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It is rotating leaders who build the swarm: social network determinants of growth for healthcare virtual communities of practice

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Abstract

Purpose – *The purpose of this paper is to identify the factors influencing the growth of healthcare virtual communities of practice (VCoPs) through a seven-year longitudinal study conducted using metrics from social-network and semantic analysis. By studying online communication along the three dimensions of social interactions (connectivity, interactivity and language use), the authors aim to provide VCoP managers with valuable insights to improve the success of their communities.*

Design/methodology/approach – *Communications over a period of seven years (April 2008 to April 2015) and between 14,000 members of 16 different healthcare VCoPs coexisting on the same web platform were analysed. Multilevel regression models were used to reveal the main determinants of community growth over time. Independent variables were derived from social network and semantic analysis measures.*

Findings – *Results show that structural and content-based variables predict the growth of the community. Progressively, more people will join a community if its structure is more centralised, leaders are more dynamic (they rotate more) and the language used in the posts is less complex.*

Research limitations/implications – *The available data set included one Web platform and a limited number of control variables. To consolidate the findings of the present study, the experiment should be replicated on other healthcare VCoPs.*

Originality/value – *The study provides useful recommendations for setting up and nurturing the growth of professional communities, considering, at the same time, the interaction patterns among the community members, the dynamic evolution of these interactions and the use of language. New analytical tools are presented, together with the use of innovative interaction metrics, that can significantly influence community growth, such as rotating leadership.*

Keywords *Virtual communities, Healthcare, Knowledge sharing, Social networks, Community building, Semantic analysis*

Paper type *Research paper*

1. Introduction

Virtual communities of practice (VCoPs) in health care are becoming increasingly popular as technology enables and facilitates knowledge exchange among health professionals from all over the world, including areas that are geographically or professionally isolated (Dieleman and Duncan, 2013). In addition to websites that more generally target professionals of any industry (e.g. LinkedIn), an increasing number of social networking platforms that are dedicated to healthcare professionals exist. This offers healthcare professionals the possibility of collaborating with their peers, to manage information and to develop and spread knowledge (Jennings Mabery *et al.*, 2013; Mairs *et al.*, 2013).

The rapid growth in dimension and popularity of VCoPs is not surprising (Dieleman and Duncan, 2013; Li et al., 2009; Ho et al., 2010) as social networking theories point out how knowledge sharing and learning in the digital era have mainly become social activities (Pettenati and Cigognini, 2007). Joining VCoPs has therefore become a great opportunity for highly knowledge-intensive and specialised healthcare professionals.

Thanks to VCoPs, healthcare professionals can access a common platform where they can learn, discuss or share resources with colleagues, thus building a professional support network and accelerating the process of translating evidence-based research into daily practice (Rolls et al., 2008; Parboosingh, 2002; Winkelman and Choo, 2003, Ho et al., 2010). VCoPs in health care can be used to discuss problems and best practices and work on research projects by sharing resources or generating new ideas, thus deriving benefits in terms of enhanced quality of care, creation of new knowledge, as well as increased productivity (Demiris, 2006; Endsley et al., 2005; Robinson and Cottrell, 2005; Sandars and Heller, 2006). Moreover, the opportunity to share knowledge while overcoming geographical barriers supports both personal professional development and the overall performance of the process of care delivery (Dieleman and Duncan, 2013).

Factors favouring knowledge sharing in VCoPs have long been the focus of interest among researchers (Aljuwaiber, 2016; Hara and Foon Hew, 2007; Stewart and Abidi, 2012), who have highlighted that the successful design and management strategies of online communities heavily depend also on the community's specific characteristics (Andrews, 2002; Li et al., 2009; Iriberri and Leroy, 2009). However, although the role played by VCoPs in health care as enablers and facilitators of knowledge exchange among health professionals, policy makers and researchers is widely recognised as pivotal (Mairs et al., 2013), there are still only a few studies examining the characteristics of online platforms in this area (Ho et al., 2010; Hara and Foon Hew, 2007; Stewart and Abidi, 2012). Moreover, even though previous studies have recognised social dynamics as one of the most important determinants of members' participation in VCoPs (Amichai-Hamburger et al., 2016; Hara and Foon Hew, 2007), there has been little research on this from the perspective of social interaction and group processes (Malinen, 2015).

The purpose of this study is twofold. On the one side, we aim to extend the theoretical body of research on VCoPs by contributing to a greater understanding of social processes between community members and their impact on the growth of healthcare VCoPs. On the other side, we aim to provide VCoP managers with useful insights to build and sustain the flourishing of their communities, specifically through the use of online-platform analytical tools.

Most studies about social processes in VCoPs (Hara and Foon Hew, 2007; Nistor et al., 2014; Stewart and Abidi, 2012) have focused on the analysis of structural metrics using social network analysis (SNA) (Wasserman and Faust, 1994; Malinen, 2015) and have disregarded other relevant aspects of social interactions, such as longitudinal dynamics, sentiment or emotionality of the language used. To the best of our knowledge, there is no research investigating the joint effects of community structure, longitudinal interactions and language used on the growth of VCoPs. To this aim, we conducted a seven-year longitudinal study on 16 healthcare VCoPs coexisting on a common Web platform. We carried out our quantitative analysis along the three dimensions of social interaction: use of language, connectivity (structural analysis) and interactivity (longitudinal analysis of the interactions) (Gloor et al., 2017a). Although the present study has been set in the healthcare domain, the general results we present here might be tested and eventually extended to VCoPs operating in other professional domains as well.

