turner, 1987; Hogg, 2006). SIT/SCT proposes that people are mainly influenced by others that are members in the same social categories; however, it also pays attention to individuals membership in multiple, different (and often independent) social categories. SIT/SCT proposes that individuals incorporate a multitude of different social identities that entail different sets of behavioural and attitudinal norms. These social identities relate to individuals' membership in different groups. In the different groups or for the different identities, norms generally relate to different attitudes and behaviours that are followed by the members[1]. In which contexts different social identities become salient and guide the behaviour of an individual, is triggered by readily available environmental factors – i.e. people that are members of different groups act very differently depending on what situation they find themselves in or who they are with (for example an average student will behave very differently in a football stadium compared to an academic seminar). Through the set of norms attached to group membership, social identities propose a set of stereotypical attitudes that the group members expect each other to take on. I.e. in situations where one identity is salient, a limited set of attitudes and behaviours are prescribed by the salient group norm. Consequently, individuals are influenced on the attitudes and behaviours relevant to this group norms by the other people in the group that uphold, and agree upon, the same stereotype. As in different groups norms regarding different attitudes and behaviours are relevant, influence on different attitudes and behaviours will be exerted in the respective groups. E.g. a white, protestant male will hold a set of values where some are connected to his gender, others to religion and again others to ethnicity. Social influence on either issue will be exerted in contexts where membership in the group that is connected to this issue is salient.

Contrasting to this and originating in Sociology and particularly social network

[1] If an individual is member of different groups that prescribe contradictory attitudes and behaviours, she is constrained in her freedom to act and will seek for a resolution of the conflict (see Krackhardt 1999).

science, observational network studies that address social influence have often focussed on methods *detecting* social influence and quantifying it in real world contexts (for an overview of the approaches see Steglich et al., 2010; Mouw, 2006). Contrasting the approaches from the different disciplines methodologically, laboratory experiments face the problem of external validity, i.e. it is difficult to infer on people's behaviour in the real world from their behaviour in an artificial laboratory setting. Observational studies on social influence – that face a set of difficulties regarding causality, see Morgan and Winship (2007) – on the other hand, have high requirements on data and methodology. They need meaningful, longitudinal social networks between individuals, in order to know who can be influenced by whom (Lomi et al., 2011). Methodologically, they have to distinguish social influence from homophily (Lyons, 2011; Shalizi and Thomas, 2011). Further, social influence and homophily should be distinguished from common external causes that influence people at potentially different rates (*ibid.*).

One of the most widely known observational studies on social influence by Christakis and Fowler (2007), while interesting in its results, was heavily criticised for its controversial data and methodology (Cohen-Cole and Fletcher, 2008b,a; Lyons, 2011; Shalizi and Thomas, 2011). Critics of their methodology go as far as to say that in principle it is nearly impossible to distinguish influence, selection, and common third causes in observational studies. Although the critique of the study points out critical weaknesses with regards to theory, data and method, fairly recent developments in SAOMs have made the distinction possible, as outlined in section 3.5. Numerous studies exist by now that model the co-evolution of networks and behaviour using SAOMs.

For example Steglich, Snijders, and Pearson (2010) showed that the adolescents in the *Glasgow data* influence each other on smoking and drinking behaviour, but show only borderline significance for selecting peers based on similarity regarding these behaviours. In a meta-analysis of 11 schools in Finland, Mercken et al. (2010) found that young adolescents (13-16) have a strong influence on the smoking behaviour of their peers and choose their friends based on similar smoking behaviour. In a different large-scale study in Finland on older adolescents (16-19), Kiuru et al. (2010) found that there is no more peer influence at this age on smoking but that peers now influence

each other's drinking behaviour. Further, these adolescents select others as friends that are similar in their drinking and smoking behaviour. Giletta et al. (2012) showed that adolescents choose each other based on, and influence each other, on drinking behaviour in three high schools in northern Italy. Lately, Haas and Schaefer (2014) contributed to explicating the mechanisms that underlie social influence for smoking by showing on a sample of networks from the *AddHealth* data on American adolescents that influence mainly contributes to smoking initiation. There is no positive influence on smoking cessation.

Most co-evolution studies employing SAOMs on adolescent data focus on behaviour that is regarded "unwanted" from an adult's point of view, such as drinking, smoking, other substance use, delinquent and aggressive behaviour. However, some literature also exists on e.g. influence in TV watching habits (Friemel, 2012), academic achievement (Lomi et al., 2011; Flashman, 2012) or pro-social behaviour (Molano et al., 2013). In one of the earliest studies employing this method, Steglich et al. (2006) showed, again using the *Glasgow data*, that adolescents influence, but do not select each other as friends, based on listening to techno and rock music. Listening to classical music shows the opposite tendency (selection but no influence).

