

Gender differences in social network development via mobile phone text messages: A longitudinal study

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ABSTRACT

We examined the development of face-to-face (FTF) social networks and mobile/cell phone text message (MPTM)-mediated social networks, and gender differences in the social network structure of 64 male and 68 female first-year undergraduate students. Social network analysis showed that MPTM social networks consisted of dyadic relationships, and its growth was slower than FTF social networks. The intimacy of friends who communicate via both FTF and MPTM was rated higher than those who communicate only via FTF. The structure of MPTM social networks coincided with known gender differences in network characteristics. Females tended to expand their MPTM social networks more than males. These findings suggest that patterns of interpersonal relationships for MPTM social networks corresponded to Matsuda's (2000) selective interpersonal relationship theory.

KEY WORDS: first-year undergraduate students • mobile phone text messages • selective interpersonal relationship theory • social network analysis

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... That was when I began to notice people on the streets of Tokyo staring at their mobile phones instead of talking to them. The sight of this behavior, now commonplace in much of the world, triggered a sensation I had experienced a few times before – the instant recognition that a technology is going to change my life in ways I can scarcely imagine.

(Rheingold, 2002, p. xi)

The widespread use of the Internet has affected the quantity and quality of interpersonal communication around the world. According to recent statistics, the number of Internet users in Japan has rapidly increased lately. A White Paper on Information and Communication in Japan (Ministry of Public Management, Home Affairs, Posts and Telecommunications, Japan, 2004) reports that about 77 million Japanese households (60.6% of the population) had Internet access by the end of 2003. This White Paper also reveals that the Japanese are most likely to use e-mail for maintaining personal relationships and the Internet provides various communication resources, such as chat rooms, message postings, mailing lists, weblogs, interest cyber communities, and online shopping. Similar findings were noted in major American Internet usage surveys (Pew Internet and American Life Project, 2005).

There is a fundamental difference, however, between Japanese and American Internet usage. Rheingold (2002) claims that Japan leads the world in providing Internet connection services via mobile/cell phones. Almost 81 million Japanese (69.7% of the population) use mobile phones. Furthermore, 89.5% of subscribers use the Internet via mobile phones in Japan, whereas only 8.9% do so in the USA (Ministry of Public Management, Home Affairs, Posts and Telecommunications, Japan, 2004). It is notable that young people are more likely to send mobile phone text messages (hereafter referred to as MPTM), including e-mail and short message service (SMS), than simply talk on the phone. They prefer using MPTM because of its low cost, or even its unique characteristics as discussed in the next section (Igarashi & Yoshida, 2003; Skog, 2002). That is, Internet usage via mobile phone has already become a basic social medium in Japan. However, very few empirical studies have examined how people engage in interpersonal relationships through MPTM (Igarashi & Yoshida, 2003; Ling & Yttri, 2002).

This longitudinal study examines the effects of first-year undergraduate students' MPTM communication on forming and sustaining personal relationships. The goals of the study are to identify how structural and functional characteristics of first-year undergraduate students' social networks vary across time, gender, and media. We chose first-year undergraduate students as participants because they communicate with friends via MPTM on a daily basis, and have many opportunities for forming new relationships upon arriving to campus. Many studies have investigated first-year undergraduate students' friendship formation and longitudinal changes in their face-to-face (FTF) social network structures (Hays & Oxley, 1986; Paul & Brier, 2001), but little is known about the effects of their MPTM usage on social network development. In the following section, we describe the

nature of MPTM, and how social network analysis can be applied to the comparison of the MPTM network structure across time, gender, and media.

Characteristics of MPTM

MPTM is similar to e-mail communication via personal computer (i.e., 'PC e-mail') as a supplement to FTF communication. The characteristics of MPTM and PC e-mail differ in at least three ways. First, MPTM is mainly used for dyadic remote communication among already existing personal relationships. PC e-mail allows for dyadic or group remote communication, the formation of new relationships, and even online matchmaking all over the world (Kraut et al., 1998; Parks & Floyd, 1996). For MPTM, most people choose their known friends as partners with whom they exchange text messages (japan.internet.com & Infoplant, 2001), and users rarely consider using MPTM for meeting new friends (Macromill, 2002).

Second, message content differs between PC e-mail and MPTM. PC e-mail is used for business and other formal communication, whereas most MPTM messages serve personal and informal purposes. Young people often use emoticons to express their feelings, and much of the MPTM content can be divided into three types of messages (Nakamura, 2001): self-sufficient messages (e.g., 'I'm on the train'); personal information ('Today I have to do a lot of homework'); and current state of feelings ('I'm tired'). These messages are used to reinforce a relationship and have a self-contained meaning (Ling & Yttri, 2002).

Finally, people are released from the spatial constraints of communication by using MPTM, which offers liberal mobility while communicating. People can send and receive messages wherever they want: in restaurants, museums, cars, buses, trains, shops and while walking in the street. Such convenience increases the frequency of MPTM use, as evidenced by 37% of young people sending text messages more than five times a day (Nakamura, 2001). Sending and receiving e-mail thus becomes ubiquitous.

At the same time, there is a significant difference between MPTM and talking on a mobile phone. The asynchronicity of communication through MPTM removes the necessity for a spontaneous response. If people receive text messages, they do not need to reply at once and can respond whenever they want. It is notable, however, that MPTM users tend to give an instant response to close friends (Nakamura, 2001). Despite this asynchronicity, such interaction allows sharing one's life with others in real time (Mäenpää, 2001).

A selective interpersonal relationship theory for MPTM social networks

To explore the effect of MPTM on interpersonal relationships, we adopted Matsuda's (2000) selective interpersonal relationship theory, which claims that mobile phones can change social networks among young people. According to Matsuda, researchers have long asserted that young people

(broadly defined as 13–30-year-olds) had extensive, but low-quality relationships with friends, and that mobile phone usage may facilitate the improvement in the quality of their relationships. However, she observes that no empirical studies have been conducted which support this claim, and that these interpretations may have been distorted by cohort effects, sampling bias, and mass media effects. Matsuda argues that young people prefer selective interpersonal relationships in which they maintain particular, partial, but rich relations, depending upon the situation.