2. Virtual communities of practice

Advances in technology are deeply changing the way people communicate and exchange knowledge. The rise of the internet started many forms of online sociality, including e-mail,

instant messaging, blogging, social networking and other online services (Heer and Boyd, 2005). In the past decades, social interaction has progressively become the most popular activity among internet users, and virtual communities (VCs) have emerged and rapidly increased in number and size (Zickuhr, 2010; Gross, 1999; Petersen, 1999). VCs can be described as "social aggregations that emerge from the net when enough people carry on public discussions long enough, with sufficient human feeling" (Rheingold, 1993, p. 5). The main purposes of VCs are knowledge sharing and social interaction (Burnett, 2000; Ridings and Gefen, 2004). VCs are characterised by a persistent interaction among members (Smith, 1999; Ridings et al., 2002), which makes them feel part of a greater social group, establishes a notion of membership and contributes to the development of relationships among participants (Figallo, 1998; Sproull and Faraj, 1997). Compared to face-to-face communities, electronic means make participation independent from the physical location and allow a larger and a more heterogeneous composition of joiners (Sproull and Faraj, 1997), thus facilitating communication and enhancing diversity inside the learning network. Allen et al. (2016) proved the value of communication regardless of physical proximity: the quality of the exchanged knowledge and the communication behaviours have a much stronger impact than physical clustering. The characteristics provided by virtual interaction lead to the development of "weak tie" relationships (Granovetter, 1973), making VCs an ideal place to exchange knowledge and information also with people not known in person (Constant et al., 1996). Consistently, knowledge exchange is one of the main motivations leading people to participate in VCs (Wasko and Faraj, 2000).

There are various types of online communities (Lazar and Preece, 1998; Gain, 1997; Stewart, 2010), each built with a different purpose and providing specific benefits to its members. In particular, online communities include communities of practice (CoPs) for professionals, enterprise communities, social network websites, wikis and creative and question-answer sites (Malinen, 2015). The so-called virtual CoPs (VCoPs) are a kind of VC.

CoP is still an evolving concept (Li et al., 2009). Several definitions of CoP have been given by different authors (Lave and Wenger, 1991; Brown and Duguid, 1991; Wenger, 1998; Wenger et al., 2002). While definitions differ from each other because they focus on different perspectives from which CoPs can be analysed (Cox, 2005), all of them agree on the key role played by social interaction in fostering learning and knowledge sharing among individuals. From the perspective of our study, we refer to COPs as:

> [. . .] groups of people who share a concern, a set of problems or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis (Wenger et al., 2002, p. 4).

Wenger et al. (2002) outlined three main elements characterizing CoPs: *domain*, *community* and *practice*. VCoPs' members participate in a process of collective learning through social interactions (*community*) within a specific domain of interest representing the "common ground" (*domain*) on which they develop, share and maintain knowledge (*practice*) (Wenger et al., 2002). These three elements should be all present and work well together to nurture the process of creation and dissemination of knowledge within a VCoP (Wenger et al., 2002; Wenger and Snyder, 2000; Wenger, 2000).

2.1 Improving participation in communities of practice

While some communities exhibit extraordinary membership growth, there are many others that languish or rapidly vanish. Recent studies show that by 2010, the majority of the Fortune 1000 companies experimented with some form of online communities and that such efforts failed to reach the desired outcome in more than half of the cases (Sarner, 2008). Market data show that 70 per cent of online communities fail (Gartner press release, 2012). It cannot be assumed that people will automatically join and actively participate in a VC. Even when people have common interests or objectives, they may have little or no intention to share it on a social network (Andrews, 2002).

In response, researchers from various disciplines are searching for conditions, strategies and guidelines to face the challenge of building and sustaining successful VCs. As a result, a wide body of theoretical and empirical literature has been developed to derive or empirically test drivers and contextual factors that are likely to play an important role in the growth of online communities (Paroutis and Al Saleh, 2009; Iskoujina and Roberts, 2015; Barker, 2015; Leimeister et al., 2005; Kraut et al., 2012; Hall and Graham, 2004; Kim, 2000; Dubé et al., 2005; Preece, 2000; Kling and Courtright, 2003). In particular, two major research streams emerged in this field:

1. Research focusing on the analysis of the steps related to creating a successful platform with active participation (Andrews, 2002; Matei et al., 2015); and

2. Research aimed at identifying and describing the important drivers of popularization of existing platforms (Gunawardena et al., 2009; Spagnoletti et al., 2015).

Factors that motivate and hinder participation within online communities have been investigated by many researchers. These studies focus on different aspects (Koh et al., 2007) and point out that participation in online communities can either be passive or active (Malinen, 2015, Jones et al., 2004; Nonnecke and Preece, 2001). While active members actively contribute to the community, passive members participate in the community taking advantage of the knowledge offered without contributing to the community activities. In our empirical research, we focus on social interactions among factors that influence active participation.

Participation represents an essential factor for the flourishing of VCoPs, as it leads to the accumulation of experience and stimulates the social construction of knowledge and the development of expertise (Bishop, 2007; Paavola et al., 2004; Nistor et al., 2014). VCoPs are characterised by self-selection and the voluntary nature of participation, as people voluntarily choose to contribute to joint activities and discussions, help other members and share information (Wasko et al., 2004). Therefore, VCoPs exist as long as participation to the community is of value to their members (Gray, 2004), and the value of a VCoP largely depends on the ongoing participation of its members (Chen, 2007; Fang and Chiu, 2010; Cheung et al., 2013).

Literature about online knowledge sharing and VCoPs points out three macro-factors affecting participation in online communities: individual factors; technological factors; and social factors (Hara and Foon Hew, 2007; Malinen, 2015; Amichai-Hamburger et al., 2016; Paroutis and Al Saleh, 2009; Ardichvili et al., 2003; Nistor et al., 2014). While technological factors involve technical and usability issues about online communities, individual factors refer to CoP members' characteristics such as motivations, personalities, values, time available and other individual traits. Social factors, on the other hand, are related to the social-group processes and include aspects such as the role of individuals within the community (e.g. moderator roles) and the social interaction among members, such as posting news or questions and answering one another.

