How Social Networks Dynamics can Affect Collaborative Decision Making on Crowdfunding Platforms

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Abstract. Despite the increasing phenomena that social interactions among contributors by emerging technologies influence crowdfunding decision making, little is known about how social network dynamics formed by these social interactions affect contributors' decision making. Drawing on a data set collected from an economic experiment conducted on Amazon Mechanical Turk (MTurk), we use a social network approach to investigate the effects of social network structure on collaborative decision making under a crowdfunding setting. Comparing four standard network structures – null, star, weak ties, mesh - Our analysis shows that the mesh network yields the best group collaboration performance, with social information displayed. The result of this research provides a specific and nuanced angle of the importance of social networks in emerging technology – enabled online crowdfunding.

Keywords: Crowdfunding decision making · Social network structure · Social information

1 Introduction

Crowdfunding is collaborative work - a group of people make mutual effort in reaching a fundraising goal. Contributors or backers at crowdfunding platforms always refer to each other's crowdfunding decisions when they make their own crowdfunding decisions. The Internet has offered entrepreneurs and contributors a new interaction and influential channel to support projects by social network and social information sharing Recent empirical studies have investigated the impact of crowdfunding platform design factors on contribution behavior [27], but the effects of social network on contributors' behavior have received less attention. Social network structure is of special relevance with backers' decision making if we interpret crowdfunding platforms as networks of interactions among backers and project creators. For instance, many crowdfunding sites have facilitated social media tools (Facebook and Twitter sharing) that promote social interactions. Through these interactions, contributors at crowdfunding platforms can refer to, learn from, and cooperate with each other's contribution decision making to reach the fundraising goal. As a crowdfunding project is a strategic campaign that requires

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backers' mutual support and collaboration to reach a fundraising goal, it is essential to understand how different network structures help with social interaction that may influence contributors' decisions to reach the fundraising goal.

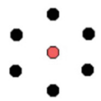
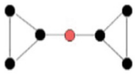
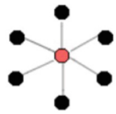
Social network structure is defined as the presence of regular relationship patterns within a single social network [25, 26]. Under online settings, social network structure typically applies to the pattern in which people interact with people by many IT artifacts. Previous literature from economics, finance, and information systems recognize social network structure relates to behaviors and well-being of people in a society. Many view social network structures as information-sharing channel which influence the economic preferences and consequences [5, 17, 20]. For instance, Allen et al. [1] examine the effects of social interaction on P2P lending and find socially connected areas with more Facebook's friendship linkages have more lending activities. In crowdfunding related settings, Thies et al. [24] indicate that social networks through social media such as Facebook sharing have positive effect on backers' funding decision. Suri and Watts [23] studied network structures on cooperation behavior and find that people conditionally cooperate in response to their neighbor's decision. Fowler and Christakis [14] implements s series of one-shot public goods experiments and find that cooperation can cascade across three degrees of separation in a network. These findings provide primary motivation for this study. However, a more nuanced investigation of how individuals react to different social networks via social interaction and thus cooperate with each other during the crowdfunding is needed.

Motivated by the practical but complex effect of social network structure on crowdfunding behaviors, in this research we examine typical social network typologies on crowdfunding contribution behavior and believe that this assessment is crucial in order to understand whether and which network structure affect contributions behavior most. In addition, there is a clear need to examine how cooperation and collaboration behavior involve and evolve in different network structures as information dissemination channels. Thus, this study attempts to answer the following research question:

How does social network structure affect contributors group collaboration performance on a crowdfunding platforms?

We design an experimental crowdfunding platform deployed on Amazon Turk that enables us to manipulate social network structure and configure four standard types with different degrees of connectedness: null, weak-tie, star, and mesh network (see Table 1). We also manipulate a second variable of interest, social information, which refers to participant-specific game information shared in the network. We conduct a series of experiments on Amazon Mechanical Turk (MTurk) by inviting online individuals play a fundraising game arranged on 4 typical typologies of social networks. Data were collected from MTurk workers as participants and analyzed with one-way ANOVA and regression methodology.