Matsuda (2000) concluded that urbanization increases the number of possible contacts, and hence, promotes selective relationship formation. Mobile phones, as well as urbanization, also increase the frequency of communication, and allot opportunities for expanding interpersonal relationships. For the most part, however, young people are likely to communicate only with close friends via mobile phones, and also, they can connect with each other regardless of their current location (e.g., regardless of people in the immediate vicinity). She argues that it is better to consider such relationships as being selective, not as qualitatively rich or poor, and also noted that such selective relationships can be regarded as partial, yet rich. That is, young people do not need fully integrated relationships with others, but partially functioning relationships in response with one's situational demand.

While this theory was intended to explain the impact of mobile phone conversations on interpersonal relationships, we believe it can be helpful in interpreting the influence of MPTM on social networks because the two forms of communication are similar in many respects. If the process of relationship formation via MPTM follows the selective interpersonal relationship theory, such relationships will be evaluated as being more important or intimate than relationships in which MPTM are not exchanged. Also, if the use of MPTM decreases the quality of relationships, then relationships based on MPTM will be evaluated as less important than FTF relationships.

Furthermore, structural analysis of the patterns of relationship formation is needed to clarify the role of MPTM social networks on FTF social networks. In this study, we use social network analysis to test this theory. Many researchers have applied social network analysis to investigate how PC e-mail affects interpersonal relationships, and they have reported that PC e-mail maintains existing friendships and family relationships, while it also increases contact and support exchanged in new relationships (e.g., Hampton & Wellman, 2001). We also expect that MPTM leads to greater communication, and thus, enhances people's connectivity, leading to a change in their social network structure.

Social network analysis

Social network analysis focuses on the exchange of resources and the patterns of relations between actors (Wasserman & Faust, 1994). The links are based on social interactions, such as friendships or transactions. Social psychologists and sociologists have used social network analysis to

recognize actors in important roles or positions within the network, and several indices have been developed to describe the nature of social networks. These indices are divided into two types: individual based (centrality measures) and group based (centralization measures).

Individual-based indices describe how well connected an actor is within his/her local environment, or *centrality*. Several measures of centrality are available. *Outdegree centrality* determines the number of friends an actor nominates, whereas *indegree centrality* refers to the number of friends who nominate the actor. *Betweenness centrality* describes frequency with which an actor falls between pairs of other actors on the shortest or geodesic paths connecting them (Freeman, 1979). If an actor has low outdegree or indegree centrality, he/she may be isolated. However, it is also possible that he/she can have high betweenness centrality in the network, and intermediate between relations. This is because an actor is dependent on another person if the paths which connect him or her to the other people pass through that person. *Information centrality* explains the proportion of total information flow in a social network controlled by an actor (Stephenson & Zelen, 1989). The more connections there are, the more observations an actor has on specific information, and the smaller the variance of the index.

Group-based indices describe the overall characteristics of a social network. We can compare different networks by group-based indices. *Group density* is defined as a proportion of the maximum possible number of relationships. It refers to the general level of linkage among the actors in a network (Scott, 2000). *Group mutuality* is the tendency for actors in a network to reciprocate choices more frequently than would occur simply by chance (Achuthan, Rao, & Rao, 1982; Katz & Powell, 1955). A value of 0 indicates no tendencies for any reciprocation, a value of 1 indicates maximal tendency, and negative values indicate the presence of many asymmetric and null dyads in the network. *Transitivity* indicates the notion that 'a friend of a friend is a friend' (Wasserman & Faust, 1994). For example, if friendship is transitive, person A chooses person B as a friend, and person B chooses person C as a friend, and subsequently person C chooses person A as a friend. *Group transitivity* indicates the proportions of transitive relations in a network. A *clique* is a maximal complete subgroup of three or more actors (Wasserman & Faust, 1994). It is a subset of actors in which every possible pair of actors is directly connected. The clique is not contained within any other clique. A network with a high *degree centralization* or *betweenness centralization* is likely to have a few actors with many relations while the majority have few relations (Freeman, 1979). *Information centralization* (Wasserman & Faust, 1994) refers to the variance of the actor information centrality. These group centralization indices are similar to individual centrality, but they pertain to particular properties of the group structure as a whole, rather than describing an individual actor's position.

These indices allow us to compare the characteristics of FTF social networks with those of MPTM social networks. To assess the quality of

friendships, we also need to measure the importance and intimacy of social networks. This allows us to hypothesize that if MPTM communication facilitates the formation of poor relationships, individual- and group-based indices will show a dilution of the network structure (e.g., high transitivity and many cliques) and, consequently, the importance or intimacy of friends communicated via MPTM, will be rated lower than those of friends communicated via FTF. However, we can also propose a contrasting hypothesis. If MPTM contributes to the development of selective interpersonal relationships, MPTM social network indices will tend to indicate segmentation of the network structure. For example, there would be low transitivity and few cliques, and furthermore, friends in MPTM social networks will be evaluated as more important or intimate than those in FTF social networks. Given these conflicting positions, a research question is posed.

RQ1: Will MPTM social networks produce more superficial ties within the network, or segmentation of the network (i.e., particular ties are strengthened while others become weak)?

In addition, we shall depict the social network data through a three-dimensional graphing technique devised by Mage (Richardson & Richardson, 1992). This procedure permits the rotation of graphs to help viewers explore the details of any structure. Visual depictions of social networks are useful in clarifying the detailed structure of the network (Brewer & Webster, 1999; Freeman, Webster, & Kirke, 1998). Such social network imagery has provided researchers with new insights into network structures, and helped them to communicate those insights (Freeman, 2000).