This study focuses on factors influencing the growth of healthcare VCoPs. The framework underlying our research is presented in Figure 1.

We focus on social factors for different reasons. First, behaviours and communication patterns in the social environment have been found to play a pivotal role in the development of CoPs and VCoPs (Amichai-Hamburger et al., 2016; Battistoni and Fronzetti Colladon, 2014; Jeon et al., 2011; Hara and Foon Hew, 2007; Nistor et al., 2014). Second, even though technological factors are recognised as important, they are not the main determinants for abandoning or preventing participation (Maloney-Krichmar and Preece, 2005; Brandtzæg and Heim, 2008).

The impact of social processes on the success of online communities has been investigated from different perspectives using qualitative methods, quantitative methods or

Figure 1 Theoretical framework
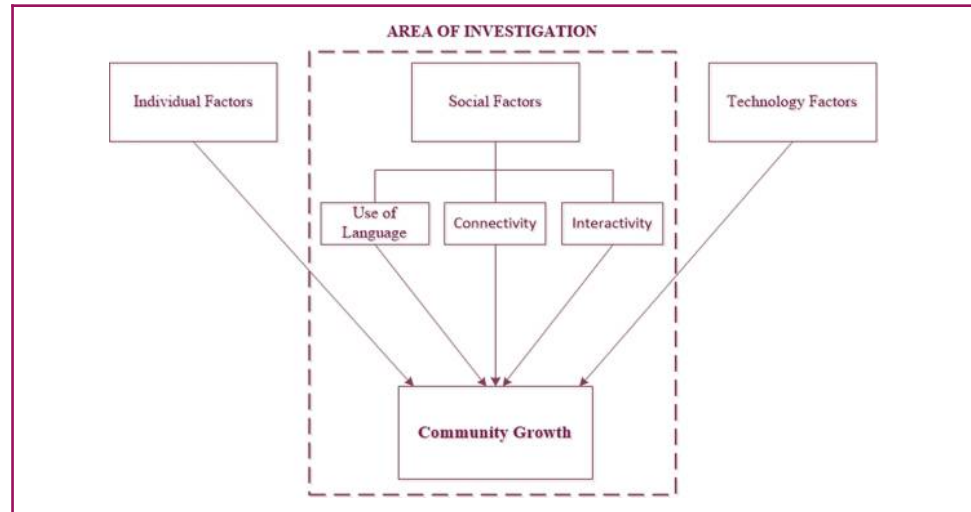
both (Malinen, 2015; Liao and Chou, 2012; Dennen, 2014). As our objective is to find success drivers for VCoPs, which could be easily assessed and monitored also by managers of online platforms with a high volume of members and information exchange, in this study we adopt a quantitative approach. In this context, SNA is recognised as a valuable investigating method (Malinen, 2015) and has been used in many previous studies to analyse the social interactions within online communities (Zaphiris and Sarwar, 2006; Pfeil and Zaphiris, 2009; Stewart and Abidi, 2012; Nistor et al., 2014). However, these studies focused mainly on the volume of communication and on the density and patterns of the network (Malinen, 2015). We maintain that a purely structural approach to social relations is not sufficient to explore the social processes underlying online community dynamics (Yuan, 2013; Malinen, 2015) – a more comprehensive understanding of social interactions requires content/sentiment metrics to be studied alongside network centrality measures.

Accordingly, we propose to analyse social processes by adopting the conceptualization of social interactions and correspondent metrics proposed by Gloor (2006, 2016), Gloor et al. (2017a, 2017b)). Their approach is the result of research conducted over the past 14 years at the MIT Center for Collective Intelligence: hundreds of communications archives (Twitter, Facebook, Wikipedia, e-mail and face-to-face network) were analysed and key characteristics of high performing groups were identified. As a result, a set of metrics was developed that is based on network structure, network dynamics and network content of communication patterns. Therefore, we conceptualise the social aspect of VCoPs on the basis of the three dimensions of social interaction described by Gloor et al. (2017b):

1. *connectivity*, where we analyse the network structure;

2. *interactivity*, where we measure the evolution of the interaction patterns over time; and

3. *language use*, where we measure the community content, in terms of sentiment, and emotionality.

Moreover, we conceptualise participation as the growth of a community. Although many previous empirical studies have used the volume of activity as a proxy of community participation (Malinen, 2015), Iriberri and Leroy (2009) have shown that the number of active members involved in the community can be used as a more reliable indicator of community participation and as a proxy for the community success.

3. Research model and hypotheses

Our research model is presented in Figure 2, and the formulation of the study hypotheses is laid out in the subsequent sections.

3.1 Use of language

Individuals are more willing to share knowledge and engage in virtual communities characterised by high levels of social trust (Huysman and De Wit, 2004; Inkpen and Tsang, 2005; Chiu et al., 2006), reciprocity and cooperation (Wasko and Faraj, 2000, 2005; Chiu et al., 2006). Hara and Foon Hew (2007) have also demonstrated that members of health-related VCoPs are more likely to voluntarily contribute (self-select) to communities having a non-competitive environment. These findings are grounded on basic principles of human psychology. In communities with a social environment characterised by trust and collaboration, it is likely that members develop positive sentiments toward each other. These positive sentiments increase the willingness of individuals to share knowledge and actively participate in virtual communities, whereas the development of negative affectivity states increases members' resistance to engage in communities' discussions (Nahl, 2005; Lin et al., 2009). Accordingly, we hypothesise a positive relationship between the sentiments expressed in community messages and participation in the community.

> H1. Communities with members showing a more positive sentiment in the language used will grow faster.