Table 1. Network structure typology and centrality measures

Network structure typology and centrality measures					
Net- works in 7 points		**Null** 	**Weak-tie** 	**Star** 	**Mesh** 
	Measure:				
Community and Social Identity	Closeness Centrali- ty: CC ' (Pk)	***** ** (Inva- lid)	0.10, 0.09, 0.09, 0.07, 0.07, 0.07, 0.07 (Average: 0.08)	0.17,0.09,0.09, 0.09,0.09,0.09, 0.09 (Average: 0.10)	0.17,0.17,0.17, 0.17, 0.17,0.17, 0.17 (Average: 0.17)
Social Identity		Null	< Weak tie	< Star	< Mesh
Connectedness and So- cial Dis- tance	Betweeness Centrali- ty: CB ' (Pk)	***** ** (Inva- lid)	9,8,8,0,0,0,0 (Average: 3.57)	15, 0,0,0,0,0,0 (Average: 2.14)	0,0,0,0,0,0,0 (Average: 0)
Social Distance		Mesh	< Weak tie <	Star	< Null

2 Theory and Hypotheses Development

2.1 Social Network Typologies

Many previous literature in crowdfunding and micro-financing have different conceptualizations for social network dynamics. For example, Hong et al. [16] have placed "network embeddedness" as a characteristic of social network that has an important role in influencing crowdfunding campaigns via social media. They acknowledge that the nature of embeddedness in social networks lead to greater social influence and higher social information sharing. Among the sociological and economic literature, the most popular view is "social capital" view that treat social ties (especially weak ties) as pool of social assets or resources embedded in social networks [3, 19, 21]. Other research conceptualizes social network dynamics as social connections that can improve people's financial performance in group lending [18]. These research measure cultural and (or) geographic proximity as a proxy of social connection between each pair of individuals. Of all the previous studies, the major concern is whether social network dynamics formed by social interactions significantly impact users' information intake, evaluation, and decision making. We exploit and discuss this question under a crowdfunding setting in this study, since such an assessment is crucial in understanding the role of social network on contribution performance, as well as helping with design of crowdfunding platforms to reap the benefits of social networks.

We design four typical types of social network structures that aligned with the typologies conceptualized by Freeman [15] (See Table 1), and identify these structures with social distance theory and social identity theory in an online crowdfunding setting. The reason we select and explore these four typologies is that they each represent a type of organization of structure that could be synthesized and compare with each other by their different structural properties. In particular, we use closeness and betweenness centrality measures theorized by Freeman to categorize these four typologies and theorize our hypotheses. Closeness centrality measures one's closeness to the others, and it indicates how "close" one's relationship with others based on a calculation of reciprocal of sum of the shortest path between him or herself as a node in a graph and all other nodes. It also can be regarded as a measure of how fast it takes to spread information from a node to the others. We can observe that the Mesh network yields the highest closeness between its all pairs of nodes, than the Star, Weak tie, and Null. Betweenness centrality is another measure of centrality and is calculated by the number of times a node that lies on the shortest path between other nodes. The higher the betweenness, the lower the social distance score for strategically located people. Therefore, the Mesh yields the shortest social distance on average than the Star, Weak tie, and the Null, by lowest betweenness centrality. We rank each type of networks with the aforementioned closeness centrality and betweenness measures, and theorize our hypotheses using social identity theory and social distance theory.

We manipulate our experiment treatments based on the four types of structures in an online fundraising setting that a fundraising project solicits donation from an online community that consists of 7 members. The null structure is designed as a pattern where members as nodes do not establish any relationship with the others. In the star structure, however, the central node can represent a community leader connecting to the other nodes. Members independently communicate to the leader who is assumed to be more structurally central than others. The weak tie structure represents two loosely connected groups linked by a leader (or influencer) who is supposed to transfer information across the two groups. Finally, in the mesh structure, every member can communicate directly with each other, but there is no essential "leader" role in this structure, representing a democratic community.

Previous studies have cited links between the structural properties of social network and sharing and creative behavior in organizational context [2, 13]. Current literatures in crowdfunding suspect structural properties of a social network may influence decision making. For example, Fowler and Christakis [14] predicts social networks influence the evolution of contribution behavior by helping spread the cooperation norm across individuals in a network. Thus, we infer that social network links and ties in social network structure help bridge individuals and information gap by promoting information sharing, which will influence people's decision making in crowdfunding. Thus, we expect

H1: Overall, Social network structure matter for crowdfunding decision making, measured by group collaboration performance.