Gender differences in social networks and MPTM use

Many studies have revealed gender differences in interpersonal relationships (see Boneva, Kraut, & Frohlich, 2001). For example, females tend to self-disclose more to their good friends (Caldwell & Peplau, 1982), change the level of self-disclosure more depending on the intimacy of relationships (Dindia & Allen, 1992), are more sociable and sensitive, have more intimate social networks (Deaux, 1976; Wheeler, Reis, & Nezlek, 1983), are more actively involved in intimate conversation (Walker, 1994), are more motivated to create and maintain relationships by the avoidance of isolation (Tannen, 1992), and to form more socio-emotion-oriented social networks (Karweit & Hansell, 1983) than males. Females would also form more stable relationships than males, because socio-emotion-oriented networks develop emotional bonds that build solid relationships (Hirschi, 1969). In contrast, males are more likely to spend time in common activities (Walker, 1994), to communicate with the purpose of gaining and maintaining social position (Tannen, 1992), and prefer task-oriented social networks (Karweit & Hansell, 1983). These results indicate that females tend to be more interested in personal and emotional communication, and in building more stable relationships than males. Some studies have also found that females have more extensive social networks (Moore, 1990; Walker, 1994),

suggesting that females' friendship behavior within their social networks may be more active than males'.

Such gender differences have already been found in computer-mediated communication. For example, females use PC e-mail to communicate about private matters more than males (Kraut et al., 1998; Pew Internet and American Life Project, 2005), and are more satisfied with communication via PC e-mail, and are more likely to utilize it to build intimate relationships (Boneva et al., 2001; McKenna, Green, & Gleason, 2002). Although few investigations exist on gender differences in communication via MPTM, we have three reasons to expect that MPTM will also facilitate the females' development of interpersonal relationships. First, MPTM makes it easy to share thoughts and feelings despite physical distance, and increase the frequency of communication. Second, MPTM (Furutani, Sakata, & Kohguchi, 2003), as well as computer-mediated communication (Tidwell & Walther, 2002), promotes self-disclosure. Finally, MPTM can be used to relieve tension in interpersonal communication, and satisfies affiliation motivation (Moroi, 2000; Tsuzuki & Kimura, 2000). Therefore, we would expect that females will have more personal, more emotionally involved, and more stable friendships, and expand their MPTM social networks when compared with males.

H1: For FTF social networks, females will have a greater number of friends, evaluate them as being more intimate or important, and form more stable relationships than males.

H2: For MPTM social networks, females will have a greater number of friends, evaluate them more as being intimate or important, and form more stable relationships than males.

H3: For FTF social networks, females tend to mutually nominate each other more than males.

H4: For MPTM social networks, females tend to mutually nominate each other more than males.

In summary, there are two major purposes of this study. First, this study tests the selective interpersonal relationship theory of MPTM communication by comparing the developmental process of MPTM social network structure with that of FTF social network structures over time. A second purpose is to explore gender differences in both FTF and MPTM social networks.

Methods

Participants

Participants were 132 first-year law undergraduates (64 males and 68 females) in an introductory psychology class at a university in central Japan. The age of the sample ranged from 18 to 23 years ($M = 18.30$, $SD = 0.62$). Sixty-two percent

of the participants lived with their parents, while the rest lived alone. No statistically significant relationship existed between gender and living environment, $\chi^2(1, N = 132) = .97, ns$.

All but one of participants had their own mobile phone. Sixty-eight percent of the participants had used mobile phones for one or more years and 92% of the participants communicated with their friends via MPTM on a daily basis.

Measures

Participants were asked to 'think of all the friends with whom you have contact, and select those who communicate with you via face-to-face or via voice telephone since entering university.' One restriction was that participants could only list persons they had seen at least once during the past 2 weeks. Participants were allowed to list up to 10 individuals' initials for each assessment.

After participants listed the members of their social networks, they were instructed to provide more detailed information about each individual listed. The following types of information were requested: the individual's gender; his or her major; and how often the respondent met the individual. Several aspects of the member's relationship to the respondent were also measured, for instance, intimacy and importance of relationships were rated on a 10-point scale.

In addition, participants were also asked to 'think of all the people with whom he/she had contact, and select those who have communicated with you via mobile phone text messages since entering this university.' Participants were then given the same network items as for FTF, except that they were asked about how often they sent text messages to these individuals per day, rather than how often they met them.

In this article, we concerned ourselves with first-year law undergraduates who communicated via FTF or MPTM among their classmates and their social networks. Although participants were allowed to select friends from both classmates and nonclassmates (e.g., old friends who attended other universities), we collected and analyzed data for only the classmate network.

Procedure

At the beginning of the first semester, participants were recruited from introductory psychology classes to participate in this study for extra course credit. The study was described as a 'survey of relationships among university students,' and was carried out in a large classroom. Questionnaires were administered at weeks 3 (time 1) and 12 (time 2) of their first semester since matriculation.

Results

Network structure

Structural properties. *RQ1* addressed whether the MPTM network assumes dilution or segmentation of structure. To assess the whole network structure in the class, we created four 132×132 matrices based on social network data and calculated several group-based indices: number of ties in group, group density, group mutuality, group transitivity, number of cliques and group centralization.

For all analyses, we dichotomized relational ties (1 = *tie of any strength*, 0 = *no tie*), and for some analyses, we symmetrized ties in these matrices based on the union rule, such that '1' refers to a reciprocated or unreciprocated tie, and '0' refers to no tie (i.e., two actors are regarded as 'connected' if at least one actor nominates another). We also counted the number of cliques with a minimum size of three participants.

