Users' Participation Motivation and Behavior Patterns in Online Health Community: A Game Theory Viewpoint

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Abstract

Online health communities (OHC) are one of the most promising health-related social media services that have been developed, increasing in numbers and users in the past decade. Studies show that patients can benefit from participating in OHC, including obtaining information and knowledge, receiving support, and releasing mental stress. The purpose of this study is to identify the motivation behind users' participation and to understand their behavior patterns across time in the online health community. A game theoretic model is used.

1. Introduction

An online health community (OHC) is a platform where people with common interests or similar health conditions gather virtually to ask/answer questions, share experiences, and provide/receive support, as well as exchange healthcare knowledge. Evidence in the literature has confirmed that the widespread use of OHCs has dramatically changed illness management and self-care [1, 2], enhanced the patient-physician relationship [3], and improved decision making and increased survival time [4-6]. However, a large number of online health communities that were initially active vanished quickly or saw reduced activity across time [7]. It is important to both health care providers and patients to have access to successful and well-maintained OHCs [7]. As such, this study focuses on the motivations that drive users to join, stay in, and participate in discussions on OHCs. This is because users may have changing priorities when they participate in the activity across time. For example, in the initial stage, users may focus on what they can get from the community, while in the later stage, their priority may evolve to what they can provide to the community. Our key interest of this study is to understand why and how the users change their behavior over time. To be specific, we use game theory to analyze users' motivation and their behavior patterns.

2. Literature review

The Information Systems professionals have been interested in the technologies that enable online communities, and they have produced a rich literature on users' participation in online communities. The success of an online health community depends on the members' loyalty in terms of continuing participation [7-9]; in other words, an online community will not survive without lasting user motivation and participation [10-12]. As such, it is necessary to understand the people who will use the service, the goals or tasks they have, and their context of use [13]. Since the goals or tasks users have in online communities are often seen in relation to motivational issues [8, 14, 15], failing to attract enough members to sustain themselves has been a primary reason that many online communities stall [16]. Because of this, motivation theory has guided researchers to study factors that inspire people to take part in an online community [17]. Existing literature on loyalty from the perspective of motivation includes social identity theory [18, 19], self-presentation theory [20], and self-efficacy theory [21]. These studies suggested several powerful factors such as experiences and needs [22], supportive and sociable relationships [23, 24], feelings of belonging [25-27], a sense of shared identity [17, 28], positive users' feedback [29, 30], and the users' perceived value-added [31, 32].

Another stream of literature touched on the issue from the perspective of communities' sustainability, suggesting that online communities provide benefits and experiences that the members seek in order to gain end-user loyalty [8, 33]. For instance, researchers have proposed rich descriptions of design features to increase members' likelihood of joining and remaining in online communities [24, 34, 35]. These studies provide rich insights into online community design and management, but they neglect

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the role of members' individual characteristics and goals and how these will affect their decisions concerning continuing participation.

Some studies have made solid theoretical contributions to the literature by investigating online communities from an individual user level of analysis. These studies suggested that the reasons individuals participate in online communities include being attracted by community benefits [33], a sense of reciprocity [36, 37], and a desire to help the community [38, 39]. These studies provided solid evidence on the user's motivation, though they neglected how the user's behavior changes over time.

In addition, there have been few studies that address why many initially active communities have degenerated or vanished after a couple of years of development due to low user activity [40]. This is because many online communities successfully attract enough members but fail to sustain themselves [16]. This is crucial in health-related social media because OHCs can best serve their members when they meet the ongoing needs of their membership across time [41]. In the initial stage, users could be interested in the beneficial information and support they could get from the community; whereas in the later stage, users transition to loyal members and pay more attention to the quality and environment of the community. The members in an OHC move through a pattern of these stages that are described and explained based on their developing needs and characteristics. Thus, understanding these needs and characteristics will help scholars and practitioners better explain users' evolving behaviors.

