Communication behavior and online knowledge collaboration: evidence from Wikipedia

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Abstract

Purpose – *This paper aims to elucidate the collaborative mechanism of knowledge collaboration in online communities. The effects of participant communication behaviors enabling knowledge collaboration, such as public discussion, private messaging and registration, are comprehensively investigated in relation to individual and group performances.*

Design/methodology/approach – *Eight communication categories of participants are defined according to their communication behaviors, and the average number of knowledge contributions at the individual level and the helpfulness toward collaboration efficiency at the group level are compared across the participant categories.*

Findings – *The results show that simultaneous participation in both task-oriented public discussion and relationship-oriented private messaging has a synergistic effect in promoting individual knowledge sharing, and that additional registration – disclosing one's identity – significantly enhances efficiency in group collaboration. The role of public discussion appears to be as significant as that of private messaging with regard to online knowledge collaboration.*

Practical implications – *First, encouraging members to participate in both task-oriented discussion and casual personal communication is important for eliciting more knowledge contributions. Second, although social capital based on one-to-one private messaging has attracted much attention with respect to knowledge sharing, many-to-many public discussions that more deeply and broadly influence knowledge conversion should be more highly emphasized. Third, the perceptions of shared value and reputation based on registration also need to be cultivated to increase collaboration efficiency.*

Originality/value – *In contrast to most previous research that focused on only one type of communication, this study offers a big-picture view of the relationship between communication and online knowledge collaboration by adopting a comprehensive approach to participant communication behavior. A systematic classification of communication behaviors enables this work to illuminate the diverse effects of different communication types or styles on both individual- and group-level performances, thereby improving the understanding of the overall collaborative mechanism. This study thus provides fresh insights on effective management of online communities.*

Keywords *Knowledge creation, Knowledge sharing, Online community, Communication behavior, Online knowledge collaboration*

Paper type *Research paper*

Introduction

Participants in an online community, where interactions occur primarily via the internet, share a common purpose, interest, or activity (Armstrong and Hagel, 1996; Hagel, 1999; Kim, 2000). There are four types of online communities varying according to participants' needs (Armstrong and Hagel, 1996), among other classifying standards; in communities of interest, participants interact extensively with one another on specific topics and a high degree of interpersonal communication takes place, whereas, in communities of relationship, participants come together around certain intense life experiences that can lead to formation of deep personal connections. Sequentially, in communities of transaction, participants primarily seek information regarding buying and selling of

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"This research discovered the synergistic effect of participating in both public discussion and private messaging, which implies that a simultaneous satisfaction of the intellectual and relational aspects of human needs greatly fosters motivation for knowledge contribution."

products and service; contrastingly, in communities of fantasy, participants create new environments, personalities or stories. These communities, however, are not mutually exclusive and a community can address multiple needs (Armstrong and Hagel, 1996).

Taking the major needs of community participants into consideration, in communities of interest, such as Wikipedia.com, Sourceforge.net and ccMixter.org, a variety of innovative products have been developed through knowledge collaboration. Many people predict that these new online forms of information and knowledge production will replace traditional offline models, affecting the very core of our society, economy and culture (Bruns, 2008; Wittke and Hanekop, 2011). Because of this transformative change, numerous companies have turned to online communities, anticipating significant benefits from knowledge collaboration. However, a large number of those companies have failed to obtain their intended goals (Ransbotham and Kane, 2011; Worthen, 2008), and the failures have been largely attributed to the lack of effective collaborative process (Ransbotham and Kane, 2011; Worthen, 2008).

Online knowledge collaboration, or knowledge collaboration in online communities (Armstrong and Hagel, 1996), includes sharing, transforming and integrating knowledge (Faraj *et al.*, 2011; Grant, 1996), which cannot take place without communication. Communication is the meaningful exchange of information between two or more people (Fayard and Metiu, 2014). It influences the collaborative process as participants exchange their own knowledge and develop new perspectives on work-related issues (Van den Hooff and de Ridder, 2004). In this respect, many studies have examined the pros and cons of specific communication types or styles, such as online public discussion (Allen, 2005; Hawkey, 2003; Motteram and Forrester, 2005), private messaging (Inkpen and Tsang, 2005; McCluskey and Korobow, 2009; McFadyen and Cannella, 2004) and registration (Kling *et al.*, 1999; Rains, 2007; Scott, 2004). However, little empirical research has been carried out from a comprehensive view of communication by considering different communication types or styles simultaneously. Unfortunately, focusing on only one type or style of communication rather than taking a big-picture point of view can be a limiting condition to investigating the overall collaborative process, because, in reality, participants can communicate using multiple communication tools in online communities (Kim, 2000). The big-picture may include the combinatorial effects of different communication types like the dual effect of public discussion and private messaging or the comparative effects like the relative strength of public discussion over private messaging. These sorts of analysis would be impossible from the past separate approach.

The authors, from the big-picture point of view, systematically classify participants in collaborating groups into eight categories according to whether participants have taken part in task-oriented public discussion or relationship-oriented private messaging and also whether they have disclosed their identity to the community. Then, the authors seek to find the answers for the following specific research questions to investigate the diverse effects of different communication types or styles and elucidate online collaborative dynamics:

RQ1. Which participant category of communication produces more knowledge contributions?

RQ2. Which participant category of communication is more conducive to group collaboration efficiency?

The number of knowledge contributions and the conduciveness to group collaboration efficiency are compared for the eight participant categories of communication. Group collaboration efficiency can be represented in terms of the time required for a group to create a reliable collaborative product. Therefore, the participant category that is beneficial to shortening the required time for creation can be regarded as conducive to group collaboration efficiency.

As a research platform, the authors chose English Wikipedia, a representative online community for knowledge collaboration. For theoretical underpinning, organizational knowledge-creation theory (Nonaka and Toyama, 2005; Nonaka *et al.*, 1996) and social capital theory (Nahapiet and Ghoshal, 1998; Putnam, 1995b) were mainly adopted in addition to other related research. This work, with the reality of participant collaborative behaviors, will provide useful implications regarding communication patterns to encourage and elicit more knowledge contributions and to promote group collaboration efficiency.

Theoretical and practical backgrounds

Communication and knowledge collaboration: related theories

As aforementioned, communication is a critical factor for knowledge collaboration. In addition to developing common meanings, norms, values and the culture of an organization, communication can change attitudes and thus the level of identification with an organization (Wiesenfeld *et al.*, 1999). Supportive communication, attained through shared understanding and organizational identification, exerts a positive effect on knowledge sharing (Van den Hooff and de Ridder, 2004).

When participants communicate through either public discussion or private messaging in online communities, three modes of knowledge conversion – combination, externalization and internalization – are likely to occur. Combination refers to knowledge conversion from separate explicit knowledge to systemic explicit knowledge, externalization from tacit knowledge to explicit knowledge, and internalization from explicit knowledge to tacit knowledge (Nonaka and Toyama, 2005; Nonaka *et al.*, 1996). In fact, the knowledge collaboration process consists of four different modes of knowledge conversion – combination, externalization, internalization and socialization – according to organizational knowledge-creation theory (Nonaka and Toyama, 2005; Nonaka *et al.*, 1996). Socialization, referring to knowledge conversion from individual tacit knowledge to group tacit knowledge, generally involves offline interaction between organizational members and is very limited in an online environment (Griffith *et al.*, 2003). Knowledge conversion has been regarded to operate on two fundamental dimensions:

1. the distinction between tacit and explicit knowledge, which is referred to as the epistemological dimension; and
2. the extent of social interaction, such as the distinction between individual and group or the size of interacting group, which is referred to as the ontological dimension.

"Public discussion appears to be more crucial than private messaging at both the individual and group levels in this study."

> **"Higher levels of knowledge sharing lead to higher collaboration efficiency only when accompanied by registration, implying the effect of reputation and commitment."**

The depth and breadth of knowledge conversion in these two dimensions may differ according to communication type, such as whether it consists of public discussion or private messaging.

On the other hand, the effect of communication on knowledge collaboration can be viewed from the perspective of social capital because communication enables one to develop relationships through interactions. In the fabric of the relationships between individuals and in an individual's connections with the community, social capital, comprising cognitive, structural and relational capital (Nahapiet and Ghoshal, 1998; Putnam, 1995b), resides. Cognitive capital refers to resources that facilitate common interpretations and understanding of a collective. Structural capital refers to the density of connections or direct ties between individual members in a collective. Relational capital refers to the affective nature of relationships formed in a collective, affecting group identification, trust in other members, willingness to help others and the obligation to conform to group norms (Nahapiet and Ghoshal, 1998; Putnam, 1995a, 1995b). Close relationships with other members in the group enhance commitment (Brass, 1984; Coleman, 1990) and a greater density of collective networks leads to a higher likelihood of collective action (Putnam, 1995b). Therefore, social capital has been used to explain why individuals in a community show pro-social behavior, such as choosing to contribute rather than taking a free ride (Coleman, 1990; Putnam, 1995a). In addition, social capital affects organizational knowledge creation as an integrative mechanism for explaining sharing and creating knowledge in organizations (Nahapiet and Ghoshal, 1998).

Communication behaviors in online communities

Because participants in online communities rely primarily on text messages to interact with others (Sproull and Arriaga, 2007), communication in online communities lacks social context cues and the establishment of common ground (Clark and Brennan, 1991; Cramton, 2001). Although, communication in online communities enables interaction among dispersed participants (Faraj *et al.*, 2011; Sproull and Arriaga, 2007). In addition, interactive communication behaviors in online communities are automatically recorded on Web 2.0 platforms (Nemoto *et al.*, 2011; Ransbotham and Kane, 2011) and reveal a great deal of information on how participants in a group collaborate, including when and who has suggested what. This is possible because communication behaviors in online communities are basically the usage behaviors of various communication tools (reflecting this aspect, the term "participant" is used interchangeably with the term "user" hereafter). There are a variety of synchronous communication tools such as instant messaging, chat, Web seminars ("webinars") and webcasts, as well as asynchronous tools such as email, email newsletters, mailing lists, online conferences or forums and bulletin boards (White, 2006). These can be also classified into one-to-one, one-to-many or many-to-many communication tools according to the number of senders and recipients.

