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# The Dynamics of Network-Religion Autocorrelation in Adolescent Friendship Networks

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THE DYNAMICS OF NETWORK-RELIGION AUTOCORRELATION

IN ADOLESCENT FRIENDSHIP NETWORKS

by

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THE DYNAMICS OF NETWORK-RELIGION AUTOCORRELATION

IN ADOLESCENT FRIENDSHIP NETWORKS

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University of Nebraska, 2013

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Similarity of religious beliefs and practices among friends, or network-religion autocorrelation, is a common aspect of many social networks. Network-religion autocorrelation is important because it strengthens plausibility structures (Berger 1967), or the combination of beliefs and strong social ties to others who share those beliefs. Plausibility structures support sacred umbrellas (Smith 1998), which may help explain the relative vitality of religiosity in the United States. In this study, Stochastic Actor-Oriented Models (SAOMs) and longitudinal, full network data from the National Longitudinal Study of Adolescent Health (Add Health) are used to test hypotheses about the dynamics of network-religion autocorrelation in adolescent friendship networks in two American high schools. Results suggest that network-religion autocorrelation is a salient aspect of both friendship networks, a total similarity effect best operationalizes religious influence, religious selection and religious influence both drive network-religion autocorrelation, and religious selection accounts for a larger proportion of network-religion autocorrelation than religious influence.

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# 1. Introduction

Religion is an important axis along which social ties are structured. For the most part, people's friends, family, and spouses maintain religious beliefs and practices similar to their own. For example, using data from the General Social Survey, Louch (2000) shows that when two people $i$ and $j$ both have a strong tie to some third person $k$, the odds that $i$ and $j$ share a strong tie increase by 45% if they belong to the same religion, whereas the odds only increase by 35% if they share the same level of education. Researchers refer to this homogeneity of religion across social ties as network-religion autocorrelation[1] (Cheadle and Schwadel 2012), and it has been found, to some extent, in all religiously pluralistic societies (McPherson, Smith-Lovin, and Cook 2001).

One reason network-religion autocorrelation is important is that it strengthens plausibility structures, which are the combination of personal religious beliefs and relationships with others who share those beliefs. According to Berger (1967), plausibility structures support a sacred canopy, an unquestioned, shared world view that gives order and meaning to life and protects individuals from anomie (Brashears 2010). But plausibility structures may also work at the small group level, supporting a "sacred umbrella," which protects religious groups from the potentially secularizing effects of a pluralistic society (Smith 1998). If this is the case, then the relationship between network-religion autocorrelation and plausibility structures may help explain the relative

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[1] McPherson, Smith-Lovin, and Cook (2001) define homophily as higher frequency contact between similar people than between dissimilar people. That is, "birds of a feather flock together." Because the term "homophily" sometimes refers to the process and sometimes refers to the outcome (Goodreau, Kitts, and Morris 2009), the less ambiguous terms "selection" and "network autocorrelation" are used to refer to process and outcome respectively.

vitality of religiosity in the United States. Thus, thoroughly understanding network-religion autocorrelation is an important goal for the sociology of religion.

The two theoretical explanations of network autocorrelation are selection and influence. The question is whether people form social ties with those to whom they are similar (selection) or people become more similar to those with whom they already have social ties (influence). The recent development of stochastic actor-oriented models (SAOMs) of social network dynamics allows researchers to model network autocorrelation and to conduct statistical inference on network and behavior dynamics, including selection and influence. These models require longitudinal, full network data. The National Longitudinal Study of Adolescent Health (Add Health) contains two waves of full network data in a saturated sample of sixteen schools. All analyses below are conducted on the two largest schools in the saturated sample ($N = 646$ and $N = 1,207$) with the Simulation Investigation for Empirical Network Analysis (SIENA) software.

In a recent paper, Cheadle and Schwadel (2012) use Add Health data and SAOMs to examine the importance of selection and influence for predicting network-religion autocorrelation in adolescent friendship networks in small school ($N < 300$) settings. Their findings suggest that although selection and influence both play important roles for several dimensions of religiosity, influence is the more important process in terms of religious service attendance, youth service attendance, and importance of religion. This paper extends the current understanding of network-religion dynamics among adolescents by (a) comparing network-religion autocorrelation to other forms of network autocorrelation, (b) testing three different operationalizations of religious influence, (c) modeling the dynamics of network-religion autocorrelation in the adolescent friendship

networks in a medium-sized school and a large-sized school, and (d) estimating the relative contributions of religious selection and religious influence toward network-religion autocorrelation.

In the medium and large school contexts being considered, this study finds that network-religion autocorrelation is a source of friendship clustering and that a total similarity effect best operationalizes religious influence. Similar to Cheadle and Schwadel (2012), findings from this study suggest that religious selection and religious influence both contribute to network-religion autocorrelation. In contrast to Cheadle and Schwadel's findings with small schools, analyses of adolescents in a medium and large school show that selection accounts for a larger proportion of network-religion autocorrelation than does influence. The significance of the main effect used to operationalize religious selection disappears in the final model for both schools; however, other mechanisms of religious selection are found to be statistically significant. Although the results are context specific, they provide some micro-level support for the notion that plausibility structures protect adolescent religiosity from pluralism via sacred umbrellas (Smith 1998).

## 2. Literature review

Social network analysts observe two types of behavioral homogeneity in social networks: status-based network autocorrelation and value-based network autocorrelation (Lazarsfeld and Merton 1954).  Status network-autocorrelation is a clustering of social ties around demographic attributes, such as race, ethnicity, gender, and age; and value-based network-autocorrelation is a clustering of social ties around chosen attributes, such

as religion, education, and other behaviors. Although there is some disagreement about the relative importance of network-religion autocorrelation compared to other forms of value-based network-autocorrelation (e.g. Kalmijn 1998; Louch 2000), the social network and sociology of religion literatures lend support to the notion that religion is a salient predictor of friendships and other strong social ties (McPherson et al. 2001; Regnerus 2003; Wuthnow 2003), especially for members of conservative religions (Bainbridge and Stark 1981; Lim and Putnam 2010; Stark and Bainbridge 1980). This pattern is partly due to factors such as a history of religious homogamy (Myers 2006), the geographic distribution of religious adherence (Park 2005), and involvement in similar organizations among religious adherents (Chaves 1993). Thus, I expect to find that social ties cluster around religiosity in adolescent friendship networks:

> Hypothesis 1: *The probability that a friendship between two randomly selected individuals exists increases with the individuals' level of religious similarity.*

Additionally, network-religion dynamics, namely religious selection and religious influence, develop and maintain network-religion autocorrelation. Religious selection is the process of people choosing friends based on religious similarity. Religious influence is the process of people becoming religiously similar to their friends over time. Table 1 displays diagrams of selection and influence. The circles, or nodes, represent individuals, the color of the nodes represents values of an attribute variable (e.g. black = more religious, white = less religious), and the arrows represent friendship nominations with the direction of the arrow indicating who nominates whom. Sections 2.1, 2.2, and 2.3 provide theoretical and empirical support for religious selection and religious influence from the existing research literature.

[Table 1 about here]

## 2.1 Plausibility structures and sacred umbrellas

The question of whether religious selection, religious influence, or both mechanisms are important determinants of network-religion autocorrelation in adolescent friendship networks has implications for theories of secularization and for explanations of the relative vitality of religiosity in the United States. According to Berger (1967), religion maintains socially defined reality effectively because it situates people within a sacred cosmos; importantly, this task is much easier for religious monopolies than for religions in pluralistic societies. In pluralistic societies, religious explanations of the existing structures of power and privilege are weaker because they are not taken for granted. Thus, as society continues to modernize and pluralism increases, the decline of religion appears inevitable.

A major criticism of Berger's theory of secularization is that it fails to account for the United States, which compared to most other nations is both highly pluralistic and highly religious. Differentiation theory takes a more moderate stance by defining secularization as the decline of religious authority. "[Religion] is one relativized sphere among other relativized spheres, whose elites jockey to increase or at least maintain their control over human actions, organizational resources, and other societal spheres" (Chaves, 1994, p. 752). Differentiation theory predicts that as the sphere of religious influence is separated from other spheres of influence, its authority over society and the individual decreases; however, this decrease is not assumed to be the result of an inevitable evolutionary trend. The extent to which differentiation occurs in a particular time and place is seen as an empirical and historical question (Gorski, 2000).

Although Berger's (1967) expectation that secularization is inevitable has not been supported in the extant literature (e.g. Finke and Stark 2005), his description of plausibility structures is useful for understanding network-religion autocorrelation. A plausibility structure is the 'base' that is required by each world, or system of meaning, in order for it to seem real to humans:

> [The individual who wishes to convert] must dissociate himself from those individuals or groups that constituted the plausibility structure of his past religious reality, and associate himself all the more intensively and (if possible) exclusively with those who serve to maintain his new one. Put succinctly, migration between religious worlds implies migration between their respective plausibility structures. This fact is as relevant for those who wish to foster such migrations as for those wishing to prevent them. (Berger 1967, p. 51).

