Reviving Dormant Ties in an Online Social Network Experiment

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Abstract

Social network users connect and interact with one another to fulfil different kinds of social and information needs. When interaction ceases between two users, we say that their tie becomes *dormant*. While there are different underlying reasons of dormant ties, it is important to find means to revive such ties so as to maintain vibrancy in the relationships. In this work, we thus focus on designing an online experiment to evaluate the effectiveness of personalized social messages to revive dormant ties. The experiment carefully selects users with dormant ties so that each user does not get mixed treatments and be affected by the responses of other users undergoing treatment. Our results show that personalized message content plays an important part in reviving dormant ties. Specifically, we find the message containing friend's recent activity information is more effective than that containing inter-friend activity information. We observe that the quality of engagement of at least 50% of the revived ties can effectively be restored to the level before the ties become dormant. We also observe that it is easier to revive dormant ties that involve users from the same country but not users with the same and different gender.

1 Introduction

1.1 Motivation

In the past decade, there has been an steady rise in the number of social networking sites such as Facebook, Twitter and Google+ on the Web, where users create online ties with other users. As users post status messages at the social networking sites or send targeted messages to one another, they are able to engage their friends and maintain their ties.

Nevertheless, the ease of forming online ties also poses several challenges to online social network users. Firstly, the continuous flow of information into online social networks and their dissemination across the ties has led to users suffering from *social overloading*. Previous research has shown that there is an upper cognitive limit to the number of active interpersonal relationships a user can maintain in a social network (McFadyen and Cannella 2004; Dunbar 1992; Killworth et al. 1990), which is also known as the Dunbar number. Anthropologists and psychologists postulate that a person would find it extremely difficult to maintain social relationships with friends exceeding the Dunbar number. Hence, even when users can create ties with hundreds and thousands of other users, many of these ties are likely to be superficial with little interaction.

In this work, we are not interested in the superficial ties. We instead focus on active ties that involve constant interaction over a significantly long period of time. Given the many online and offline opportunities for users to interact with each other, a healthy number of active ties is critical to keeping a user engaged with a particular online social network. Fewer such ties means fewer opportunities for marketing, less user generated content to engage other users, and possibly even losing a user altogether (Levin, Walter, and Murnighan 2011). It could be of great value to a social network to keep active ties active and encourage previously active ties to re-engage. In this paper, we focus on ways in which a network can revive *dormant* ties – those in which two users communicated regularly for a period but then ceased communication for one of many potential reasons.

1.2 Research Objectives

We conduct an online social network experiment to evaluate how different personalized messages can help to revive dormant ties. Previous work shows that personalized messages can be used as an effective strategy for better user engagement (Choi et al. 2010; Geiger et al. 2012) although that have not been tried on dormant ties. Our exploratory study is conducted on the MG network[1], a large-scale mobile online social network used by 6.2 Million people from many countries. Users in this social network are largely from the young and middle-aged group. They use mobile phones to create directed friend links with one another. Other than creating friendships, these users can chat, send direct messages, write testimonials, and use a variety of other services. In this social network, chat messaging – which is not restricted to declared friends – is the most actively used service. Every user maintains a profile page (see Figure 1) that contains a recent activity feed that can be viewed by other users.

The challenges of this online experiment to revive dormant ties consist of the following research questions to be

[1]The exact name of the social network site cannot be revealed due to non-disclosure agreement.

addressed:

- How can the online experiment be designed to determine the effectiveness of personalized messages while avoiding undesirable network effects that may affect the validity of the experiment results?
- How can the personalized messages be crafted and what are factors are to be considered in the message content? The content should not be fictitious as users can easily verify the message content. At the same time, we want the content to create the appropriate desire for the users to revive their dormant ties.
- How can the personalized messages be delivered such that the users do not find these messages intrusive? The messages should also minimize disruptions to the online social network business, a key concern expressed by our collaborating company.
- What are the measurable variables to determine the success of dormant tie revival? How are the relevant data collected throughout the experiment?

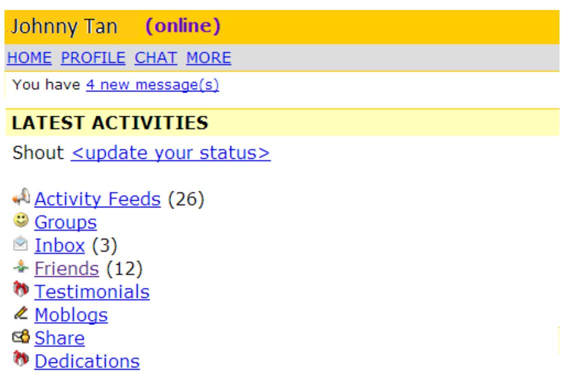

Figure 1: User Profile Page

This paper addresses the above challenges with a detailed design and implementation of an online social network experiment. The contributions in the paper are as follows.

