

Longitudinal Changes in Friendship Networks: An Approach from Exponential Random Graph Models

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ABSTRACT

This research examined longitudinal changes in friendship network structures using exponential random graph models (ERGM). Seventy first year undergraduates identified friends whom they had greeted and/or with whom they had discussed personal matters face-to-face and/or via mobile phone text messages at four points in time during their school year. Longitudinal ERGM showed that, in face-to-face networks, 'reassessments' of dyadic friendships might occur after a school vacation, and that group formation processes were stronger at the beginning of the year but then diminished. In text message-mediated greeting networks, however, dyadic friendship formation processes were constant over time; whilst groups built around new hubs emerged at a later time.

Categories and Subject Descriptors

A.0 [General]: Conference proceedings.

General Terms

Human Factors

Keywords

Longitudinal network changes, exponential random graph models (ERGM), first year undergraduates, mobile phone text messages

1. INTRODUCTION

Social networks change over time. In a group situation, such as a classroom or an organization, once members know each other, they try to form, maintain and sometimes resolve their relationships. As a consequence, particular properties of relationship structures, such as reciprocal relationships, hubs and subgroups among group members, can be observed, and continue changing over time. Particular network ties may change, but the processes that drive the network evolution may remain stationary.

This study examined changes in friendship network structure among first year undergraduates. We sought to understand whether patterns of network changes vary in accordance with strength of friendship ties (weak ties: greetings; strong ties: disclosing personal matters) and types of communication media (face-to-face communication and mobile phone text messages).

We posed two hypotheses about changes in friendship networks. One was 'reassessments of dyadic friendship' in self-disclosing

networks. In other words, reconstruction of mutual friendship selection would occur in close relationships over time. First year undergraduates would be eager to form new friendships in the classroom at the beginning of their school year. With the passage of time, however, they would come to know much about their classmates, and would reconsider their close relationships after short separation from classmates during a summer vacation. On the other hand, this reconstruction would not occur in text message-mediated greeting networks, because it is easy to keep casual contact with classmates via text messages during the vacation. We also proposed that group formation processes, such as formation of transitive triangles and stars, would be most active at the beginning of their school year, and then decline.

An exponential random graph model (ERGM) is a probability model that can effectively capture structural properties in social networks [5]. ERGM emancipates researchers from dyadic independence assumptions in social networks, and enables them to practically elaborate on network dynamics. ERGM includes two subclasses: a *Markov random graph model* and a *higher-order model*. The Markov model tends to be degenerate in complex social networks, e.g. networks with high transitivity [1]. To overcome this limitation, models with new specifications have been recently proposed [3]. This new model contains higher order parameters that relate to weighted combinations of stars (*alternating k-in-stars* and *alternating k-out-stars* in directed graphs) and weighted combinations of triangles (*alternating k-triangles*) The new specifications are dramatically more successful than Markov models in overcoming degeneracy.

In a context of social network transition, *longitudinal ERGM* is useful for capturing structural changes of networks [2]. Longitudinal ERGM estimates parameters based on evolution from the fixed initial network to the network at time 2. *Cross-sectional ERGM* estimates parameters based on single observations of a network. We suppose that *network stationarity*, defined as no systematic change in network processes in the time series, could be in evidence when the estimates of cross-sectional ERGM correspond with those of longitudinal ERGM.

2. DATASETS

The network was composed of 70 first year undergraduates (12 males and 58 females) in the same discipline at a university in central Japan. We measured four types of friendship networks; participants were asked to choose up to five of their classmates with whom (1) they had greeted face-to-face (face-to-face greeting networks), (2) they had disclosed personal matters face-to-face (face-to-face self-disclosing networks), (3) they had greeted via mobile phone text messages (text message-mediated greeting networks), and (4) they had disclosed personal matters via mobile

phone text messages (text message-mediated self-disclosing networks) during the past two weeks. Questionnaires were administered four times, at the 3rd (t0), 12th (t1), 28th (t2) and 41st (t3) weeks of their academic year since matriculation. Summer vacation (four weeks) occurred between t2 and t3.

3. PARAMETER ESTIMATION

The four types of the friendship network data were respectively fitted into the two subclasses of longitudinal ERGM at each period, using the network at the previous period as an initial state. There were six parameters in the higher-order model [1]: *arc*, *reciprocity*, *star* (*k*-in-star and *k*-out-star), *transitive triangle* (TK-triangle) and *transitive indirect path* (TK-2-path).

We used the PNet program to estimate the parameters [4]. The models successfully converged and fitted the data well at each transition in time from *tk-1* to *tk* (hereafter *Trk* for *k* = 1, 2, 3). *Tr1* represents the transition of the friendship networks during the first semester; *Tr2* describes the transition during the summer vacation; and *Tr3* shows the transition during the second semester. Table 1 shows the final estimates of the longitudinal higher-order model. The Markov models also converged during each transition but not for cross-sectional models. Parameter estimates in the cross-sectional models corresponded to those in the longitudinal models with few exceptions reported below, so there is evidence of stationarity here within the three transitions.