Friendships among people who are religiously similar to one another strengthen their plausibility structures. Smith's (1998) subcultural identity theory of religious strength provides a framework for understanding the relationship between plausibility structures and religious vitality. "In a pluralistic society, those religious groups will be relatively stronger which better possess and employ the cultural tools needed to create both clear distinction from and significant engagement and tension with other relevant outgroups, short of becoming countercultural" (Smith, 1998, p. 118-119). According to the subcultural identity theory of religious strength (simply referred to as subcultural identity theory below), religions that distinguish themselves from the culture at large while simultaneously engaging with society will thrive. Pluralism provides a religious organization with abundant cultural out-groups that strengthen the identity of the in-group by making clear distinctions. In response to Berger's (1967) notion of sacred canopies, Smith argues that in the modern world, religion takes the form of sacred umbrellas that envelop religious in-groups.

Applied at a micro-level, subcultural identity theory predicts that network-religion autocorrelation is a function of both religious selection and religious influence. That is, youth who remain religious or even increase their religiosity over time, must distinguish from and engage with an otherwise secular environment. Religious youth maintain distinction from the school culture by favoring friendships with similarly religious youth. Simultaneously, religious youth engage with the rest of the student population by influencing both members of the in-group and members of the out-group (Clasen and Brown 1985). Whether intentionally or not, they can do this by maintaining a small number of social ties with less religious youth, by inviting students to youth groups or religious services, and by talking about their religious preferences. In accordance with subcultural identity theory (Smith 1998) and previous research (Cheadle and Schwadel 2012), I expect to find that religious selection and religious influence are both important contributors to network-religion autocorrelation:

> Hypothesis 2: *Religious selection and religious influence are both statistically significant predictors of network-religion autocorrelation.*

## 2.2 Religious selection

A large body of research points to religion as a prominent basis for friendship selection. Similarity of attitudes, beliefs and values leads to attraction and interaction (e.g. Kossinets and Watts 2009; Rivera, Soderstrom, and Uzzi 2010) and people demonstrate a strong preference for friends with political orientations, education levels, and income levels similar to their own. Additionally, religion is inherently social. Durkheim ([1897] 1951, p. 43) writes, "...wherever we observe religious life, its foundation is a defined group." Finally, similarity of religion has been empirically observed to increase the

probability of a friendship (e.g. Verbrugge 1977). Adolescents may select friends based on religion for a number of reasons. Those who share a common religion are more likely to belong to the same congregation or youth group, providing them with more opportunities to interact. Religious parents may also encourage their children to seek out friendships with religious adolescents in order to promote values and behaviors they find desirable (Smith 2003).

Although most studies cannot give a credible, empirical estimate of religious selection due to data constraints and/or limitations with the modeling technique, Cheadle and Schwadel (2012) use SAOMs to estimate a coefficient for religious selection as a driver of network- religion autocorrelation, while controlling for religious influence. They find that in small schools ($N < 300$), religious selection is a statistically significant predictor of network-religion autocorrelation along every dimension of religiosity they consider. Decomposing the relative importance of selection as a contributor to network-religion autocorrelation for the same dimensions of religiosity, they find that religious selection is responsible for between 9.2% and 26.6% of the network-religion autocorrelation in their final models, depending on the dimension of religiosity being considered. Accordingly, it is possible that religious selection is more important than religious influence for producing network-religion autocorrelation:

> Hypothesis 3a: *Religious selection accounts for a greater proportion of network-religion autocorrelation than does religious influence.*

## 2.3 Religious influence

Attitudes and behaviors such as happiness, obesity and smoking can spread through social networks via strong social ties (Christakis and Fowler 2009) in a process of social

contagion. In much the same way, religiosity spreads through social networks. Although parents are important in the process of religious socialization, other social network ties create shifts, even dramatic shifts, in religious preference (Stark and Bainbridge 1980). Indeed, interpersonal bonds are an essential element in religious recruitment since membership in religious organizations often spreads through social networks (Lofland and Stark 1965; Schwadel 2012).

As with religious selection, the best test of religious influence to date is conducted by Cheadle and Schwadel (2012) because they estimate it while controlling for religious selection. Their results suggest that in small schools, religious influence is the more important driver of network-religion autocorrelation for almost every dimension of religiosity they consider. They find that religious influence is responsible for between 18% and 35.3% of the network-religion autocorrelation in small schools, depending on the dimension of religiosity. Since, Cheadle and Schwadel find that religious influence is a more important determinant of network-religion autocorrelation in small schools, it is possible that the same pattern holds in larger school settings:

> Hypothesis 3b: *Religious influence accounts for a greater proportion of network-religion autocorrelation than does religious selection.*

Cheadle and Schwadel operationalize religious influence with an average similarity effect, which implies that the more similar an individual is to his or her friends on average, the higher the odds he or she will become more religious. Other possibilities for operationalizing religious influence are discussed in the next section.

## 2.4 Operationalizing religious influence

Because the development of a class of statistical models capable of conducting inference on selection and influence is relatively new, little work has been done to understand how best to operationalize these processes. Three primary operationalizations, called effects in SIENA terminology, have been developed to estimate social influence. Which effect best represents the process of religious influence remains an empirical (Steglich, Snijders, and Pearson 2010) and theoretical question.

Three common operationalizations of social influence are the average similarity effect (e.g. Cheadle and Goosby 2012; Cheadle and Schwadel 2012), the total similarity effect (e.g. Kiuru et al. 2010), and the average alter effect (e.g. Cheadle et al. Forthcoming). To understand average similarity and total similarity, similarity for actors $i$ and $j$ on behavior variable $z$ is defined as:

$$\text{sim}_{ij}^{z} = \frac{\text{range}(z) - |z_i - z_j|}{\text{range}(z)}$$

where range($v$) is the range of the behavior variable in the entire network[2]. Defined this way, similarity ranges from zero to one. It is zero only when either actor $i$ or actor $j$ has the minimum score on the behavior variable $z$ and the other actor has the maximum score on the behavior variable $z$. Similarity is equal to one only when actors $i$ and $j$ have the same score on the behavior variable $z$. The average similarity effect, then, is the mean of the centered similarity scores between an ego and all of the actors whom ego has nominated:

$$\text{average similarity}_i = \frac{\sum_j x_{ij} \left( \text{sim}_{ij}^{z} - \overline{\text{sim}^{z}} \right)}{\sum_j x_{ij}}$$

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[2] Following Ripley, Snijders, and Preciado (2011), $z$ denotes a mean-centered dependent attribute variable and $v$ denotes an independent attribute variable.

where $x_{ij} = 1$ if actor $i$ nominates actor $j$ and $x_{ij} = 0$ otherwise. Average similarity for actor $i$ is a measure of how closely actor $i$ resembles his or her friends relative to how closely other actors resemble their friends in terms of behavior variable $z$. The total similarity effect is the sum of the centered similarity scores between ego and all of the actors to whom ego is tied:

$$\text{total similarity}_i = \sum_j x_{ij}\left(\text{sim}_{ij}^z - \overline{\text{sim}^z}\right)$$

For both average similarity and total similarity, an ego that is similar to his or her alters on a behavior variable will have a positive score, and thus (assuming a positive coefficient), a relatively high probability of increasing his or her score on the behavior variable. Conversely, an ego that is highly dissimilar to his or her alters on a behavior variable will have a negative score, and thus (assuming a positive coefficient), a relatively low probability of increasing his or her score on the behavior variable. The substantive difference between average similarity and total similarity is that total similarity takes into account the number of actors in ego's network because it is not normalized by the actor's out-degree (the number of friends ego nominates, or $\sum_j x_{ij}$). For example, using the total similarity effect to model influence, given two egos that are maximally similar to their alters on a behavior variable, the ego with more alters will have a higher probability of increasing his or her score on the behavior variable. Another consequence of not normalizing by out-degree is that total similarity can "tolerate" some dissimilar friendships while maintaining a high effect size.

The average alter effect approaches the problem in a different way. It is defined as the product of ego's behavior score and the average behavior score of ego's alters:

$$\text{average alter}_i = \frac{z_i\left(\sum_j x_{ij} z_j\right)}{\sum_j x_{ij}}$$

Substantively, the average alter effect is a kind of "rich get richer" phenomenon. Ego has the highest probability of increasing his or her score on a behavior variable if his or her score is high to begin with and the average score of his or her alters is high. Actor $i$'s behavior score is multiplied by the behavior score of each of his or her friendship nominees so the maximum of the average alter effect occurs when all of the alters nominated by ego have the maximum score possible for the behavior variable.

Table 2 diagrams a prototypical case for each of the three operationalizations of influence. As before, the color of the node represents a behavior variable, but this time with three levels, black = very religious, gray = somewhat religious, and white = not religious. Since average similarity is normalized by ego's out-degree, the maximum possible score for this effect is one. Average similarity will be equal to one when ego has the same value on the attribute of interest as each of his or her friends, regardless of how many friends he or she has (see Table 2, Frame 1). Total similarity is not normalized by out-degree, which means that ego's maximum total similarity score is equal to the number of friends he or she has. In practice, total similarity scores will tend to be less than the maximum, but friends who are dissimilar to ego can be "out-voted" by friends who are similar to ego if ego has enough friends (see Table 2, Frame 2). Alternatively, the average alter effect assumes that high values of an attribute variable drive social influence. The maximum value of the average alter effect occurs when ego has a high value of the attribute and all of ego's friends have a high value of the attribute, regardless of how many friends ego has (see Table 2, Frame 3).