- To the best of our knowledge, this work is the first experimental study on reviving dormant ties in an online social network. The experiment involves identifying and dividing the dormant ties into treatment and control groups so as to evaluate the responses from real users when given different treatments of personalized messages. The experiment is also designed to minimize interference between treatments which often happens in a network setting.
- The use of personalized messages as a social tactic to revive dormant ties is novel. We design two types of personalized message, one containing recent activity information, and another containing recent inter-friend activity information. The information contained in the messages are generated from historical user data. We also embed the URL of the friend in the message to facilitate checking of the friend's online profile as well as sending messages.
- To conduct this experiment, we develop an automated agent to send personalized messages to the selected dormant ties and a URL shortening service to collect user responses to the messages. These are useful software modules which serve as the core components of our online social network experiment. With them, our experiment does not require any existing service of the MG network to be modified.
- Our experiment shows that personalized message containing an account of a friend's activity can revive dormant ties and is more effective than than personalized message containing inter-friend activity information. We measure the effectiveness by the fraction of dormant ties that achieve a minimum level of re-engagement and the level of re-engagement of revived ties.

1.3 Paper Outline

We organize the rest of the paper as follows. Related work is covered in Section 2. We give our definition of dormant tie in Section 3 and a description of our experiment design in Section 4. The results of our experiment are analyzed in Section 5.

2 Related Work

The research on dormant ties and their revival is at the nascent stage. Quinn studied the reconnection of dormant social ties for midlife adults using email, social network sites and search engines (Quinn 2013). In their work, a small group of 23 participants were interviewed and their responses were analyzed. The key findings include: (a) context of the lost social contacts is useful for the latter to be located and reconnected; (b) internet communication allows the temporal identity of individuals to be compressed and examined by their lost contacts; and (c) reconnection of dormant ties may not be actively pursued as individuals find it satisfying enough to passively engage their lost contacts by reading their online profiles.

Unlike the above work, our research focuses on reviving online social ties which are dormant for short duration instead of creating new ties with long lost friends. To help users uncover the latter, several online social network sites such as Facebook and LinkedIn have implemented a variety of friend recommendation services making use of user profile attributes (e.g., high school/university attended, age, etc.) as well as already known common friends between users to suggest new friends to be added to the online friend lists. A summary of the link prediction methods that can be used for friend recommendation can be found in (Liben-Nowell and Kleinberg 2007; Aiello et al. 2012).

Quercia et al. analyzed Facebook friendships and concluded that a friendship is more likely to become dormant (or broken) if the users are not embedded in the same social circle, the users have considerable age difference, and one of them is a neurotic or introvert (Quercia, Bodaghi, and Crowcroft 2012). Their work however does not introduce nor experiment any means to revive the dormant ties. Dormant ties can be a cause of user churns. There are several previous works on churn analysis and prediction in online social networks (Karnstedt et al. 2011; Oentaryo et al. 2012) but none of them attempts to prevent churns by reducing dormant ties of likely-to-churn users.

Recently, Tian *et al.* studied the problem of maintaining active interactions among users who are already connected by online social links (Tian et al. 2010). They proposed a tie revival method to recommend friends to interact with so as to maximize the interaction connectivity among users. The proposed method has been evaluated on a large scale cellphone call network and the Facebook network without involving real users. In a similar spirit to improve information dissemination among users, Papagelis *et al.* proposed a heuristic-sampling based method to add *ghost ties* to a social network so as to reduce the average shortest-path distance between pairs of users (Papagelis, Bonchi, and Gionis 2011). Both the above works however do not include the design of recommendation mechanisms for the users to perform new interaction or to add new links. They also do not evaluate the effectiveness of their methods on real users.

Our work is unique in that it conducts a carefully designed online experiment with real users. Instead of optimizing some objective function defined based on simple assumptions about user behavior in making friends and interactions, we evaluate the effectiveness of personalized messages on reviving dormant ties of real users. Our focus is therefore on the study of factors that affect the effectiveness of messages and on the development of a principled way to evaluate the tie revival outcomes.

3 Dormant Ties in Social Networks

Dormant ties are not a new issue for social network sites, but there is no commonly adopted definition. In this section, we describe the MG network and give our definition of dormant ties.