2.2 Community and Social Identity Theory

We define community as a property of such networks that are highly compact and almost everyone in the networks has relational ties with each other. Social identity theory has defined social identity as an individual's perception about his or her membership and belonging to the social group or community We relate community with social with social identity since the sentiment of social identity tends to depersonalize the individual but contribute to the development of group or community attachment and community success especially as one develops self-categorization and collective-identification that relate to perceived similarities among group members [10, 22]. For the mesh network structure, it possesses the highest graph closeness centrality since it has most links and bridges between all individual which promote communication and perceived similarity among group members, we infer the mesh network yields the highest group collaboration performance by linking and bridging individuals to efficiently cooperate with each other. Thus we expect

Hypothesis 2: *Degree of social identity is positively associated with group collaboration performance.*
Hypothesis 2a: Degree of social identity is positively associated with total group contribution.
Hypothesis 2b: Degree of social identity is negatively associated with distance to threshold equilibrium.
Hypothesis 2c: Degree of social identity is positively associated with success rate.

2.3 Connectedness and Social Distance Theory

Social connectedness by previous literature has been defined as intensity of friendship links, in particular, by geographic distance [4]. Social connectedness is of great relevance with users and group decision making if we explain it from the impact of social distance theory. Previous studies [11, 12] have conceptualized three dimensions of social distance: affective social distance, normative social distance, and interactive social distance. Here, we take interactive social distance which focuses on the frequency and intensity of interaction facilitate social distance of two social groups. By communicating and interacting with each other, interpersonal bonds arise and social distance between two social groups decrease [22]. For instance, researchers found that entrepreneurs who build a network of direct ties could shorten the social distance, induce a trustful relationship in which both parties are motivated to maintain, and generate a sense of obligation and cooperation between investors and them. Previous literature also find that decrease of social distance promotes social interactions and empathy among individuals which result in higher levels of cooperation [6]. That is to say, when individuals' social distance decreases, "others" are not just some unknown ones but ones deserve other-regarding behaviors. Because the mesh network gains the lowest social distance by owning highest number of strategically located people that result in lowest betweenness centrality, than the star, weak tie and the null, we expect

Hypothesis 3: *The lower the social distance is, the higher the group collaboration performance yields. Therefore, degree of social distance is negatively associated with group collaboration performance.*
Hypothesis 3a: Degree of social distance is negatively associated with total group contribution.

Hypothesis 3b: Degree of social distance is positively associated with distance to threshold equilibrium.
Hypothesis 3c: Degree of social distance is negatively associated with success rate

2.4 Group Collaboration Performance

Our theoretical concern is group collaborative decision making by group performance in this study. In this study, we define collaboration as a cooperation process in which individuals interact, share information, and make mutual effort to reach the fundraising goal. We measure group collaboration performance by 1) group total contribution 2) distance to threshold equilibrium 3) Success and failure rate.

These three dependent variables each points to a different but important angle of measurement of group collaboration performance. Group total contribution is the indicator of generosity of contributors [8, 9] The second measure distance to threshold equilibrium is calculated by the absolute value between group total contribution and the economically most efficient outcome (threshold value 17.5 points). A shorter absolute distance to threshold indicates the group coordinated closely around the threshold, which shows efficiency of collaboration regardless of whether group total contribution is surpass or below the fundraising threshold. Finally, the third measure, success and failure rate, calculated by rounds that successfully reach the funding goal, indicates the principle success of the collaboration (See Fig. 1).

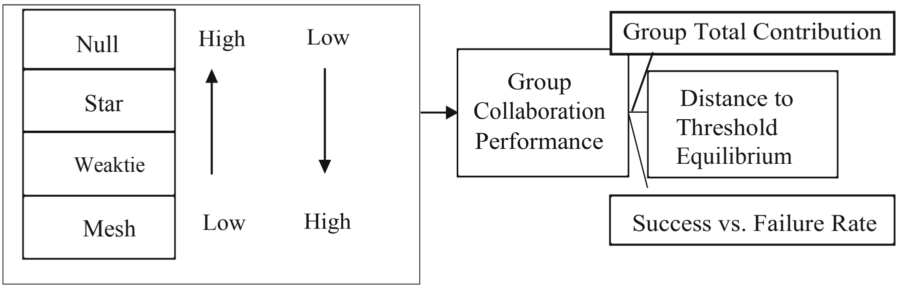


Fig. 1. Research model

3 Research Methodology

3.1 Experimental Design

We implement our fundraising game by adapting a widely used public goods game from the economics literature [8]. It allows us to theoretically examine optimal, rational collaborative decision making behavior. Our use of this fundraising game is aimed to present the participants with non-trivial tradeoff decisions. The rational is that if the group reaches the fundraising goal it will suffice to implement the proposed project. Hence, there is the question of how much should the individual group member contribute, and what is too little and what would be too much to efficiently reach the goal? How does the group respond to possible free-riding behavior? To what extend does the group learn to collaborate better over the course of multiple, repeated rounds of the experiment. This represents a non-trivial collaborative decision making problem.