[Table 2 about here]

Coming back to the two primary components of subcultural identity theory (Smith 1998), distinction from and engagement with secular society, it is possible to make a prediction about which operationalization best represent religious influence. As noted above, friendships with religiously similar others strengthen plausibility structures and plausibility structures support sacred umbrellas. Furthermore, one of the main functions of sacred umbrellas is to distinguish the in-group from the out-group. This implies that among adolescents with some predisposition toward religiosity, being religiously similar to one's friends should lead to increases in religiosity, suggesting either the average similarity effect or the total similarity effect as the best operationalization of religious influence.

Importantly, distinction from secular society is necessary but not sufficient. Successful maintenance of religiosity also requires engagement with secular society (Smith 1998). If ego is predisposed to religiosity, then each social tie to an adolescent with low religiosity decreases the average similarity and thus, assuming a positive coefficient, decreases the odds that ego will become more religious (and increases the odds that he or she will become less religious). While this makes intuitive sense and agrees with the findings from Cheadle and Schwadel (2012), subcultural identity theory predicts that as long as ego maintains some ties to high religiosity adolescents, a small number of ties to low religiosity adolescents (i.e. secular society) should promote ego's own religiosity. The total similarity effect allows ego to have a limited number of less religious friendships while maintaining a high effect size. Assuming a positive coefficient, a high effect size increases the likelihood of increases in religiosity; thus, I

expect to find that the total similarity effect best represents religious influence in SAOMs of network-religion autocorrelation:

Hypothesis 4: *Of the three operationalizations of influence, the total similarity effect will produce the biggest improvement in model fit.*

## 2.5 Purpose of study

The purpose of the present study is to address four research questions: (1) Is network-religion autocorrelation a salient aspect of adolescent friendship networks in large schools? (2) What is the best way to operationalize religious influence? (3) What are the important sources of network-religion autocorrelation in adolescent friendship networks? and (4) What are the relative contributions of religious selection and religious influence toward network-religion autocorrelation? SAOMs and longitudinal, full network data from the Add Health survey are used to test the hypotheses for the medium ($N = 646$) and large ($N = 1,207$) schools in the saturated sample. All hypotheses are directly or indirectly supported by theoretical arguments in the sociology of religion literature and empirical findings from Cheadle and Schwadel (2012). The next section details the data, variables, and analysis techniques to be used.

# 3. Methods

## 3.1 Data

The data come from in-home surveys, parent surveys and administrator surveys conducted during waves 1 and 2 of the National Longitudinal Study of Adolescent Health (Add Health). Add Health is a four-wave longitudinal study of adolescents who were in $7^{th}$ – $12^{th}$ grade in the United States in 1994 – 1995. The investigators used stratified

random sampling to select 80 schools from all U.S. high schools. Some of the selected high schools included grades 7 – 12. For the high schools that did not include grades 7 – 12, feeder junior high schools were identified and randomly selected with probability proportional to the number of attending students. This resulted in a sample of 132 schools that are nationally representative in terms of region of the country, urbanicity, size, type and ethnicity. In order to be eligible, a high school had to include an 11th grade and have more than 30 students. The sampling frame was a database collected by Quality Education Data, Inc.

The analyses for this study are conducted on two of the schools that were chosen to be "saturated" settings, in which the researchers attempted to conduct in-home surveys for all enrolled students and their parents. Data from the saturated school settings are needed because they include two waves of network and attribute data, which makes it possible to estimate SAOMs. The medium-sized school (N = 646) is missing 2.1% at the first wave and 13.9% at the second wave. The large school (N = 1,207) is missing 4.9% at the first wave and 17.1% at the second wave. These levels of missingness adhere to the recommendations of Ripley, Snijders, and Preciado (2011) to use networks with no more than 20% missing data for SAOMs. Less than 1% of the sample at each school is missing from both waves and these data are dropped from the analyses. For more information about the Add Health survey see Harris et al. (2009).

## 3.2 Conceptualization and measurement

Two variables serve as dependent and focal independent variables: religiosity and friendship. The religiosity variable is an index of four ordinal variables: frequency of religious service attendance, frequency of youth service attendance, frequency of prayer,

and importance of religion (Cronbach's α = 0.833 at wave 1 and Cronbach's α = 0.920 at wave 2). Frequency of prayer ranges from 0 to 4 and the other three variables that make up the religiosity index range from 0 to 3. The religiosity index, then, ranges from 0 to 13. Due to an Add Health design decision, respondents who report no religious affiliation ("nones") were skipped for all other questions about religion; therefore, they are assigned a zero for the religiosity index (Cheadle and Schwadel 2012). Table 3 presents a summary of the "nones" in the medium and large schools.

[Table 3 about here]

In order to measure friendship, respondents were asked to nominate their five best male friends and their five best female friends. This results in an $n \times n$ adjacency matrix X, where $n$ is the number of students in the school and $x_{ij} = 1$ if student $i$ nominates student $j$ and $x_{ij} = 0$ otherwise. Because students are not allowed to nominate themselves, the diagonals of the matrices are defined as zero. Religiosity at wave 1 is an independent variable predicting friendship, or network structure, at wave 2 (selection); and network structure at wave 1 is an independent variable predicting religiosity at wave 2 (influence).

It is important to control for a number of network tendencies so the role played by selection and influence in network-religion autocorrelation can be properly estimated (Steglich et al. 2010) and so the structure of the network can be adequately modeled. The most important network effects controlled for in the model are out-degree, reciprocity, and the triadic effects of transitive triplets and three-cycles (Burt, 1980; Ripley et al., 2011). Out-degree is simply the number of friends ego nominates. Table 4 provides diagrams of reciprocity, transitive triplets and three-cycles. Reciprocity is the number of dyads for which actor $i$ nominates actor $j$ and actor $j$ also nominates actor $i$ (see Table 4,

Frame 1). Transitivity is the tendency for friends of friends to become friends with one

another. This is represented by the number of ego's transitive triplets, which is calculated

by counting the number of pairs of friends nominated by actor $i$, actors $j$ and $k$, for which

actor $j$ also nominates actor $k$ (see Table 4, Frame 2). This type of triadic effect is

consistent with hierarchical ordering (Veenstra and Steglich 2012). Three-cycles, on the

other hand, may be interpreted as a more egalitarian friendship pattern, in which actor $i$

nominates actor $j$, actor $j$ nominates actor $k$, and actor $k$ nominates actor $i$ (see Table 4,

Frame 3). Another network control is distance-two, the number of actors two degrees

away from ego. Finally, controls are added for the number of off-list friendship

nominations and friend flag, a dummy variable indicating membership in the restricted

nomination sample[3].

[Table 4 about here]

In order to accurately model religious selection, three effects are necessary: the

religious ego effect, the religious alter effect, and the religious similarity effect. The

religious ego effect is defined as the product of ego's religiosity score and his or her out-

degree. This effect is included in the model to assess the effect of religiosity on the

propensity to nominate friends. The religious alter effect is defined as the sum of

religiosity scores for all of ego's friendship nominees. This effect is included in the

model to assess the effect of religiosity on the probability of being selected as someone

else's friend. After including the religious ego effect and the religious alter effect, it is

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[3] Off-list nominations occur because respondents were allowed to nominate friends outside of their schools. Including those friendships in analyses would blur the boundary of the social networks; therefore, the number of off-list nominations is simply controlled for. The friend flag is necessary because of a survey implementation error: some respondents were only allowed to nominate one male friend and one female friend.

possible to operationalize religious selection as religious similarity, the sum of the

centered similarity score for religiosity between ego and each of his or her alters.  The

mathematical definition of each of the network effects is defined in Table 5, and Table 6

presents the observed counts of these network phenomena in the medium and large

schools.

[Table 5 about here]

[Table 6 about here]

It is also important to control for attributes of the respondents. Dummy variables

are created for gender (female = 1), several race/ethnicity categories (non-Hispanic white,

non-Hispanic black, Hispanic, Asian, other race), parent marital status (single = 1), and

for a religious tradition variable with the following categories: evangelical Protestant,

mainline Protestant, Catholic, other religious affiliation, and no religious affiliation[4]

(Steensland et al. 2000). The Jewish and other religious affiliation categories are

combined, and the evangelical Protestant and black Protestant categories are combined,

due to small sample sizes[5]. Grade ranges from 8 to 12 in the two schools used for these

analyses so that an entire school can be used for both waves. Parent religiosity is an index

created from the ordinal variables frequency of service attendance, frequency of prayer,

and importance of religion (Cronbach's $\alpha$ = 0.685). Finally, parent education is an ordinal

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[4] Some religious affiliations used in the Add Health survey are ambiguous. Baptists, Lutherans, Presbyterians, and "other Protestants" were classified as evangelical Protestants if they reported being born again and mainline Protestants if they did not report being born again.
[5] Across both schools, five respondents report belonging to a black Protestant denomination.

variable ranging from 2 = neither parent graduated from high school[6] to 10 = both parents received postgraduate training.  All attribute control variables were measured at wave 1. Table 7 presents basic descriptive statistics, which show that the medium and large schools represent two very different social contexts in terms of race/ethnicity, religious affiliation, and overall religiosity.