8.1.1 Sources and Targets of Social Influence

Different research traditions have very different theoretical ideas about who is influenced by whom. The previously cited network studies use ties within a network to analyse social influence. This means it is assumed that people are influenced by those others they are tied to. In most of the previous studies these were friends of the actors, i.e. the underlying model is that people adopt the behaviour of their friends. Other traditions, such as SCT/SIT or social comparison theory (Festinger, 1954), propose that people are influenced by others that are similar to themselves, or more precisely by norms of groups that they are part of.

This distinction between the Sociological (social networks) approach and the Psychological approach (as represented here by SCT/SIT), is is mirrored in the perspectives on identity in the two fields, as discussed by Deaux and Martin (2003). Sociological

identity theory (Stryker, 1980, 2007), which is grounded in symbolic interactionism, focusses on the interaction between individuals to construe identity, while the psychological theories concentrate on how people's identity is formed by membership in groups or social categories.

Social influence studies in the network paradigm that analyse whether different friends are influencing one another to varying degrees, are rare. One well-known approach distinguishes individuals by their popularity in the network and analyses the extent to which interpersonal influence depends on this feature. As early as 1955, Katz and Lazarsfeld proposed that the most connected individuals in a network are the ones that are also the most influential ones. This approach was elaborated and re-emphasised (Merton, 1968; Gladwell, 2000; Rosen, 2000); the highly connected and influential individuals were called opinion leaders or hubs and took a central role in research on opinion formation. New developments in RSiena allow similar analyses; further they allow to research whether people with certain exogenously defined characteristics are more influential on their friends or more easily influenced by their friends.

Research that takes an explicit network approach and distinguishes friends by common category membership is even rarer. The previously mentioned study by Christakis and Fowler (2007) analyses whether the study participants are mainly influenced by their same sex peers. However, in the article this was neither theoretically motivated nor were the results discussed. A further study by de Klepper et al. (2010) analyses selection and influence of military discipline in a group of the Royal Netherlands Naval College students. The authors try to distinguish whether students influence each other on military discipline mainly if they have the same military specialisation. However, it is not entirely clear how they did this methodologically.

This chapter continues in similar vein, as it suggests to analyse particularly which friends of an individual influence her most in her attitudes and behaviours. In particular, I examine through which ties in a network social influence is exerted with regards to similarity in attributes, and embeddedness of the actors. This is done with reference to social situations in which people influence one another.

8.2 Theory

Following SIT/SCT, I presume that people feel as members of multiple social categories and groups, and follow – and are influenced by – the attitudinal norms of these groups when in a context where this group-membership is salient. Attitudes regarding different issues are important in different social categories. The relation between social categories and social networks has already been discussed in this thesis. Social categories (e.g. boys) stratify activities of individuals (e.g. play football) and provide a forum for interaction between members of this category. Individuals take part in these activities, because they perceive this as a proper activity for somebody "like them". Spending time in social situations together that are stratified by social identities gives rise to homophily, which we observe regularly and on many dimensions.

Similar to the assumption that friendships are formed and maintained in real social situations, I suggest that social influence also takes place in real social situations in which people spend time together. This means that social influence on certain attitudes most likely takes place within contexts and situations in which these attitudes are deemed important.

Combining SIT/SCT and the explicit network perspective, I suggest that in different social situations, or contexts, different social identities are salient; as a consequence, in these different situations, different attitudes are salient that individuals follow. A simple example for such a context is a football fan club. Here people are brought together by their common support for a team; in these clubs and situations, additional homogeneity on other attitudes is also important for the club members. These can be political attitudes, sentiments on other football clubs etc.. These common attitudes define and provide borders for the members of the club and these are the attitudes that are subject to influence in the club. People in this example are influenced on these particular issues by co-members of the club and influence is exerted in situations in which the club members meet. Other attitudes (such as opinions on taxation) might not be salient for the group; as a result there shall be no influence on these issues within the club, as they are either not important in this context, or even not discussed at all.

Previously I developed that different social situations are connected to different

dimensions of homophily; if this is the case it follows that people are influenced on certain issues only by peers that are co-members of these situations and therefore are similar to themselves in some dimension. Combining this with the network approach to social influence – people are influenced by their friends – we can hypothesise that they are influenced on different issues only by a subgroup of their friends; a subgroup they share the relevant social situation with and that they therefore are homophilous to in a dimension that is related to the issue in question. For example within sport clubs, which are stratified by gender and age, norms for what is considered gender-appropriate behaviour might be important within the group. People that are members in these clubs will be influenced on gender norm issues that are salient in the club by their friends that are co-members, which are homophilous to themselves in the dimensions stratifying the club, i.e. by their friends of the same sex and similar age. Contrarily, they will *not* be influenced on these issues by those friends with whom they do not share a common situation in which these issues are salient.

Additionally, there are also sport clubs that are connected to social and political views, such as "working class clubs", "posh clubs", racist or socialist clubs. For these clubs the members will be influenced in their attitudes regarding e.g. politics also by their friends that are of the same sex and similar age. As a result I postulate:

Postulate 1: Individuals are influenced in their attitudes predominantly by those peers in a social network that share membership in groups, in which these attitudes are normatively important, while shared membership in other groups is irrelevant for social influence.