Among these, many-to-many asynchronous communication tools such as online conferences or forums, which can support public discussion in a manner that transcends time and space, have gained popularity and form the most visible nucleus for online communities (Sproull and Arriaga, 2007; White, 2006). On the other hand, conflicting views about public discussion have been reported in the academic domain. Some researchers

have suggested that asynchronous online discussion enables deeper understanding and in-depth analysis through a process of interaction, discovery, reflection and adaptation (Allen, 2005; Motteram and Forrester, 2005). However, other researchers have argued that online discussion is more shallow or superficial than offline discussion (Hawkey, 2003; Ravenscroft and Matheson, 2002). In addition, online discussion has limitations of lower levels of user involvement, higher levels of information overload and a relatively long feedback time (Motteram and Forrester, 2005).

According to the contextual needs of a community, asynchronous public discussion could be effectively combined with one-to-one asynchronous private messaging tools such as email (Bieber *et al.*, 2001; White, 2006). From the theoretical perspective of social capital accumulated primarily through private messaging, contrasting opinions also exist. Social capital allows individuals to have privileged access to tacit organizational knowledge (McCluskey and Korobow, 2009), work-related problems (Baldwin *et al.*, 1997), task information and strategic advice and social support (Podolny and Baron, 1997). Social capital also fosters an individual's influence, reputation and understanding of group norms and expectations (Brass, 1984; Inkpen and Tsang, 2005). At the same time, social capital can impose a burden on the members of a community. Social networks with strong norms and identification can constrain openness to divergent information and opinions (Nahapiet and Ghoshal, 1998). A previous study showed that the number and strength of relations that an individual maintains have an inverted U-shaped relationship with knowledge creation (McFadyen and Cannella, 2004). The researchers argued that there is a reflection point at which the benefits from personal relationships are eventually outweighed by the costs incurred in maintaining them.

As well as in the combination of communication tools, online communities can vary in the provision of an option for registration. Many communities demand participants' registration for the use of their communication tools, whereas some communities are open to anonymous users (Anthony *et al.*, 2009). Studies have also found conflicting results with respect to anonymity in knowledge collaboration. The positive effect of anonymity seems to stem from the freedom from social constraints or evaluation (Kling *et al.*, 1999), which can increase participation and produce better ideas (Nunamaker *et al.*, 1991; Parent *et al.*, 2000). In contrast, the negative aspects of anonymity appear to result from weaker accountability and trustworthiness (Rains, 2007), which lead to an increased risk of deception (Scott, 2004) and disorderly conduct (Jessup *et al.*, 1990). Anonymity can also result in reduced motivation for knowledge contribution because the contributor cannot be rewarded (Scott, 2004).

Research issues and hypotheses

Wikipedia provides many-to-many asynchronous public discussion and one-to-one asynchronous private messaging tools to support communication between participants of article groups. Public discussion progresses on article talk pages where ideas are exchanged on each article topic. An article talk page is often divided into several sections that address specific types of issues raised during article development. Diverse opinions, which range from trivial issues to highly professional ones that require expertise, are shared, negotiated and improved over the course of the discussion. As a private messaging tool, Wikipedia provides personal user talk pages. On these pages, diverse personal messages, such as casual greetings, stories about activities on Wikipedia and ordinary affairs of life, are exchanged. If one wants to personally communicate with another participant, he or she visits the person's user talk page and leaves a message. Although a user talk page is not specific to a particular article, a communication network comprising a group of editors can naturally emerge through such interactions.

Editors of each article, an article group, exhibit different behaviors in using these communication tools – some participate in both public discussion and private messaging, others in only one of these, and still others edit an article without participating in either of

these communications. These collaborators also differ in communication style – some participants prefer communicating with their identity disclosed and others with their identity hidden. From the performance viewpoint, collaboration efficiency, measured as the time needed for an article to be promoted to "featured article" (the highest among the seven article quality grades in Wikipedia), differs greatly among article editing groups. Some article groups succeed in having their articles promoted to the featured article level within days, whereas others take as long as 10 years. There also exist differences in the contributions of individuals; some editors participate in numerous editing sessions of an article before its promotion to featured article, but most edit just once.

To systematically and comprehensively investigate the effect of communication behaviors on knowledge collaboration, the authors first classified editors into eight categories listed in Table I. The dimensions distinguish whether users take part in task-oriented public discussion or relationship-oriented private messaging and whether they have registered a profile accessible by the community. User category 1R comprises editors who have registered and participated in both public discussion and private messaging ("R" stands for "Registered users"). Category 1A includes editors who are anonymous but have participated in both public discussion and private messaging ("A" stands for "Anonymous users"), and the remaining categories are defined in a similar fashion (The category numbers were attached in the order of anticipated desirability of communication). Each category represents a different behavioral combination that enables comparison of singular and combinatorial effects of distinctive behaviors.

For the second step, the authors defined two performance measures: the quantity of knowledge sharing measured as the number of article edits at the individual level and the magnitude of the effect on the group collaboration efficiency at the article group level. Many past studies on knowledge sharing used the number of knowledge contributions to a knowledge repository or community as an indicator of the quantity of knowledge sharing (Anthony *et al.*, 2009; Kankanhalli *et al.*, 2005; Wasko and Faraj, 2005). Similarly, the quantity of individual knowledge sharing can be measured by the number of article edits an individual makes on an article in Wikipedia. Eventually, the authors investigate the differences of average numbers of article edits across user categories at the individual level. At the group level, the authors focus on the magnitude of helpfulness in the collaboration efficiency varying according to user categories. The collaboration efficiency of an article group is measured by the time required for an article to be promoted to the featured article level. The featured articles of Wikipedia are perceived to have high credibility and are viewed, on average, by seven times as many people as non-featured ones (Ransbotham and Kane, 2011). Therefore, early promotion as a featured article has a significant influence on information adoption and diffusion.

The most desirable communication pattern

Which communication pattern will generally result in the highest number of knowledge contribution? It is not easy to designate a user category with the most desirable communication pattern because previous research reported conflicting views about public discussion, private messaging and registration. However, in the context of online knowledge collaboration, public discussion will make individuals encounter diverse perspectives and contemplate them (Allen, 2005; Motteram and Forrester, 2005), despite its limitations when compared to offline discussion (Hawkey, 2003; Motteram and Forrester,

Table I User categories by public discussion, private messaging and registration

User category	*1R*	*1A*	*2R*	*2A*	*3R*	*3A*	*4R*	*4A*
Registration	Yes	No	Yes	No	Yes	No	Yes	No
Public Discussion	Yes		Yes		No		No	
Private Messaging	Yes		No		Yes		No	

2005; Ravenscroft and Matheson, 2002). Through the speculation on the opinions of others, participants' expertise and experiences will improve (Allen, 2005; Motteram and Forrester, 2005). Resultantly, public discussion will positively affect individual contributions to article edits, as individuals with more expertise are likely to contribute more knowledge to an online community (Wasko and Faraj, 2005).

On the other hand, one-to-one private messaging in online knowledge collaboration, through developing relationships and thus generating social capital, also likely contributes to the promotion of individual contribution (Coleman, 1990; Putnam, 1995a). Participants with greater structural centrality contribute more knowledge to electronic networks of practice (Wasko and Faraj, 2005). The drawbacks of excessive structural and relational capital found in offline environments (McFadyen and Cannella, 2004) may not occur in online environments due to the lower intensity of virtual relationships (Clark and Brennan, 1991; Cramton, 2001). In addition, maintaining virtual relationships requires less effort than maintaining offline relationships, thanks to the convenience of online tools.

As for registration, the authors also anticipate it to have a positive effect on knowledge sharing. Registered contributors in online knowledge collaboration are likely to be motivated mainly by reputation and will therefore contribute more, whereas participants who are indifferent to reputation may remain anonymous and make fewer contributions (Anthony *et al.*, 2009). Building reputation has been shown to be a significant motivator for active online knowledge sharing, including open-source software projects (Constant *et al.*, 1996; Lakhani and Wolf, 2005; Wasko and Faraj, 2005). Tangible extrinsic rewards, such as money or additional points for promotion, can be detrimental to intrinsic motivation for knowledge sharing (Bock *et al.*, 2005; Deci *et al.*, 1999; Eisenberger and Cameron, 1996) because of the decreased feeling of autonomy (Gagne and Deci, 2005; Sheldon *et al.*, 2003). However, this sort of undermining effect may not exist because reputation is an intangible extrinsic reward, and autonomy is preserved in an online environment (Gagne and Deci, 2005; Sheldon *et al.*, 2003; Wighting *et al.*, 2008).

Registration behavior can also be an expression of personal agreement with the values of the community and individual commitment. Personal value is an enduring preferential belief with respect to a specific mode of conduct or end-state of existence compared to that of a counterpart (Rokeach, 1973). Organizational values can be defined as those valued and promoted by the management of an organization (Money and Graham, 1999). When congruency (Balazs, 1990) occurs between personal and organizational values, individual commitment to an organization increases (O'Reilly, 1989), and such an occurrence can eventually lead to more contributions from the individual (Anthony *et al.*, 2009; Raymond, 2001).

Consequently, the authors posit the following hypothesis (the letter I indicates "Individual level"):

H1-I. Participants who take part in both public discussion and private messaging and who have registered will make more contributions than those who do not take part in at least one of those activities.

With respect to the helpfulness for the collaboration efficiency at the group level, there are also mixed results to consider before determining a user category with the most desirable communication pattern. Task-related conflicts that take place during public discussion can deter collaboration (Saavedra *et al.*, 1993), but in online communities, task-related conflicts are likely to be controlled because the community norms and procedures prevent them from evolving into exhaustive personal conflicts (Arazy *et al.*, 2011). In addition, conflicts can rather have positive effects because they can increase the range of alternatives and drive participants to verify their assumptions and thus lead to a deeper understanding of a given task (Amason, 1996; Pelled *et al.*, 1999), contributing to group performance, especially when tasks are complex (Jehn, 1995).