[Table 7 about here]

## 3.3 Analyses

The primary data analysis technique uses SIENA software to estimate SAOMs for the longitudinal network and attribute data in the sample. SAOMs are continuous-time Markov Chains with sub-models for the network dynamics and for the behavior dynamics. The network portion of these models takes network tendencies and individual-level attributes as explanatory variables and models the change in the structure of the network from the first time point, $T_1$, to the final time point, in this case $T_2$, by iterating through a series of micro-steps. At each micro-step, one actor is given the opportunity (so to speak) to change a tie (from 0 to 1 or from 1 to 0) or to make no change. The decision to change or not change a tie is probabilistic and based on the network evaluation function, which is a linear combination of effects whose weights are estimated with a method of moments procedure:

$$f^{net}(x) = \sum_l \beta_l s_{il}(x) + U$$

where $\beta_l$ is the weight for the $l^{th}$ effect in the model, $s_{il}(x)$ is the effect (defined in Table 5) computed for actor $i$, and $U$ is a random disturbance term. The average number of

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[6] Actually, values of 1 occur when the responding parent did not graduate from high school and did not know the level of education of the other parent.

opportunities that each actor receives to make a change to his or her network is determined by a rate parameter, $\rho^{net}$, which is also estimated with the method of moments procedure. The behavior portion of the models is defined analogously. The attribute variables must be ordinal so that at each micro-step, one actor is given the opportunity to increment the variable by one, decrement the variable by one, or make no change. The decision about whether or not to change the attribute variable (in this case religiosity) is based on the behavior evaluation function:

$$f^{beh}(x,z) = \sum_l \beta_l s_{il}(x,z) + U$$

where $z$ is the dependent behavior variable and the other terms are defined as before. The behavior sub-model also requires a rate parameter, $\rho^{beh}$. Both the behavior evaluation function and $\rho^{beh}$ are estimated with the same method of moments procedure as the network evaluation function and $\rho^{net}$(Ripley et al. 2011).

Since the separate portions of the SAOMs are estimated simultaneously, they model changing behavior scores and network structures as joint dependent variables while controlling for each other and additional network dependencies and attributes. Therefore, the effect of selection is estimated while controlling for the effect of influence and vice versa. For model building, Ripley et al. (2011) recommend starting with a simple model, deleting non-significant effects and adding further effects in groups of one to three. They also note that all models should include an out-degree effect and reciprocity effect. Effects for triadic effects are included in most models because they are basic network tendencies (Burt 1980).

The adequacy of competing operationalizations of influence is assessed with score-type tests, which determine whether including any of the three effects, the average

similarity effect, the total similarity effect, or the average alter effect, improves model fit. To test one of the influence effects, a model is run in which the parameter of interest is fixed to zero, which is the null hypothesis. The test statistic, $c$, is a function of:

The expected value of the effect $-$ The observed value of the effect

and its distribution is approximately $\chi^2$ with one degree of freedom (Ripley et al. 2011).

To understand whether or not network-religion autocorrelation is a salient aspect of adolescent friendship networks, Moran's I (Moran 1950) is computed for several attribute variables:

$$I = \frac{N}{\sum_i \sum_j x_{ij}} \frac{\sum_i \sum_j x_{ij}(z_i - \bar{z})(z_j - \bar{z})}{\sum_i (z_i - \bar{z})^2}$$

where $z_i$ is the score of the behavior variable for actor $i$. Commonly used to operationalize network autocorrelation (e.g. De La Haye et al. 2011; Steglich et al. 2010), Moran's I ranges from -1 to 1, with -1 being complete heterogeneity of attribute values among friends (that is, no two people with the same attribute value share a social tie) and 1 being complete autocorrelation (that is, social ties only occur among those who share the same attribute value). The first term, $N/\sum_i \sum_j x_{ij}$, together with the residual sum of squares in the denominator of the second term, constitute a normalizing constant to ensure that the statistic ranges from -1 to 1. The $x_{ij}$ in the numerator of the second term ensures that only those pairs in which there is a tie from $i$ to $j$ are included in the statistic. Finally, $(z_i - \bar{z})(z_j - \bar{z})$, in the numerator of the second term is positive when $z_i$ and $z_j$ are on the same side of the mean and negative when $z_i$ and $z_j$ are on different sides of the mean, capturing how similar or different the score of the attribute variable is for two actors $i$ and $j$. Although this form of analysis is purely descriptive, it gives some idea

about how network-religion autocorrelation compares to other forms of network autocorrelation.

The relative contributions of religious selection and religious influence to network-religion autocorrelation are estimated by computing Moran's I from the simulated networks of a series of SAOMs. The models estimated are baseline models with only the behavior shape effects included, a control model with all of the effects except for selection and influence, a control model plus selection, a control model plus influence, and a full model. SIENA produces 1,000 simulated networks and behavioral score vectors for each model so Moran's I is averaged over all simulations and then used to compute the relative importance of each contributor to network-religion autocorrelation (Mercken et al. 2010; Steglich et al. 2010). The results section is broken up into subsections; each subsection corresponds to a research question presented in Section 2.5.

# 4. Results

## 4.1 Network-religion autocorrelation

The first question to be addressed is whether or not network-religion autocorrelation is a salient aspect of the adolescent friendship networks in the medium and large schools, compared to other forms of network autocorrelation. Table 8 presents estimates of Moran's I for several types of network autocorrelation. Although religiosity is not the primary axis of friendship clustering in either school, Moran's I is positive and substantial across both waves for both schools. In the medium school, Moran's I for religiosity is higher than Moran's I for all of the religious tradition indicator variables,

and Moran's I for parent religiosity, race (only white/non-white autocorrelation is measured), and parent education. In the large school, Moran's I is greater for the Catholic religious tradition indicator variable than for religiosity. The high degree of clustering for Catholics probably partially reflects the large Moran's I for race/ethnicity since Latinos are disproportionately Catholic and there is a large Latino population in the large school (see Table 7). Also in the large school, the magnitude of Moran's I for religiosity is smaller than that for gender, grade, all race indicator variables except for other race, and parent education. This suggests that network-religion autocorrelation, as estimated with the religiosity index, is relatively less salient in the large school, however it is still an important driver of network clustering since the magnitude of the religiosity Moran's I is comparable for both schools and larger than Moran's I for evangelical Protestants and "nones" in both cases.

[Table 8 about here]

## 4.2 Operationalizing religious influence

The second research question asks how best to operationalize religious influence, or the degree to which the religiosity of one student is affected by the religiosity of his or her friends. As described above, score-type tests are used to address this question. The null models in the score-type tests use the other effects from model 1 (see Tables 10 and 11) and the results are presented in Table 9. These results strongly suggest that the total similarity effect best represents religious influence. For both schools, the magnitude of the test statistic for the total similarity effect is greatest. For the medium school the total similarity effect is the only one with statistical significance. Accordingly, the weight of

the evidence suggests that the total similarity effect is the most appropriate specification across both schools.

[Table 9 about here]

## 4.3 SAOMs for the medium and large schools

The third research question addresses the dynamics of network-religion autocorrelation in adolescent friendship networks and is assessed with SAOMs. There are several differences in the dynamics of network-religion autocorrelation between the medium school and the large school. Tables 10 and 11 display the results for the medium school and large school SAOMs, respectively. Sections 4.3.1 and 4.3.2 describe these findings.

### 4.3.1   Network models

Coefficients for the network and behavior models are analogous to coefficients for ordinal logit models and are interpreted as such[7]. The out-degree coefficients for all models for both schools are strongly negative indicating that, all other things equal, the odds that a tie exists between two randomly selected individuals is low. The out-degree coefficients are more negative for the large school models than for the medium school models indicating lower network density in the large school, which is expected since network size typically has a negative correlation with network density (Anderson, Butts,

_____

[7] Although the rate parameters are not substantively meaningful, they are a mathematical necessity for continuous-time Markov Chains and are presented at the top of Tables 10 and 11.  The rate parameters represent the number of opportunities that an average actor has to change his or her out-going network ties or religiosity score. So, for example, model 5 estimates that an actor at the medium school is given on average 15.07 opportunities to change his or her network composition between waves. Not all of those opportunities result in a change; the actor makes a decision based on the evaluation function. Somewhat interestingly, at the medium school, actors have more opportunities to change network composition than opportunities to change religiosity scores, whereas at the large school, opportunities to change religiosity scores occur more frequently than opportunities to change network composition.

and Carley 1999). In both schools, the large positive reciprocity coefficients indicate a strong tendency toward reciprocated friendship ties. In agreement with most studies of social network dynamics, adolescents tend to maintain friendships with a low proportion of the entire network and to reciprocate friendships (e.g. Cheadle and Schwadel 2012; Schaefer, Kornienko, and Fox 2011; Snijders, de Bunt, and Steglich 2010).

[Table 10 about here]

[Table 11 about here]

Having a high tendency toward transitive ties relative to the tendency toward three- cycles is an indicator of hierarchical friendship structures (Veenstra and Steglich 2012). This pattern is evident in both schools, but it is more distinct in the large school. Model 5 in Table 10 shows that the transitive triplets coefficient is 0.59 and the three-cycles coefficient is -0.50 in the medium school, whereas model 5 in Table 11 shows that the transitive triplets coefficient is 1.02 and the three-cycles coefficient is -1.02 in the large school. T-tests indicate that the difference between the two coefficients is significant for both schools ($p < 0.01$ for the medium school and $p < 0.001$ for the large school), which means that both schools exhibit hierarchical friendship structures.