This is completely in line with SIT/SCT and is tested in a network context e.g. in the article by de Klepper et al. (2010), where the authors presume that influence on military discipline is only exerted between friends that have the same military specialisation. However, there is no reason to presume that this specific influence, where only a subgroup of friends is influential, is limited to homophilous groups. Socially defined friendship groups, as represented by transitivity, can as well establish a set of norms

for attitudes and behaviour on which members agree upon and are homophilous. As a result, influence on certain issues can also be exerted in the context of social situations that are defined by social, transitive groups. These norms can range from trivial habits, such as a person drinks wine with one group of friends and beer with a different group of friends, to contentious political or philosophical issues that are only discussed within a certain group of friends. Only friends that commonly take part in situations of this friendship group will exert social influence on one another regarding the issues that are salient only within this group. In consequence, I develop *Postulate 2*:

Postulate 2: The groups in which people are influenced by their peers can be defined by common characteristics (i.e. homophily) or by social cohesion (i.e. transitivity).

Finally, I extend the logic to the third type of social situations that I discussed in Chapters 4 and 5, dyadic situations, represented by reciprocity. These close friendships where people spend time in a dyad can also converge in attitudes on certain issues. Especially privately held opinions and behaviours that are generally kept secret, such as criminal activities or sexual preferences, are more likely to be disclosed and discussed in dyadic, as opposed to group based situations. Influence on these issues is most likely to take place here, compared to group-based situations, as these issues are not discussed in a group-context. Therefore, the third postulate is:

Postulate 3: For issues that are shared, discussed or salient in dyadic situations, individuals are mainly influenced by peers they share these dyadic situations with, i.e. reciprocated friends.

8.2.1 Hypothesis Building from the Postulates

In the previous section I developed why I expect individuals to be influenced not by all their social contacts on all issues, but that influence is specific to sharing certain kinds of social situations. These situations are connected to specific network evolution

mechanisms. With regards to some issues, people should only be influenced by friends that are similar, on others by friends that are members of a common group and they are transitively connected to, and again on further issues by reciprocated friends. However, the question arises what issues, attitudes or behaviours are connected to which network evolution mechanisms, and in the case of homophily, to which dimension of homophily? Who influences whom when it comes to smoking, drinking, delinquency, political engagement, xenophobic attitudes, etc.? I do not have a universal solution for this problem. Connecting situations to attitudes requires grounded theorising and detailed knowledge of the different attitudes and behaviours, and in what type of situations and setting they are salient and discussed. As a result, applying this perspective to a substantive problem requires a lot of subject specific knowledge of the behaviours under analysis.

While this sounds discouraging at first, at the same time it calls for, and potentially provides an approach for studies on selection and influence that elaborate theory and mechanisms of social influence in more detail. Further, it might encourage an integration of qualitative and quantitative network research. The ever growing number of articles that employ SAOMs to study selection and influence often neglect to specify how and in what contexts social influence is assumed to take place.

Having said this, I alert the reader that the empirical analysis that follows is not a carefully designed analysis that aims at explaining how adolescents influence each other. Rather, it is an illustration how an empirical analysis could be conducted after the necessary research for hypothesis specification has been undertaken. As the topic for this illustration, I choose how adolescents influence each other on drinking alcohol in the *Glasgow data*, as it is a well studied topic in the social networks literature on social influence. I test whether adolescents influence each other on drinking alcohol more if they are reciprocally tied to each other and whether they influence each other more if they have the same sex or listen to the same type of music.

8.3 Empirical Approach

In order to illustrate how influence can be specific to certain types of friendships, I use the *Glasgow data* to analyse the co-evolution of alcohol drinking behaviour and friendship using SAOMs as outlined in Chapter 3.5. The model specification for the network evolution is mostly identical to the previous chapters, therefore I do not discuss it further, with the addition is that I model *Ego*-, *Alter*- and *Similarity*-Effects of drinking alcohol, to see if peers select their friends dependent on their drinking behaviour.

For the behavioural evolution, I specify a series of models that analyses which friends influence each other on drinking alcohol. Controls that I include in each model are the *Linear Shape* effect, the *Quadratic Shape* effect, the *Effect from Sex*, and the *Effect from Pocket Money*. The first model uses the *Average Alter* effect to establish a baseline of social influence between the adolescents. However, in the same model the *Average Reciprocated Alter* effect is fixed at zero and tested using a score-type test. This means that although the *Average Reciprocated Alter* effect is not estimated, it is tested whether inclusion of this effect makes a substantive difference to the model. In other words, it is tested whether reciprocated friendships are differentially influential compared to one-sided friendships. In the second model the *Average Reciprocated Alter* effect is estimated, and the *Average Alter* effect fixed at zero and tested using the score-type test. This means the second model tests whether one-sided friendships are likely to also have an influence on their friends behaviour, if only the influence of reciprocated friendships is tested. The reason to use two models with score-type tests rather than estimate a model with both effects included is that estimation procedure is unstable if both effects are included in the model specification at the same time.