Table 1 shows network properties for FTF and MPTM social networks. For both networks, the number of ties in the group and the level of reciprocated ties generally increased as the semester progressed. Throughout the semester, almost all people nominated as a friend in MPTM social networks were also nominated as a friend in FTF social networks (94% at time 1 and 98% at time 2). Similarly, the mutuality of friendship choices increased slightly. The number of cliques increased substantially for the symmetrized data based on the union rule. In contrast, the number of cliques based on the intersection rule (i.e., two actors are regarded as 'connected' if they nominate each other) remained fairly stable over time, though this number in the FTF social network was roughly triple that of MPTM. For the FTF social network, the symmetrized degree centralization and outdegree centralization increased as the semester progressed. The indegree centralization for the FTF social network, and all centralization indices for the MPTM social network, however, did not change

TABLE 1
Social network properties

	FTF social networks		MPTM social networks	
	Time 1	Time 2	Time 1	Time 2
Number of ties in group				
All	218	295	109	162
Reciprocated	132	168	64	82
Group density				
Symmetrized	0.02	0.02	0.01	0.01
Asymmetrized	0.01	0.02	0.01	0.01
Group mutuality				
Katz-Powell's ρ_{kp}	0.60	0.56	0.58	0.50
Achuthan-Rao-Rao's ρ_b	0.61	0.57	0.59	0.51
Group transitivity				
Symmetrized	0.22	0.29	0.15	0.23
Asymmetrized	0.24	0.27	0.14	0.23
Number of cliques [symmetrized data]				
Union rule	84	113	30	64
Intersection rule (reciprocated)	31	38	11	12
Degree centralization [%]				
Symmetrized	2.87	4.50	2.98	3.23
Indegree	2.58	2.90	2.44	2.90
Outdegree	2.58	5.20	2.44	2.90
Betweenness centralization [%]				
Symmetrized	11.61	11.13	3.45	16.82
Asymmetrized	7.81	26.77	0.58	1.69
Information centralization [variance]	0.03	0.05	0.01	0.01

dramatically over time. The asymmetrized betweenness centralization for the FTF social network, and the symmetrized betweenness centralization for the MPTM social network developed as the semester progressed, whereas the symmetrized betweenness centralization for the FTF social network and the asymmetrized betweenness centralization for the MPTM social network hardly changed. The information centralization remained quite low for both networks.

In addition, to test the influence of the MPTM social network on friendship intimacy, participants were divided into three groups by characteristics of their social network: Group A consisted of participants who communicated nearly exclusive via FTF to friends, Group B contained participants who communicated via both FTF and MPTM to all their friends, and Group C was composed of participants who communicated via FTF to some friends, while they used both FTF and MPTM for others. Figure 1 shows the intimacy of friends in the FTF social network. Comparisons indicated that participants in Group B had more intimate friendships than those in Group A, $t(33) = 4.38$ at time 1, $p < .01$, and $t(39) = 4.65$ at time 2, $p < .01$. Analyses for Group C also revealed that friends with which both FTF and MPTM were used were evaluated as being more intimate than those in which only FTF was used, $t(65) = 3.12$ at time 1, $p < .01$, and $t(67) = 2.85$ at time 2, $p < .01$. These results indicate that first-year undergraduate students use MPTM to communicate with intimate friends, even at the beginning of the semester.

Correlations of social networks. To explain the development of social network structure over time, we used the quadratic assignment procedure (QAP; Hubert & Schultz, 1975). QAP computed several standard measures of the correlation between the two matrices first, and then computed an estimate of the significance of the correlation by permuting the elements of the matrix

FIGURE 1
Effects of MPTM social networks on intimacy of friendship.

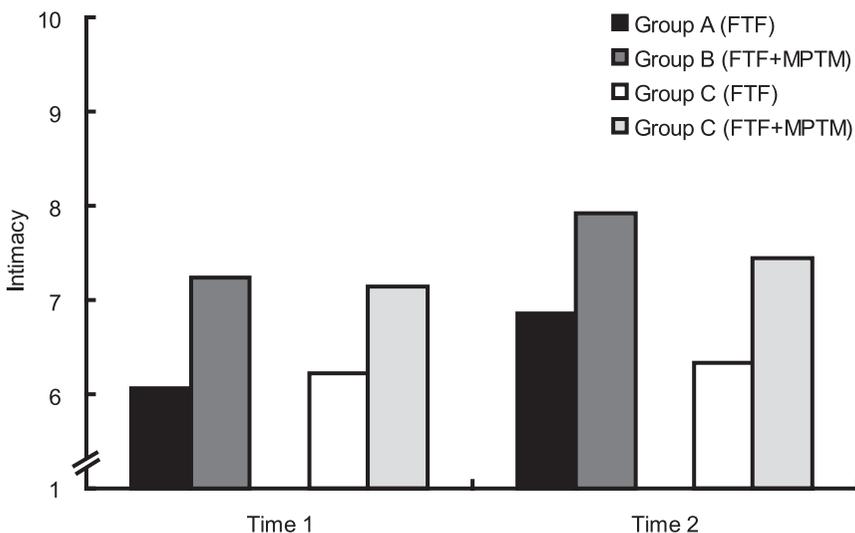


TABLE 2
QAP correlations of social networks across time and media

	<i>r</i>
FTF at Time 2 – MPTM at Time 2	.77
FTF at Time 1 – MPTM at Time 1	.72
FTF at Time 1 – FTF at Time 2	.61
MPTM at Time 1 – FTF at Time 2	.52
MPTM at Time 1 – MPTM at Time 2	.52
FTF at Time 1 – MPTM at Time 2	.48

multiple times, and counting the number of correlations. For the analysis, we also applied dichotomous asymmetric matrices.

Table 2 presents QAP correlations. Strong correlations ($r > .60$) were found between FTF and MPTM social networks during the same period, and between FTF social networks over time. However, the correlation value ($r = .52$) between MPTM social networks over time was weaker.