However, studies related to health communities have been focused on perspectives that are different from users' motivation and behavior patterns over time, like understanding the helping process of online health communities [42-44], social networking service support types [45-47], reasons to provide support [48, 49], and users' continuing intention of co-creation [50]. To our best knowledge, a study on user motivation and behavior with respect to continuing participation in OHCs has been lacking. This research gap presented us with two research questions: 1) What are the motivations behind online health community members' participation? 2) How do these drivers work together to affect members' strategies of participation in different stages? In this study, we seek to understand users' motivation behind continuing participation in an online health community, and we establish a game theoretic model to investigate the factors that affect user's participation behavior.

3. Theory building

Game theory is the study of multi-agent decision problems. It utilizes mathematical models of conflict and cooperation between intelligent, rational decision-makers. Game theory is widely used in the field of economics, political science, psychology, and biology, as well as other social science that involves individuals who have different goals or preferences [51].

In game theory, a game refers to any social situation involving two or more individuals, which may be called the players. There are two basic assumptions that game theorists generally make about players: 1) they are rational, and 2) they are intelligent. A decision-maker is rational if he makes decisions consistently in pursuit of his own objectives. Building on the fundamental results of decision theory, we assume that each player's objective is to maximize the expected value of his own payoff, which is measured in some ordinal utility scale.

Originally, game theory addressed zero-sum games, in which one person's gains result in losses for the other participants. As it evolved, game theory was applied to a wide range of behavioral relations and is an umbrella term for the science of logical decision making in humans, animals, and computers. Modern game theory, which starts with the work of von Neumann [52], began with the idea of the existence of mixed-strategy equilibria in two-person zero-sum games. Neumann and Morgenstern [53] wrote a book on games and economic behavior that considered cooperative games of several players. The theory was then developed extensively by many scholars, and there are different types of games that are studied: cooperative/non-cooperative, symmetric/ asymmetric, zero-sum/non-zero-sum, simultaneous/ sequential, perfect information/ imperfect information, two-player/many-player, and so on .

Evolutionary game theory [54] studies the behavior of a large population of agents who repeatedly engage in strategic interactions. Changes in behavior in the population are driven either by natural selection or by the application of myopic decision rules by individual agents. While traditional game theory assumes agents are completely rational with perfect information, evolutionary game theory upholds that agents learn, adapt, and evolve with a focus on the population dynamics that emerge due to boundedly-rational individual behavior.

Evolutionary game theory has two core concepts — the Evolutionarily Stable Strategy (ESS) and the Replicator Dynamic (RD). An ESS is a strategy which, if adopted by a population in a given environment, cannot be invaded by any

alternative strategy that is initially rare. Two factors affect an ESS. The first factor is the randomness and mutation of agents. A mutation in this context means that one or more agents stochastically choose a different tactic than what they were previously playing. The selection mechanism is the second factor that affects an ESS. It depicts how a player chooses their behavior based on trial and error, and it is an inherent part of the evolutionary process. While the initial trial and error determines an initial solution with respect to behavior, it may not be the best one, and its payoff may be higher or lower than the population average. However, the payoff of the final solution derived after learning and imitating will be better than the population average, and the second core concept of evolutionary game theory, the Replicator Dynamic (RD), describes how the game moves to that result. The RD constructs an explicit model to capture the dynamics of strategy changes in the population[55]. Specifically, the RD postulates gradual movement from "worse" to "better" strategies. RD and ESS describe the dynamic evolutionary process toward the stable equilibrium and the state of stable equilibrium itself, respectively.

The users in the online health community can make the decision to stay or leave at any time during their participation. As a rational individual, a user will make the decision based on their own judgment as they pursue their objectives. We use evolutionary game theory to capture the dynamic process of learning and sharing performed by the participants of the online health community in response to the observation and expectation of the other users of the community and the community as a whole.

4. The Model

In this section, we use the concepts of ESS and RD to demonstrate how the benefits and costs of members drive their motivation and behavior when it comes to participating in discussions on OHCs. For OHCs to thrive and provide their healthcare benefits to users, it is essential to fully understand these issues.

Butler [56] proposed that participation in the online community can be defined as the actions that members take to be exposed to the communication activities, including reading messages, posting messages, as well as replying to messages. The utility-like logic underpinning game theory suggests that each member would assess their expected benefits and costs in order to choose the behavioral strategies that would maximize their welfare. As such, we assume that a member will stay active in the online health community and log in to read, post, or reply to messages when the expected benefit from participation exceeds the expected cost.