In the third model, the *Average Alter* effect is included in two variants: Once it is modelled whether adolescents are influenced by friends that have the same sex and additionally whether they are influenced by different sex peers in the newly programmed *Average Alter Same Sex* effect and the *Average Alter Different Sex* effect. In order to show an intuitive interpretation of a situational understanding that will be discussed in Section 8.5, the fourth and fifth model test whether the adolescents are particularly influenced by their friends that share their music taste with regards to techno and rock

music[2]. To this end, the *Average Alter Same Techno Taste* effect and the *Average Alter Different Techno Taste* are included in the fourth model and the respective effects with regards to rock music in the fifth model. These effects model if peers that have the same music taste and peers that have a different music taste exert influence on each other with regards to drinking alcohol to a differing extent.

8.4 Results

The results of the co-evolution models are presented in Table 8.1 and Table 8.2. As the results for the Network evolution are no different than in the analysis of the Glasgow data in Chapters 5 and 6, I only display the three effects that consider network selection, which depend on drinking alcohol. For all models, the estimates for alcohol based popularity (*Drinking Alter*) and activity (*Drinking Ego*) are non-significant. However, there is a tendency of the adolescents to befriend others that are similar in terms of drinking behaviour, as displayed in the *Drinking Similarity* estimates. This mirrors previous studies using the same data (Steglich et al., 2010).

The effects of most interest for the behavioural evolution in the context of this chapter, are the different versions of the *Average Alter* effect. Model 1 and 2 analyse whether reciprocated friends are more influential for their friends than one-sided friendships. The results are clear: While when estimated on its own, both, the *Average Alter* and the *Average Reciprocated Alter* effects are estimated significant, the score-type tests give a different picture. In the first model the score-type test whether including the *Average Reciprocated Alter* effect is likely to contribute to the model is non-significant. Further, the one-step estimate (results not reported in Table 8.1) for the *Average Reciprocated Alter* effect is negative[3]. Consequently, if anything there is some indication that one-sided friends are more influential than reciprocal friends, although it is not statistically significant [4]. Model 2 suggest the same: When only modelling the influence of

[2]For the definition of taste for Rock music and Techno music refer to Section 2.2. These variables were dichotomised for practical reasons that are related to the implementation of the social influence effects.

[3]This means that the "first guess" of the parameter size for the *Average Reciprocated Alter*, if it were included in the model, is negative.

[4]This proposition is highly counter-intuitive; however, if it were confirmed in further analyses with higher statistical power, it could, for example, be accounted for by reference group theory (Merton,

	Model 1			Model 2		
Network Evolution	est.		s.e.	est.		s.e.
...		...			...	
Drinking Alter	-0.05		0.07	0.03		0.09
Drinking Ego	0.10		0.09	0.08		0.11
Drinking Similarity	0.84	**	0.31	0.86	*	0.38
Behavioural Evolution	est.		s.e.	est.		s.e.
Rate Period 1	1.69	***	0.31	1.61	***	0.32
Rate Period 2	2.50	***	0.60	2.49	***	0.50
Linear Shape	0.46	**	0.14	0.41	***	0.11
Quadratic Shape	-0.68	***	0.21	-0.47	***	0.12
Effect from Sex	0.04		0.21	0.10		0.20
Effect from Pocket Money	0.02		0.02	0.02		0.01
Average Alter	1.37	**	0.23	p-val = 0.016		
Average Reciprocated Alter	p-val n.s.			0.65	*	0.30

p-values:*< 0.05;**< 0.01;***< 0.001; p-values related to hypothesis testing one-sided

Table 8.1: Social Influence Drinking - Reciprocated and Unreciprocated Friends

reciprocated friends, the score-type test for the *Average Alter* effect is significant and the one-step estimate large and positive. In combination, this suggests that mutual friends are not more influential than friends that do not reciprocate the friendship.

Models 3 to 5 analyse whether the adolescents in the study are influenced differently by friends that are similar to themselves compared to friends that are dissimilar on different dimensions and attitudes. Model 3 shows that there is evidence that the studied pupil are influenced by their same sex friends (as modelled in the *Average Alter Same Sex* effect); at the same time, there is no reason to assume that they are also influenced by different sex friends (see the *Aver Alter Different Sex* estimate). In Model 4 a similar pattern can be seen. The adolescents are mainly influenced by others that share their taste for techno music. Friends that have a different taste with regards to techno music exert no influence on drinking alcohol. Model 5 exhibits that this pattern does not hold for taste in listening to rock music. The adolescents are influenced by both, friends that have the same opinion of rock music as well as others

1968). This interpretation would suggest that people are influenced by those they admire and want to be similar to. If one-sided admiration can lead to one-sided friendships, this proposes a potential explanation for this finding.