Visualizing social networks

To visually understand changes in social network structures, we created three-dimensional sociometry for each communication medium and period. We regarded intimacy symmetrized by the mean values of two actors as similarity, and then plotted the observed relations using the spring-embedding algorithm method (Fruchterman & Reingold, 1991) as shown in Figure 2. A point represents each actor. Black (or red in the color version online) points indicate females, whereas gray (or yellow) points are males. A line connects two points if one member nominated the other. Although the two-dimensional figure can provide a vague description of the network structures, a three-dimensional figure should be viewed in order to appreciate the network structure characteristics fully. This three-dimensional figure can be seen at <http://www.educ.nagoya-u.ac.jp/yoshida/igarashi/jspr/>.

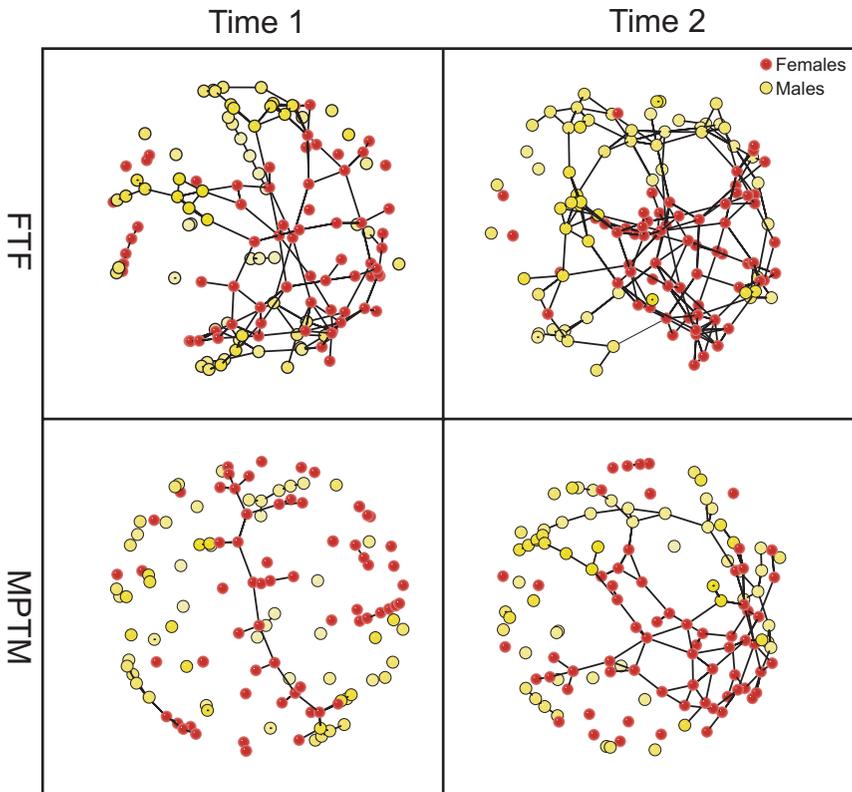
We can see that FTF networks had some nonspherical properties through the semester, and then converged. In contrast, actors were placed in a roughly spherical arrangement over time for MPTM social networks. These visualizations show that actors in the MPTM social networks tended to make connections dyadically rather than in groups. At time 2, however, these relations diverged into more distinct groups. With respect to *RQI*, these findings suggest that the MPTM social network showed segmentation of the network structure in both quantity and quality of relationships.

Gender differences in social networks

Gender and time effects on social network variables. *H1* and *H2* predicted that females would have a greater number of friends, evaluate them as more intimate or important, and build more stable relationships than males for both FTF and MPTM social networks. Table 3 presents the means and standard deviations of the social network variables at each period for males and females. Note that we computed contact frequency, importance and intimacy for participants who listed one or more classmates at both periods, and then conducted separate analyses for network size and other variables.

FIGURE 2

Three-dimensional visualization of FTF and MPTM social networks. These graphs were plotted by the spring embedding algorithm separately for each medium and period. Further details can also be seen at the website, <http://www.educa.nagoya-u.ac.jp/yoshida/igarashi/jspr/>.



First, 2 (gender: males, females) \times 2 (time: time 1, time 2) mixed design analyses of variance (ANOVA) on network size were performed separately for each medium (FTF, MPTM). Results focusing on the size for the FTF network indicated a significant gender main effect, $F(1,130) = 7.42, p < .01$. As predicted, females had a larger network than males. In addition, there was also a significant main effect for time on network size for FTF, $F(1,130) = 27.45, p < .01$, and MPTM, $F(1,130) = 16.64, p < .01$. In both cases, networks were larger at time 2 than at time 1.

Second, 2 (gender) \times 2 (time) mixed design multivariate analyses of variance (MANOVA) on the three network variables (contact frequency, importance and intimacy) were conducted separately for each medium. Results showed that gender had a significant multivariate main effect for the FTF social network, $F(3,94) = 2.83, p < .05$, Wilks' $\lambda = .92$. Univariate F -tests revealed a significant main effect of gender on importance for the FTF network, $F(1,96) = 5.67, p < .05$. As predicted, females described their friendships as more

TABLE 3
Means and standard deviations of social network variables

	FTF social networks				MPTM social networks			
	Males		Females		Males		Females	
	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
Network size								
<i>M</i>	1.50	2.02	1.79	2.44	0.63	1.01	0.98	1.46
<i>SD</i>	(1.38)	(1.58)	(1.42)	(1.56)	(0.97)	(0.97)	(1.08)	(1.24)
<i>n</i>	64		68		64		68	
Contact frequency								
<i>M</i>	1.25 ^a	1.20 ^a	1.30 ^a	1.29 ^a	0.91 ^b	0.99 ^b	1.03 ^b	1.41 ^b
<i>SD</i>	(0.58)	(0.43)	(0.54)	(0.39)	(3.11)	(1.55)	(2.40)	(2.09)
<i>n</i>	43		55		20		42	
Importance								
<i>M</i>	6.01	6.81	6.85	7.30	6.58	6.86	7.11	7.02
<i>SD</i>	(1.79)	(1.73)	(1.71)	(1.74)	(1.89)	(2.04)	(2.06)	(2.22)
<i>n</i>	43		55		20		42	
Intimacy								
<i>M</i>	6.54	7.19	6.76	7.33	7.46	7.68	7.16	7.74
<i>SD</i>	(1.44)	(1.39)	(1.47)	(1.62)	(1.18)	(1.74)	(1.32)	(1.59)
<i>n</i>	43		55		20		42	

^aContact frequency is made on four categories (1, *every day*; 2, *once a week*; 3, *once a month*; 4, *less than once a month*).