High levels of personal involvement and emotional attachment increase community members' engagement and lead them to be more willing to exchange opinions, information and ideas (Blanchard and Markus, 2004; Chang and Chuang, 2011). Moreover, members who actively interact and discuss topics in a specific community in cyberspace tend to develop the same emotional attachment to the virtual site as if they were in a physical place (Koh and Kim, 2004). Therefore, we expect that communities where people are more emotionally involved (members deviate from neutral sentiment) will increase the desire for new members to join and actively participate in the community.

> H2. Communities where conversations are more emotional will grow faster.

The use of a shared language or codes between members increases the social capital of a community (Chang and Chuang, 2011; Tsai and Ghoshal, 1998). Common language is important because it increases the likelihood that members understand each other more easily, thus assisting them in sharing community objectives and behavioural adequacy in VCs (Tsai and Ghoshal, 1998). Sharing a common language fosters the efficiency and efficacy of communication in VCs (Wenger et al., 2002; Chiu et al., 2006; Chang and Chuang, 2011). It enables members to gain access to information, helps them evaluate the quality of information exchanged, reduces misunderstandings between participants and enhances their capability to catch the knowledge through social exchange (Chiu et al.,

Figure 2 Research model
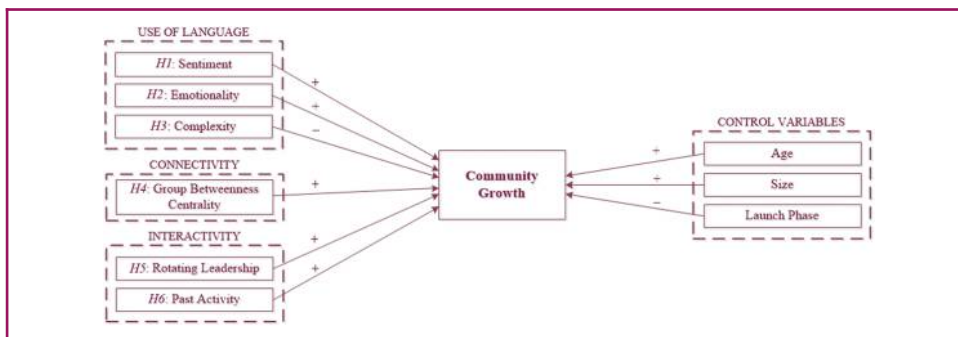
2006; Chang and Chuang, 2011; Nahapiet and Ghoshal, 1998). Conversely, when members' languages and codes are different, they tend to be isolated and their ability to access information is much more limited (Nahapiet and Ghoshal, 1998). Hence, shared language is considered essential for motivating participants to be more actively involved in the community's life (Chiu *et al.*, 2006; Chang and Chuang, 2011). We operationalise the concept of shared language through the measure of complexity (described in Section 4). Accordingly, we hypothesise that the use of a common language makes VCoPs more attractive.

> *H3.* Communities in which members use a less complex language (i.e. with a smaller vocabulary) will grow faster.

3.2 Degree of connectivity

According to the theories of social capital and collective action, the network structures derived by social interactions between individuals are important predictors of collective and individual actions (Burt, 2009; Putnam, 1995; Rogers and Kincaid, 1981). In particular, the individual position in a network structure of a VCoP influences the willingness of community members to share knowledge with others (Wasko and Faraj, 2005).

The structural position within a community network represents the social dimension of the identity of CoP members, and it "serves as a pivot between the social and the individual" (Wenger, 1998, p. 145) and can be defined according to their levels of expertise. The identity of CoP members might range from novice to expert (Lave and Wenger, 1991; Wenger, 1998). The status of an "expert" within a community is the result of a negotiation process, which takes place through the interactions and communications in the social environment. Members with a higher expertise are socially recognised as experts (Nistor *et al.*, 2014). Other than to be characterised by superior knowledge and skills, experts within a CoP are also involved in more activities and contribute a higher quality dialogue, thus increasing the level of participation and the attractiveness of the community discussions. Experts, therefore, often have a central position, and the status of an expert in a VCoP can be quantitatively measured through SNA centrality measures (Nistor *et al.*, 2014, Nistor and Fischer, 2012).

For this reason, we expect that communities with a more centralised communication structure, often suggesting the presence of more major experts, are likely to have a higher growth rate. Network centralisation is calculated as the group betweenness centrality score (Freeman, 1977; Wasserman and Faust, 1994).

> *H4.* Communities with a more centralised communication structure will grow faster.

3.3 Degree of interactivity

Rotating leadership, revealed by rapidly changing network structures where actors oscillate between peripheral and more central network positions, can have a relevant impact on communication styles. In particular, a democratic leadership style and the adoption of distributed responsibilities enhance knowledge-sharing dynamics in virtual communities and nurture the engagement level of participants (Kayworth and Leidner, 2002; Lin *et al.*, 2009). Moreover, a rotating leadership style increases the perceived value of joining the community, as it positively affects individual and group creativity and has been found to be a predictor of innovative performance (Gumusluoglu and Ilsev, 2009; Allen *et al.*, 2016). Consistently, we expect that a more democratic participation in the community discourse, with members oscillating between low and high betweenness centrality scores, will increase the attractiveness of the community.

> *H5.* Communities where actors rotate more – changing their position from being central to being peripheral, and vice versa – will grow faster.

Communication activity is at the core of social interaction processes. Activity and responsiveness in the communication process play a vital role in keeping a community alive, and greater knowledge-sharing activity leads to wider active participation (Koh and Kim, 2004). Consistently, Koh and Kim (2004) showed that community knowledge-sharing activity predicts both community participation and community promotion. By contrast, a social structure where there is no communication cannot provide benefits for its members (Butler, 2001). Moreover, in public online environments, more active discussions can produce a more intense information exchange between participants, leading to a better indexing on search engines (Van Looy, 2016). This promotes the community and attracts new members.