4.1 The benefits of participation

Ridings and Gefen [33] identified four types of motivations that drive the user to join the online community: information exchange, social support exchange, friendship, and recreation. Based on the motivation types, Ren and Kraut [57] classified them into three types of benefits derived from the online community, including the benefit from informational support, social attachment, and other benefits such as recreation and reputation. Following this, we adopted the above mentioned three types of benefits and added the benefit from emotional support. This is because emotional support is an important characteristic of the online health community, and it is part of the benefit from social support exchange. Particularly, informational and emotional support have been found as the most frequently offered types of support, as well as the types that are deemed most helpful by participants in OHCs [58]. Therefore, the member benefits of participation are summarized in the following table.

Table 1. Member benefits of participation

Benefits of Participation	Description	Indicator
Informational support	Members can get benefits from informational support by reading informational posts in the OHC and getting answers about their informational-seeking questions from the OHC	Topic entered Post read Topic count Reply count
Emotional support	Members can get benefits from emotional support by reading emotional/experience-sharing posts in the OHC and getting answers about their emotional/experience-seeking questions from the OHC	Topic entered Post read Topic count Reply count
Social attachment	Members can get benefits from being connected with peers	Social networking Eigenvector centrality
Recreation	Members can get	Received

and reputation	benefits from participating itself (entertainment) and build up their reputation in the online health community	Badge Received Likes

Benefit from Informational Support: Members can get access to the information and knowledge they need to manage their condition or disease by reading the messages posted by other members in the OHC, or by posting their own question and waiting for the answers from other members in the OHC.

Benefit from Emotional Support: Members can get emotional support to help them cope with the stress of living with their disease and thereby improve their quality of life. We use the benefit of emotional support in accordance with the motivation of social support exchange in literature [33]. Social support is the perception or actualization of care or assistance from a social network [59]. Social coping refers to the seeking of social support in the presence of stressful situations. Prior studies show social support and coping enhance patients' satisfaction by providing a solution to their problem and helping regulate their emotions [60]. Satisfaction refers to "the psychological state that is related to and resulting from a cognitive appraisal of the expectation performance discrepancy (confirmation)" [61].

Benefit from social attachment: Previous studies assert that members' interpersonal bonds with other members can lead them to become committed to the community [62, 63]. Commitment refers to the state or quality of being dedicated to a cause or activity. In organizational behavior and organizational psychology, organizational commitment is the individual's psychological attachment to the organization [64]. The organizational commitment enacts an engagement or obligation that prevents employees from leaving their organizations. Organizational commitment has long been studied by scholars to predict work variables such as turnover, organizational citizenship behavior, and job performance [65, 66]. In studying the widespread diffusion of online virtual communities, some researches utilized organizational commitment theory to understand the users' sharing and support behavior in online communities [67, 68]. Young [69] believed that the success of an OHC "depends, in part, on an organization's commitment to sustained organizational and financial support for dedicated community management." To establish the users' organizational commitment, online healthcare communities need to possess a strong sense of community, which incorporates four elements according to McMillan and Chavis [70]): membership (feeling of belonging to and identifying with the community), integration and fulfilment of needs (the goals of the users match those of the membership as a whole), influence (members feel they can influence and be influenced by the community), and attachment (members share an emotional connection). These four components are built up gradually along with the general process of accepting an online healthcare community, and also associated with each other.

In our model, we assess social attachment by investigating how members interact and connect with each other. To do so, we examine social networking among members using the discussion thread in the OHC.

Benefit from recreation and reputation: Members can also get benefits from recreation. In other words, members may enjoy reading posts and sharing personal experiences in the community. The participation itself can provide the members with satisfaction or enjoyment. For example, some posts discuss non-health-related topics, including greetings and chatting with no purposive value but to build a friendly environment in the OHC. Users' purpose for posting this type of posts usually has nothing to do with obtaining information or getting emotional support, but instead is provides a friendly atmosphere.