The experiment is designed with a financial incentive to induce rational decision-making behavior. If the group contribution does not reach the fundraising goal, no reward will is be given to the contributors But if it succeed, every contributor individually receives a fixed reward for successfully supporting the project. In either case, the contribution amount will not be returned. Our model is different from all-or-nothing mechanism in some crowdfunding sites such as Kickstarter in that we don't give back contribution if members do not reach the fundraising goal. We design our experiment mechanism as such because we need to induce a non-trivial decision for each participant to either cooperate to contribute to the goal, or contribute an amount cautiously since contributions out will never be returned. Through this way, we can examine group collaboration behavior more directly.

During the fundraising campaign, the stated funding goal is 17.5 game dollars. We convert the threshold 17.5 from Cadsby and Maynes paper based on our group size of 7. Each session involves 7 individuals who are each provided with an endowment 10 game dollars. Each participant must privately decide how much to contribute, Ci, Ci $\in$ [0, 10] where i $\in$ [1,…, N] to the fundraising project. If the threshold 17.5 is reached (project succeed), each participant will receive a reward of 5 game dollars; If not (project failed), each participant receive nothing. After each round, participants are displayed with others contribution amount based on the social network assigned to them, as well as their own earnings so that they have a clue of how many to contribute in next round. The game is played repeatedly 10 rounds. The points the participants earn in each round will be converted to U.S. dollars at the end of the game, according to the conversion rate: 1 point = 6 cents. Each participant is able to earn around \$3 plain fee plus an average of \$5–\$10 performance-based payment, which was paid out after the game. (See feuqations below and Table 2. Experimental Parameters). Ui (individual's payoff) =

$$10 - \text{Ci},\ \text{if}\ \Sigma_{i=1}^{N} = \text{Ci} < 17.5 \tag{1}$$

$$10 - \text{Ci}\ + 5,\ \text{otherwise} \tag{2}$$

Table 2. Experiment parameters

Group size:	7
Endowment	10
Threshold level	17.5
Reward level	5
Rounds	10 rounds
Conversion	1 = 0.06 US dollars

3.2 Procedures

We hire participants through Amazon Mechanical Turk (MTurk) where a flat participation fee plus performance payment are paid to the platform workers. We use MTurk workers as our participant pool because MTurk is a suitable platform for interactive experiments where participants need to wait for others to form a group, exchange information, and make joint decisions. MTurk workers are recruited through posting of HIT on the MTurk platform where workers can freely accept the HIT. We manipulate one treatment variables, social network structure at four levels (null, star, weak-tie, mesh). Conceptually, we model also social information facilitation but keep it fixed at one level in the current study (social information present). We separately measure three dependent variables (total group contribution, distance to equilibrium, success rate). The experiment was conducted with a total of 12 sessions, with 3 sessions for each of the 4 network structures. A total of 84 participants are recruited. The subjects are organized into a group of size 7 per session to play the fundraising campaign.

We manipulate online social network structures by social profile sharing and at the same time displaying social information (others' contribution amount). At the beginning of the experiment, we induce the participants' perception of social interaction by asking participants to answer a series of Facebook-like questions and complete their social profile (see Fig. 2). Then, to induce a sense of social interaction to other members in the group, participants as community members will share their social profile based on the social network structure they stay in. For instance, in the star network, User 4 as a regular member can only see User 1 (influencer)'s contribution amount while the influencer can see all others' contributions (see Fig. 3). These two features together allow us to draw social interactions between participants by knowing and learning from others' social information and contribution amount. These two features are automatically created for the participants when the experiment begins based on the given social network structure in the particular treatment. The profile sharing is done automatically done by the system after participants complete the profile creation. The profiles are only shared along the direct connections in the given network structure. In the null structure, no profiles are shared, while everyone gets to see everyone else's profiles in the mesh structure. In the star structure, everyone gets to see the leader's profile but none of the others, while the leader sees everyone's profiles. Similarly, in the weak-tie structure, the influencer (leader) sees profiles from both subgroups, while the peripheral members only see some profiles from members within their subgroup.