During public discussion, tacit knowledge is transformed into explicit linguistic expressions, namely, externalized. At the same time, public discussion helps improve knowledge through integration and reorganization of externalized explicit knowledge. Briefly speaking, public discussion in online communities facilitates knowledge collaboration by externalization and combination of knowledge (Nonaka and Toyama, 2005; Nonaka *et al.*, 1996). Additionally, positive effects of online discussion on the student' performance in e-learning environments demonstrate that online public discussion supports the internalization of knowledge (Davies and Graff, 2005; Webb *et al.*, 2004). Public discussion allows group members to share common interpretations and meanings of the task-related concepts; therefore, the exchange of knowledge requiring a shared understanding among group members (Nahapiet and Ghoshal, 1998; Nonaka *et al.*, 1996) can be facilitated through public discussion. In this line, those who participate in public discussion will enhance their own knowledge and simultaneously contribute to the enhancement of others' knowledge, promoting the collaboration efficiency.

On the other hand, social interactions through private messaging can solidify trust and perceived trustworthiness (Tsai and Ghoshal, 1998; Jarvenpaa and Leidner, 1999); trusting relationships, in turn, lead to greater knowledge exchange (Dirks and Ferrin, 2001; Mayer *et al.*, 1995; Tsai and Ghoshal, 1998). When people trust each other, they are more likely to share and accept useful knowledge (Levin, 1999; Mayer *et al.*, 1995) with minimal conflict (Currall and Judge, 1995; Zaheer *et al.*, 1998). In contrast, knowledge resources can be homogenized as a result of rigid strong relationships among members (McFadyen and Cannella, 2004), which limits informational diversity and thus knowledge creation. However, online environments may have a less noticeable homogenizing effect because of the high membership fluidity of online communities (Faraj *et al.*, 2011) and weakness of virtual relationships.

When it comes to registration, it is more likely that registration can positively affect collaboration efficiency by inducing knowledge contributors who care about their reputations to focus more on the validity of the contributed knowledge. In an online environment, registered participants tend to make more reliable contributions (Anthony *et al.*, 2009), leading to a higher collaboration efficiency. Based on the value congruency effect of individuals and groups (Balazs, 1990; O'Reilly, 1989), they will also make more helpful contributions to achieve the goal of the community such as creating neutral, reliable and verifiable articles of Wikipedia.

As a result, the following hypothesis is postulated (the letter G indicates "group level":

H1-G: Participants who take part in both public discussions and private messaging and who have registered will exert a stronger positive impact on group collaboration efficiency than those who do not take part in at least one of those activities.

Public discussion versus private messaging

Despite the importance of public discussion with respect to knowledge collaboration, previous studies have largely focused on private messaging or person-to-person interaction in terms of social capital (Inkpen and Tsang, 2005; Nemoto *et al.*, 2011; Wasko and Faraj, 2005). If there are those who take part only in public discussion or those only in private messaging, who will make more knowledge contributions? Whereas private messaging is associated more with structural and relational social capital because it is based on person-to-person relationships (Inkpen and Tsang, 2005; Nahapiet and Ghoshal, 1998; Nemoto *et al.*, 2011), public discussion relates more closely to cognitive capital because of its many-to-many communication mode and task-oriented purpose.

Even though structural and relational capital exert beneficial effects in encouraging pro-social behaviors (Ahuja *et al.*, 2003; Inken and Tsang, 2005; Putnam, 1995b; Wasko and Faraj, 2005), in online environments, the intensity will not be so strong because of the weakness of virtual relationships, especially in knowledge-seeking rather

than relationship-oriented communities. In contrast, during online public discussion, participants get to consider "the wisdom of crowds", which is far more diverse than those alternatives obtained in an offline setting or in online private messaging. Additionally, written communication of online public discussion will convey knowledge content with higher accuracy than oral communication of an offline setting. As a result, those who participate in public discussion will find more issues to write on, make more improvements and consequently make more contributions (Wasko and Faraj, 2005). Thus, the following hypothesis is proposed:

H2-I: Participants who take part only in public discussion will contribute more than those who take part only in private messaging.

More rapid externalization, combination and internalization of knowledge in the epistemological dimension will be enabled by task-oriented public discussion than by relationship-oriented private messaging. Through public discussion, misunderstandings can be resolved and concepts can be clarified more quickly as many participants ask and answer questions, paraphrase ideas and provide examples. Moreover, the exchange of information in asynchronous Web-based conference systems, similar to public discussions, is no less effective than that in face-to-face interactions (Warkentin *et al.*, 1997). In the ontological dimension, knowledge will be propagated and amplified faster in a many-to-many public discussion than in a one-to-one private messaging. Conversions between tacit and explicit knowledge tend to become larger and faster as the number of participants increases (Nonaka, 1994; Nonaka and Toyama, 2005; Nonaka *et al.*, 1996).

Several studies have illustrated the positive effects of private messaging. Group-level research conducted on Wikipedia showed that higher pre-existing social capital in the user talk network of editors resulted in an article reaching the featured article level faster (Nemoto *et al.*, 2011). Researchers have also shown the importance of social capital generated by one-to-one relationships in online environments (Ahuja *et al.*, 2003; Bulkley and Alstyne, 2006; Robert *et al.*, 2008; Wasko and Faraj, 2005).

In contrast, other researchers have suggested that social capital is difficult to develop in electronic networks. Social capital is most likely to be accumulated in collectives characterized by a shared history, high interdependence, frequent interaction and closed structures (Nahapiet and Ghoshal, 1998; Nohria and Eccels, 1992). Online relationships based on one-to-one interactions produce less intimate relationships than face-to-face relationships in general (Warkentin *et al.*, 1997), and virtual interactions provide less satisfaction in the group interaction process (Warkentin *et al.*, 1997). The strength and depth of one-to-one relationships developed through private messaging may not be sufficiently strong to exceed the effects of public discussion, especially when the community is not tailored to develop relations, as with a knowledge-seeking community.

Thus, the authors postulate that the effect of private messaging will be positive but weaker than that of task-oriented public discussion and posit the following hypothesis:

H2-G: Participants who take part only in public discussion will exert more positive impact on group collaboration efficiency than those who take part only in private messaging.

Public discussion and private messaging versus registration

In general, registered participants are regarded as making more contributions than anonymous participants because of reputation (Anthony *et al.*, 2009) and value alignment (Anthony *et al.*, 2009; Raymond, 2001). Even when public discussion and private messaging are considered, will this phenomenon hold true? Specifically, for example, will registered users who participate in neither public discussion nor private messaging contribute more than anonymous users who participate in either activity?

Although public discussion and private messaging correspond to a particular article, registration applies to the overall Wikipedia community. Therefore, public discussion and

private messaging, rather than registration, may indicate relatively stronger intention to contribute to a specific article. Even though registration could imply the likelihood of a greater contribution because of reputation (Anthony *et al.*, 2009; Lakhani and Wolf, 2005; Wasko and Faraj, 2005; Wei *et al.*, 2015), commitment (O'Reilly, 1989) and value alignment (Anthony *et al.*, 2009; Raymond, 2001), its significance might be weaker than that of public discussion and private messaging because of its indirectness to any particular article. In addition, the accumulation of social capital may be achieved at a higher level through interactive public discussion and private messaging than through independent registration. Consequently, individual knowledge sharing might be more highly promoted through public discussion (Wasko and Faraj, 2005) and private messaging (Inkpen and Tsang, 2005; Kaše *et al.*, 2009; Wasko and Faraj, 2005) than by registration. This implies that anonymous participants who take part in both public discussion and private messaging might contribute more than registered participants who do not take part in either type of communication.

Hence, the authors postulate the following hypothesis:

H3-I: Participation in public discussion or private messaging will be more positively related to individual knowledge contribution than mere registration.

With respect to the collaboration efficiency of an article group, public discussion and private messaging may have a greater effect than registration because of their supportive function in knowledge conversion. Registration may positively affect the quality of contribution and the effectiveness of communication via the reputation-seeking or value-congruent effect (Anthony *et al.*, 2009; Nonaka and Toyama, 2005) or by mitigating the negative effect of anonymity (Jessup *et al.*, 1990; Rains, 2007; Scott, 2004). Nonetheless, taking into account the indirectness between registration and contribution, the authors assume that public discussion and private messaging will be more influential to collaboration performance.

Thus, the authors posit the following hypothesis:

H3-G: Participation in public discussion and private messaging will be more positively related to group collaboration efficiency than registration.

Research methodology and setting

In this study, the authors analyzed data from 2,978 featured articles in the English Wikipedia from the initiation of each article until its promotion to the featured article level. The data include the editing histories of the articles, article talk histories and user talk histories for each article. All data generated by "bots" or "scripts", which are automated programs, were eliminated to focus on human behavior. Each unique IP address was counted as a unique anonymous user as in a previous study focusing on Wikipedia (Anthony *et al.*, 2009). The user talk histories of anonymous users are composed only of "talking-out" behavior, which refers to leaving messages on registered editors' user talk pages. Using the classifications in Table I, the authors conducted a two-level analysis of individuals and groups. Namely, the authors examined the degree of individual knowledge sharing and collective contribution to the collaboration efficiency of an article group for each user category.

Individual knowledge sharing

We examined how individual editors from each of the eight defined categories performed in terms of the number of edits. In a Kolmogorov–Smirnov test, the number of edits did not exhibit a normal distribution and the Levene statistics show equal variance. Thus, a Kruskal–Wallis test was used to assess the overall homogeneity of distribution of user categories, and Mann–Whitney U tests and median tests with Bonferroni correction for pair-wise post hoc comparisons were also carried out. Auxiliary descriptive statistics are evaluated as given in Table AV.