In both schools, gender and grade are important sources of friendship selection. All other things equal, gender is an especially important predictor of friendship formation at the large school where the odds of a friendship nomination are $e^{0.45} \approx 1.57$ times greater for same gender pairs than for mixed gender pairs, compared to the medium school where the odds of a friendship nomination are $e^{0.18} \approx 1.20$ times greater for same gender pairs than for mixed gender pairs. The magnitude of the grade coefficient is similar at both schools, indicating that grade plays a similar role in friendship selection

across contexts. No coefficient for race/ethnicity selection can be estimated from the medium school due to the limited number of non-white students in that school, but in the large school, the odds of a friendship nomination for same race/ethnicity pairs are $e^{0.99} \approx 2.69$ times greater as the odds of a friendship nomination for mixed race/ethnicity pairs. Although, parent education and whether a respondent lives in a single-parent home do not significantly predict network structure in the large school, they are both statistically significant sources of friendship selection in the medium school. Since parent education and family structure both serve as proxies for social class, this finding suggests that at the medium school, social class is an important dimension of friendship formation. At the large school, race is an important dimension of friendship clustering and social class is not. This is evidence that the two schools represent different social contexts, which may also affect religious selection and religious influence.

The picture of religious selection in both schools is somewhat more complex. In model 1, Tables 10 and 11 both display a positive, significant coefficient for religious similarity, which operationalizes religious selection (see Table 9). The coefficient is especially robust (0.83) at the large school and although it decreases in magnitude in models 2 and 3 with the inclusion of other sources of friendship selection, it remains significant until model 4 with the inclusion of selection based on religious tradition. Also in the large school, religious tradition selection is significant at the $p < 0.001$ level, whereas the religious similarity coefficient is no longer significant. In the medium school, the religious similarity coefficient loses significance in model 2 with the inclusion of other friendship selection effects. Interestingly, the coefficient regains significance in model 4 with the inclusion of the religious tradition coefficient, but is no longer

significant in model 5 with controls for parent religiosity. This result suggests that religious selection involves more than how religiously similar two potential friends are to one another. Instead, multiple forms of religious selection occur simultaneously.

In sum, the adolescent friendship networks in the medium and large schools are not unlike most other social networks researchers have observed in that they have low density and a high tendency toward reciprocity (Snijders et al. 2010), friendships are hierarchically structured (Ripley et al. 2011), and gender, grade, race, and social class help structure friendships (e.g. Hartup 1993). Religious selection predicts network-religion autocorrelation at both schools, but the mechanisms of religious selection differ. The fact that in the full models, parent religiosity is the statistically significant mechanism in the medium school and religious tradition is the statistically significant mechanism in the large school is a surprising finding. It suggests that religious selection operates differently across contexts. As with Moran's I, the religious tradition effect in the large school may be partly driven by the high correlation between being Latino and being Catholic. The significant parent religiosity effect in the medium school suggests that religious selection at the medium school may be a function of interaction at religious activities outside of school, since it is not similarity of religiosity among the adolescents themselves that predicts friendship.

## 4.3.2 Behavior models

Independent of other attribute variables and of the structure of the social network, the linear and quadratic shape parameters give a baseline definition of the evaluation function for religiosity (Snijders, de Bunt, and Steglich 2010). Figure 1 plots these linear and

quadratic terms for the medium school[8]. The positive quadratic term can be interpreted as a "preference" for the extremes of the religiosity distribution among actors. Another way to understand the positive quadratic term is as positive feedback. According to this interpretation, changes in religiosity will be self-reinforcing so that the religious students will become more religious over time and the non-religious students will become less religious over time. For the large school, neither the linear shape coefficient nor the quadratic shape coefficient is significantly different from zero, which suggests that there is no baseline tendency toward changes in religion at the large school.

[Figure 1 about here]

For both the medium school and the large school, the total similarity coefficient, which best operationalizes religious influence (see Section 4.1) is positive and significant. In both cases, the coefficient decreases slightly in magnitude across models (from 0.55 to 0.54 for the medium school and from 0.60 to 0.55 for the large school) and significance (from the $p < 0.01$ level to the $p < 0.05$ level for both schools). It is noteworthy, however, that the effect is relatively robust across all five models for both schools. This means that religious influence, as operationalized by total similarity, is a robust and consistent predictor of network-religion autocorrelation.

Other factors influence religiosity differently across the two schools. For example, increasing grade level is associated with lower religiosity in the large school and no effect on changes in religiosity in the medium school. At the large school, compared to non-Hispanic white respondents (reference category), Asian respondents tend to increase their religiosity between waves. Compared to Catholics (reference category), mainline

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[8] A similar plot was not produced for the large school since its coefficients are not significantly different from zero.

Protestants and those with no religious affiliation tend to increase their religiosity. An alternative explanation is that compared to other groups, whites and Catholics tend to decrease their religiosity over later adolescence. Although the increase in religiosity among students with no religious affiliation is surprising at first, it can be attributed to the fact that in the Add Health survey respondents who reported no religious affiliation were not asked any questions about religiosity. This means that all of the "nones" are automatically assigned a zero on the religiosity scale (see Section 3.2). If at the second wave, the respondent goes from no religious affiliation to any other religious affiliation, his or her religiosity score is likely to increase. A similar result was found in Cheadle and Schwadel (2012).

What is perhaps more surprising is that the coefficient for the effect of having no religious affiliation on increasing religiosity is not significant in the medium school. This null result reflects the fact that, compared to the large school, a much lower proportion of "nones" in the medium school convert to a religion between waves. Table 3 demonstrates the difference between "nones" at the medium school and "nones" at the large school by reporting the breakdown of those who report no religious affiliation at wave 1. It is also important to point out that a much larger proportion of students at the medium school report no religious affiliation (20.3 %) than at the large school (5.2 %).

## 4.4 Relative contributions of selection and influence to network-religion autocorrelation

Finally, answering the fourth question requires estimating the relative contributions of religious selection and religious influence toward network-religion autocorrelation. Figures 2 and 3 show estimates of the extent to which selection and influence drive network-religion autocorrelation. Here the results are different from those found by

Cheadle and Schwadel (2012) because religious selection plays a larger role than religious influence in determining network-religion autocorrelation in the medium and large schools. Interestingly, religious selection and religious influence both play a larger role in the medium school than in the large school, whereas the controls play a larger role in the large school, implying that context plays a major role in the network-religion dynamics of friendship networks.

[Figure 2 about here]

[Figure 3 about here]

## 5. Discussion

Results from the analyses of network-religion autocorrelation in the adolescent friendship networks in the medium and large school extend those found by Cheadle and Schwadel (2012) and provide insight into the network-religion dynamics of adolescents in larger school settings.

The results presented in Section 4.1 indicate that religion helps shape social structure among adolescents, but religion is not the most important predictor of friendship ties, being surpassed by gender and grade. This finding is not surprising since adolescence is the time when youth are just starting to desegregate in terms of gender (Johnson 2004; Shrum, Cheek Jr, and Hunter 1988). Furthermore, students at large schools often take courses with students in their own grades and grade reflects key age differences. As it pertains to social relationships among adolescents, religion seems to be simply one sphere among others, which may suggest a lack of traditional religious authority as predicted by differentiation theory (Chaves 1994; Gorski 2000). Still,

Hypothesis 1 is supported since Moran's I for religiosity is much greater than zero across both waves in both schools, meaning that the probability of a friendship between two randomly selected individuals is greater if those two individuals are religiously similar.

Religious selection and religious influence both play a role in determining network-religion autocorrelation; however, Hypothesis 2, which predicts that both religious selection and religious influence are statistically significant predictors of network-religion autocorrelation, is only partially supported since the effect used to operationalize religious selection is not statistically significant in the full model. However, the results do provide additional support for subcultural identity theory (Smith 1998) because the religious influence effect is statistically significant and robust for both schools and because other religious selection mechanisms are statistically significant (similarity of parent religiosity in the medium school and same religious tradition in the large school). Returning to the theoretical explanation, micro-level sacred umbrellas are formed when religious students select friendships with other religious students, a process that distinguishes religious students from the rest of the student population. In order for religiosity to thrive among these students, they must also engage with the secular school culture, which can result in religious influence.

Interestingly, the simulation analysis decomposing network-religion autocorrelation suggests that selection plays a larger role than influence in determining network-religion autocorrelation. Hypothesis 3a, which predicts selection accounts for a greater proportion of network-religion autocorrelation is supported, while Hypothesis 3b, which predicts influence accounts for a greater proportion of network-religion

autocorrelation is not supported.  This finding, opposite from results found by Cheadle and Schwadel (2012), may be due to the larger schools used in the present study.

Another difference between the present study and Cheadle and Schwadel (2012) is in the way that religious influence is operationalized. Using empirical, score-type tests, the total similarity effect is shown to improve model fit more than other potential influence operationalizations, especially at the medium school. This implies that Hypothesis 4, which predicts total similarity is the best way to operationalize religious influence, is supported.  This finding provides additional support for subcultural identity theory (Smith 1998) at the micro-level, which predicts that the situation in which ego is most likely to increase his or her religiosity occurs when ego is distinct from secular society while engaging with it. This happens when ego and the majority of ego's friends are religious, and yet ego has a limited number of friends who are less religious.  The total similarity effect best captures this "ideal" scenario since being religiously similar to one's friends creates a large effect size and religiously dissimilar friends do not decrease the effect size as much as they would if it were normalized by out-degree (as in average similarity).  When Cheadle and Schwadel use the simulation decomposition technique, they find that religious influence, as operationalized with average similarity, is a bigger driver of network-religion autocorrelation than religious selection.  It is possible that in the smaller schools, average similarity better represents religious influence than total similarity. Alternatively, it may be that Cheadle and Schwadel actually underestimate the importance of religious influence as a determinant of network-religion autocorrelation in small school settings because of the way influence was operationalized in their study.