3.1 Mobile Social Network Dataset and Active Users

Through collaborating with the operator of MG, we have gained access to the user profile data including country affiliations, gender, age and preferred language, as well as user message statistics including number of messages posted, message recipients, dates and times. These data are collected on a monthly basis beginning from January 2012 to December 2012. At the beginning of each month, we receive the previous month's profile and activity data. Our online experiment with the real MG users was conducted in October 2012.

We first identify a set of active users who could participate in our experiments should their active ties become dormant. We define an *active user* to be one who contributes at least 30 messages in each of the months from January to August 2012. The August 2012 data was the latest we had during the time active users were determined. The 30 message threshold is equivalent to sending on average one message per day over a month. Such active users will be eligible to get our treatment, and will also have sufficient propensity to send messages in response to our treatment to revive dormant ties within a month's time. After applying the above active user criteria, we are left with 1973 consistently active users. We denote this set of users as U_a ($|U_a| = 1973$).

3.2 Dormant Tie Detection

We are interested in ties that turn inactive after some months of staying active. As a churn user is one who does not chat at all over 30 consecutive days, we empirically define an *inactive tie* to be one without any two-way chat messages over 30 consecutive days in a month. An active tie is defined to be one where each user sends the other at least one message every month. In our experiment, we therefore define a *dormant tie* to be: (a) a tie active in the January-July 2012; and (b) inactive for the entire month of August 2012.

We construct the relevant *dormant graph*, $G_d = \langle U_d, E_d \rangle$ where:

- $E_d = \{(u_i, u_j) | u_i, u_j \in U_a \wedge$ (u_i, u_j) is dormant in August 2012.$\}$
- $U_d = \{u_k | (u_k, u_j) \in E_d \vee (u_i, u_k) \in E_d\}$

Among the 1973 active users, we found 1691 of them having at least one dormant tie in G_d. This shows that dormant ties are common even among active users. There are 5128 dormant ties in G_d which are potentially the targets for our message treatments. The average degree (i.e., number of dormant ties) of users in G_d is around 6. G_d therefore consists of a large connected component of 1681 active users, and other 4 small connected components with sizes not larger than 3. Since many users are involved in multiple dormant ties, we cannot treat all the ties without the potential for significant network effects complicating experimental results. We attempt to avoid this problem by requiring that each user is involved in at most one connection designated for one of the treatment or control groups.

4 Experiment Design

In this randomized controlled experiment research, we aim to answer the following research questions:

- Q1: *Are personalized messages effective in reviving dormant ties?* If so, *what type of messages will be more effective?*
- Q2: *Do user attributes affect the success rate of dormant tie revival?* In this experiment, we would like to study the role of gender and country attributes of users in reviving ties.

To answer question Q1, we design different types of personalized messages as described in Section 4.2. Q2 can be addressed by considering a randomized block design in our experiment with blocks of dormant ties defined by different user attribute combinations. Both the two dormant tie selection and randomized block design will be covered in Section 4.1. We finally describe the experiment mechanisms to send users messages and track the dependent variables.

Overview of Experiment. Figure 2 depicts the overall experiment design. The active user selection and dormant tie detection are first performed using the January to August 2012 data as described in Section 3. We further restrict the subset of dormant ties to ensure each user is represented at most once and then divide the remaining ties into treatment groups and control groups to be described in Section 4.1. Each treatment group of dormant ties is given personalized messages of the same type to be given in Section 4.2. These messages will be sent to the users involved using an automated agent. To track users clicking on URLs embedded in the messages, we also deploy a URL shortening service. Finally, the results of experiment are analyzed.

4.1 Independent Dormant Ties Selection

In Section 3.2, we determine a set of dormant ties in the dormant graph $G_d = \langle U_d, E_d \rangle$. Randomly assigning these ties to treatment and control groups would result in the same user appearing in multiple treatment groups or appearing multiple times in the same treatment group. This could introduce a number of complications.

Therefore, we select only those dormant ties from G_d such that they share no common users. We use a simple iterative removal strategy to find an independent dormant tie set. The strategy randomly selects one dormant tie (u_i, u_j) for each iteration and remove the dormant ties connected to u_i or u_j. In the next iteration, another dormant tie is selected and its connected dormant ties are removed. We repeat the step until all dormant ties in G_d are examined.