We, therefore, expect a positive relationship between the volume of communication and the capacity of a community to retain existing members and attract new joiners.

> *H6*. Communities with higher levels of activity (number of posts per month) will grow faster.

Finally, community growth can be deeply influenced by its size and age. Larger and older communities can often benefit from the presence of a bigger number of active members who can promote their communities among colleagues via word of mouth. Moreover, since each community is accessible and searchable on the Web, being older and with a larger number of posts will improve the indexing of relevant search engines such as Google (Van Looy, 2016). This may increase the likelihood of attracting new members. New-born communities, on the other hand, will not benefit from past contributions.

Consistently, research findings show that the impact of factors underlying the flourishing of online communities varies according to the distinctive phases characterising the online community lifecycle (Malhotra *et al*., 1997; Wenger *et al*., 2002; Andrews, 2002). Therefore, strategies and recommendations to help online communities to succeed should be developed and calibrated on the basis of the specific lifecycle-phase of the online community (Iriberri and Leroy, 2009). For these reasons, we include in our models three control variables, indicating the age and size of a community, as well as the specific stage of its lifecycle.

4. Methodology

To test the proposed research model and the relative hypothesis, we conduct an empirical research on a set of health professionals' online communities, namely, 16 VCoPs, all operating on the same web platform. Communication among members takes place in all of the 16 communities, each covering a specific topic of interest. The analysed platform includes contents and discussions on healthcare delivery and management. It connects over 19,000 members representing 185 countries, thus enabling the exchange and dissemination of knowledge and information among professionals having different roles in the healthcare system (e.g. policy decision makers, academics, physicians, etc.). The data set is composed of forum discussion records collected from April 2008 to April 2015, comprising more than 14,000 community members and about 20,000 community posts. Data collection for each community started from its creation. We analyse all the data available for the communities operating on the Web platform at the time of data collection – accordingly, our study includes the entire population and is not restricted to a random sample.

More specifically, we analyse the GHD online's professional virtual communities, created in 2008 with the aim to diffuse knowledge by enabling researchers and practitioners to share all forms of data, expertise and resources widely and quickly. Built on this foundation of creating public goods, GHDonline has developed an approach to community management focused on fostering high-quality, dynamic conversations among a group of diverse healthcare professionals. GHDonline membership is free and is open to the public.

Members create profiles that can be viewed by other members. This level of transparency enhances accountability among the members and helps professional dialogue.

For the analysis, we use SNA tools and metrics, a well-known set of methods for the analysis of social interactions (Wasserman and Faust, 1994). We represent each community member as a network node, drawing a link between two nodes when one member comments or responds to another during online conversation. This allows us to study the interaction among all members and its evolution over time.

In addition, a content/sentiment analysis is carried out. We use the social network and semantic analysis software Condor[1] to calculate the structural and content metrics and their evolution over time (Gloor, 2006, 2016; Gloor *et al.*, 2017a, 2017b).

4.1 Definition of variables

We use the number of new members joining a community as a proxy for community success, measured in terms of community growth.

Joiners is our dependent variable, calculated as the number of new members who join a community each month, contributing at least one post to the online discussion.

As discussed in Section 3, community growth can be deeply influenced by its size and age and by the fact of being in a launch phase. Accordingly, we include the following control variables in our models.

Size represents the size of a community, measured as the number of members who contribute at least once to the discussion of the community topics.

Age refers to the age of the community, expressed in months since its start-up.

Launch Phase is a binary control variable meant to identify whether a community is in this phase or in a later life stage. Specifically, within our experimental setting, we determine two thresholds that identify communities in the launch phase: when a community's age is 3 months or younger and when the number of members is less than 50.

In the remaining part of this section, we present the variables we use as potential predictors of community growth. These variables represent the three dimensions of social interaction in virtual environments, as illustrated in the work of Gloor *et al.* (2017a). As suggested by these authors, we refer to the research model presented in Section 3 and we include variables to measure the degree of connectivity, i.e. the social network structure; the degree of interactivity, i.e. the dynamic changes in the network structure over time; and the use of language, i.e. the sentiment, emotionality and complexity of the community posts.

4.1.1 Use of language. Sentiment, emotionality and complexity are important dimensions of the language used, which have proved their value in past research. These metrics – calculated by means of the multilingual classifier included in the software Condor – are used, for example, to assess virtual behaviours of employees and optimise communication styles, with the objective of improving customer satisfaction (Gloor *et al.*, 2017a) or to forecast turnover intentions and disengagement of company managers (Gloor *et al.*, 2017b). As discussed in Section 3, we hypothesise that a less complex and more positive and emotional language will support community growth.

Sentiment represents the sentiment of the language used in the community posts. It varies in the range [0,1], where 1 is the most positive value and values below 0.5 indicate a negative sentiment. This variable is calculated using a multi-lingual classifier based on a machine learning method trained on large data sets extracted from Twitter (Brönnimann, 2014).

Emotionality is a variable that measures the level of emotionality of the language used, calculated as the standard deviation of sentiment (Brönnimann, 2014). In a community

where the level of emotionality is high, there is a more vivid debate in which sentiments frequently alternate between positive and negative (Grippa *et al.*, 2014).

Complexity represents the average complexity of the vocabulary used and is calculated as the likelihood distribution of words within a forum post, i.e. the probability that each word of a dictionary appears in the text (Brönnimann, 2014). The more the language is shared, the less is its complexity, indicating that the same set of words is more frequently used among the community members, even if these words could be classified as complex or rare.

4.1.2 Degree of connectivity. Degree of connectivity reflects the social structure of a community network and is therefore analysed using metrics from SNA. To evaluate the overall network structure, we choose group degree centrality, among the many possible centrality measures (Freeman, 1979). Our choice depends on the fact that this metric provides us with an important indication about how much dominated a social network is. It describes whether the network is more or less dependent on overly connected nodes, which more frequently lie in the paths that interconnect the other social actors. Group betweenness centrality is, therefore, a useful proxy for the identification of community leaders, and, in past research, it has been correlated to community success and creativity of community members (Kidane and Gloor, 2007).