# 6. Conclusions

The conclusions from this study should be considered tentative due to some important limitations. For instance, automatic coding of students with no religious affiliation as a zero on the religiosity index is not realistic and may bias results. As with many social network studies, generalization is limited due to a small number of networks. The two schools constitute a convenience sample, which implies that the results are not representative of the population of adolescent friendship networks; therefore, more research is needed to understand how these complex processes work.

Still, this study provides a deeper understanding of the four research questions: (1) network-religion autocorrelation is a salient aspect of adolescent friendship networks, but it may not be the most salient aspect. Although statistical inference was not conducted on the relative importance of various types of network autocorrelation, gender and grade seem to be more important determinants of network structure than religion. (2) The dynamics of network-religion autocorrelation are complex and context specific, however some patterns emerge. Religious selection and religious influence are both important drivers of network-religion autocorrelation. During the high school years, parent religiosity does not predict increases in religiosity. (3) In the medium and large school, the total similarity effect best captures religious influence. This implies that religious influence operates through religious similarity. The odds of ego increasing his or her religion increase with the number of friends to whom ego is religiously similar. (4) Although the primary operationalization of religious selection, religious similarity, loses significance in the full model for both schools, the simulation decomposition suggests

that religious selection actually contributes more to network-religion autocorrelation than does religious influence in the medium and large schools.

Context matters for the dynamics of network-religion autocorrelation in adolescent friendship networks. The fact that findings from an aggregation of small school SAOMs (Cheadle and Schwadel 2012) differs substantially from those estimated for the medium and large schools suggests that these phenomena are not simple or universal, but rather, vary in complex ways across social contexts. Still, consistent patterns do emerge from the present study and from Cheadle and Schwadel (2012). Although religion may not be the primary axis of friendship clustering, it remains an important dimension of network autocorrelation. Religion affects the structure of adolescent friendship networks, while flowing through them in a process of social contagion. These network-religion dynamics are important to understand because sacred umbrellas, strengthened by network-religion autocorrelation, can protect adolescent religiosity from the effects of secularization, thus promoting religious vitality in the United States.

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## Tables

### Table 1: Diagrams of selection and influence

|  | Time 1 | Time 2 |
|---|---|---|
| Selection: |  |  |
| Influence: |  |  |

### Table 2: Diagrams of prototypical ego networks for influence operationalizations

| avSim | totSim | avAlt |
|---|---|---|
|  |  |  |

**Table 3: Proportion of respondents who report no religious affiliation at wave 1**

|                                    | Medium School | Large School |
| ---------------------------------- | ------------- | ------------ |
| No religious affiliation at wave 2 | 0.68          | 0.32         |
| Religious affiliation at wave 2    | 0.16          | 0.46         |
| Missing at wave 2                  | 0.16          | 0.22         |
| N                                  | 131           | 63           |

**Table 4: Diagrams of network controls**
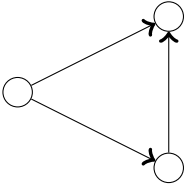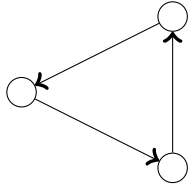
| Reciprocal tie | Transitive triplet | Three-cycle |
| -------------- | ------------------ | ----------- |

**Table 5: Definition of effects for stochastic actor-oriented models**

| Effect Name | Formula |
|---|---|
| **Network Effects** | |
| Out-degree | $\sum_j x_{ij} = x_{i+}$ |
| Reciprocity | $\sum_j x_{ij} x_{ji}$ |
| Transitive triplets | $\sum_j \sum_k x_{ij} x_{ik} x_{jk}$ |
| Three-cycles | $\sum_j \sum_k x_{ij} x_{jk} x_{ki}$ |
| Distance-two | $\sum_{j \neq i} x_{j+}$ |
| Ego effect | $v_i x_{i+}$ |
| Alter effect | $\sum_j x_{ij} v_j$ |
| Same effect | $\sum_j x_{ij} I\{v_i = v_j\}$ |
| Similarity effect | $\sum_j x_{ij}(\text{sim}_{ij}^v - \overline{\text{sim}}_{ij}^v)$ |
| **Behavior Effects** | |
| Linear shape | $z_i$ |
| Quadratic shape | $z_i^2$ |
| Covariate effect | $v_i z_i$ |
| Total similarity | $\sum_j x_{ij}(\text{sim}_{ij}^z - \overline{\text{sim}}_{ij}^z)$ |

Note: $\text{sim}_{ij}^z = \frac{\text{range}(z) - |z_i - z_j|}{\text{range}(z)}$

**Table 6: Counts of network controls**

| | Medium School | Large School |
|---|---|---|
| Ties | 2,040 | 1,709 |
| Reciprocated ties | 832 | 538 |
| Transitive triplets | 1,558 | 746 |
| Three-cycles | 356 | 139 |
| Distance-two | 5,085 | 2,354 |
| Friend flag | 34 | 58 |
| Off-list nominations | 1,590 | 3,715 |

**Table 7: Descriptive statistics for attribute variables**

|  | Medium School | | Large School | | | |
|---|---|---|---|---|---|---|
|  | Mean | St. Dev. | Mean | St. Dev. | Min. | Max. |
| Religiosity - Wave 1 | 5.81 | 4.25 | 8.59 | 3.42 | 0 | 13 |
| Religiosity - Wave 2 | 5.15 | 4.21 | 8.35 | 3.38 | 0 | 13 |
| Female | 0.46 | – | 0.49 | – | 0 | 1 |
| Grade | 9.92 | 0.81 | 10.50 | 0.56 | 8 | 12 |
| Race/Ethnicity |  |  |  |  |  |  |
| non-Hispanic White | 0.98 | – | 0.06 | – | 0 | 1 |
| non-Hispanic Black | 0.00 | – | 0.23 | – | 0 | 1 |
| Hispanic | 0.01 | – | 0.40 | – | 0 | 1 |
| Asian | 0.00 | – | 0.30 | – | 0 | 1 |
| Other Race | 0.01 | – | 0.02 | – | 0 | 1 |
| Single Parent | 0.22 | – | 0.26 | – | 0 | 1 |
| Parent Education | 6.08 | 1.94 | 5.27 | 2.70 | 1 | 9 |
| Religious Tradition |  |  |  |  |  |  |
| Catholic | 0.28 | – | 0.47 | – | 0 | 1 |
| Evangelical Protestant | 0.11 | – | 0.11 | – | 0 | 1 |
| Mainline Protestant | 0.35 | – | 0.29 | – | 0 | 1 |
| No Religious Affiliation | 0.20 | – | 0.05 | – | 0 | 1 |
| Other Religion | 0.04 | – | 0.06 | – | 0 | 1 |
| Parent Religiosity | 6.49 | 2.96 | 8.33 | 2.38 | 0 | 10 |
| Fr_Flag | 0.05 | – | 0.05 | – | 0 | 1 |
| Off-list Nominations | 2.46 | 2.03 | 3.08 | 2.32 | 0 | 10 |

**Table 8: Moran's I for several types of network autocorrelation**

|  | Medium School | | Large School | |
|---|---|---|---|---|
|  | Wave 1 | Wave 2 | Wave 1 | Wave 2 |
| Religiosity | 0.137 | 0.148 | 0.135 | 0.108 |
| Religious Tradition | | | | |
|   Catholic | 0.000 | -0.016 | 0.384 | 0.386 |
|   Evangelical | 0.026 | -0.028 | 0.106 | 0.071 |
|   Mainline | -0.035 | -0.065 | 0.153 | 0.146 |
|   Other Religion | 0.033 | 0.041 | 0.149 | 0.140 |
|   No Religious Affil. | 0.049 | 0.023 | 0.038 | 0.067 |
| Parent Religiosity | 0.039 | 0.071 | 0.034 | 0.016 |
| Gender | 0.236 | 0.285 | 0.311 | 0.407 |
| Grade | 0.692 | 0.641 | 0.470 | 0.443 |
| Race | | | | |
|   White | 0.008 | -0.027 | 0.187 | 0.128 |
|   Black | —[1] | — | 0.649 | 0.607 |
|   Hispanic | — | — | 0.724 | 0.721 |
|   Asian | — | — | 0.871 | 0.857 |
|   Other Race | — | — | 0.039 | 0.070 |
| Parent Education | 0.089 | 0.099 | 0.542 | 0.519 |

[1]: Due to small sample sizes, only white/non-white network autocorrelation was estimated for the medium school.