Group collaboration efficiency

For collaboration efficiency at the group level, the authors examined the likelihood of promotion using a semi-parametric proportional hazards model. Specifically, the authors used a Cox regression, expressed as $h_i(t) = h_0(t)\, e^{b_0 + b_1 x_{i1} + b_2 x_{i2} + \cdots + b_p x_{ip}}$, where $h_i(t)$ is the hazard rate for the *i*-th case at time *t*. The variable $h_i(t)$ implies a measure of the potential or likelihood of an event to occur at time *t*, given that the event has not occurred, and it corresponds to a conditional probability density function. The variable $h_0(t)$ is a baseline hazard at time *t*, and *p* is the number of covariates. In our case, a "hazard" or "event" is "promotion to the featured article level". The covariates are the variables, including focal and control variables, that represent the characteristics of each article group. In other words, the authors investigated the influence of the characteristics of each article group on the promotion potential of an article. Cox regression does not require an assumption on the functional form of the baseline likelihood of an event, which implies that it is regarded only as a function of time and not of any covariate. Instead, it assumes that covariates exert a proportional effect on the baseline likelihood. This makes it possible to analyze how the likelihood for promotion can change relative to one unit of change in a focal variable, even without knowing the exact form of the baseline hazard.

The model-building process was carried out in two blocks: control variables and both control and focal variables. All the focal variables are user-ratio variables with a standardized percentage unit to compare the relative magnitudes of their effects on the efficiency of collaboration. The focal variable Cat1R_UserRatio represents the ratio of the number of editors belonging to the user category 1R to the number of total editors of an article, and the other focal variables are named in the same manner. Four Cox regressions for different sets of focal variables were conducted with a constant set of control variables across the models. This is not only because the sum of the user ratios of the eight categories is equal to 1 but also because the authors attempted to produce robust results through alternative model specifications. COX 1 compares only the user ratios of registered users, whereas COX 2 considers only anonymous user categories. The "enter" method of SPSS was used in the second block of COX 1 and COX 2 to simultaneously incorporate all the intended focal variables. In contrast, the focal variables in the second block of COX 3 and COX 4 were selected automatically from all eight user-ratio variables through the "forward and backward stepwise likelihood ratio" methods of SPSS.

Control variables

We included the number of editors (NumOfUsers), mean inter-arrival time (MeanInterArrivalTime), mean retention time (MeanRetentionTime), total number of article sections and subsections (NumOfSections) and the number of article references (NumOfReferences) as control variables. Inter-arrival time is the period between consecutive edits in an article group, and retention time is the length of stay of an editor within an article, measured by the time difference between the first and last edits by a specific editor. This is based on the assumption that the speed of quality improvement of an article depends on the number of editors, the editing frequency and the re-editing time spent by the editors, as well as the characteristics of the article topic.

The number of editors involved in an article before it is promoted to the featured level may affect the time needed from initiation to promotion. As more editors work on an article, a broader and more diverse knowledge base is established and may help to enhance article quality. At the same time, however, errors and incomplete information might also be included and in turn be more rapidly discovered and corrected. Mean inter-arrival time, as an indirect measure of frequency, may likewise have an influence. When editing frequency increases, improvements to an article can be made more quickly. In addition, a shorter inter-arrival time is likely to result in an earlier promotion because an edit can be regarded as feedback to a preceding editor, and immediate feedback is essential for eliciting more absorbed behavior (Csikszentmihalyi *et al.*, 2005). Mean retention time represents the time

duration that editors commit to improving an article. The unit for all of the time-related linear variables was unified to day.

Different article topics vary in terms of difficulty to promote as a featured article. Thus, the authors assumed that the difficulty of article creation consists of descriptive, structural and referential complexity and is operationalized with the length of an article in terms of bytes (ArtLength), NumOfSections and NumOfReferences, respectively. When the authors applied both the "forward and backward stepwise likelihood ratio" algorithms to the first block of the four COX regressions, ArtLength appeared to be insignificant and was therefore discarded. This implies that the number of sections and references can explain the major part of the task complexity represented by the article length. The squared mean retention time (MeanRetentionTime2) was found through refinement analysis to be significantly related to collaboration efficiency and was thus included.

Results and analysis

Testing results of hypotheses about individual knowledge sharing

Figure 1 illustrates the average number of edits of users belonging to each user category; the specific numerical data are presented in Table AV.

At a significance level lower than 0.001, the Kruskal–Wallis test shows that the distributions of the number of edits differ across all user categories. The results of the Mann–Whitney U tests between category pairs for testing individual-level hypotheses are provided in Table II. Even after applying a Bonferroni correction, the distributions of the number of edits differ between category pairs. Additionally, from the median tests, the authors obtained similar results: the medians of the number of edits tend to vary across all the listed category pairs.

Using the mean differences in the number of edits between user categories and the combined results of the Mann–Whitney U and the median tests, the authors verified hypotheses *H1-I*, *H2-I* and *H3-I*. First, the mean of the number of edits of user category 1R is conspicuously larger than those of the other user categories; thus, *H1-I* is supported. Even though the difference is not as large as that of 1R, the mean number of edits in user category 1A is also much higher than those of other user categories except for 1R. Hence, a synergistic effect is obvious with participation in both activities. The synergistic effect for users in categories 1R and 1A was statistically verified through a subsidiary robust regression analysis differentiating the level of participation, as shown in Table AVI. Second, users in categories 2R and 2A contribute more than users in categories 3A and 3R, supporting *H2-I*. Third, Figure 1 indicates that the average numbers of edits are more

Figure 1 Average number of edits in each user category

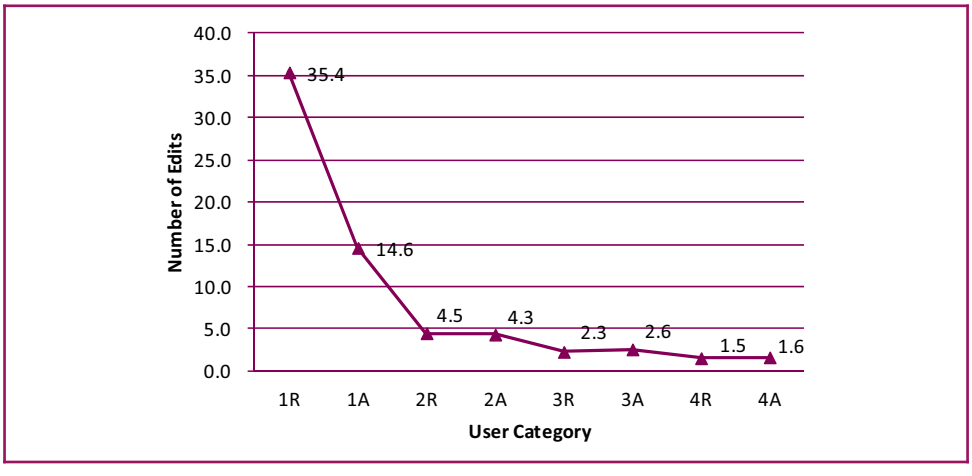

Table II Mann–Whitney U with Bonferroni correction[a]

Hypothesis	*User category pair*	p-*value*
H1-I	1R vs 1A	0.000
H2-I	2R vs 3R	0.000
	2R vs 3A	0.000
	2A vs 3R	0.000
	2A vs 3A	0.000
H3-I	1A vs 2R	0.000
	2A vs 3R	0.000
	3A vs 4R	0.000
	3R vs 3A	0.000
	4R vs 4A	0.000

Note: [a]The authors apply the Bonferroni correction at the 0.05 significance level to all user categories ($_8C_2 = 28$ pairs, 0.05/28 = 0.00179)

affected by participation in either article talk or user talk than by registration. As expected, anonymous users who participate in both article and user talks contribute more than registered users who do not participate in either talk. Moreover, registration does not always exert positive influence on the quantity of individual contribution. The average edit numbers of users in categories 3R and 4R are smaller than those of 3A and 4A, respectively; hence, *H3-I* is supported as well.

Testing results of hypotheses on group collaboration efficiency

Table III provides the results of the four Cox regressions on collaboration efficiency. The dependent variable is the likelihood that an article will be promoted to the featured article level, which is positive in contrast to the negative meaning generally used in the hazard model. All of the included control variables were confirmed with a significance level of 0.001 in a two-tailed test. All the improvement chi-square statistics indicate that the effects of adding the focal variables to the previous block model are significant at a level of 0.001. In addition, the hypothesis that all regression coefficients in the model are zero was rejected in all models by the overall chi-square statistics.