Group Betweenness Centrality indicates how centralised is the communication within a community. The higher the group betweenness centrality, the more the information revolves around few key people – – or hubs, or moderators – – that have a major role in the network and contribute to keeping different subgroups together. A perfectly dominated network would look like a star, with one central social actor and all the others just interacting with her/him (Wasserman and Faust, 1994). In general, we can consider community networks as oriented graphs of n nodes (user accounts), referred to as $G = \{g_1, g_2, g_3 [...] g_n\}$, and of m directed arcs (community posts) linking these nodes, when one user responds to another. Individual betweenness centrality scores are calculated as suggested by Wasserman and Faust (1994):

$$B_C(g_i) = \sum_{j<k} \frac{d_{jk}(g_i)}{d_{jk}}$$

where d_{jk} is the number of shortest paths linking the generic couple of nodes g_j and g_k, and $d_{jk}(g_i)$ is the number of paths that contain the node g_i. This measure can be standardised by dividing it by $[(n-1)(n-2)/2]$. The group betweenness centrality score is then given by,

$$GB_C = \frac{2 \sum_{i=1}^{n} [B_C(g^*) - B_C(g_i)]}{[(n-1)^2(n-2)]}$$

where $B_C(g^*)$ is the largest $B_C(g_i)$ score for the actors in the group.

4.1.3 Degree of interactivity. In this study, the degree of interactivity is represented, for the first part, by past activity of community members, which can enrich the knowledge shared in a VCoP and be a determinant of attraction for new members, and for the second part, by the oscillations in betweenness centrality for the members of a community (rotating leadership). A communication style based on rotating leadership proves to favour knowledge sharing and to foster innovative performances (Allen *et al.*, 2016). Having high scores of rotating leadership means that a community is operating more "democratically", being less dominated by few static leaders. In such a community, one could expect a more free and dynamic knowledge sharing activity, which can attract more community members (Davis and Eisenhardt, 2011; Kidane and Gloor, 2007).

Past Activity is the number of messages posted in a community in the month that precedes the current one.

Rotating Leadership is measured as the average number of oscillations in betweenness centrality for the members of a community each month (Davis and Eisenhardt, 2011). Specifically, considering the individual betweenness centrality scores of the members of a group, rotating leadership counts the number of times individual scores reach local maxima or minima. It can also be interpreted as a measure of the liveliness of a discussion, reflected in network structures that change frequently, with actors fluctuating between peripheral and central network positions (Kidane and Gloor, 2007).

5. Results

In our models, we study – longitudinally – the influence of content and network metrics on the number of new active members. The communities we analyse are homogeneous with respect to the target audience and the Web platform used, so we do not need to control for such differences. In addition, none of the analysed communities received external promotion through any marketing campaign. Attraction of new members was mainly based on word of mouth, with the additional possibility of finding the communities by crawling the web: contents are publicly available and indexed by the major search engines.

In the empirical data analysis, we first examine the correlation among the abovementioned variables. Then we test the influence of predictor variables on the number of joiners through a multilevel regression model to take into account the nested nature of data (Fidell and Tabachnick, 2007; Young, 2013). Pearson's correlation coefficients are presented in Table I.

Table I shows that the number of new members is correlated with a lower complexity of the language (initially supporting *H3*) but not significantly with sentiment and emotionality. Therefore, it seems that the use of a common language, regardless of its sentiment and emotionality, is beneficial to community building. We posit this result is also influenced by the topics covered by each community, here all meant for a specific audience of healthcare professionals. With regard to structural and interaction metrics, we find that both group betweenness centrality and rotating leadership are positively correlated with the number of new joiners, thus supporting *H4* and *H5* and pointing to the importance of the role of informal leaders within a community. New members will be attracted by a community where some key people act as connectors with different subgroups and contribute significantly to the online discussion, sharing their knowledge and advice. In addition, it seems that newcomers prefer communities where rotating leadership is higher, with more members fluctuating frequently from central to peripheral discussions, not holding a static position. We also find a significant correlation between joiners and past activity levels, as expected in *H6*. This is probably due to the greater visibility that a community acquires when discussions become more active. Moreover, there is a positive association between size and past activity, probably due to the fact that the number of messages exchanged

Table I Community growth: correlation coefficients ($N = 754$)										
Variable name	1	2	3	4	5	6	7	8	9	10
1 Joiners	1									
2 Age	0.195**	1								
3 Size	0.292**	0.889**	1							
4 Launch phase	−0.170**	−0.575**	−0.530**	1						
5 Emotionality	−0.080*	0.047	0.013	−0.065	1					
6 Sentiment	0.063	0.055	0.105**	−0.053	−0.012	1				
7 Complexity	−0.229**	−0.244**	−0.265**	0.129**	0.046	−0.202**	1			
8 Past activity	0.300**	0.261**	0.396**	−0.233**	−0.082*	0.053	−0.167**	1		
9 Group betweenness centrality	0.374**	0.147**	0.149**	−0.045	−0.056	−0.131**	−0.325**	0.171**	1	
10 Rotating leadership	0.234**	0.086*	0.132**	−0.104**	−0.056	0.002	−0.122**	0.219**	0.146**	1

Notes: **$p < 0.01$; *$p < 0.05$

increases with the number of members and the age of the community. On the other hand, size and activity are significantly smaller in the launch phase. Additionally, age significantly correlates with size and joiners, once again confirming the greater attractiveness of older communities. Our main control variables – age, size and launch phase – are correlated to one another, thus leading to potential collinearity problems. Further, the conceptual link among these three variables is strong: we observe that communities that are older, bigger and not anymore in the launch phase attract more new members, supporting the concept of preferential attachment, where older and more connected nodes show a higher attractive power (Jeong *et al.*, 2003). One solution to collinearity is performing a principal component factoring by combining our control variables and retaining just one single factor accounting for 80 per cent of the variance, with the following factor loadings: 0.94 for age, 0.93 for size and −0.77 for launch phase. This results in an additional factor variable that we call *Maturity*, which is higher for communities that are older and of a bigger size and smaller when communities are in the launch phase. We use this new control variable in the multilevel regression models presented in Table II. When dealing with repeated measures over time, using a mixed model is more appropriate than using multiple regression models: it allows random intercepts and slopes to control for significant differences between communities.