^bNumber of text messages sent per day.

important when compared with males. Time also had a significant multivariate main effect on the FTF social network variables, $F(3,94) = 6.51, p < .01$, Wilks' $\lambda = .83$. Univariate F -tests showed that the effect of time was significant for both importance, $F(1,96) = 8.21, p < .01$, and intimacy, $F(1,96) = 18.41, p < .01$, for FTF. Friendships were rated as more important and intimate at time 2 than at time 1.

In contrast, in the MPTM social networks, neither gender nor time influenced contact frequency, importance, or intimacy (contact frequency did not vary significantly in either the FTF or MPTM networks). In order to confirm the effect of contact frequency of the FTF social network on the MPTM social network, we also conducted regression analyses for contact frequency, importance and intimacy of the MPTM social network at each period. Results showed that contact frequency of the FTF social networks did not predict these variables for the MPTM social networks at either period.

Network stability. To examine social network stability, we calculated individual-based indices for each network, i.e., indegree centrality, betweenness centrality and information centrality. Outdegree centrality corresponds to network size computed above. Table 4 presents the correlations among FTF and MPTM social networks depending on time for each centrality measure, respectively for males and females.

TABLE 4
Correlations of centrality indices

	Males				Females			
	FTF social networks		MPTM social networks		FTF social networks		MPTM social networks	
	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
Outdegree centrality								
FTF at Time 1	–				–			
FTF at Time 2	.59**	–			.67**	–		
MPTM at Time 1	.65**	.41**	–		.58**	.54**	–	
MPTM at Time 2	.21	.47**	.38**	–	.46**	.71**	.50**	–
Indegree centrality								
FTF at Time 1	–				–			
FTF at Time 2	.51**	–			.68**	–		
MPTM at Time 1	.64**	.25*	–		.63**	.47**	–	
MPTM at Time 2	.22	.65**	.23	–	.63**	.81**	.56**	–
Betweenness centrality								
FTF at Time 1	–				–			
FTF at Time 2	.20	–			.48**	–		
MPTM at Time 1	.80**	.06	–		.36**	.29	–	
MPTM at Time 2	–.09	.39**	.01	–	.50**	.44**	.19	–
Information centrality								
FTF at Time 1	–				–			
FTF at Time 2	.31**	–			.74**	–		
MPTM at Time 1	.48**	.17	–		.48**	.52**	–	
MPTM at Time 2	.31**	.45**	.13	–	.58**	.63**	.60**	–

* $p < .05$; ** $p < .01$.

Gender differences were found in patterns of correlations for each centrality measure between time 1 and time 2. For females, most centrality measures at time 1 correlated strongly with time 2 measures. For males, however, the betweenness centrality for FTF and information centrality for MPTM at time 1 did not correlate with their corresponding centralities at time 2 for either network. For both females and males, betweenness centrality measures for MPTM were not correlated across time.

These findings generally support *H1*. For FTF social networks, females had a greater number of friends, evaluated them as being more important, and formed more stable relationships than males. However, *H2* was only partially supported. For MPTM social networks, females had more stable relationships than males, but no gender differences were found in the quality and quantity of the network.

Gender effects on selection behavior. *H3* and *H4* predicted that females would nominate each other more than males for both FTF and MPTM social networks. To explore gender differences in the actors' selection behavior within their social networks, we used log-linear modeling as developed by Fienberg and

Wasserman (1981), and revised by Wasserman and Faust (1994). Here, we briefly elaborate on the way in which we applied the log-linear approach to our data.

First, this model is based on the p_1 distribution introduced by Holland and Leinhardt (1981). The basic model of p_1 is the four-dimensional \mathbf{Y} -array, whose component Y_{ijkl} describes the interaction between i and j , where $k = 1$ if i interacts with j , and $l = 1$ if j interacts with i . Therefore, a pair of actors has one of four possible states: mutual silence ($Y_{ij00} = 1$), mutual interaction ($Y_{ij11} = 1$), or asymmetric interaction ($Y_{ij01} = 1$ or $Y_{ij10} = 1$). The natural log of the probabilities of each of these four dyadic states as a function of parameters is represented by p_1 :

$$\begin{aligned} \log P(Y_{ij00} = 1) &= \lambda_{ij} \\ \log P(Y_{ij10} = 1) &= \lambda_{ij} + \theta + \alpha_i + \beta_j \\ \log P(Y_{ij01} = 1) &= \lambda_{ij} + \theta + \alpha_j + \beta_i \\ \log P(Y_{ij11} = 1) &= \lambda_{ij} + 2\theta + \alpha_i + \alpha_j + \beta_i + \beta_j + \rho. \end{aligned} \tag{1}$$

or expressed by Wasserman and Faust (1994),

$$\log P(Y_{ijkl} = 1) = \lambda_{ij} + (k+l)\theta + k\alpha_i + l\alpha_j + k\beta_i + l\beta_j + (kl)\rho, \tag{2}$$

where $k, l = 0, 1$.