Members are also motivated to contribute to online health communities by the reputation they gain from participation. Many online communities establish the reputation mechanism with badges (stackoverflow.com) or top reviewer lists (Amazon.com). Even when official recognition is absent [57], active contributors often get recognized and respected as an expert in certain topics or areas by other members.

4.2 The Cost of Participation

While members can get different types of benefits from participating in the online health community, there are always costs in engaging in any activity, such as the time spent on finding the needed information, the time spent on reading messages, and the time spend on posting messages. In this study, we assess the time and effort members spend on reading and posting messages as their cost of participation. Additionally, we consider the opportunity cost of the member based on their demographic information, where the opportunity cost is affected by the age of the member. For example, members who are mid-

career wage earners usually have higher opportunity costs than teenagers or retirees. Table 2 shows the member costs of participation.

Table 2. The member costs of participation

Costs of Participation	Description	Indicator
Reading cost	Members need to spend the time to log in and read the messages they are interested in.	Reading count (topic entered and post read)
Posting cost	Members need to spend time and effort to post the messages to either create a new thread or reply to others' posts	Topic count Post count
Opportunity cost	The benefit that a member can get if he/she didn't spend their time participating	Member's age

The following section denotes the payoff equation of the members participating in the online health community. We start with a two-player game.

Suppose members i, j in the online health community are participating in the discussions, the payoff for the member i is:

$$Payoff_i = B_{info} + B_{emot} + B_{soc} + B_{(rec+rep)} - C_{(re+po+opp)}$$

$$= R_j Ir_i + R_j Ip_i + R_j Er_i + R_j Ep_i + K_1^{-1} \sum_j A_{ij} x_j + Rc_i + R_i - (Cr_i + Cp_i + Co_i) \quad (1)$$

Where

B_{info} is the member benefit from informational support;

B_{emot} is the member benefit from emotional support;

B_{soc} is the member benefit from social attachment;

$B_{(rec+rep)}$ is the member benefit from recreation and reputation;

$C_{(re+po+opp)}$ is the member cost from participation;

R_i is the reputation benefit of the ith member in the OHC;

Ir_i is the informational support the ith member gets from reading the messages;

Ip_i is the informational support the ith member gets from posting the questions;

Er_i is the emotional support the ith member gets from reading the messages;

Ep_i is the emotional support the ith member gets from posting the questions;

$\sum_j A_{ij}$ is the adjacency matrix of the ith member's social networking;

K_1^{-1} is the eigenvalues of the ith member's social networking adjacency matrix;

x_j is the eigenvector of the ith member's social networking;

Rc_i is the recreation benefit of the ith member from participation;

Cr_i is the reading cost of the ith member from participation;

Cp_i is the posting cost of the ith member from participation;

Co_i is the opportunity cost of the ith member from participation;

To model the scenario of multiple members in the online health community, we can extend the formula to N-dimensions. We assume that there is a population consisting of many distinct members k (k ∈ (1, 2, . . . , n)), which implies that i, j ∈ (1, 2, . . . , n). As we are interested in the process through which each member makes the final choice via learning and imitation, so we add a new variable—the probability that a member stays to participate in the OHC, P_i , P_i ∈ [0, 1]. The payoff to player i therefore becomes

$$Payoff_i = Ir_i \sum_{j,j\neq i}^{n} R_j + Ip_i \sum_{j,j\neq i}^{m} R_j + Er_i \sum_{j,j\neq i}^{n} R_j + Ep_i \sum_{j,j\neq i}^{m} R_j + K_1^{-1} \sum_{j}^{m} A_{ij} x_j + Rc_i + R_i - (Cr_i + Cp_i + Co_i)$$

$$= (Ir_i + Er_i) \sum_{j,j\neq i}^{n} R_j + (Ip_i + Ep_i) \sum_{j,j\neq i}^{m} R_j + K_1^{-1} \sum_{j}^{m} A_{ij} x_j + Rc_i + R_i - (Cr_i + Cp_i + Co_i) \quad (2)$$

As mentioned earlier, the RD studies the dynamic process of the game as driven by its individual players. It includes a system of nonlinear first-order differential equations in the continuous case and a system of nonlinear differential equations in the discrete case, and it describes the asymptotic behavior of the system. The RD equation is a differential equation that describes the probability or frequency of a particular strategy that has been chosen in a population.