**Table 9: Score-type test statistics and p-values for operationalizations of influence**

|  | Medium School | | Large School | |
|---|---|---|---|---|
|  | $c$ | p-value | $c$ | p-value |
| Average Similarity | 2.26 | 0.134 | 7.09 | 0.008 |
| Total Similarity | 7.16 | 0.007 | 8.02 | 0.005 |
| Average Alter | 0.58 | 0.446 | 0.65 | 0.420 |

**Table 10: Model results from the medium school**

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| Rate Parameters | | | | | |
| Network Change Opportunities | 14.37 | 15.08 | 15.08 | 15.06 | 15.07 |
| Behavior Change Opportunities | 10.29 | 10.23 | 10.28 | 10.89 | 11.20 |
| Network Model | | | | | |
| Out-degree | −2.82 (0.06)*** | −3.10 (0.07)*** | −3.15 (0.08)*** | −3.15 (0.07)*** | −3.16 (0.07)*** |
| Reciprocity | 2.66 (0.07)*** | 2.52 (0.07)*** | 2.52 (0.08)*** | 2.52 (0.09)*** | 2.52 (0.07)*** |
| Transitive triplets | 0.64 (0.04)*** | 0.59 (0.04)*** | 0.59 (0.04)*** | 0.59 (0.03)*** | 0.59 (0.04)*** |
| Three-cycles | −0.54 (0.09)*** | −0.50 (0.07)*** | −0.49 (0.08)*** | −0.49 (0.07)*** | −0.50 (0.08)*** |
| Distance-two | −0.13 (0.02)*** | −0.14 (0.02)*** | −0.14 (0.02)*** | −0.14 (0.02)*** | −0.14 (0.02)*** |
| Ego: friend flag | 0.44 (0.08)*** | 0.46 (0.11)*** | 0.46 (0.08)*** | 0.47 (0.08)*** | 0.46 (0.08)*** |
| Alter: off-list nominations | −0.04 (0.01)*** | −0.04 (0.01)*** | −0.04 (0.01)*** | −0.04 (0.01)*** | −0.04 (0.01)** |
| Similarity: off-list nominations | 0.02 (0.12) | −0.01 (0.12) | −0.02 (0.11) | −0.02 (0.13) | −0.01 (0.11) |
| Same: gender | | 0.17 (0.04)*** | 0.17 (0.03)*** | 0.18 (0.04)*** | 0.18 (0.04)*** |
| Alter: grade | | 0.02 (0.03) | 0.02 (0.02) | 0.02 (0.03) | 0.02 (0.03) |
| Same: grade | | 0.48 (0.05)*** | 0.48 (0.04)*** | 0.48 (0.04)*** | 0.48 (0.04)*** |
| Alter: single parent status | | | 0.08 (0.06) | 0.08 (0.06) | 0.10 (0.05)* |
| Same: single parent status | | | 0.09 (0.05) | 0.09 (0.05) | 0.10 (0.04)* |
| Similarity: parent education | | | 0.36 (0.10)*** | 0.36 (0.13)** | 0.35 (0.10)*** |
| Religious Selection | | | | | |
| Alter: religiosity | 0.01 (0.00)** | 0.01 (0.01)** | 0.02 (0.01)** | 0.02 (0.01)** | 0.01 (0.01) |
| Ego: religiosity | 0.01 (0.01) | 0.01 (0.01) | 0.01 (0.01) | 0.01 (0.01) | 0.01 (0.01) |
| Similarity: religiosity | 0.19 (0.10)* | 0.17 (0.14) | 0.17 (0.10) | 0.21 (0.09)* | 0.17 (0.10) |
| Same: religious tradition | | | | −0.07 (0.04) | −0.07 (0.04) |
| Alter: parent religiosity | | | | | 0.01 (0.01) |
| Ego: parent religiosity | | | | | −0.01 (0.01) |
| Similarity: parent religiosity | | | | | 0.21 (0.10)* |
| Religiosity Model | | | | | |
| Linear shape | −0.24 (0.02)*** | −0.24 (0.02)*** | −0.24 (0.02)*** | −0.24 (0.02)*** | −0.24 (0.03)*** |
| Quadratic shape | 0.03 (0.00)*** | 0.03 (0.01)*** | 0.03 (0.00)*** | 0.02 (0.00)*** | 0.02 (0.01)** |
| Covariate effect: female | | 0.07 (0.04) | 0.07 (0.04) | 0.07 (0.04) | 0.06 (0.04) |
| Covariate effect: grade | | 0.01 (0.03) | 0.00 (0.03) | 0.00 (0.03) | 0.00 (0.03) |
| Covariate effect: single parent status | | | −0.06 (0.05) | −0.06 (0.05) | −0.04 (0.05) |
| Covariate effect: parent education | | | 0.00 (0.01) | 0.00 (0.01) | 0.00 (0.01) |
| Covariate effect: evangelical | | | | −0.01 (0.07) | −0.01 (0.07) |
| Covariate effect: mainline | | | | −0.05 (0.05) | −0.05 (0.05) |
| Covariate effect: "none" | | | | −0.14 (0.09) | −0.15 (0.09) |
| Covariate effect: other religion | | | | 0.00 (0.11) | 0.00 (0.11) |
| Covariate effect: parent religiosity | | | | | 0.02 (0.01) |
| Religious Influence | | | | | |
| Total similarity | 0.55 (0.20)** | 0.54 (0.22)* | 0.53 (0.21)* | 0.53 (0.22)* | 0.54 (0.27)* |

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

**Table 11: Model results from the large school**

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| **Rate Parameters** | | | | | |
| Network Change Opportunities | 7.63 | 8.05 | 8.01 | 8.03 | 8.03 |
| Behavior Change Opportunities | 12.52 | 12.45 | 12.39 | 10.82 | 10.92 |
| **Network Model** | | | | | |
| Out-degree | $-3.94 (0.07)^{***}$ | $-5.02 (0.10)^{***}$ | $-5.01 (0.09)^{***}$ | $-5.06 (0.10)^{***}$ | $-5.07 (0.10)^{***}$ |
| Reciprocity | $3.15 (0.10)^{***}$ | $2.82 (0.10)^{***}$ | $2.81 (0.11)^{***}$ | $2.81 (0.10)^{***}$ | $2.81 (0.10)^{***}$ |
| Transitive triplets | $1.19 (0.07)^{***}$ | $1.03 (0.05)^{***}$ | $1.03 (0.06)^{***}$ | $1.02 (0.06)^{***}$ | $1.02 (0.06)^{***}$ |
| Three-cycles | $-1.16 (0.14)^{***}$ | $-1.03 (0.11)^{***}$ | $-1.03 (0.13)^{***}$ | $-1.02 (0.14)^{***}$ | $-1.02 (0.12)^{***}$ |
| Distance-two | $-0.09 (0.03)^{**}$ | $-0.10 (0.03)^{***}$ | $-0.11 (0.02)^{***}$ | $-0.12 (0.04)^{**}$ | $-0.12 (0.03)^{***}$ |
| Ego: friend flag | $0.20 (0.13)$ | $0.18 (0.12)$ | $0.18 (0.17)$ | $0.20 (0.13)$ | $0.20 (0.14)$ |
| Alter: off-list nominations | $-0.06 (0.01)^{***}$ | $-0.05 (0.01)^{***}$ | $-0.05 (0.01)^{***}$ | $-0.05 (0.01)^{***}$ | $-0.05 (0.01)^{***}$ |
| Similarity: off-list nominations | $0.16 (0.13)$ | $0.12 (0.13)$ | $0.12 (0.14)$ | $0.11 (0.13)$ | $0.11 (0.12)$ |
| Same: gender | | $0.45 (0.06)^{***}$ | $0.45 (0.05)^{***}$ | $0.45 (0.05)^{***}$ | $0.45 (0.05)^{***}$ |
| Alter: grade | | $0.22 (0.05)^{***}$ | $0.22 (0.05)^{***}$ | $0.22 (0.05)^{***}$ | $0.22 (0.05)^{***}$ |
| Same: grade | | $0.46 (0.05)^{***}$ | $0.46 (0.05)^{***}$ | $0.46 (0.05)^{***}$ | $0.46 (0.05)^{***}$ |
| Same: race/ethnicity | | $1.05 (0.06)^{***}$ | $1.03 (0.06)^{***}$ | $0.99 (0.05)^{***}$ | $0.99 (0.07)^{***}$ |
| Alter: single parent status | | | $-0.28 (0.08)^{***}$ | $-0.28 (0.09)^{**}$ | $-0.26 (0.08)^{***}$ |
| Same: single parent status | | | $-0.05 (0.06)$ | $-0.06 (0.06)$ | $-0.06 (0.06)$ |
| Similarity: parent education | | | $0.24 (0.13)$ | $0.23 (0.14)$ | $0.23 (0.13)$ |
| **Religious Selection** | | | | | |
| Alter: religiosity | $0.00 (0.01)$ | $0.00 (0.01)$ | $0.00 (0.01)$ | $0.00 (0.01)$ | $-0.01 (0.01)$ |
| Ego: religiosity | $-0.01 (0.02)$ | $-0.01 (0.01)$ | $-0.01 (0.01)$ | $-0.01 (0.01)$ | $-0.01 (0.01)$ |
| Similarity: religiosity | $0.83 (0.29)^{**}$ | $0.57 (0.24)^{*}$ | $0.57 (0.21)^{**}$ | $0.38 (0.26)$ | $0.36 (0.21)$ |
| Same: religious tradition | | | | $0.22 (0.05)^{***}$ | $0.22 (0.05)^{***}$ |
| Alter: parent religiosity | | | | | $0.04 (0.02)^{*}$ |
| Ego: parent religiosity | | | | | $0.00 (0.02)$ |
| Similarity: parent religiosity | | | | | $0.02 (0.27)$ |
| **Religiosity Model** | | | | | |
| Linear shape | $0.01 (0.01)$ | $0.01 (0.01)$ | $0.01 (0.01)$ | $0.02 (0.01)$ | $0.02 (0.01)$ |
| Quadratic shape | $0.00 (0.00)$ | $0.00 (0.00)$ | $0.00 (0.00)$ | $0.01 (0.00)$ | $0.00 (0.00)$ |
| Covariate effect: female | | $-0.01 (0.02)$ | $-0.01 (0.02)$ | $-0.01 (0.03)$ | $-0.01 (0.03)$ |
| Covariate effect: grade | | $-0.06 (0.02)^{*}$ | $-0.06 (0.03)^{*}$ | $-0.06 (0.02)^{*}$ | $-0.06 (0.03)^{*}$ |
| Covariate effect: black | | $0.09 (0.06)$ | $0.08 (0.06)$ | $0.09 (0.06)$ | $0.08 (0.06)$ |
| Covariate effect: hispanic | | $-0.01 (0.06)$ | $0.00 (0.06)$ | $0.08 (0.06)$ | $0.06 (0.06)$ |
| Covariate effect: asian | | $0.09 (0.06)$ | $0.09 (0.06)$ | $0.16 (0.06)^{**}$ | $0.14 (0.07)^{*}$ |
| Covariate effect: other race | | $0.12 (0.08)$ | $0.12 (0.08)$ | $0.18 (0.09)$ | $0.16 (0.10)$ |
| Covariate effect: single parent status | | | $-0.02 (0.04)$ | $-0.02 (0.04)$ | $-0.01 (0.04)$ |
| Covariate effect: parent education | | | $0.01 (0.01)$ | $0.01 (0.01)$ | $0.01 (0.01)$ |
| Covariate effect: evangelical | | | | $0.10 (0.05)$ | $0.08 (0.05)$ |
| Covariate effect: mainline | | | | $0.10 (0.04)^{**}$ | $0.10 (0.04)^{**}$ |
| Covariate effect: "none" | | | | $0.56 (0.10)^{***}$ | $0.57 (0.09)^{***}$ |
| Covariate effect: other religion | | | | $0.06 (0.06)$ | $0.07 (0.06)$ |
| Covariate effect: parent religiosity | | | | | $0.02 (0.01)^{*}$ |
| **Religious Influence** | | | | | |
| Total similarity | $0.60 (0.22)^{**}$ | $0.50 (0.23)^{*}$ | $0.50 (0.26)$ | $0.56 (0.23)^{*}$ | $0.55 (0.24)^{*}$ |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