The λ_{ij} parameters have no substantive meaning, ensuing that the probabilities sum up to 1 for each dyad. The θ parameters reflect an overall volume of interaction in the network. The ρ parameter is called ‘mutuality,’ or the likelihood of mutual relationship in the network. The α parameters are called ‘expansiveness’ parameters reflecting the tendency of each actor to nominate others in the network. The β are called ‘popularity’ parameters indicating the tendency of each actor to be nominated by others in the network. Note that we will not interpret $\lambda_{ij}, \theta, \rho$ parameters in this article, because we are interested only in gender differences of expansiveness and popularity.

Second, we consider the subsets of actors, using the attribute of gender. Wasserman and Faust (1994) introduced the approach of placing actors into subsets using relevant actor characteristics. It is assumed that actors within a subset behave similarly. Based on this approach, we modify the $132 \times 132 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2$ \mathbf{Y} -array into a smaller $2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2$ \mathbf{W} -array defined as:

$$W_{s(i)s(j)kl} = \sum_{i \in s(i)} \sum_{j \in s(j)} Y_{ijkl}, \tag{3}$$

where $s(i)$ and $s(j)$ denote the subgroup of actors i and j respectively ($s[i], s[j] = 1, 2$).

Finally, we used the version of base model introduced by Wasserman and Faust (1994), as follows:

$$\log P(Y_{ijkl} = 1) = \lambda_{ij} + \theta_k + \theta_l + \alpha_k^{[s(i)]} + \alpha_l^{[s(j)]} + \beta_k^{[s(j)]} + \beta_l^{[s(i)]} + \rho_{kl}. \tag{4}$$

The statistics necessary to estimate the model parameters defined above are margins of the original \mathbf{W} -array. Fitting a model to the data implies finding the best estimates of all parameters in the model that could produce the interaction data represented in the aggregated resultant matrix (\mathbf{W} -array). To test the significance of the parameters, we computed how much the expected and observed matrices differed. We first fitted a baseline model containing all

parameters, and then checked which of them could be excluded, and which of them could be included. Results are shown in Tables 5 and 6.

For FTF social networks, no gender differences were found in both expansiveness and popularity at time 1. However, at time 2, popularity was slightly significant. The α estimate suggested that females were more likely to have expansive FTF networks than males at time 2. Incidentally, for MPTM social networks, there were essential gender differences in friendship nominations. Females expanded their MPTM social network more than males over time, and had a tendency to be more popular than males at time 2.

Overall, *H3* was partially supported: females were more active than males in their FTF networks, but only at time 2. In contrast, these findings generally support *H4*, which predicted that females would have a more expansive and popular MPTM social network than males. Friendship nominations for MPTM seemed to be quite gender specific.

TABLE 5
Goodness-of-fit statistics for gender differences in FTF and MPTM social networks

Time 1				Time 2			
Model	G^2	Δdf	ΔG^2	Model	G^2	Δdf	ΔG^2
FTF social networks							
1 ^a	212.42			1 ^a	335.31		
2 ^b	213.93	1	1.50	2 ^b	338.96	1	3.65 [†]
3 ^c	212.62	1	0.19	3 ^c	335.28	1	-0.03
MPTM social networks							
1 ^a	125.75			1 ^a	180.21		
2 ^b	132.39	1	6.64**	2 ^b	184.90	1	4.69*
3 ^c	125.81	1	0.06	3 ^c	183.36	1	3.15 [†]

^aBased on equation (4).

^b $H_0: \alpha_k^{[s(i)]} = 0$ for all i and k .

^c $H_0: \beta_k^{[s(j)]} = 0$ for all j and k .

[†] $p < .10$; * $p < .05$; ** $p < .01$.

TABLE 6
Parameter estimates for social networks and gender

	Time 1		Time 2	
	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\alpha}$	$\hat{\beta}$
FTF social networks				
Males	-0.07	-0.03	-0.10	0.00
Females	0.07	0.03	0.10	0.00
MPTM social networks				
Males	-0.22	-0.03	-0.14	-0.12
Females	0.22	0.03	0.14	0.12

Three-dimensional network arrangement. The three-dimensional spatial analysis also clearly shows gender differences in social network structures. For the FTF social network, females had already formed a large group at time 1, with the exception of a few solitary actors, and this tendency was maintained through time 2. Males showed divisions into three small groups at time 1, but they became integrated into one large group at time 2.

For the MPTM social network, there were some dyadic ties and isolates at time 1, but no large groups were found for males or females. At time 2, however, females formed one large MPTM social network as they did for the FTF network for the same time period. In contrast, males tended to build many sub-groups, although they did not form any large networks.

Discussion

The results of this study facilitated our understanding of the way in which FTF and MPTM social networks develop by demonstrating the structural differences between these networks. We tested first-year undergraduates' social network development and found that the structural and functional characteristics of social networks tended to vary with the actor's gender, time, and the communication medium.

Network structure

This study suggests that characteristics of MPTM social networks are quite different from those of FTF networks. FTF networks are twice the size of MPTM networks. In addition, participants rated friendships in which they communicated via both FTF and MPTM as being more intimate than those in which communicated solely via FTF. These results indicate that first-year undergraduate students make new relationships with FTF communication at an early stage, and then use MPTM to increase their contact later on. Also, as a particular relationship grows more intimate in FTF, the frequency of MPTM increases as well.

Furthermore, the findings of this study suggest that MPTM social network development, at least during early stages, follows a course analogous to that proposed by models of development of interpersonal relationships in computer-mediated communication (Parks & Roberts, 1998; Walther, 1996). These models claim that the development of interpersonal relationships in computer-mediated communication takes more time than in FTF contexts, and that frequent and long-term communication is needed to overcome restricted channels and cues. In this study, group transitivity indices for FTF social networks were stable over time, whereas it increased from time 1 to time 2 for MPTM social networks. In addition, the number of cliques in the MPTM social network was about three times that in the FTF network. These results indicate that first-year undergraduate students' MPTM networks consist of small groups and some dyadic relationships at early stages, expanding to triadic and indirect relationships at later stages, due perhaps to the closed nature of communication with particular friends via MPTM. Consistent with selective interpersonal relationship theory

(Matsuda, 2000), MPTM promoted selective relationship formation, versus large and loose relationships.