Results from the multilevel regression models (Table II) support *H4*, *H5* and *H6*, with a relevant effect of group betweenness centrality over the other predictors. These findings provide evidence about the importance of having formal or informal leaders in a community, who can support and facilitate the discussion; community attractiveness will be even higher when leaders are not static but rotate more, supporting a more distributed participation. Past activity is also a relevant driver of community growth, supporting the idea that a more active community is more attractive and potentially more popular on the Web. *H3* is supported by our models, even if the effect of language complexity is much smaller when considered together with the other predictors. Sentiment and emotionality, on the other hand, do not contribute significantly in this context. Finally, our findings are reinforced by an intraclass correlation coefficient of 10.61 per cent, suggesting that only a small part of variance is accountable to the differences between the communities.

Adding random slopes to the models did not significantly improve them. We also controlled for seasonal trends with no big relevance for our models. We only noticed a significant negative effect of Christmas holidays on the number of new members. Figure 3 summarises our results.

Table II Determinants of community growth

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	6.054**	6.252**	28.071**	1.697**	7.385**
Maturity		1.137**			
Sentiment			−2.126		
Complexity			−2.892**		−0.846*
Emotionality			−7.294		
Past activity				0.039**	0.038**
Group betweenness centrality				6.029**	5.730**
Rotating leadership				1.951**	1.914**
Variance Level 2	2.871	2.252	2.381	1.836	1.748
Variance Level 1	24.196	23.184	23.292	19.458	19.340
ICC	10.61%				
Change in variance Lev. 2		−21.56%	−17.07%	−36.02%	−39.11%
Change in variance Lev. 1		−4.18%	−3.74%	−19.58%	−19.82%
N	754	754	754	754	754
Groups	16	16	16	16	16

Notes: **$p < 0.01$; *$p < 0.1$

Figure 3 Significant predictors of community growth
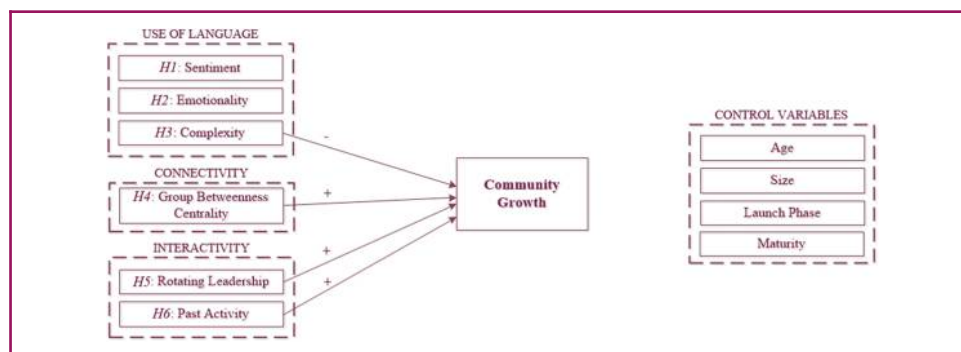
6. Discussion and practical implications

According to the results presented in Section 5, the most important factors fostering the growth of VCoPs for healthcare professionals are the level of past activity, the use of a less complex language and the presence of a centralised leadership structure and of rotating leaders frequently changing their position over time.

As expected, our findings show that communities where people interact more, attract more members. This result confirms previous studies exploring the dynamics of virtual communities (Koh and Kim, 2004; Butler, 2001) and suggests a virtuous circle, where an increase in the knowledge-sharing activity leads to greater participation and so forth.

In consistence with the theories of collective action and social capital (Burt, 2009; Putnam, 1995), our study also reveals that the growth of a VCoP is influenced by the behaviours of people playing a major role in the community. Activities in CoPs and VCoPs are informal and highly voluntary, and they heavily rely on members' self-motivation and initiative. Thus, informal leadership structure, other than formal structure, plays a pivotal role in the success of the community. Inside CoPs, informal communities' leadership is indeed considered one of the most critical success factors in the increase of activity and participation in the community (Wenger, 1998; Zboralski, 2009). Individuals who are centrally embedded in the social network of a community are more likely to cooperate and share knowledge with others (Wasko and Faraj, 2005). Moreover, community members assume a central position within a network as a result of a negotiation process within the social environment, in which they are recognised as experts by other participants (Nistor *et al.*, 2014). People who are embedded in the centre of the social network of a VCoP are likely to have a greater expertise in the field discussed as compared to other members, and therefore, they are more likely to provide a greater contribution in terms of quality of the discussion. This explains our result about the positive link between network centralization and the attractiveness of a community. These findings are also aligned with previous research highlighting the importance of moderators and people with high centrality scores on the overall members' participation (Wasko and Faraj, 2005; Hara and Foon Hew, 2007; Barnett *et al.*, 2012; Nistor *et al.*, 2014; Baek and Kim, 2015).

We also find that VCoPs having a network structure that rapidly changes over time, with rotating leaders, are likely to attract more active members. This result is aligned with previous research showing how a "democratic" leadership style positively contributes to the improvement of knowledge-sharing dynamics within VCoPs, thus positively affecting members' participation (Kayworth and Leidner, 2002; Lin *et al.*, 2009).