# Figures

**Figure 1: Basic shape of the behavior evaluation function for the medium school**

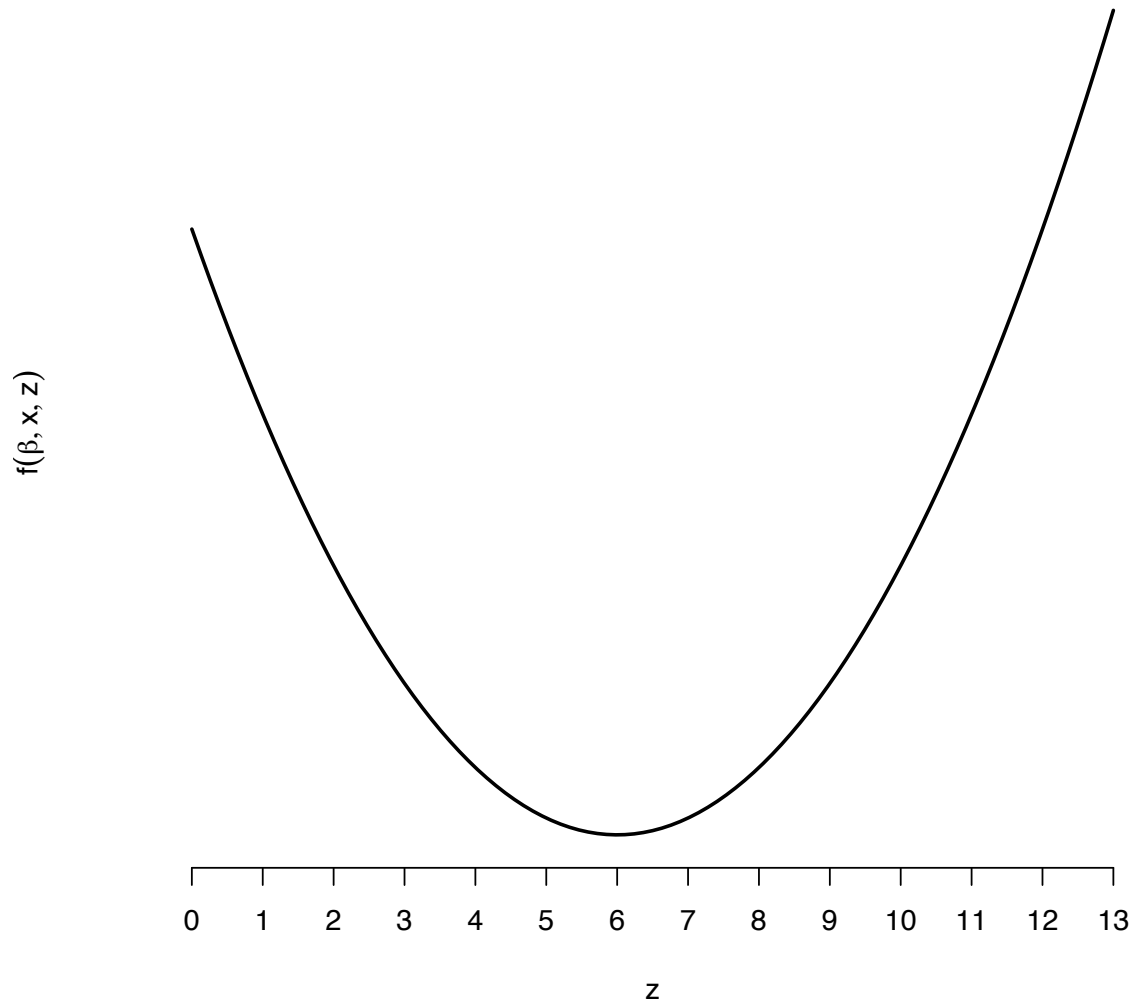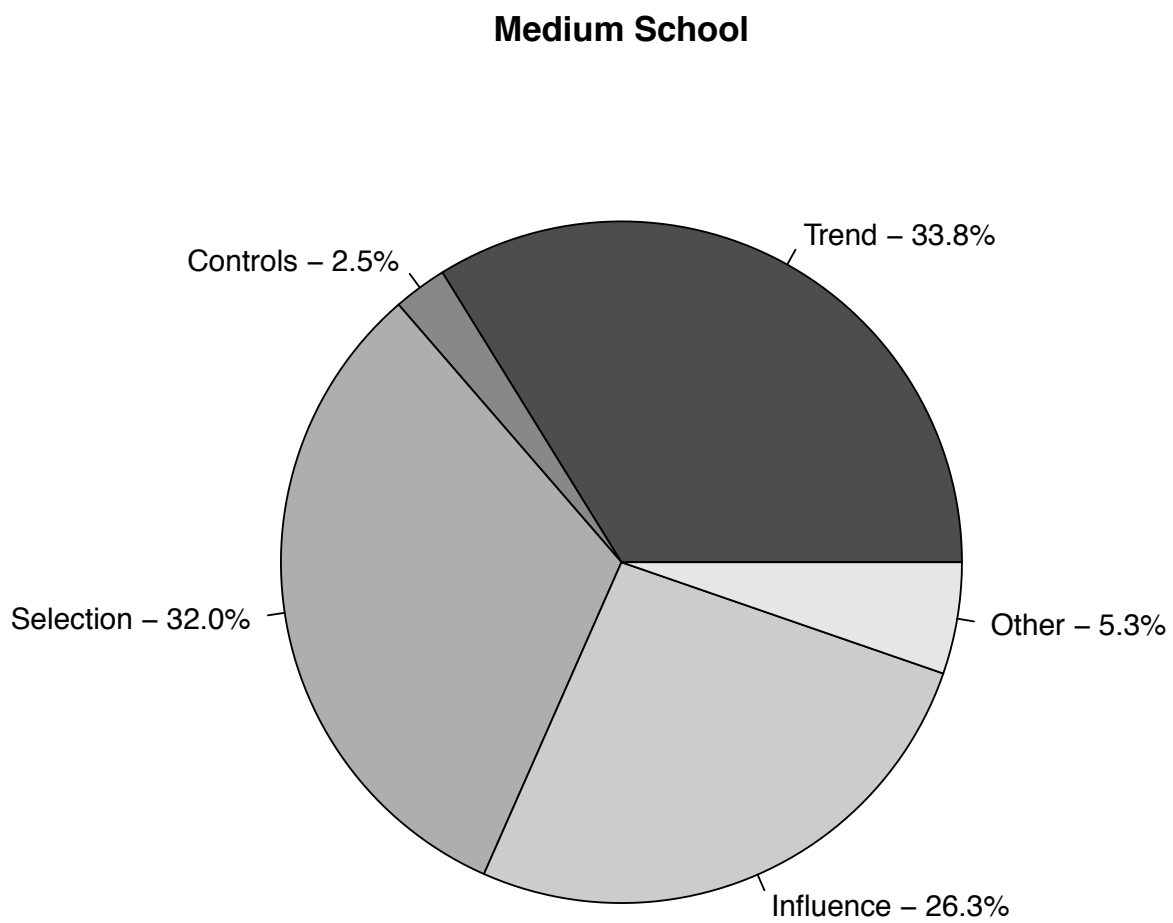**Figure 2: Relative contributions to Moran's I for the medium school**



Medium School

**Figure 3: Relative contributions to Moran's I for the large school**



**Large School**