Given an evolutionary game with pure strategies $S = (S_1, S_2, S_3, \cdots, S_n)$, the proportion of the population playing strategy S_1 at the time t, denoted x, has dynamics described by the differential equation: $\frac{dx}{dt} = x(U_{si} - \overline{U})$, where U_{si} represents the expected payoff of selecting strategy S_i at the time t, and $\overline{U}$ is the average payoff of the population at the time t.

We define U_i^s to express the payoff of the ith member when he/she chooses to continue participating in the OHC

$$U_i^s = \sum_{j,j\neq i}^{n} P_j \times \Bigg[(Ir_i + Er_i) \sum_{j,j\neq i}^{n} R_j + (Ip_i + Ep_i) \sum_{j,j\neq i}^{m} R_j + K_1^{-1} \sum_{j}^{m} A_{ij} x_j + Rc_i + R_i - (Cr_i + Cp_i + Co_i) \Bigg] + \sum_{j,j\neq i}^{n} (1 - P_j) \times \Bigg[K_1^{-1} \sum_{j}^{m} A_{ij} x_j + Rc_i + R_i - (Cr_i + Cp_i + Co_i) \Bigg] \quad (3)$$

And we define U_i^l to express the payoff of the ith member when he/she chooses to stop participating in the OHC

$$U_i^l = \sum_{j,j\neq i}^{n} P_j \times \Bigg[(Ir_i + Er_i) \sum_{j,j\neq i}^{n} R_j + Rc_i - (Cr_i + Co_i) \Bigg] + \sum_{j,j\neq i}^{n} (1 - P_j) \times \Bigg[K_1^{-1} \sum_{j}^{m} A_{ij} x_j + Rc_i + -(Cr_i + Co_i) \Bigg] \quad (4)$$

The average payoff of the ith member is:

$$\overline{U} = P_i U_i^s + (1 - P_i) U_i^l \quad (5)$$

Based on Taylor and Jonker's replicator equation, the dynamics are described by the differential equation:

$$\frac{dP_i}{dt} = P_i \left(U_i^s - \overline{U} \right) \quad (6)$$

If we substitute equation (3) and (5) into (6), the integrated equation is

$$\frac{dP_i}{dt} = P_i(1 - P_i) \Bigg[(Ip_i + Ep_i) \sum_{j,j\neq i}^{m} R_j \sum_{j,j\neq i}^{n} P_j + K_1^{-1} \sum_{j}^{m} A_{ij} x_j \sum_{j,j\neq i}^{n} P_j + (R_i - Cp_i) \Bigg] \quad (7)$$

To find the ESS, given (7) equals zero , the general solution of this equation: $P_i^* = 0$ or $P_i^* = 1$ or

$$\sum_{j,j\neq i}^{n} P_j^* = \frac{Cp_i - R_i}{(Ip_i + Ep_i) \sum_{j,j\neq i}^{m} R_j + K_1^{-1} \sum_{j}^{m} A_{ij} x_j}$$

Let's use a two-user example to demonstrate the solution. Suppose there are two members i, j. The differential equation for each member would be as follows.

$$\frac{dP_i}{dt} = P_i(1 - P_i) \Bigg[(Ip_i + Ep_i) R_j P_j + P_j K_1^{-1} \sum_{j}^{m} A_{ij} x_j + (R_i - Cp_i) \Bigg]$$

$$\frac{dP_j}{dt} = P_j(1 - P_j) \Bigg[(Ip_j + Ep_j) R_i P_i + P_i K_1^{-1} \sum_{i}^{m} A_{ij} x_i + (R_j - Cp_j) \Bigg]$$

The stable equilibria for a two-player game would be: O (0, 0), A (1, 0), B (0, 1), C (1, 1), and D $\left(\frac{Cp_i - R_i}{(Ip_i + Ep_i) R_j + K_1^{-1} \sum_{j}^{m} A_{ij} x_j}, \frac{Cp_j - R_j}{(Ip_j + Ep_j) R_i + K_1^{-1} \sum_{j}^{m} A_{ij} x_i} \right)$, where 0 means the users

don't want to stay at all, 1 means the user will stay no matter what, and $0<\frac{Cp_j - R_j}{(Ip_j+Ep_j)R_i+K_1^{-1}A_{ij}x_j}$, $\frac{Cp_i - R_i}{(Ip_i+Ep_i)R_j+K_1^{-1}A_{ij}x_i}<1$, otherwise point D won't exist.