	Model 3			**Model 4**			**Model 5**		
Network Evolution	est.		s.e.	est.		s.e.	est.		s.e.
...		...			...			...	
Drinking Alter	-0.09		0.07	-0.05		0.07	-0.05		0.08
Drinking Ego	0.10		0.08	0.10		0.09	0.10		0.10
Drinking Similarity	0.84	*	0.38	0.94	*	0.44	0.92	*	0.41
Behavioural Evolution	est.		s.e.	est.		s.e.	est.		s.e.
Rate Period 1	1.58	***	0.30	1.66	***	0.34	1.60	***	0.38
Rate Period 2	2.56	***	0.46	2.51	***	0.58	2.39	***	0.46
Linear Shape	0.42	***	0.12	0.44	**	0.14	0.48	***	0.14
Quadratic Shape	-0.62	**	0.20	-0.65	**	0.20	-0.60	**	0.18
Effect from Sex	-0.01		0.25	0.02		0.22	0.05		0.22
Effect from Pocket Money	0.02		0.02	0.02		0.02	0.02		0.02
Average Alter Same Sex	1.24	**	0.54						
Average Alter Different Sex	-0.09		1.05						
Av. Alt. Same Techno Taste				1.22	*	0.54			
Av. Alt. Different Techno Taste				-0.02		0.44			
Av. Alt. Same Rock Taste							0.54	*	0.32
Av. Alt. Different Rock Taste							0.79	*	0.42

p-values:*< 0.05;**< 0.01;***< 0.001; p-values related to hypothesis testing one-sided

Table 8.2: Social Influence Drinking - Homophilous and Heterophilous Friends

that have a different opinion of rock music. Although the parameter sizes are a little different for both effects, the difference is not significant.

The effects in the behavioural evolution that are not connected to social influence are consistent throughout all models. The linear shape is estimated positive, which means that in a hypothetical mini-step there is a tendency towards higher values of drinking. This is not surprising, as the adolescents grow older in the analysis and drinking at least some alcohol is widely accepted. The quadratic shape effect is negative and significant in all models. This can be interpreted that there is a tendency to drink moderate amounts of alcohol, rather than none at all or very frequently. Finally, there is no detectable effect of pocket money or sex on drinking alcohol.

8.5 Study Discussion

A substantive amount of research on interpersonal influence has been conducted in different disciplines. While (Social) Psychology focusses mostly on theory of influence and experimental studies, sociological studies are concerned with observational studies on interpersonal networks. The focus of these studies lies often on distinguishing between selection and influence methodologically, which does not pose problems in experimental research design. Since the development of SAOMs a comprehensive method is available that allows modelling and empirically analysing influence in observational studies of complete social networks. While many studies have been conducted, and concepts from social psychology have been discussed to motivate this research, so far the empirical analyses have not incorporated these positions in some respects; especially whether different friends are differentially influential.

In this chapter I argued that adolescents might not be influenced by all of their friends on each issue, but merely a subgroup of them. This is because they spend time with different friends in different situations and in different situations different issues are relevant. Following the approach outlined in the previous chapters, I distinguish friends by whether they spend time in dyadic situations (as represented by reciprocity), or in group-based situations, which are reflected by friends being either homophilous on some dimensions or also transitively connected and therefore member of a common

group.

The empirical analysis in this chapter is intended as an illustration how these considerations can be implemented in a statistical network model. The necessary groundwork that deals with situations in which alcohol is consumed in the research context to establish research hypotheses was not conducted beforehand. As such, the results should not be over-interpreted. Nevertheless, I provide a brief, intuitively plausible interpretation of the results, which is in line with the theoretical approach of this chapter. However, at this stage the interpretation which follows is largely speculative. I provide it nevertheless, because I feel that an empirical analysis without interpretation, even is it is only for illustrative purpose, is intellectually unsatisfying.

Drinking alcohol is often understood as a social activity, which is done in groups of people (unless used in unhealthy ways). Especially for adolescents that are not allowed to drink alcohol yet, it is likely that it is confined to certain occasions, which are likely to differ from drinking habits of adults, who sit at dinner parties or go to a pub with one friend to talk. The forbidden nature of alcohol for adolescents prohibits this casual, regular and on the side drinking behaviour. Departing from the assumption that adolescents only drink in certain and very confined occasions, we can think which type of friends are most likely influential on an adolescents drinking behaviour.

Reciprocity is connected to dyadic situations, which probably do not qualify as drinking occasions for 14 year old adolescents. Therefore, I have no reason to believe that reciprocated friends have a higher influence on drinking behaviour than one-sided friends, which is confirmed in the empirical analysis.