Table III Proportional hazards analysis of the effects on promotion likelihood

Variable	*First block b (Exp(b))*	*COX1 b (Exp(b))*	*COX2 b (Exp(b))*	*COX3 b (Exp(b))*	*COX4 b (Exp(b))*
NumOfUsers	−0.0017*** (0.9983)	−0.0004*** (0.9996)	−0.0004*** (0.9996)	−0.0004*** (0.9996)	−0.0004*** (0.9996)
MeanInterArrivalTime	−0.1422*** (0.8674)	−0.2032*** (0.8161)	−0.2285*** (0.7957)	−0.2018*** (0.8173)	−0.2029*** (0.8164)
MeanRetentionTime	−0.0338*** (0.9667)	−0.0432*** (0.9577)	−0.0449*** (0.9561)	−0.0434*** (0.9575)	−0.0433*** (0.9576)
MeanRetentionTime2	0.0002*** (1.0002)	0.0002*** (1.0002)	0.0002*** (1.0002)	0.0002*** (1.0002)	0.0002*** (1.0002)
NumOfSections	−0.0281*** (0.9723)	−0.0186*** (0.9816)	−0.0175*** (0.9827)	−0.0187*** (0.9815)	−0.0188*** (0.9814)
NumOfReferences	−0.0061*** (0.9939)	−0.0075*** (0.9925)	−0.0081*** (0.9920)	−0.0075*** (0.9925)	−0.0075*** (0.9925)
Cat1R_UserRatio		0.0983*** (1.1033)		0.0556*** (1.0572)	0.0986*** (1.1037)
Cat1A_UserRatio			0.0292 (1.0296)		
Cat2R_UserRatio		0.0962*** (1.1010)		0.0532*** (1.0546)	0.0954*** (1.1001)
Cat2A_UserRatio			0.0373 (1.0380)		0.0556* (1.0572)
Cat3R_UserRatio		0.0422*** (1.0431)			0.0431*** (1.0441)
Cat3A_UserRatio			−0.0292 (0.9713)		
Cat4R_UserRatio		0.0497*** (1.0509)		0.0076** (1.0076)	0.0506*** (1.0519)
Cat4A_UserRatio			−0.0591*** (0.9426)	−0.0433*** (0.9577)	
Focal variable selection		Enter	Enter	Forw. LR	Back. LR
−2LogLikelihood	40,032.260	38,506.186	38,778.947	38,499.574	38,501.320
Overall chi-square	1,195.643***	3,599.097***	2,884.701***	3,608.867***	3,603.504***
Improved chi-square	1,666.714***	1,526.074***	1,253.313***	1,532.686***	1,530.940***
R^2 (%)	42.9	65.8	62.5	65.9	65.9
Effect size		0.670	0.523	0.674	0.674[a]

Notes: *$p < 0.1$; **$p < 0.01$; ***$p < 0.001$; −2LogLikelihood for null model: 41,698.974; [a]the effect size (Cohen's f^2) was calculated by dividing the change in R^2 by the unexplained variance in the full model, that is, (0.659 − 0.429)/(1 − 0.659) = 0.674

The pseudo R^2 values are shown in Table III. The comparison of R^2 values in the first block to those in the second block of each Cox model shows that the inclusion of focal variables increases the values by more than 20 per cent. Moreover, the effect sizes of the three models are large (Cohen, 1988), indicating that the focal variables are clearly significant in explaining collaboration efficiency. The Kaplan–Meier curves drawn for all the categorized covariates indicated that the proportionality assumption is fulfilled in the four Cox models.

The outputs in Table III explain the following findings. First, when more editors (NumOfUsers) collaborate, more time is needed to attain featured article status. This is consistent with the results of Nemoto and Gloor (2010) and can be partly attributed to the fact that an article's entire group of editors does not collaborate from the initiation of the article, but rather that many editors contribute to articles at will. This longer duration may also result from the complexity and confusion that result from a larger group size. Second, a shorter mean inter-arrival time (MeanInterArrivalTime) is likely to result in faster promotion. This could partly be because of the feedback effect: an immediate response can induce more flow or commitment, with a subsequent edit acting as feedback for the preceding edit. Third, mean retention time (MeanRetentionTime) was related to collaboration efficiency in a curvilinear fashion. Before the inflection point of the curve, adaptation to the article editing process may occur, reducing collaboration efficiency. After that point, however, longer revisits by participants seem to induce higher collaboration efficiency. Finally, a larger number of article sections and references (NumOfReferences) leads to slower promotion. This result is in agreement with our inference that articles with higher structural and referential complexity might be more difficult to complete.

By synthesizing the results of the four Cox regressions, the authors conclude that *H1-G* is supported. The coefficient of user category 1R is larger than that of any other user category. This means that the predicted change in promotion likelihood for a 1 per cent increase in the ratio of user category 1R is the largest, which implies that the users belonging to user category 1R have the greatest effect on group collaboration efficiency. For example, the value Exp(b) = 1.1037 of COX 4 means that promotion likelihood increases by approximately 10.4 per cent for each per cent increase in the ratio of 1R editors.

It is notable, however, that the difference between the coefficients for user categories 1R and 2R in COX 4 is very small compared to the difference between the average numbers of edits, that is, 10.4 and 10.0 per cent versus 35.4 and 4.5 edits, respectively. In contrast, the difference between the coefficients of user categories 2R and 3R in COX 4 is larger than the difference between the average numbers of edits (10.0 and 4.4 per cent vs 4.5 and 2.3 edits). This trend also applies to COX 1, which demonstrates that public discussion substantially facilitates collaboration at the group level, whereas the effect of private messaging is relatively weak.

Because the coefficients of user categories 2R and 2A are greater than that of 3R and the coefficient of 3A is insignificant, the authors can also infer that *H2-G* is supported. For the registered participants in COX 4, increases in promotion likelihood of 10.0 and 4.4 per cent occur for each per cent increase in the ratios of user categories 2R and 3R, respectively. In COX 1, the corresponding increases are 10.1 and 4.3 per cent.

All of the registered user categories have a positive effect on group collaboration efficiency, whereas the anonymous users show an insignificant effect (1A, 3A), a weaker positive effect than the registered counterpart (2A) or an obvious negative effect (4A). Participation in article talk or user talk does not determine the ordering of the magnitude of the effect on group collaboration efficiency. For example, in contrast to the overall trend, the coefficient of 3R is slightly smaller than that of 4R. It can be noted that an incremental effect of participation in user talk does not appear to be as significant at the group level, as it is at the individual level. In particular, an increase in 4A participants has a strong negative influence, in contrast to the effect of 4R participants, which demonstrates that registration

makes a substantial difference for these categories. As a consequence, *H3-G* is not supported. Additional robust regressions with *R* on the same model specifications as used in the four COX models produced the same results as those from Cox regressions for all hypotheses, confirming the methodological validity of analysis.

Summary of testing results and further analysis

As shown in Table IV, all hypotheses regarding the relationships between communication behaviors and collaborative outcomes are supported, except for *H3-G*. Interestingly, although the average number of edits of each user category increases with incremental effect in joining public discussion and private messaging regardless of registration, the effects of the former two activities on collaboration efficiency are not overwhelming.

With the eight user categories defined in this study, a multi-faceted analysis can also be performed because each user category represents a different combination of the three user behaviors, as described in Table I. Those results are shown in Appendix 1.

Discussion

This research discovered the synergistic effect of participating in both public discussion and private messaging, which implies that a simultaneous satisfaction of the intellectual and relational aspects of human needs greatly fosters motivation for knowledge contribution. This is somewhat consistent with similar research, as reported regarding the significance of knowledge self-efficacy (Hsu *et al.*, 2007; Kankanhalli *et al.*, 2005; Wasko and Faraj, 2000), and enjoyment of helping others (Kankanhalli *et al.*, 2005; Hsu *et al.*, 2007). However, the findings go further and draw attention to the dual effect of each type of motivation. In some respect, the findings may indicate the importance of simultaneous accumulation of cognitive, structural and relational capital (Ahuja *et al.*, 2003; Inken and Tsang, 2005; Putnam, 1995b; Wasko and Faraj, 2005).

This study also noted that the synergistic phenomenon becomes more salient when combined with registration. This signifies that reputation-seeking (Anthony *et al.*, 2009; Lakhani and Wolf, 2005; Wasko and Faraj, 2005; Wei *et al.*, 2015) and value-congruent effects (Anthony *et al.*, 2009; Yang and Lai, 2010), together with intellectual and relational satisfaction, can act as a more significant motivator of knowledge contribution. However, while the unique effect of registration is strong, the synergistic effect from public discussion

Table IV Results of hypothesis testing

Hypotheses	*Results*
H1-I. Participants who take part in both public discussion and private messaging and who have registered will make more contributions than those who do not take part in at least one of these activities	Supported
H1-G. Participants who take part in both public discussion and private messaging and who have registered will exert a stronger positive impact on the group collaboration efficiency than those who do not take part in at least one of these activities	Supported
H2-I. Participants who take part only in public discussion will contribute more than those who take part only in private messaging	Supported
H2-G. Participants who take part only in public discussion will exert more positive impact on the group collaboration efficiency than those who take part only in private messaging	Supported
H3-I. Participation in public discussion or private messaging will be more positively related to individual knowledge contribution than registration	Supported
H3-G. Participation in public discussion or private messaging will be more positively related to group collaboration efficiency than registration	Not supported

and private messaging is not observed at the group level. Thus, reputation-seeking and value-congruent effects of registration result in contributions that are more helpful to the group outcome. Similarly, a large number of contributions by anonymous users do not always result in greater collaboration efficiency, which may be explained by the lack of commitment of anonymous users, who might not share the goals of the community (Gagne, 2009).

When comparing public discussion and private messaging, the authors, on the one hand, confirmed a significant effect of private messaging, which is in accordance with previous research (Ahuja *et al.*, 2003; Bulkley and Alstyne, 2006; Nemoto *et al.*, 2011; Wasko and Faraj, 2005). However, on the other hand, public discussion appears to be more crucial than private messaging at both the individual and group levels in this study. This result indicates that cognitive capital may be more crucial than structural or relational capital, and contrasts with the outcome that structural capital exerts a more conspicuous effect than cognitive or relational capital in electronic networks of practice for offline organizations (Wasko and Faraj, 2005). This contrast may be partly attributed to the difficulty of article creation on Wikipedia, which is a complex and non-routine task that requires much cognitive effort, multiple perspectives and creativity (Arazy *et al.*, 2011). There is also a relative weakness in relationships in an online environment where strangers congregate.

When the effect of registration compared to that of public discussion and private messaging, anonymous users who are indifferent to reputation but who participate in both public discussion and private messaging were discovered to contribute more than registered users who do not participate in either of those activities. It is notable that the edit distribution over anonymous user categories is very similar to that over registered ones. Comparing only the registered user categories or only the anonymous user categories illustrates that the amount of knowledge sharing is more highly impacted by public discussion and private messaging than by registration status. On the other hand, higher levels of knowledge sharing lead to higher collaboration efficiency only when accompanied by registration, implying the effect of reputation and commitment. Although anonymity exerts ambivalent effects, the benefits of registration appear to be significant for collaboration efficiency. In sum, registration seems to have a stronger effect on quality than quantity of knowledge contribution and alter the feedback effectiveness of public discussion and private messaging.