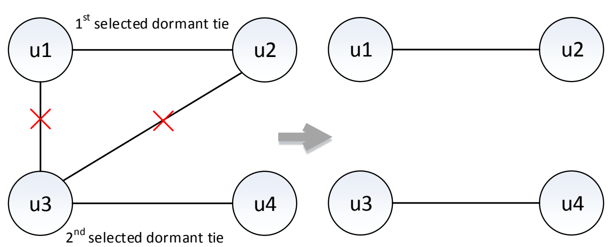

Figure 3: Independent Dormant Tie Selection

Figure 3 depicts a simple dormant graph with (u_1, u_2) and (u_3, u_4) selected as independent dormant ties. The other two dormant ties are not selected due to the already selected u_1 and u_2 in the first step. After applying independent dormant tie selection on the dormant graph G_d obtained earlier, we are left with 1338 active users and 669 dormant ties that can be used in our experiment. As users in three of the dormant ties do not carry gender and country attribute information, we exclude them and keep a final set of 1332 users and their 666 dormant ties. Recall that the users of the 666 dormant ties are active (i.e., have sent at least 30 messages each month between January 2012 to August 2012) and the dormant ties are pairs of users interacting in July 2012 but not in August 2012. Figure 4 depicts the scatterplot of number of messages exchanged between users of each dormant tie. It shows that there could be as many as 705 messages between two users of a tie in July before it becomes dormant in August. Most of the dormant ties have less than 10 messages in July.

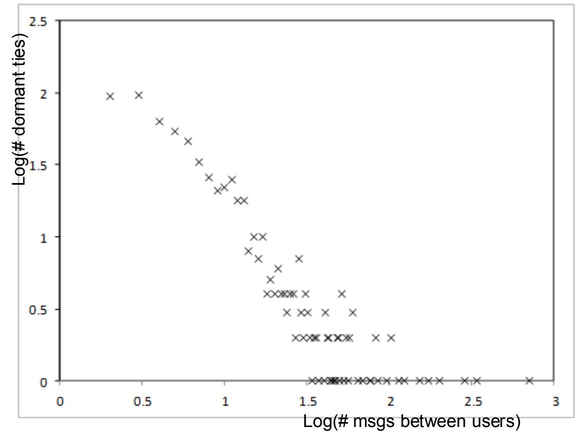

Figure 4: Message Distribution of Dormant Ties in July

4.2 Treatment of Dormant Ties

Given a dormant tie involving two users, we send personalized messages to the two users involved to examine if their tie will be revived subsequently. The message has to be personalized as we need to make the users aware of the specific target dormant tie to be revived. As it is unclear which of the two users will receive and act upon the personalized message, we decided to send both users the messages with the content appropriately crafted.

MG supports both online and offline message exchanges between users. The online messages are similar to real-time chat messages which may involve two or more online users in an interactive chat session. An offline message can be sent when the recipient is offline and the message received is stored in the recipients inbox. Offline messages involve only two users, i.e., sender and recipient. Both online and offline messages cannot exceed 255 characters while most of them are shorter than 160 characters. To make the personalized messages easy to read on mobile devices, we decide to keep them no longer than 160 characters.

Previous research in recommender systems has shown that users prefer more detailed information on their recommendation rather than just a plain recommendation (Swearingen and Sinha 2002). Generally, we can treat users with social or informational messages depending on the information contained in the messages. A *social message* contains some knowledge about friends while an *information message* contains population or community level knowledge. Bond et. al, have shown that social messages may be more effective than informational messages in mobilizing users to declare their political self-expression and to seek information (Bond et al. 2012). We therefore focus on designing social messages to our users with dormant ties.

Two kinds of social messages have been crafted in our experiment as follows:

- *Social message containing friend's activity information (M1)*: The information content of this type of message consists of messaging activity statistics of the friend in-

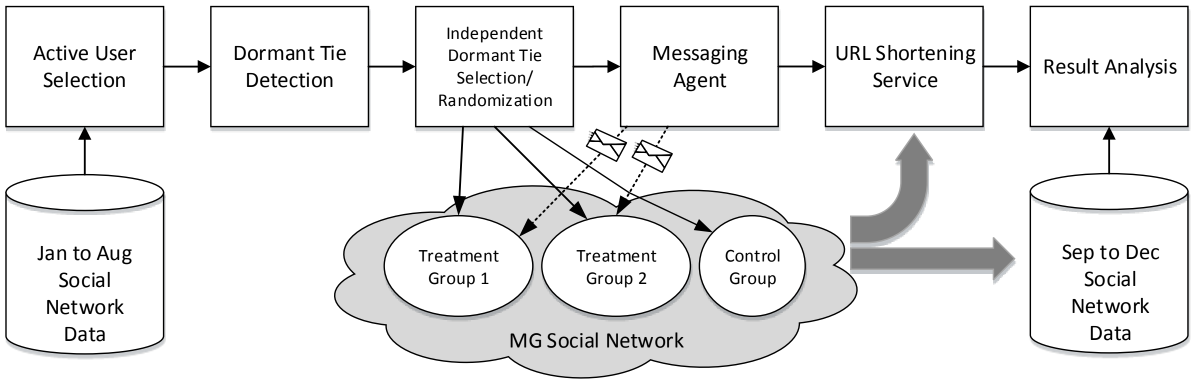

Figure 2: Experiment Design

volved in a dormant tie as shown in Table 1[2]. The intuition is that a user may interact with another user if is aware that the other user is active on the network.