This leaves group-based situations as occasions for consuming alcohol. The empirical analysis allows the interpretation that occasions where same sex friends meet to spend time together is where influence happens. As these occasions are manifold and cover a range of activities, it is difficult to speculate which occasion is important and which is not. However, one important situation in which adolescents consume alcohol is at parties. Parties are group-based interactions and I presume that they are one of the occasions where influence on drinking behaviour is exerted.

In other words, the adolescents are most likely to be influenced on their alcohol

drinking behaviour by those of their friends they go to party with. I do not have data on which friends go to parties together, however, there is an indicator whether it might be more or less likely that they do: music is often a central theme to parties. I do have information on what music adolescents listen to, and I suggest that adolescents that listen to the same type of music influence each other on alcohol drinking. This should be especially true for "party music", such as techno and might not be the case for types of music that is less suitable for parties, such as rock music. The influence specific to listening similarly to techno music but not rock music that was found in the analysis might be explained this way. However, let me stress once more that this interpretation is very speculative and the empirical analysis was aimed at illustrating how such an study could be conducted.

8.6 Conclusion

This concludes the series of substantive chapter in the thesis. It extends the situational reasoning that was introduced in the previous chapters to the field of social influence research. The perspective brought forward converges neatly with approaches developed in Social Psychology and network social influence research, and can directly be applied to the statistical modelling of the co-evolution of networks and behaviour. However, as opposed to the previous chapters, this one does not develop research hypotheses and empirically tests them, as this requires further subject-specific work.

This chapter develops a perspective that can be applied in the future to gain a more intimate knowledge of processes of interpersonal influence. This could relate to relevance for policy oriented research. If it is of interest which adolescents influence each other on substance use or deviant behaviour, exploring which friends specifically are responsible for influencing one another might prove to be relevant, too. Further, this chapter makes a methodological contribution, by showing how this perspective can be operationalised in empirical research. The effects that test for homophilous influence were especially programmed for this chapter and are intended to be added to RSiena to make them available for public use in the near future.

Chapter 9

Conclusion, Limitations and Future Directions

9.1 Summary, Discussion and Conclusion

Within the course of this thesis I developed a theoretical framework based on the assumption that friendships are formed and maintained in social situations. Further, I proposed that different social situations can be connected to different network evolution mechanisms. Situations where adolescents meet in social cliques, in its colloquial meaning, can be connected to individuals being tied directly and transitively. Dyadic situations where two adolescents spend time vis-a-vis without others surrounding them are related to reciprocal friendships between the two involved parties. Finally, homophily is connected to group-based activities and situations that are typical for a certain demographic group.

I propose that when two adolescents have one forum for interaction with one another, i.e. they regularly meet within one of the social situations, further meeting in additional other situations does not increase the likelihood for the existence of a friendship tie as much as could be expected from the sum of the effects connected to the situations. In other words: the first, joint forum for interaction in which people meet increases the likelihood for friendship formation and maintenance most; every additional social situation to meet is less important. Consequently, the interaction between

different network evolution mechanisms that can be related to different social situations is generally negative. This could be shown in empirical analyses in Chapters 4 to 6 on a variety of datasets employing SAOMs.

This theoretical model presumes, and explicitly states at some points, that having a forum for interaction is a necessary condition for forming and maintaining a friendship. While this is obvious and might seem trivial on its own, the situations in which friendships can flourish are quite narrowly defined. I claimed that friendships cannot exist outside of social groups, homophilous groups or reciprocated dyads. The implicit consequences of this claim are that outside of these situations a social void exists in which friendship ties should not be present, even though adolescents that are not connected through either of these situations in the analysed data still share the same classroom and meet each other on a daily basis, in which they could in principle interact to form friendships. Thus, the assumption is that the "normal" school-day routine does not provide a relevant forum in which friendships can be formed and maintained. This seemingly strong assumption was checked for plausibility on the Glasgow data and the ASSIST data.

I calculated which proportion of all existing ties in the networks at different timepoints are neither embedded in a transitive triplet, reciprocated, nor between peers of the same sex. For the tested networks, the proportion of these ties in the "social void" was consistently below 2%. In light of this very low proportion, the assumption that the normal school-day routine does not provide necessary forums for interaction seems warranted. However, this does not mean that there is no interaction within a school that is of social nature; rather, it suggests that even within the school, social interactions take place in smaller situations that are equally structured by transitivity, homophily, or reciprocity.

After the original set of research questions was studied using this model, I applied it to two other problems to which the perspective seemed promising. The nature of the social situations that are connected to different network evolution mechanisms varies between endogenous (reciprocity and transitivity) and exogenous (homophily) mechanisms. For endogenous mechanisms, situations are a consequence of tie formation,

while for exogenous mechanisms, situations are antecedents of friendship formation. In consequence, endogenous mechanisms stabilise an existing tie and make friendships maintenance more likely, while exogenous mechanisms have no effect on friendship stability. This could be shown in Chapter 7. Chapter 8 approached social influence from a situational perspective, hypothesising that people are influenced on different issues by varying subsets of their friends, depending on co-membership and salience of issues in different situations. This approach neatly integrates perspectives developed in SIT/SCT and network studies on social influence.