Despite the aforementioned fruitful findings, this research has some limitations. First, for further generalization of the results, this research needs to be extended to other languages of Wikipedia and other social media platforms. In other online communities, the actual value ranges for variables and interactive dynamics among them may differ from those of the English Wikipedia. It will be interesting to observe the differences and identify specific contextual conditions that drive different consequences. Second, this study was carried out on a cross-sectional rather than a longitudinal basis. The user category of a participant may change as he or she newly joins public discussion or private messaging. However, for brevity, the authors used only the condition of each participant just before article promotion to derive his or her category. Thus, the duration of a participant's stay in a specific category was not reflected in this study. Finally, the number of knowledge contributions may not exactly reflect the quantity of contributed knowledge, as the quantity increase in text volume per contribution may differ across contributions, and there even exist cases where a participant deletes something. Nevertheless, it works as a satisfactory and convenient proxy, and this seems to be why other past studies (Anthony *et al.*, 2009; Kankanhalli *et al.*, 2005; Wasko and Faraj, 2005) have also used this measure.

Conclusion

In this research, the authors investigated relationships among communication behaviors, and individual knowledge sharing and group collaboration efficiency. User classifications based on communication characteristics enabled a systematic analysis that included

relative comparisons of different communication patterns. This work demonstrated the existence of a synergistic effect of public discussion and private messaging in online knowledge sharing. In particular, the function of task-oriented public discussion was highlighted relative to that of private personal messaging, and the role of registration was investigated in terms of communication effectiveness and collaboration efficiency. This research enhances the understanding of participants based on their behaviors and the dynamics of online knowledge collaboration.

Based on the findings, this research suggests that encouraging members to participate in both task-oriented discussion and casual personal communication is important to enhance the efficiency of online knowledge collaboration. Registered members who do not participate in both of these activities tend to contribute far less than anonymous members who participate in both activities. Moreover, the effect of registration is more salient when there is simultaneous participation in public discussion and private messaging. The efforts of online communities to promote only registration seem to be insufficient considering the value of participating in both public discussion and private messaging. Designing online communities to encourage participants to communicate through both channels is a good strategy. A mechanism that encourages participants to send invitations to competent acquaintances both online and offline may have a ripple effect, enhancing the intellectual and relational satisfaction level of participants.

Although social capital based on one-to-one relationships has attracted much attention with respect to knowledge sharing, the many-to-many public discussions influencing knowledge conversion more deeply and broadly should be more highly emphasized. Anonymous participants who participate in public discussion contribute more than registered participants who take part only in private messaging. In the absence of relationships with others within their article group, participants taking part in public discussion are essential for knowledge collaboration in an online environment. Participation in public discussion may be facilitated by user-friendly interfaces or personalized support tools. To support an active discussion culture, other measures can be implemented as well, such as ranking the number of public discussions of each participant and voting for the participants who have been most helpful.

The perceptions of shared value and reputation based on registration also need to be cultivated to increase collaboration efficiency. When knowledge seekers express their appreciation to the knowledge contributors, feelings of shared value such as altruism (Oreg and Nov, 2008) may be enhanced. If feelings of enhanced reputation are created, participants might contribute more knowledge to the group. Although reputation is in itself an extrinsic motivation, it can indirectly improve feelings of competence and relatedness (Deci and Ryan, 1985, 2000; Gagne, 2009), and thus its effect can be greater than initially expected.

In Wikipedia's case, approximately 62 per cent of editors participate in neither article talk nor user talk. Furthermore, about 79 per cent of them do not register. The principle of "the more, the better" with respect to collaboration efficiency does not hold true for those in the no-talk-no-registration category. If the 32 per cent of editors who are participating only in user talk began participating in article talk, collaboration efficiency could be significantly improved.

Online communities are an essential element of the global knowledge ecosystem and an effective platform for knowledge collaboration. Organizations will increasingly rely on them as a source of continuous innovation and competitive advantage. Hence, understanding the collaborative dynamics in online communities will become ever more critical in this virtualized and globally competitive world. There remains an opportunity for further research to complement the limitations of this research and to shed light on the hidden parts of online knowledge collaboration.

References

Ahuja, M.K., Galletta, D.F. and Carley, K.M. (2003), "Individual centrality and performance in virtual R&D groups: an empirical study", *Management Science*, Vol. 49 No. 1, pp. 21-38.

Allen, K. (2005), "Online learning: constructivism and conversation as an approach to learning", *Innovations in Education and Teaching International*, Vol. 42 No. 3, pp. 247-256.

Amason, A.C. (1996), "Distinguishing the effects of functional and dysfunctional conflict on strategic decision making: resolving a paradox for top management teams", *Academy of Management Journal*, Vol. 39 No. 1, pp. 123-148.

Anthony, D., Smith, S.W. and Williamson, T. (2009), "Reputation and reliability in collective goods: the case of the online encyclopedia Wikipedia", *Rationality and Society*, Vol. 21 No. 3, pp. 283-306.

Arazy, O., Nov, O., Patterson, R. and Yeo, L. (2011), "Information quality in Wikipedia: the effects of group composition and task conflict", *Journal of Management Information Systems*, Vol. 27 No. 4, pp. 71-98.

Armstrong, A. and Hagel, J. III (1996), "The real value of ON-LINE communities", *Harvard Business Review*, Vol. 74 No. 3, pp. 134-141.

Balazs, A.L. (1990), "Value congruency", *Journal of Business Research*, Vol. 20, pp. 171-181.

Baldwin, T.T., Bedell, M.D. and Johnson, J.L. (1997), "The social fabric of a team-based M.B.A. program: network effects on student satisfaction and performance", *The Academy of Management Journal*, Vol. 40 No. 6, pp. 1369-1397.

Bieber, M., Hiltz, S.R., Stohr, E.D., Engelbart, C., Noll, J., Turoff, M., Furuta, R., Preece, J. and Van De Wallei, B. (2001), "Virtual community knowledge evolution", *Proceedings of the Thirty-Fourth Hawaii International Conference on System Sciences*.

Bock, G.W., Zmud, R.W. and Kim, Y.G. (2005), "Behavioral intention formation in knowledge sharing: examining the roles of extrinsic motivators, social-psychological forces, and organizational climate", *MIS Quarterly*, Vol. 29 No. 1, pp. 87-111.

Brass, D.J. (1984), "Being in the right place: a structural analysis of individual influence in an organization", *Administrative Science Quarterly*, Vol. 29, pp. 518-539.

Bruns, A. (2008), *Blogs, Wikipedia, Second Life, and Beyond: From Production to Produsage*, Peter Lang, New York, NY.

Bulkley, N. and Alstyne, V.M. (2006), "An empirical analysis of strategies and efficiencies in social networks", Boston University School of Management Research Paper No. 2010-29, MIT Sloan Research Paper No. 4682-08, available at: http://ssrn.com/abstract=887406 (accessed 11 August 2015).

Clark, H.H. and Brennan, S.E. (1991), "Grounding in communication", *Perspectives on Socially Shared Cognition*, Vol. 13, pp. 127-149.

Cohen, J. (1988), *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed., Lawrence Erlbaum Associates.

Coleman, J.S. (1990), *Foundations of Social Theory*, Belknap Press, Cambridge, MA.

Constant, D., Sproull, L. and Kiesler, S. (1996), "The kindness of strangers: the usefulness of electronic weak ties for technical advice", *Organization Science*, Vol. 7 No. 2, pp. 119-135.

Cramton, C.D. (2001), "The mutual knowledge problem and its consequences for dispersed collaboration", *Organization Science*, Vol. 12 No. 3, pp. 346-371.

Csikszentmihalyi, M., Abuhamdeh, S. and Nakamura, J. (2005), "Flow", in Elliot, A. (Ed.), *Handbook of Competence and Motivation*, The Guilford Press, New York, NY, pp. 598-698.

Currall, S.C. and Judge, T.A. (1995), "Measuring trust between organizational boundary role persons", *Organizational Behavior and Human Decision Processes*, Vol. 64 No. 2, pp. 151-170.

Davies, J. and Graff, M. (2005), "Performance in e-learning: online participation and student grades", *British Journal of Educational Technology*, Vol. 36 No. 4, pp. 657-663.

Deci, E.L., Koestelr, R. and Ryan, R.M. (1999), "A nieta-anualytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation", *Psychological Bulletin*, Vol. 125, pp. 627-668.

Deci, E.L. and Ryan, R.M. (1985), *Intrinsic Motivation and Self-Determination in Human Behavior*, Plenum, New York, NY.

Deci, E.L. and Ryan, R.M. (2000), "The 'what' and 'why' of goal pursuits: human needs and the self-determination of behavior", *Psychological Inquiry*, Vol. 11 No. 4, pp. 227-268.

Dirks, K.T. and Ferrin, D.L. (2001), "The role of trust in organizational settings", *Organization Science*, Vol. 12 No. 4, pp. 450-467.

Eisenberger, R. and Cameron, J. (1996), "Detrimental effects of reward: reality or myth?", *American Psychologist*, Vol. 51 No. 11, pp. 1153-1166.

Faraj, S., Jarvenpaa, S.L. and Majchrzak, A. (2011), "Knowledge collaboration in online communities", *Organization Science*, Vol. 22 No. 5, pp. 1224-1239.

Fayard, A.L. and Metiu, A. (2014), "The role of writing in distributed collaborations", *Organization Science*, Vol. 25 No. 5, pp. 1391-1413.

Gagne, M. (2009), "A model of knowledge-sharing motivation", *Human Resource Management*, Vol. 48 No. 4, pp. 571-589.

Gagne, M. and Deci, E. (2005), "Self-determination theory and work motivation", *Journal of Organizational Behavior*, Vol. 26, pp. 331-362.

Grant, R.M. (1996), "Prospering in dynamically-competitive environments: organizational capability as knowledge integration", *Organization Science*, Vol. 7 No. 4, pp. 375-386.