- *Social message containing inter-friend activity information* (*M2*): The information content of this type of message consists of interaction statistics between mutual friends (see Table 1) of the two users sharing a dormant link, say u_1 and u_2. The intuition is that if we inform both u_1 and u_2 that each is interacting with some mutual friends of u_1 and u_2, this will arouse some curiosity in u_1 and u_2 to find out more about each other, thus reviving their common tie.

In Table 1, both the message templates contain a URL, i.e., $URL(u_2)$, to allow the treated user u_1 to click so as to quickly view u_2's profile page and to send a message to u_2 if so decided by u_1.

We use a randomized block design to assign treatments to ties. We create four blocks of ties described in Table 2 based on the similarity of gender and country of the two users. We then randomly assign three treatments within each of the four blocks:

- *Treatment group I (TGroup1)*: Users of dormant ties in this group are treated with type M1 messages;
- *Treatment group II (TGroup2)*: Users of dormant ties in this group are treated with type M2 messages; and
- *Control group (CntGroup)*: Users of dormant ties in this group are not given any messages.

The control receives no message so that we can measure the impact of the network operator's interaction. There is no systematic difference between treatment and control other than the personalized messages sent by the network operator.

4.3 Online Evaluation of Message Treatment

MG maintains several official user accounts to interact with her users providing both technical and administrative support. In our experiment, we created another official user account and operated the account using an automated agent.

[2]The message to u_2 is similar except that u_1's information is now given.

Table 2: Randomized Assignment of Dormant Ties

Group \ Block	**B1**	**B2**	**B3**	**B4**	# Ties
TGroup1	44	105	20	54	**223**
TGroup2	44	105	20	54	**223**
CntGroup	42	104	20	54	**220**
Subtotal	130	314	60	162	**666**

B1: (same country, same gender)
B2: (same country, different gender)
B3: (different country, same gender)
B4: (different country, different gender)

The agent is programmed to inject appropriate personalized messages to both the users involved in dormant ties. The personalized messages were sent out on 10 October 2012. The timing of the messages means that it is possible some ties classified as dormant could become active prior to the message being received. Since treatments were assigned randomly this was as likely to happen in either of the three treatment or control groups and has no impact on the statistical analysis of the experiment. In fact, only 38 of the dormant ties had activity in this period and they are excluded from our subsequent analysis.

Not every user of treated dormant ties received our messages. This is attributed to privacy settings of several users that prevent messages from reaching them. We tabulate (a) the number of dormant ties with only one user receiving our personalized message (denoted by *Reach-One*); and (b) the number of dormant ties with both users receiving the message (denoted by *Reach-Both*) as shown in Table 3. Note that there are some cases our personalized messages could not reach both users of dormant ties. For example, our messages were not able reach any users of 28 (13%) and 33 (15%) dormant ties in TGroup1 and TGroup2 respectively.

Considering only the reachable dormant ties, we revise Table 2 and obtain the reachable dormant tie distribution shown in Table 4. We restrict our analysis to those ties able to receive at least one message (including identifying the same subset of the control group). Since users with different privacy settings may behave differently, we can extend

Table 1: Message Table

Message Type	Message Template to u_1
M1 (with friend's activity info.)	Your friend u_2 has sent x messages. Check it out $\langle URL(u_2)\rangle$
M2 (with inter-friend activity info.)	u_3 and y other of your friends have exchanged x messages with your friend u_2. Check it out $\langle URL(u_2)\rangle$

Table 3: Statistics of Message Reach: Reach-One = Reach One of the Users in the Tie; Reach-Both = Reach Both Users in the Tie; # Treated Ties = Number of Ties where Personalized Messages are Sent; Max # Clicks = Maximum Number of Reached Users that Potentially Click the URL in the Personalized Message.

Group	Reach-One	Reach-Both	# Treated Ties	Max # Clicks
TGroup1	87 (39%)	108 (48%)	223 (100%)	302
TGroup2	79 (35%)	111 (50%)	223 (100%)	301

any conclusions to the entire population. Since the same restrictions applied to the control group, however, we can still measure the impact of personalized messages on those we are able to reach.