4 Data Analysis and Preliminary Findings

4.1 Descriptive Analysis and Group Homogeneity

In total, 12 sessions (groups) of the experiment were conducted with 3 sessions (groups) run for each type of the social network structure. A total of 84 participants Data were collected from each group over 10 repeated rounds of the experiment. As one of the assumptions for running ANOVA test, group homogeneity should be tested. We ran Levene's test and get $p = 0.043$ which is close to the recommend $p = 0.05$ value that is satisfying ANOVA test group equal variance assumption (See Table 3). We proceed

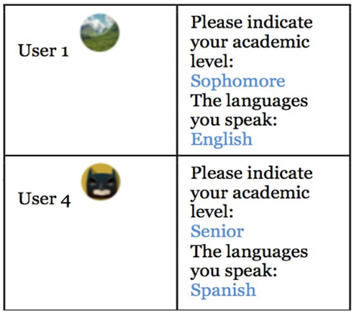


Fig. 2. User 1 screen for social profile sharing process in the star network

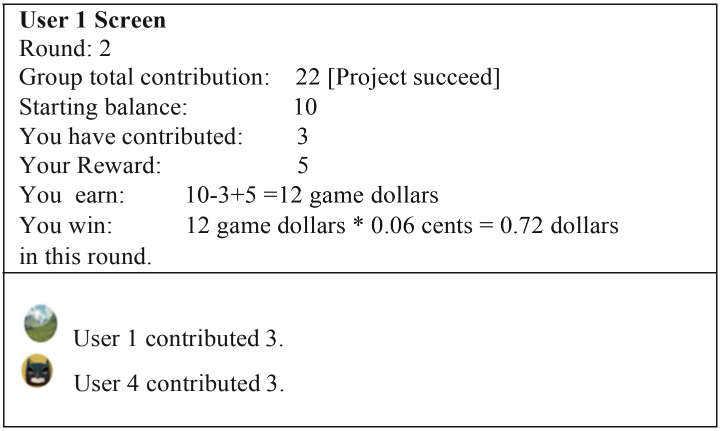


Fig. 3. User 1 screen for contributing screen in the star network

to run an ANOVA F test to test whether the 4 network structures differ significantly in influencing group collaboration performance by group total contribution.

Table 3. Group homogeneity test

Levene statistic		df1	df2	Sig.
Based on mean	2.80	3	126	.043
Based on median	2.72	3	126	.047
Based on median and with adjusted df	2.72	3	115.13	.048
Based on trimmed mean	2.81	3	126	.042

Table 4. Descriptive for group total contribution

N		Mean	Std. deviation	Std. error	Minimum	Maximum
Null	30	26.00	4.71	.86	15.00	35.00
WeakTie	30	25.10	3.74	.68	15.00	33.00
Star	30	23.97	5.75	1.05	15.00	37.00
Mesh	30	22.40	4.15	.76	17.00	33.00
Total	120	24.37	4.78	.44	15.00	37.00

4.2 Group Total Contribution

In total, 12 sessions (groups) of the experiment were conducted. ANOVA test (see Table 5) shows that the 4 social network structure yields significantly different group total contribution with a p-value of 0.007. Group members contribute most in the null (mean = 26.00) and least in the mesh network (mean = 22.40), which indicates a decreasing trend due to the increased interaction of the members within a network structure (see Table 4). This result support hypothesis 1 that group collaboration performance by total contribution differ significantly across four structures. However, contributing more than the threshold is inefficient as it will not bring more reward to the members and may cause a waste of social welfare. Therefore, we present the second dependent variable, distance to threshold equilibrium, on group collaboration performance.