Griffith, T., Sawyer, J.E. and Neal, M. (2003), "Virtualness and knowledge in teams: managing the love triangle of organizations individuals, and information technology", *MIS Quarterly*, Vol. 27 No. 2, pp. 265-287.

Hagel, J. (1999), "Net gain: Expanding markets through virtual communities", *Journal of Interactive Marketing*, Vol. 13 No. 1, pp. 55-65.

Hawkey, K. (2003), "Social constructivism and asynchronous text-based discussion: a case study with trainee teachers", *Education and Information Technologies*, Vol. 8 No. 2, pp. 165-177.

Hsu, M.H., Ju, T.L., Yen, C.H. and Chang, C.M. (2007), "Knowledge sharing behavior in virtual communities: the relationship between trust, self-efficacy, and outcome expectations", *International Journal of Human-Computer Studies*, Vol. 65 No. 2, pp. 153-169.

Inkpen, A.C. and Tsang, E.W.K. (2005), "Social capital, networks, and knowledge transfer", *Academy of Management Review*, Vol. 30 No. 1, pp. 146-165.

Jarvenpaa, S.L. and Leidner, D.E. (1999), "Communication and trust in global virtual teams", *Organization Science*, Vol. 10 No. 6, pp. 791-815.

Jehn, K.A. (1995), "A multimethod examination of the benefits and detriments of intragroup conflict", *Administrative Science Quarterly*, Vol. 40 No. 2, pp. 256-282.

Jessup, L.M., Connolly, T. and Tansik, D.A. (1990), "Toward a theory of automated group work: the deindividuating effects of anonymity", *Small Group Research*, Vol. 21 No. 3, pp. 333-348.

Kankanhalli, A., Tan, B. and Wei, K. (2005), "Contributing knowledge to electronic knowledge repositories: an empirical investigation", *MIS Quarterly*, Vol. 29 No. 1, pp. 113-143.

Kaše, R., Paauwe, J. and Zupan, N. (2009), "HR practices, interpersonal relations, and intra-firm knowledge transfer in knowledge-intensive firms: a social network perspective", *Human Resources Management*, Vol. 48 No. 4, pp. 615-639.

Kim, A.J. (2000), *Community Building on the Web: Secret Strategies for Successful Online Communities*, Addison-Wesley Longman Publishing, Boston, MA.

Kling, R., Lee, Y., Teich, A. and Frankel, M.S. (1999), "Assessing anonymous communication on the internet: policy deliberations" *The Information Society*, Vol. 15, pp. 79-90.

Lakhani, K. and Wolf, R. (2005), "Why hackers do what they do: understanding motivation and effort in free/open source software projects", in Feller, J., Fitzgerald, B., Hissam, S. and Lakhani, K. (Eds), *Perspectives in Free and Open Source Software*, MIT, Cambridge.

Levin, D.Z. (1999), "Transferring knowledge within the organization in the R&D Arena", PhD dissertation, Northwestern University.

McCluskey, T. and Korobow, A. (2009), "Leveraging networks and social software for mission success", *The Public Manager*, Vol. 38 No. 2, pp. 66-70.

McFadyen, M.A. and Cannella, A. (2004), "Social capital and knowledge creation: diminishing returns of the number and strength of exchange relationships", *Academy of Management Journal*, Vol. 47 No. 5, pp. 735-746.

Mayer, R.C., Davis, J.H. and Schoorman, F.D. (1995), "An integrative model of organizational trust", *Academy of Management Review*, Vol. 20, pp. 709-734.

Money, R.B. and Graham, J.L. (1999), "Salesperson performance, pay and job satisfaction: test of a model using data collected in the United States and Japan", *Journal of International Business Studies*, Vol. 30, pp. 149-172.

Motteram, G. and Forrester, G. (2005), "Becoming an online distance learner: what can be learned from students' experiences of induction to distance programs?", *Distance Education*, Vol. 26 No. 3, pp. 281-298.

Nahapiet, J. and Ghoshal, S. (1998), "Social capital, intellectual capital and the organizational advantage", *Academy of Management Review*, Vol. 23 No. 2, pp. 242-266.

Nemoto, K. and Gloor, P.A. (2010), "Analyzing cultural differences in collaborative innovation networks by analyzing editing behavior in different-language Wikipedias", *Proceedings of COINs 2010, Collaborative Innovations Networks Conference*, *Savannah GA*.

Nemoto, K., Gloor, P.A. and Laubacher, R. (2011), "Social capital increases efficiency of collaboration among Wikipedia editors", *Proceedings of the 22nd ACM Conference on Hypertext and Hypermedia*.

Nohria, N. and Eccels, R.G. (1992), "Face-to-face: making network organizations work", in Nohria, N. and Eccels, R.G. (Eds), *Networks and Organizations: Structure, Form and Action*, Harvard Business School Press, Boston, MA, pp. 288-308.

Nonaka, I. (1994), "A dynamic theory of organizational knowledge creation", *Organization Science*, Vol. 5 No. 1, pp. 14-37.

Nonaka, I. and Toyama, R. (2005), "The theory of the knowledge-creating firm: subjectivity, objectivity and synthesis", *Industrial and Corporate Change*, Vol. 14 No. 3, pp. 419-436.

Nonaka, I., Umemoto, K. and Senoo, D. (1996), "From information processing to knowledge creation: a paradigm shift in business management", *Technology in Society*, Vol. 18 No. 2, pp. 203-218.

Nunamaker, J.F., Dennis, A.R., Valacich, J.S. and Vogel, D.R. (1991), "Information technology for negotiating groups: generating options for mutual gain", *Management Science*, Vol. 37 No. 10, pp. 1325-1346.

Oreg, S. and Nov, O. (2008), "Exploring motivations for contributing to open source initiatives: the role of contribution context and personal values", *Computers in Human Behaviors*, Vol. 24 No. 5, pp. 2055-2073.

O'Reilly, C. (1989), "Corporations, culture, and commitment: motivation and social control in organizations", *California Management Review*, Vol. 31 No. 4, pp. 9-25.

Parent, M., Gallupe, R.B., Salisbury, W.D. and Handelman, J.M. (2000), "Knowledge creation in focus groups: can group technologies help?", *Information and Management*, Vol. 38 No. 1, pp. 47-58.

Pelled, L., Eisenhardt, K. and Xin, K. (1999), "Exploring the black box: an analysis of workgroup diversity, conflict, and performance", *Administrative Science Quarterly*, Vol. 44 No. 1, pp. 1-28.

Podolny, J.M. and Baron, J.N. (1997), "Resources and relationships: social networks and mobility in the workplace", *American Sociological Review*, Vol. 62, pp. 673-693.

Putnam, R. (1995a), "Bowling alone: America's declining social capital", *Journal of Democracy*, Vol. 6, pp. 65-78.

Putnam, R. (1995b), "Tuning in, tuning out: the strange disappearance of social capital in America", *Political Science and Politics*, Vol. 28 No. 4, pp. 664-683.

Rains, S.A. (2007), "The impact of anonymity on perceptions of source credibility and influence in computer-mediated group communication: a test of two competing hypotheses", *Communication Research*, Vol. 34 No. 1, pp. 100-125.

Ransbotham, S. and Kane, G. (2011), "Membership turnover and collaboration success in online communities: explaining rises and falls from grace in Wikipedia", *MIS Quarterly*, Vol. 35 No. 3, pp. 613-627.

Ravenscroft, A. and Matheson, M.P. (2002), "Developing and evaluating dialogue games for collaborative e–learning", *Journal of Computer Assisted Learning*, Vol. 18 No. 93, pp. 93-101.

Raymond, E.S. (2001), *The Cathedral and the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary*, O'Reilly, Sebastopol, CA.

Robert, L.P., Dennis, A.R. and Ahuja, M.K. (2008), "Social capital and knowledge integration in digitally enabled teams", *Information Systems Research*, Vol. 19 No. 3, pp. 314-334.

Rokeach, M. (1973), *The Nature of Human Values*, Free Press, New York, NY.

Saavedra, R., Earley, P.C. and Van Dyne, L. (1993), "Complex interdependence in task performing groups", *Journal of Applied Psychology*, Vol. 78, pp. 61-72.

Scott, C.R. (2004), "Benefits and drawbacks of anonymous online communication: legal challenges and communicative recommendations", in Drucker, S. (Ed.), *Free Speech Yearbook*, National Communication Association, Washington, DC, pp. 127-141.

Sheldon, K., Turban, D., Brown, K., Barrick, M. and Judge, T. (2003), "Applying self-determination theory to organizational research", *Research in Personnel and Human Resource Management*, Vol. 22, pp. 357-393.

Sproull, L. and Arriaga, M. (2007), "Online communities", in Bidgoli, H. (Ed.), *Handbook of Computer Networks: Distributed Networks, Network Planning, Control, Management, and New Trends and Applications*, John Wiley & Sons, New York, NY, Vol. 3.

Tsai, W. and Ghoshal, S. (1998), "Social capital and value creation: the role of intrafirm networks", *The Academy of Management Journal*, Vol. 41 No. 4, pp. 464-476.

Van den Hooff, B. and De Ridder, J.A. (2004), "Knowledge sharing in context: the influence of organizational commitment, communication climate and CMC use on knowledge sharing", *Journal of Knowledge Management*, Vol. 8 No. 6, pp. 117-130.

Warkentin, M.E., Sayeed, L. and Hightower, R. (1997), "Virtual teams versus face-to-face teams: an exploratory study of a web-based conference system", *Decision Sciences*, Vol. 28 No. 4, pp. 975-996.

Wasko, M. and Faraj, S. (2000), "It is what one does: why people participate and help others in electronic communities of practice", *Journal of Strategic Information Systems*, Vol. 9 Nos 2/3, pp. 155-173.