Table 4: Reachable Dormant Tie Distribution

Group \ Block	**B1**	**B2**	**B3**	**B4**	# Ties
TGroup1	42	88	22	43	**195**
TGroup2	39	85	21	45	**190**
CntGroup	40	92	14	50	**196**
Subtotal	121	265	57	138	**581**

B1: (same country, same gender)
B2: (same country, different gender)
B3: (different country, same gender)
B4: (different country, different gender)

There are two dependent variables we use to track two kinds of responses from the users, namely (a) *Passive engagement*: this is measured by *clicks on the URL* embedded in the personalized messages (for TGroup1 and TGroup2), (b) *Active engagement*: this is measured by the *number of messages between users of dormant ties* (for TGroup1, TGroup2 and CntGroup).

By clicking on the URL (say, $URL(u_j)$) embedded in a message, a user will get to see the profile page of the other user (e.g., u_j) of the treated dormant tie. This is also known as the passive engagement as it does not involves any real communication (Marlow et al. 2009).

We track URL clicks by creating a URL shortening service such that each shortened URL encodes the identity of the user who originally received a personalized message from our automated agent. Hence, whenever a user clicks on the URL, his identity will be recorded and the URL of his friend's profile page is returned. Depending on whether a single user or both users of treated dormant ties receive our personalized messages, we can determine the maximum number of clicks of TGroup1 and TGroup2 by $(1\times$#Reach-One$)+(2\times$#Reach-Both$)$ as shown in Table 3. We collected the click data from till the end of August.

Learning science theory says that the recall of humans deteriorates after a certain time duration (Clark and Mayer 2011). The specific time duration varies from domain to domain. In our experiment, we send the same personalized messages to the treated users again if they have not clicked our URLs in 14 days (i.e., October 24, 2012). When a user actually sends a message to his friend in a dormant tie with him in the month of October 2012, we will be able to detect this using the user data supplied to us at the beginning of November 2012.

5 Experiment Results

5.1 Effectiveness of Personalized Messages

Hypothesis tests. We first set up the following hypotheses to evaluate the effectiveness of personalized messages M1 and M2. The effectiveness can be measured by the amount of passive engagement and active engagement. The former can be accounted by number of clicks while the latter can be accounted by number of revived ties. We define a *revived tie* to be a dormant tie with at least one message between its users between 10 October 2012 and 31 October 2102. While one message alone does not imply a serious revival of activity, it is the necessary first step – and our experiment measures whether the network operator can instigate that first step with a simple message.

For passive engagement, only users in TGroup1 and TGroup2 are given personalized M1 and M2 messages respectively. We therefore compare the amount of passive engagement for TGroup1 and TGroup2 only. For active engagement, we evaluate the effectiveness of M1 and M2 messages on users from TGroup1/TGroup2 groups versus those from control group. Our null hypotheses include:

- *Null Hypothesis A* (H_{A0}): There is no difference in the number of clicks (passive engagement) between users receiving M1 messages (i.e., TGroup1) and users receiving M2 message group (i.e., TGroup2).
- *Null Hypothesis B* (H_{B0}): There is no difference in number of revived ties (active engagement) between users receiving M1 messages (i.e., TGroup1) and users in control group.
- *Null Hypothesis C* (H_{C0}): There is no difference in the number of revived ties (active engagement) between users receiving M2 messages (i.e., TGroup2) and and users in control group.

We conduct two-tailed Fisher's Exact Tests on our collected data using two contingency tables as shown in Tables 5, and 6. The resulting p-values are: (a) 0.033 for null hypothesis H_{A0}; (b) 0.0044 for null hypothesis H_{B0}; and (c) 1.0 for null hypothesis H_{C0}.

Group \ Outcome	# Click	# No-Clicks
TGroup1	147	155
TGroup2	120	181

Table 5: TGroup1 versus TGroup2 by number of clicks

Group \ Outcome	# Revived Ties	# Non-revived Ties
TGroup1	66	131
TGroup2	39	151
CntGroup	40	156

Table 6: TGroup1 and TGroup2 versus CntGroup by number of revived ties

There is moderate evidence that personalized messages of type M1 are more effective in getting users of dormant ties to passively engage their friends than personalized messages of type M2. There is stronger evidence that personalized messages of type M1 are more effective in actively engaging their friends by sending them messages. There is no evidence that personalized messages of type M2 have any effect on reviving ties. While the test results are consistent with one another, it is intriguing to see that type M2 messages do not lead to the same outcome as type M1 messages. We could not contact the users directly to solicit feedback, but a possible explanation is that users may feel that it is not necessary to contact someone which is already engaged in some active interaction with their other friends given that most ties in the network are weak.