In face-to-face greeting networks, the arc parameters remained stable over time, while the reciprocity parameter during *Tr2* was weaker than that during *Tr1*, and then re-increased during *Tr3*; that is, the process of mutual selection was stronger during the first and third transitions. The TK-triangle parameter decreased during *Tr3*, suggesting that group formation was less strong at the end of the school year. In face-to-face self-disclosing networks, *Tr2* sees interesting changes in the arc and the reciprocity parameters, with the arc parameter less negative and the reciprocity parameter less positive. So students were inclined to select more people but with lower levels of reciprocity. This suggests that in *Tr2* there is some reassessment of close friendship links. The variation to the K-In-Star parameter suggests that in *Tr2*, some of the more popular students become less popular in this process of reassessment. In *Tr3*, however, the parameters revert to values closer to their *Tr1* values, suggesting that the reassessment settles down after the vacation. Again we see that the TK-triangle parameter declined during *Tr3*. In text message-

mediated self-disclosing networks, changes in reciprocity parameter were similar with the other two networks. Hence, structural properties of friendship networks with strong ties were relatively consistent.

In text message-mediated greeting networks, however, the arc and the reciprocity parameters were stable over time, implying that friendship reassessment did not occur in such a weak friendship network. The TK-triangle parameter, however, declined during *Tr2* and then increased during *Tr3*. Additionally, the K-out-star parameter, although not significant, changed signs from *Tr1* to *Tr2*. This suggests that some students increased text message activity, perhaps creating new hubs in the network, but ties emanating from these hubs were not triangulated in *Tr2*. These could be the basis on which increased triangulation is observed in *Tr3* in line with the hypothesis about group formation. Furthermore, the TK-triangle parameter during *Tr2* was relatively smaller than that obtained by cross-sectional estimation. Thus, there is some evidence that the underlying group formation process within these friendship networks with weak ties might not be stationary during *Tr2*.

In conclusion, the results mainly supported our hypotheses about the difference in network changes between weak and strong ties. Future research should tap into effects of network overlapping and actor attributions to further investigate network dynamics.

4. REFERENCES

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Table 1. Parameter estimates of the longitudinal higher-order ERGM in friendship networks

Parameters	Face-to-face networks			Text message-mediated networks		
	Tr1 (t0 to t1)	Tr2 (t1 to t2)	Tr3 (t2 to t3)	Tr1 (t0 to t1)	Tr2 (t1 to t2)	Tr3 (t2 to t3)
Greeting						
Arc	-3.10 (0.48)	-3.33 (0.53)	-2.30 (0.70)	-3.03 (0.46)	-3.14 (0.48)	-3.40 (0.42)
Reciprocity	3.29 (0.34)	2.44 (0.38)	3.07 (0.37)	3.65 (0.38)	3.88 (0.34)	3.42 (0.36)
K-In-Star	-0.50 (0.24)	-0.43 (0.25)	-0.49 (0.30)	-0.29 (0.26)	-0.55 (0.31)	-0.09 (0.26)
K-Out-Star	0.68 (0.21)	0.81 (0.23)	0.77 (0.23)	-0.16 (0.26)	0.28 (0.26)	0.01 (0.25)
TK-Triangle	1.19 (0.11)	1.09 (0.11)	0.78 (0.11)	1.19 (0.13)	0.52 (0.12)	1.31 (0.12)
TK-2-Paths	-0.45 (0.05)	-0.43 (0.06)	-0.57 (0.07)	-0.36 (0.08)	-0.32 (0.10)	-0.32 (0.08)
Self-disclosing						
Arc	-4.56 (0.33)	-3.51 (0.46)	-4.39 (0.39)	-4.65 (0.36)	-3.57 (0.48)	-5.49 (0.36)
Reciprocity	4.07 (0.42)	3.66 (0.44)	4.53 (0.40)	4.27 (0.46)	3.25 (0.53)	4.28 (0.53)
K-In-Star	-0.13 (0.26)	-0.95 (0.33)	-0.32 (0.31)	-0.20 (0.27)	-0.52 (0.29)	-0.21 (0.29)
K-Out-Star	0.55 (0.25)	0.52 (0.26)	0.67 (0.27)	0.82 (0.24)	0.81 (0.25)	1.20 (0.25)
TK-Triangle	1.34 (0.16)	1.34 (0.18)	0.71 (0.16)	1.54 (0.16)	1.18 (0.18)	1.19 (0.19)
TK-2-Paths	-0.30 (0.08)	-0.59 (0.13)	-0.27 (0.12)	-0.43 (0.09)	-0.75 (0.12)	-0.29 (0.11)

Notes. Parentheses delineate standard errors. Significant parameters (at least twice their standard errors) are printed boldface.