Wasko, M. and Faraj, S. (2005), "Why should I share? Examining social capital and knowledge contribution in electronic networks of practice", *MIS Quarterly*, Vol. 29 No. 1, pp. 35-57.

Webb, E., Jones, A., Barker, P. and Van Schaik, P. (2004), "Using e-learning dialogues in higher education", *Innovations in Education and Teaching International*, Vol. 41 No. 1, pp. 93-103.

Wei, X., Chen, W. and Zhu, K. (2015), "Motivating user contributions in online knowledge communities: virtual rewards and reputation", *Hawaii International Conference on System Sciences (HICSS)*, pp. 3760-3769.

White, N. (2006), *The Tools of Online Connection*, available at: www.fullcirc.com/community/connecttools.htm (accessed 1 August 2015).

Wiesenfeld, B.M., Raghuram, S. and Garud, R. (1999), "Communication patterns as determinants of organizational identification in a virtual organization", *Organization Science*, Vol. 10 No. 6, pp. 777-790.

Wighting, M.J., Liu, J. and Rovai, A.P. (2008), "Distinguishing sense of community and motivation characteristics between online and traditional college students", *The Quarterly Review of Distance Education*, Vol. 9 No. 3, pp. 285-295.

Wittke, V. and Hanekop, H. (2011), *New Forms of Collaborative Innovation and Production on the Internet*, Universitätsverlag Göttingen.

Worthen, B. (2008), "Why most online communities fail", *Wall Street Journal*, 16 July.

Yang, H. and Lai, C. (2010), "Motivations of Wikipedia content contributors", *Computers in Human Behavior*, Vol. 26, pp. 1377-1383.

Zaheer, A., McEvily, W. and Perrone, V. (1998), "Does trust matter? Exploring the effects of inter-organizational and interpersonal trust on performance", *Organization Science*, Vol. 9 No. 2, pp. 141-159.

Further reading

Brandon, D.P. and Hollingshead, A.B. (2004), "Transactive memory systems in organizations: Matching tasks, expertise and people", *Organization Science*, Vol. 15 No. 6, pp. 633-644.

Hinds, P. and Kiesler, S. (1995), "Communication across boundaries work, structure, and use of communication technologies in a large organization", *Organization Science*, Vol. 6 No. 4, pp. 373-393.

Moon, J.Y. and Sproull, L.S. (2008), "The role of feedback in managing the internet-based volunteer workforce", *Information Systems Research*, Vol. 19 No. 4, pp. 494-515.

Ryan, R.M. and Deci, E.L. (2008), "Self-determination theory and the role of basic psychological needs in personality and the organization of behavior", in John, O.P., Robbins, R.W. and Pervin, L.A. (Eds), *Handbook of Personality: Theory and Research*, Guilford Press, New York, NY, pp. 654-678.

Sparrowe, R.T. (2001), "Social networks and the performance of individuals in groups", *Academy of Management Journal*, Vol. 44 No. 2, pp. 316-325.

Appendix 1

Further analysis of other behavioral combinations

Using the results in Figure 1 and Table AV, the authors can estimate the order of influential magnitude of the three respective behaviors toward the level of knowledge sharing: public discussion, private messaging and registration. This sequence is inferred from the decreasing trend in the average edit numbers and medians for user categories 2A, 3A and 4R, representing the effect of each behavior, respectively. Registration results in very little difference among the three pairs, (2R, 2A), (3R, 3A) and (4R, 4A). In contrast, a concurrency of public discussion and private messaging shows conspicuous differences between the 1R and 1A categories. At the group level, the order of importance with regard to group collaboration efficiency appears to be public discussion, registration and private messaging. This sequence was directly drawn from the magnitude of each corresponding coefficient, namely, the Cat2A_UserRatio, Cat4R_UserRatio, and Cat3A_UserRatio (zero) coefficients] of COX 4 in Table III.

Comparing combinatory effects of two of the three activities on knowledge sharing, the sequence is public discussion and private messaging, public discussion and registration and private messaging and registration, judging from the descriptive statistics of the 1A, 2R and 3R categories in Table AIV corresponding to each pair of behaviors. With respect to collaboration efficiency, public discussion and registration comes first, while the combination of discussion and private messaging is insignificant, indicated by the Cat2R_UserRatio, Cat3R_UserRatio, Cat1A_UserRatio (zero) coefficients of COX 3.

Clearly, the coexistence of the three behaviors exhibits the most desirable effects for both knowledge sharing and collaboration efficiency. The opposite extreme of this is that anonymous users who do neither of the two activities edit the least and significantly impede group collaboration efficiency. However, if they join either of the two activities, the negative effect becomes insignificant (1A, 3A) and can even become positive (2A).

Appendix 2

Table AI Descriptive statistics for COX 1-COX 4

Variable	*Minimum*	*Maximum*	*Mean*	*SD*
NumOfUsers	2	5,782	247.42	500.33
MeanInterArrivalTime	0.02	58.67	3.86	4.10
MeanRetentionTime	0.33	238.92	35.05	26.87
MeanRetentionTime2	0.11	57,083.86	1,950.04	3763.26
NumOfSections	0	43	14.02	6.11
NumOfReferences	0	456	67.45	50.82
Cat1R_ParticipantRatio	0.00	80.00	10.11	8.57
Cat1A_UserRatio	0.00	5.00	0.05	0.26
Cat2R_UserRatio	0.00	25.00	0.75	1.69
Cat2A_UserRatio	0.00	18.75	0.40	0.92
Cat3R_UserRatio	0.00	100.00	42.16	14.90
Cat3A_UserRatio	0.00	16.67	0.47	0.91
Cat4R_UserRatio	0.00	72.73	17.48	8.84
Cat4A_UserRatio	0.00	73.08	28.58	18.38

Table AII Variable correlations for COX 1-COX 4

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
1. NumOfUsers	1.00												
2. MeanInterArrivalTime	−0.27	1.00											
3. MeanRetentionTime	−0.13	0.34	1.00										
4. NumOfSections	0.34	−0.30	−0.03	1.00									
5. NumOfReferences	0.40	−0.24	0.04	0.59	1.00								
6. Cat1R_UserRatio	−0.32	0.04	0.14	−0.28	−0.23	1.00							
7. Cat1A_UserRatio	0.05	−0.10	−0.01	0.06	0.04	−0.02	1.00						
8. Cat2R_UserRatio	−0.06	0.02	−0.11	−0.02	−0.08	0.00	0.01	1.00					
9. Cat2A_UserRatio	0.10	−0.07	−0.07	0.09	0.04	−0.09	0.13	0.03	1.00				
10. Cat3R_UserRatio	−0.35	0.27	0.30	−0.24	−0.14	0.26	−0.10	−0.12	−0.23	1.00			
11. Cat3A_UserRatio	0.24	−0.10	−0.04	0.14	0.11	−0.10	0.13	−0.03	0.05	−0.20	1.00		
12. Cat4R_UserRatio	−0.27	0.13	−0.13	−0.13	−0.18	−0.04	−0.04	0.10	−0.04	−0.31	−0.10	1.00	
13. Cat4A_UserRatio	0.55	−0.30	−0.23	0.37	0.31	−0.65	0.08	−0.04	0.20	−0.75	0.21	−0.22	1.00

Table AIII Registered and anonymous user distributions

Variable	*Registered*	*Anonymous*	*Total*
Total users	364,344	372,462	736,806
Distinct users	107,733	320,624	428,357
Articles/User	3.38	1.16	1.72

Table AIV Correlations describing online behaviors of users

Variable	*1*	*2*	*3*
1. Number of edits	1.000		
2. Number of public discussion	0.499	1.000	
3. Number of private messaging	0.202	0.123	1.000

Table AV User and edit distributions over categories[a]

User category	N	*User ratio (%)*	*Mean (edits/editor)*	*SD*	*Median*	*Minimum*	*Maximum*	*Edit ratio (%)*
1R	33,263	4.5	35.4	108.5	5.4	1	3338	47.0
1A	533	0.1	14.6	37.6	3.8	1	493	0.3
2R	4,131	0.6	4.5	15.1	1.9	1	431	0.7
2A	4,222	0.6	4.3	10.7	1.8	1	207	0.7
3R	233,462	31.7	2.3	7.2	1.4	1	814	21.3
3A	6,686	0.9	2.6	6.3	1.5	1	346	0.7
4R	93,488	12.7	1.5	1.9	1.3	1	259	5.7
4A	361,021	49.0	1.6	2.1	1.3	1	199	23.5
Total	736,806	100.0	3.4	24.6	1.4	1	3338	100.0

Note: [a]The number of editors having edited an article was counted independently from those of other articles, meaning that, if an editor had edited two articles, he or she was counted twice for each article

Table AVI Results of robust regression for user category 1R or 1A[a]

Variable	*b*	*p-v. of t for b*	*R^2*	*Adjusted R^2*
ln_ArtTalks	0.53053	0.000	46.8%	46.8%
ln_UserTalks	0.08569	0.000		
ln_ArtTalks × ln_UserTalks	0.07607	0.000		

Notes: [a]Dependent variable: the natural log value of the number of edits of each user in category 1R or 1A (ln_Edits); independent variables: the natural log value of the number of article talks of each user in category 1R or 1A (ln_ArtTalks), the natural log value of the number of user talks of each user in category 1R or 1A (ln_UserTalks) and the interaction term for determining the synergistic effect of these two variables (Dev_ln_ArtTalks × Dev_ln_UserTalks). To avoid multicollinearity, deviations of the variables are used; the *F*-value for verifying the significance of adding the interaction term to the additive model at the degree of 1 and 33,846 confirms the synergistic effect; Robust Regression: Function "lmRob" of Package "robust" of R; R^2: (robR2w.WithCorrection), Adj. R^2: (robR2w.AdjustedWithCorrection); we transformed our variables with the natural log to fit them into the linear regression model. Thus, the editors of the other categories were excluded from the analysis because at least one of their independent variables could not be defined (If the number of article talks is zero, the natural log of zero cannot be defined)

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