5.2 Quality of Engagement for Revived Ties

Hypothesis tests B and C only consider revived ties defined by at least one message sent between users of dormant ties. They however do not consider the quality of active engagement among users after their ties are revived. Ideally, we would like to restore the engagement to the quality level prior to the time the ties became dormant.

In this part of our experiment, we use:

1. the average number of messages per month between two users in a dormant tie during the months of May to July 2012 as the *pre-dormant engagement quality*,
2. the number of messages between the two users in October after treatment as the *early post-treatment engagement quality*, and
3. the average number of messages between the two users in November and December 2012 as the *late post-treatment engagement quality*.

As users of different ties may exchange different number of messages as part of their normal communication, we cannot apply the some threshold to determine if the quality of engagement has been restored. We instead perform normalization on early and late post-treatment engagement qualities, i.e., items (2) and (3), dividing them by pre-dormant engagement quality. The normalized post-treatment engagement quality is 1.0 if it has been fully restored. If the normalized post-treatment engagement quality is < 1.0, the engagement quality is not fully restored. If the normalized post-treatment engagement quality is > 1.0, we say that the engagement quality is restored beyond the the expected quality.

Analysis of early effect. The early post-treatment engagement quality is derived between October 10 and the end of October, a period shorter than a month, the normalized early post-treatment engagement quality is expected to be around $\frac{2}{3}$ if it is restored to the level before the revived ties became dormant. Figures 5 depicts the early effect of personalized messages using boxplot that shows in log-scale the maximum, upper quartile, median, lower quartile, and minimum normalized engagement quality *for the revived ties*. Only the median values are shown in the figure. The figure shows that the post-treatment engagement quality values are mostly less than 1 suggesting that we are not able to restore the quality of engagement even for TGroup1. We however notice that revived ties in TGroup1 has shown better quality than those in TGroup2 and CntGroup. A few revived ties in TGroup1 manage to enjoy much higher than expected quality (e.g., 5 times the pre-treatment engagement quality). Interestingly, the revived ties in CntGroup show slightly better post-treatment engagement quality than those in TGroup2. This again could be due to M2 messages containing inter-friend activity information which actually turn users away from active engagement, but there is little evidence that the message has any effect whatsoever.

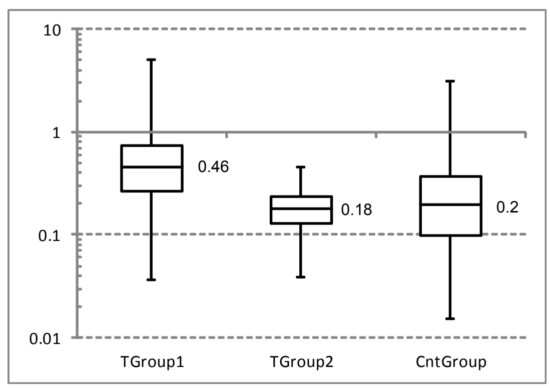

Figure 5: Normalized early post-treatment engagement quality

Analysis of late effect. We now turn to Figure 6 that depicts the late effect of personalized messages. Among the three revived ties groups, TGroup1 still yields the best engagement quality with median equal to one. This suggests that at least half the revived ties have restored or even outperformed their pre-dormant engagement quality. Revived (or more accurately the Still-Alive) ties in CntGroup has poorer quality than those in TGroup1 suggesting that without any treatment, the overall engagement quality of ties deteriorates compared with their pre-dormant engagement quality.

Again, we notice that TGroup2 gives the worst quality. This strengthens the argument that M2 personalized message has a negative effect on restoring engagement quality.

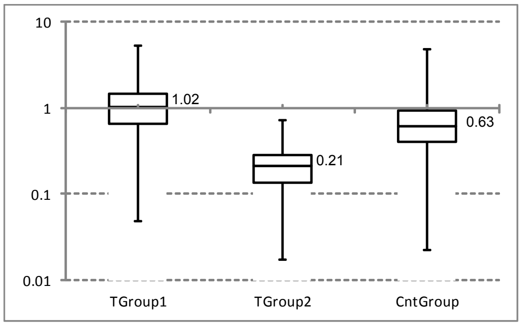

Figure 6: Normalized late post-treatment engagement quality

5.3 Other Observations

Country factor in dormant tie revival. We also investigate how the user factor blocks may affect the effectiveness of personalized message in reviving dormant ties. We first examine if it is easier to revive dormant ties involving users from the same country for ties in treatment group TGroup1. Table 8 show the distribution of revived/non-revived ties for dormant ties involving users from same countries and from different countries. The numbers in parentheses are the expected number of revived/non-revived ties. There is weak evidence that it is easier to revive ties for dormant ties involving users from the same countries – we have a two-tailed p value of 0.0505 when applying Fisher's Exact Test.