The empirical analysis further revealed some interesting side-products of the empirical analyses that are not directly related to the research questions. I could show that the previously found and canonically interpreted negative three-cycle estimate is spurious and a result of a misspecified model. Further, the analysis of tie creation and maintenance revealed potentially interesting degree dynamics in networks, where indegree is related to attractiveness as a friends in opposite directions for creation and maintenance of friendships.

Finally, the empirical analyses in the thesis required some methodological innovation; most noteworthy are the newly programmed effects for RSiena in Chapters 4 and 8, and the developed guidelines for the simultaneous analysis of tie creation and maintenance as well as parameter interpretation for these models. However, it remains to be seen whether they prove to be useful in the long run.

9.2 Limitations and Future Directions

Although I think that this thesis makes some interesting contributions to the study of adolescent friendships network evolution, many questions remain open. While I am convinced the empirical results from Chapters 4 to 6 will be confirmed in analyses using other datasets, the findings from Chapter 7 on creation and maintenance need support from further studies. The empirical analysis in Chapter 8 on specific influence is for illustration purposes only; as such how useful this perspective proves has to be established in well grounded empirical research. Further, the analysis of the interrelation between homophily and transitivity should be treated further, both theoretically and

empirically.

Within this thesis, I employ only one type of method (SAOMs) and one type of data (complete, longitudinal networks in school cohorts or classes). Using other methodology and data could strengthen the argument. E.g. analysis of ego-networks or large-scale networks that are increasingly available from social media sites on the internet could be insightful. Exponential Random Graph Models (ERGMs) are a viable alternative to SAOMs applying to cross-sectional data[1], with which the same hypotheses could be tested on cross-sectional datasets.

On theoretical grounds, the most interesting question that remains open is how social situations are created and how individuals select themselves into social situations. For the analysis of the relationship of different evolution mechanisms it is sufficient to assume and show their existence, however, intellectually it would be more satisfying to explain how these situations come about. Further, it would be interesting to know the relative occurrences of the different situations and whether there are person-specific patterns to the choice of situations in which people interact. Hand in hand with this theoretical question, empirical research should focus on observing the social situations that take a central role in the theoretical perspective. To what extent can the assumptions about the relation between situations and mechanisms can be confirmed in direct observation, as opposed to the indirect evidence that stems from the empirical analysis of its consequences, as outlined in the empirical chapters of this thesis.

The developed perspective focusses on the interaction between people within social situations; however, we know that important social cognitive mechanisms also guide the evolution of friendship networks, such as those underlying balance theory or social exchange theory. It is important to either integrate those, or define clearly how they relate to the situational perspective.

Further, the question remains open whether this approach can only be applied to adolescent networks and only to friendship networks. Potentially similar dynamics are at play in adult friendship networks, although this needs to be tested. Adult friendships differ from adolescents friendship in many respects, e.g. the amount of time spend

[1] Although recent developments also allow the analysis of cross-sectional data using SAOMs and the analysis of longitudinal data with ERGMs

with friends, friendships maintained from different past stages in life, the content and activities that friends do together, and not least the impact of romantic relations and own children on friendships. As such it is not clear whether the same logic that proves useful for adolescents can be applied to adults. Finally, can the logic be applied to other types of networks, such as advice or co-operation networks? As my knowledge of these kinds of networks is limited, I abstain from speculation.

Appendix A

Descriptive Statistics

Statistic	Value
Participants	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 (mean (min - max))	8.8 (0-40)
Pocket Money wave 2 (mean (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

Table A.1: Descriptive Statistics Glasgow data

Statistic	School 15	School 22	School 33	School 35	School 41	School 62
Participants	188	149	153	158	172	144
Indeg w 1 (mean, min, max)	4.23, 0, 14	3.66, 0, 10	4.63, 0, 11	4.66, 0, 17	3.88, 0, 10	4.34, 0, 13
Indeg w 2 (mean, min, max)	4.07, 0, 11	3.97, 0, 12	4.91, 0, 11	4.82, 0, 16	4.35, 0, 12	4.33, 0, 11
Indeg w 3 (mean, min, max)	4.39, 0, 13	3.57, 0, 9	4.78, 0, 11	4.82, 0, 15	4.21, 0, 10	4.31, 0, 13
% girls	54	49	46	46	54	58
Moran's I sex (w 1, 2, 3)	0.88, 0.86, 0.83	0.89, 0.89, 0.87	0.80, 0.88, 0.88	0.88, 0.81, 0.73	0.95, 0.87, 0.89	0.89, 0.84, 0.82
FAS (mean (min - max))	4.11 (0-6)	3.93 (0-6)	4.19 (0-6)	4.06 (1-6)	3.61 (0-6)	3.71 (1-6)
Moran's I FAS (w 1, 2, 3)	0.15, 0.11, 0.06	0.02, 0.02, 0.02	-0.02, -0.08, 0.01	0.03, 0.13, 0.12	0.04, 0.08, -0.04	-0.03, -0.04, -0.09
% Missing Periods 1, 2	11, 7	1, 4	5, 1	1, 4	3, 16	3, 7
Jaccard Index Periods 1, 2	0.36, 0.35	0.38, 0.38	0.35, 0.41	0.37, 0.35	0.35, 0.43	0.38, 0.39