To evaluate the stability of the fixed points we find the derivative of

$$f(P_i) = P_i(1-P_i)\left[(Ip_i + Ep_i)R_jP_j + P_jK_1^{-1}\sum_j^m A_{ij}x_j + (R_i - Cp_i)\right]$$

And find that point D ($\frac{Cp_j - R_j}{(Ip_j+Ep_j)R_i+K_1^{-1}\sum_j^m A_{ij}x_i}$, $\frac{Cp_i - R_i}{(Ip_i+Ep_i)R_j+K_1^{-1}\sum_j^m A_{ij}x_j}$) is stable.

5. Discussion

The model result shows that the possibility of a user's decision to stay or leave the OHC at a certain time is $\frac{Cp_i - R_i}{(Ip_i+Ep_i)R_j+K_1^{-1}\sum_j^m A_{ij}x_j}$. The stable fixed point suggests some interesting findings.

Firstly, a member staying active in the OHC has a positive relationship with other members' posting cost. This is reasonable because if other members spend more time on posting information to the community, it implies that the posts have a higher value. A member who obtains great benefits will stay active in the community. Additionally, a higher posting cost means more members are participating in the OHC. From a macro-perspective, this means the overall quality and value of the OHC is high. A member is more likely to stay in the OHC if the perceived the value is high.

Secondly, a member staying active in the OHC has a negative relationship with other members' reputation benefits. One possible explanation for this interesting result is that high reputations may prevent a member from posting and making efforts because he/she can easily get the answers he/she wants. Studies about participatory patterns in OHCs showed that there are two types of users: help-seekers and influential users [71]. When a member initially joins an OHC, most likely, he/she is a help-seeker. Members with high reputations are influential users. This finding is consistent with the first finding in terms of the overall quality and value of the OHC. The more influential users with high reputation there are, the easier it is for the new help-seekers to find high-quality answers to the questions they have. It might lower the number of question-postings from help-seekers, though it can increase their willingness to get connected with the users in the community.

Thirdly, a member staying active in the OHC has a negative relationship with the other members' benefits from received informational and emotional support they obtain from posting questions. This finding can be explained by the overall value of participating in the OHC. When other members are receiving support other than providing support, they are providing no or less value-adding activities to the OHC. As such, it makes sense that a member's motivation of staying active is slight negatively impacted.

Fourthly, a member staying active in the OHC has a negative relationship with the other members' benefit from social attachment. It might be hard for a member to find the feeling of belonging if other members are very closely connected. Based on the formula, the possibility of a member staying active in the OHC will be increased when any type of other members' benefit decreases except their own enjoyment (the recreation benefit). This might be because the recreation benefit is a personal subjective judgment, and it is less affected by others' behavior in the OHC.

6. Conclusion and future study

The impact of this research can be seen from two perspectives.

For the online healthcare community owner or manager, it provides insight into the factors that affect users' continuing participation in different periods of the membership life cycle. As such, the manager can better motivate the users in different stages of the membership life cycle with strategies to maintain a high level of activity in the online healthcare community, and this can help the community be successful. The findings of this study can be used by the managers or coordinators as guidelines to facilitate the activities in the OHCs. For example, the manager can encourage members to spend more time on answering questions by rewarding them badges for high quality answers.

For healthcare providers, a good understanding of users' seeking and supporting behaviors in OHC can help them to establish a channel to disseminate healthcare information, enhance communication and interactions with patients, and even facilitate healthcare education. For example, studies show that the interaction between patients and physicians in online health communities can increase the trust of patients [3]. This can enable patients to better follow their physician's treatment instructions.

Future studies will be conducted as follows; we will attempt to use simulation to test our research model, and users' participation data will be collected from popular online health communities and tested to validate our research model.

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