Outcome / Group	# Revived Ties	# Non-revived Ties	Total
TGroup1 (same) country)	51 (45)	98 (104)	149
TGroup1 (different country)	13 (19)	51 (45)	64
Total	64	149	213

Table 7: Same Country vs Different Countries by number of revived ties

Figure 7 depicts the normalized early post-treatment engagement quality for revived ties in TGroup1. It shows that the revived ties involving users from the same country enjoy slightly better quality of engagement (with median = 0.5) than those from different countries (with median = 0.31).

Gender factor in dormant tie revival. We next examine if it is easier to revive dormant ties in treatment group TGroup1 involving users with the same/different gender. Table 8 show the distribution of revived/non-revived ties for dormant ties involving users with the same gender and users with different genders. Again, the numbers in parentheses are the expected number of revived/non-revived ties. There is little evidence that gender similarity has any impact on tie

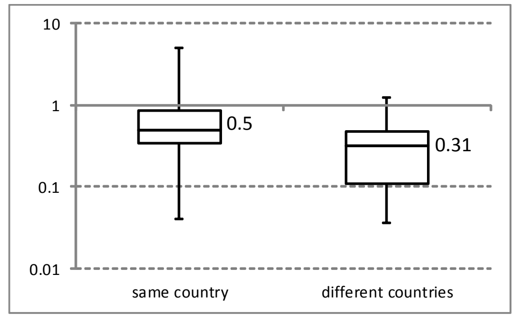

Figure 7: Normalized early post-treatment engagement quality for TGroup1

revival – we have a two-tailed p value = 0.424 when applying Fisher's Exact Test. The normalized early post-treatment engagement quality in Figure 8 (with y-axis in log scale) also shows that the ties involving users with different gender enjoy slightly better engagement quality (median = 0.5) after treatment than ties involving users with the same gender (median = 0.46).

Outcome / Group	# Revived Ties	# Non-revived Ties	Total
TGroup1 (same) gender)	19 (22)	45 (42)	64
TGroup1 (different gender)	47 (44)	84 (87)	131
Total	66	129	195

Table 8: Same Gender vs Different Gender by number of revived ties

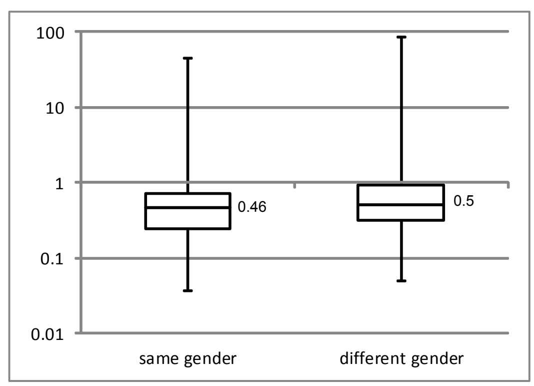

Figure 8: Normalized early post-treatment engagement quality for TGroup1

Other unexpected user feedback. Throughout our experiments, our automated agent operates a special official account to send personalized messages to treated users. Other than the user responses which we have already presented, the account also received close to 15 friendship requests from the users who received our messages. Our special user account also received 6 testimonials from the users and each testimonial carries some positive comments. This shows that users actually appreciated the personalized messages. Note that the agent was not programmed to respond to any of these user feedbacks in compliance with the rule of agent-user engagement at the MG site.

6 Conclusion

Dormant tie revival is a new research problem which has not yet seen many solutions as there is a lack of some experimental study that seeks to unravel the critical factors contributing to dormant ties. In this research, we have devised an online randomized controlled experiment to evaluate the effectiveness of personalized messages on reviving ties. This experiment design avoids the pitfalls of mixed message treatment to connected users and can be generalized for other tie based experiments.

Among the interesting findings obtained by our experiment are: (a) personalized messages with the appropriate content motivate users to revive their dormant ties but those with the "wrong" content might do the reverse; (b) the quality of engagement of at least 50% of the revived ties can be restored 2.5 months after their users receive the personalized messages containing friend's activity information; and (c) dormant ties involving same country users are easier to be revived.

This online experiment represents an early effort to evaluate the effectiveness of new social network services such as the personalized messages. Such a highly automated live experiment is able to scale with large social networks and to produce statistically sound results. The work can also be further extended to consider dormant ties involving less active users, dormant ties that are originally weak. Finally, with the known revived and non-revived ties after personal message treatment, we can continue to develop methods for recommending new users who can benefit from the personal message reminders and methods for predicting dormant ties that can be revived using personal messages.

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