Statistic	School 63	School 64	School 68	School 69	School 71
Participants	236	170	164	80	102
Indeg w 1 (mean, min, max)	4.67, 0, 11	4.34, 0, 11	2.98, 0, 10	3.87, 0, 12	4.14, 0, 13
Indeg w 2 (mean, min, max)	4.95, 0, 11	4.65, 0, 14	3.35, 0, 10	4.26, 0, 10	4.37, 0, 14
Indeg w 3 (mean, min, max)	4.49, 0, 12	4.10, 0, 11	3.08, 0, 11	4.20, 0, 9	4.19, 0, 10
% girls	48	55	55	41	56
Moran's I sex (w 1, 2, 3)	0.84, 0.84, 0.85	0.88, 0.76, 0.71	0.94, 0.89, 0.90	0.84, 0.81, 0.88	0.79, 0.76, 0.75
FAS (mean (min - max))	4.25 (0-6)	3.89 (1-6)	3.24 (0-6)	4.14 (1-6)	3.78 (1-6)
Moran's I FAS (w 1, 2, 3)	0.03, 0.08, 0.12	0.00, 0.00, 0.07	0.06, 0.05, 0.03	-0.04, -0.02, 0.06	0.08, 0.00, 0.03
% Missing Periods 1, 2	0, 5	9, 8	10, 11	1, 9	8, 5
Jaccard Index Periods 1, 2	0.33, 0.37	0.37, 0.35	0.29, 0.32	0.35, 0.35	0.32, 0.30

Table A.2: Descriptive Statistics ASSIST data

Statistic	School 1	School 2	School 3	School 4	School 6	School 13
Participants	117	184	129	122	192	188
Indeg w 1 (mean, min, max)	3.1, 0, 15	4.5, 0, 14	3.1, 0, 9	4.7, 0, 17	3.6, 0, 11	2.9, 0, 10
Indeg w 2 (mean, min, max)	4.9, 0, 17	4.4, 0, 12	2.1, 0, 6	4.3, 0, 15	3.3, 0, 11	2.5, 0, 10
Indeg w 3 (mean, min, max)	3.6, 0, 15	5.1, 0, 15	1.9, 0, 6	4.7, 0, 14	4.7, 0, 14	1.9, 0, 7
Indeg w 4 (mean, min, max)	4.6, 0, 14	4.2, 0, 14	2.1, 0, 5	3.7, 0, 12	3.5, 0, 14	1.9, 0, 8
% girls	48	55	50	53	51	51
Moran's I sex (w 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 sex (w 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	62	78	80	81	83	51
% Latin	11	13	3	3	13	42
% Native	15	11	9	17	9	9
% Other	27	16	19	24	15	13
% 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

Table A.3: Descriptive Statistics DyNet data

			Av. Degree		Jaccard	% Friendships at t_2		
Nr.	N	% Male	t_1	t_2	$t_1 - t_2$	s. sex	recip.	trans.
1	45	44	2.31	3.16	0.35	70	61	78
2	37	46	1.05	1.86	0.24	93	58	68
3	33	48	1.36	1.09	0.38	81	56	53
4	36	67	1.67	2.44	0.28	74	50	77
5	54	37	2.24	2.85	0.38	91	56	72
6	91	54	1.95	2.22	0.24	80	41	54
7	47	38	2.09	2.52	0.27	85	56	63
8	31	48	1.68	2.52	0.24	60	47	77
9	82	48	1.26	1.82	0.33	79	51	64
10	*31*	*65*	*0.81*	*1.26*	*0.13*	*37*	*58*	*49*
11	90	53	1.91	3.40	0.26	89	57	80
12	61	57	1.36	1.97	0.30	77	53	48
13	45	47	1.29	1.56	0.24	73	66	61
14	38	50	1.61	1.37	0.28	94	42	44
15	43	56	2.07	2.51	0.31	85	52	69
16	48	63	1.08	1.29	0.35	77	43	56
17	53	51	1.43	2.23	0.32	82	59	64
18	52	54	1.69	2.21	0.28	76	53	60
19	73	53	1.77	2.27	0.29	84	61	75

Nr.: classroom number; N: Number of pupil; Jaccard: Jaccard index denoting network change between two time points; s. sex: between same sex peers; recip.: reciprocated; trans.: embedded in a transitive triplet; *Classroom 10* excluded from the analysis due to low Jaccard index..

Table A.4: Descriptive Statistics of Dutch Data

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