Table 5. ANOVA test of group total contribution variance

Group total contribution					
Sum of squares		df	Mean square	F	Sig.
Between groups	260.03	3	86.68	4.206	.007
Within groups	2596.77	126	20.61		
Total	2856.80	129			

4.3 Distance to Threshold Equilibrium

Figure 4 displays group total contribution by each of the four networks, and Fig. 5. illustrates the averaged 10 rounds distance to threshold equilibrium by the four network structures. Group members in the mesh gets the closest to the threshold equilibrium (mean = 4.90) than the other network structures (Star = 6.47, Weak tie = 7.60, Null

= 8.50), which indicate the mesh groups collaborate most efficiently by getting close to the fundraising goal. The ANOVA test displays significant differences among the four structures with F = 6.185 and p = 0.001. This suggests averaged distance to threshold equilibrium across four network structures differ significantly. Overall, the mesh network yields the best group collaboration performance by collaboration efficiency, following by the star, weak tie, and the null. The result supports hypothesis 2a, 2b and 3a, 3b that lower social distance and higher social identity among members help passing information across individuals in a network and bring high group cooperation via low distance to threshold equilibrium. In a mesh network, individuals are more likely to see and evaluate the others' contribution amount then make their cooperative or non-cooperative decision.

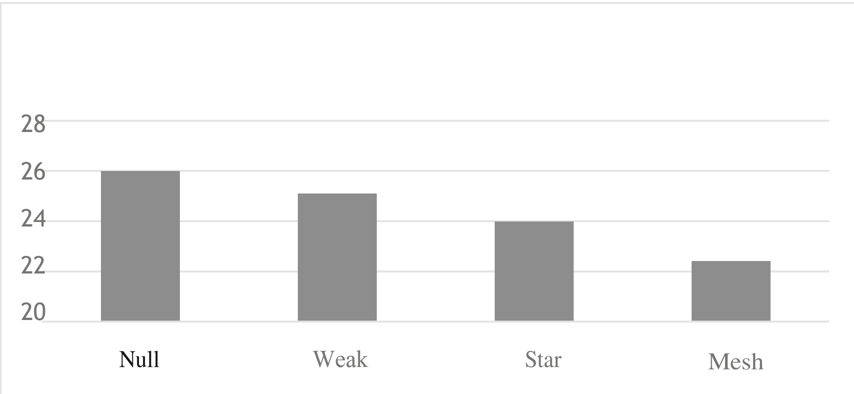


Fig. 4. Group total contribution by 4 social networks

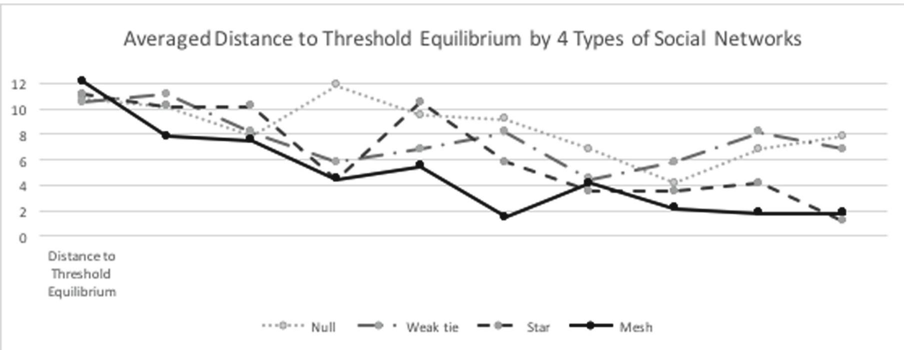


Fig. 5. Distance to threshold by 4 social networks

Because we would also like to know how often the project was successfully funded over the 10 rounds, we count the number of rounds that reached the group contribution threshold level. We can observe that the star groups yield the lowest success rate, which suggest a lower cooperation and collaboration accuracy in achieving the threshold equilibrium – 17.5 point, than the other 3 groups. The results are not quite supporting our hypothesis H2c and H3c.

Our analysis indicates a wider standard deviation of contributions among the star group members. The star network limited connections between members by only depicting leader's decision to each of the other group members. We may infer that A dyad relationship may not act as efficiently as a triangle to transmit useful information among the members. Members could not observe how many points others have contributed but only the leader's, thus leading to a deficiency in calculating themselves contribution points to efficiently coordinate around the threshold but only following the leader's decision making. Table 6 presents the success rate statistics for each of 4 network structures.