A review of cross-cultural studies regarding trust in relationships (Hayashi & Yamagishi, 1998) indicates that Japanese, as collectivists, prefer secure and stable relationships. However, the communication technologies available via the Internet, promote the formation of an open society, which is more likely to access advantaged positions and resources, and in turn enhance the opportunity to obtain additional resources (Quan-Haase, Wellman, Witte, & Hampton, 2002). The result of this study suggests that the use of MPTM facilitated the development of strong, narrow and stable relationships at an early stage, but first-year undergraduate students expanded their intimate relationships within their closed networks, forming several groups, and connecting to each other in a way that is similar to FTF networks at a later stage. Granovetter's (1973) classic study defines intimate relationships with people with whom one frequently spends time as 'strong ties.' Young people build such strong ties by using text messages. Although the QAP correlation between MPTM social networks throughout the period was not so strong, MPTM may have potential for increasing social capital (Putnam, 2000) that generates collaborative behavior, hence, enriching a person's life. Future research needs to examine the openness of MPTM communication, and investigate cultural differences in the effects of MPTM on social network development.

Social identity theory (SIT; Tajfel, 1978) also offers an important perspective in explaining the reason why MPTM social networks are less dense than FTF social networks. This theory revealed that both: (i) relationship formation and maintenance, and (ii) group belonging and peer-acceptance are associated with group or social identity (e.g., Turner, Hogg, Oakes, Reicher, & Wetherell, 1987). SIT suggests that identification at the group level should be distinguished from that at the group member level (Karasawa, 1991). Recent empirical studies suggested that one's feelings about membership in a group correspond directly to one's pattern of within-group relations (Paxton & Moody, 2003). In addition, cross-cultural research revealed that Japanese tend to trust an out-group when there is an acquaintance in that out-group, whereas Americans tend to trust an out-group by category-based information (Yuki, Maddux, Brewer, & Takemura, 2005). In a group, individual relationships are likely to be somewhat blurred. Consequently, there is little, if any, self-disclosure. What matters to group members is the actual belonging to a group, and therefore, group interaction in FTF is limited to merely hanging out together. Instead, dyadic relationships permit a greater number of communication modalities. Hence MPTM may be useful for the enhancement of within-group relationships and group membership identification that underlies FTF communication. The effects of MPTM communication on group identity should be elaborated in the future.

Gender differences

We discovered gender differences in patterns of interpersonal relationships for both FTF and MPTM social networks. For FTF social networks, females were likely to form a large group over time, whereas males were apt to develop several small groups at an early stage, while forming large groups later. For MPTM social networks, both females and males developed dyadic relationships with their network members in the initial stages. At a later stage, however, females tended to form a large group comparable with that for FTF social networks, whereas males maintained their dyadic relationships as the semester progressed.

Several studies attest that the increase in the depth and breadth of interpersonal exchange facilitates the development of dyadic relationships (Altman & Taylor, 1973), and that the female's social network tends to expand more than the male's (Moore, 1990). Moreover, female friendships are more intimate and emotionally involved than male friendships (e.g., Booth, 1972), and females interact more frequently with their network members and exchange more support than males (Hays & Oxley, 1986). MPTM may discharge the tension in interpersonal communication due to its mediated nature, and may simultaneously satisfy affiliation motivations. Accordingly, the mobility of MPTM communication increases the frequency of contact with others.

Gender differences in the estimates of expansiveness and popularity suggest that females were more active than males in their MPTM social networks even at an early stage. It should be noted that the three-dimensional graphs also showed few cross-sex relationships, although the number of relationships increased over time. In FTF, cross-sex relationships are rare among the broad range of generations – from adolescents to middle-aged (Babchuk, 1965; Duck, 1975). However, recent studies of Instant Messenger (IM) usage on the Internet have reported that adolescents' IM usage encourages cross-sex communication with known friends (Schiano et al., 2002), and that both males and females nominate females as more important and interesting IM relationship partners than males (Wolak, Mitchell, & Finkelhor, 2003). These findings give a promising clue to the relative popularity of females in the MPTM social network.

Likewise, gender differences in the patterns of correlations among individual centrality measures show that females formed more stable relationships than males. However, both males' and females' betweenness centrality for their MPTM social network at time 1 did not associate with that for FTF and MPTM networks at time 2. This pattern can be interpreted as reflecting the general structural instability of the MPTM social network.

Interestingly, the volume of text messages sent did not differ significantly between males and females. It is likely that it was not the volume, but the contents of text messages that allowed females' MPTM social network structure to expand over time. Previous research has shown that females are more self-disclosing than males (Caldwell & Peplau, 1982), and that computer-mediated communication promotes self-disclosure (Joinson, 2001). In addition, females rated the FTF social network more important

than males. One explanation for this result is that females value FTF communication with their classmates, and that MPTM use supplements FTF communication, whereas males are more passive in making friends, and their MPTM social networks do not converge. However, this study did not assess the content of text messages. Future investigations into the content of text messages are necessary to elaborate on a model of interpersonal relationship using MPTM communication.

Limitations

There are several limitations to this study. First, because our sample consisted predominantly of Japanese students, the findings of this study should not be assumed to hold true for individuals of other age, cultural, and social groups. The size of social network may also affect patterns of interpersonal relationships. Future studies using a variety of subject populations in diverse settings are needed. In addition, we collected data in this study only during one semester. Needless to say, first-year undergraduates' social network development continues beyond a single semester. Future research should trace the developmental process of social networks over a longer period.

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