Table 6. Averaged distance to equilibrium and public goods project success rate

Social network structures	Mesh	Star	Weak tie	Null
Success rate: number of rounds project was funded	29/30	27/30	29/30	29/30
Averaged group distance to threshold equilibrium	4.90	6.47	7.60	8.50

We conduct regressions (Table 7) for average group total contribution in 10 rounds (first column), average group total contribution in last 5 rounds (second column), and average distance to threshold (third column). We make first column dummy variables and set the mesh structure as baseline, which means that group contribution in the star network is 1.567 game dollar higher than the mesh; group contribution in the weak-tie network is 2.700 game dollar higher than the mesh; and finally, group contribution in the null network is 3.600 game dollar higher than the mesh. Since extra amount of group contribution can cause waste of resource which cannot be used into the crowdfunding project, we conclude that group members in the mesh network achieve the best and most efficient collaboration performance, since their members cooperate most closely around the project threshold of 17.5 by arriving a group contribution at 22.4 game dollars. All of the social networks yield significant effect on group collaboration performance, except the star network ($p = 0.194$). Interestingly, the last 5 rounds average results are interesting because they indicate a higher R square (0.261) that may show greater social network's effect on group collaboration performance, suggesting a propensity that members collaboration ability and learning effect evolve more quickly and significantly in the last 5 rounds of the fundraising campaign. We involve distance to threshold as another important dependent variable. Regression to distance to threshold yield same coefficient and p-value with those for the GT (group total contribution) because in our data, all groups contributed over the threshold, which means no groups made a group contribution lower than 8.75 (a threshold under which free-riding tendency is determined). However, we include this dependent variable since it is another essential measure of group collaboration performance that is distinct with group total contribution. A higher group total contribution indicates generosity of group members but not necessary the efficiency of their collaboration; instead, closeness to threshold equilibrium indicates group collaboration efficiency-how close the members contribute around the threshold. Finally, we also examine the success and failure, since collaboration efficiency by distance to threshold can be either positive or negative. A negative number means a group contributes under threshold and project fails to get enough fund. From Table 7 we can conclude that the mesh still yields the best collaboration performance. However, the star network is unstable since it yields that lowest success rate.

Table 7. Regression table (coefficient, t - test statistics and p - values)

Independent variables	Dependent variables		
	GT (10 rounds)	GT (last 5 rounds)	DTT
Constant	22.400 (26.392) (0.000)	19.800 (22.100) (0.000)	4.900 (5.773) (0.000)
Null (compare to Mesh)	3.600 (2.999) (0.003)	4.667 (3.683) (0.001)	3.600 (2.999) (0.003)
Weak tie (compare to Mesh)	2.700 (2.249) (0.026)	4.400 (3.473) (0.001)	2.700 (2.249) (0.026)
Star (compare to Mesh)	1.567 (1.305) (0.194)	1.333 (1.052) (0.297)	1.567 (1.305) (0.194)
Adjusted R square	0.080	0.261	0.080

5 Conclusion

In this study we provide strong experimental evidence that social network structure with sufficient social information does matter to group collaborative decision making in a fundraising campaigns. Our experiment has offered us a unique opportunity to directly observe the influence of social network dynamics on the contribution behavior in crowdfunding through MTurk experiments. Group in mesh network yields the better collaboration performance than the other three social network structures by passing social information most efficiently through the most connected channels. People in the mesh network cooperate most closely around fundraising goal. This suggests that people exposed to a highly - connected social network where everybody is linked with each other tend to coordinate and collaborate most efficiently around the threshold. From a social psychology perspective, highly connected social network may escalate the helping and social learning behavior that each member accommodates behavior by seeing and knowing what others are doing through social interaction during profile sharing and contribution procedures.

The investigation as well as the results of this study have important implications for project initiator or promoter as well as crowdfunding sites design in IT-enabled environments. Crowdfunding sites as well as project initiator might seek intentionally to leverage social interactions to nudge contributors to form more online social relationships. In addition, showing sufficient social information, such as crowdfunding goal and other members' contribution amount, provide especially important background for online contributors to infer and adjust their decision to reach the crowdfunding goal.

One limitation of this preliminary study deals with the typical but small network typology, which may limit the generalizability of the findings. Future research could investigate more topologies of structures by involving larger and more complex networks in field experiment to examine whether the results still hold. Our research takes a first step in understanding the domain of social network structure with social information on crowdfunding contribution decision making. We hope our analysis provide initial evidence of impact of social network dynamics on crowdfunding decision making, which serves reasonable recommendations to the crowdfunding platform as well as project initiators.

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