The fact that a VCoP grows more when its structure is more reliant on the communication of central people and when there is more rotating leadership can be explained by the important role of "experts" played by people within highly specialised communities. In fact,

in this type of community, the presence of "experts" on the specific topic being discussed is extremely beneficial to the value of the debate (Wasko and Faraj, 2005; Nistor *et al.*, 2014).

In addition to factors related to the network structure and dynamics, our findings provide some evidence that the use of a less complex, more shared language in communication between communities' members contributes to the growth of VCoPs. These results are aligned with previous studies pointing to the importance of a shared language as a key enabler of knowledge-sharing dynamics within VCoPs (Wenger *et al.*, 2002; Chiu *et al.*, 2006; Chang and Chuang, 2011). This holds particularly true in our study focusing on VCoPs in the healthcare setting. In fact, like for other highly specialised communities, discussions between healthcare professionals are characterised by specific conventions of language, which are known only by the experts of the field in question (Diesner and Evans, 2015). However, our findings also indicate that, although the use of a shared language is important for the growth of a VCoP, it is not as important as the network structure and dynamics.

Chiu *et al.* (2006) have suggested that shared language can increase the quality of shared knowledge, but not its quantity. However, when a language is too limited, with the members of a group repeatedly discussing the same topic without adding new knowledge, it could hinder the creation of new concepts and the introduction of new ideas.

Finally, our results show that the expression of positive (or negative) sentiment and intense emotional states in the messages exchanged by community members does not have a significant impact on the growth of VCoPs. This contrasts with previous studies maintaining the beneficial impact of a positive sentiment (Nahl, 2005; Lin *et al.*, 2009) and emotionality (Blanchard and Markus, 2004; Chang and Chuang, 2011) on community success. However, professional communities are indeed characterised by slightly positive sentiments and low emotionality, given the professional conventions of the language used (Diesner and Evans, 2015). As compared to other types of VCs, within VCoPs for healthcare professionals, it is unlikely that practitioners express strong negative or positive feelings towards colleagues, especially in public discussions (Chmiel *et al.*, 2011). This is also evident in our experiment where the average sentiment is positive but slightly above neutral and with a low standard deviation (M 0.57, SD 0.11); similarly, we find a low average emotionality with a very low standard deviation (M 0.27; SD 0.02), proving that the sentiment of the messages is almost always positive or neutral.

This study contributes to the advancement of both literature and practice in the field of online community building. It represents probably the first attempt to analyse the impact of social aspects on the growth of VCoPs by taking into account simultaneously the joint effect of the three dimensions of social interactions (use of language, connectivity and interactivity). In addition, we investigate the effects of new promising metrics such as the betweenness centrality oscillations (rotating leadership). While the level of past activity is commonly recognised as an important contributor to the growth of VCoPs, the role of rotating leadership in supporting the interaction and creating a more fluid communication environment is a new factor, which has not been previously investigated by other studies.

As compared to other studies using qualitative methods (e.g. surveys, interviews), which prevail in the field and are mostly descriptive (Bolisani and Scarso, 2014), we offer an overview of an analytical approach that could be easily replicated by community managers and practitioners interested in improving the management of VCoPs.

As the role of healthcare VCoPs as an important means for knowledge sharing and professional support between healthcare professionals is increasingly recognised (Rolls *et al.*, 2008; Parboosingh, 2002; Winkelman and Choo, 2003; Ho *et al.*, 2010), the identification of success drivers and practical strategies potentially leading to their

flourishing should not be overlooked. Dholakia et al. (2004, p. 261) have suggested that virtual communities are:

> [. . .] only likely to grow in importance, influence, and the activities for which they are used as consumers become more comfortable and acclimatised to these environments and marketers learn how to forecast, monitor and design their communication programs to take advantage of such opportunities.

The way an online community is managed decisively influences the willingness of members to contribute to the community (Iskoujina and Roberts, 2015).

Practical implications for community managers are twofold. First, we confirm previous research findings pointing to the importance of social interactions in the success of VCoPs (Amichai-Hamburger et al., 2016; Jeon et al., 2011; Hara and Foon Hew, 2007; Nistor et al., 2014).

Second, the perspective of analysis adopted in this study as well as the choice of relative metrics has been purposefully designed to provide managers of VCoPs with relevant information, which can be easily derived from data available on online platforms. As compared to qualitative approaches of studying social interactions within VCs (Malinen, 2015), the quantitative approach proposed in this study supports the development of more data-driven analytic tools.

On the basis of these insights, platform managers could, for example, monitor past activity, identify attractive discussion topics and split or merge existing communities on the basis of their similarities in the language used or in the network structure; most importantly, they could better measure the role of experts and elect formal moderators or recruit participants with high skills in a specific knowledge domain.

Finally, our findings are particularly relevant for practitioners interested in starting new online communities involving healthcare professionals; our insights motivate further research on testing our methods and tools in other knowledge-intensive industries or professional contexts.

7. Limitations and conclusion

This study has identified factors leading to the growth of healthcare VCoPs using a new quantitative approach to the analysis of social interactions in this setting, taking into account simultaneously the content, the structure and the longitudinal dynamics of community communication.

One of the major findings of this study is that, differently from what is reported for other types of online communities, within VCoPs, emotionality and sentiment of the messages exchanged are less important than structural and dynamic aspects of the network – the growth of VCoPs is mostly related to the presence of leaders/experts and to their ability to rotate and foster a more democratic participation.

The fact that some of the variables identified in this study significantly impact the growth of the communities also suggests that the use of analytical tools to monitor social dynamics within VCoPs is a promising approach for increasing their success.

Limitations of this study and directions for future research are presented here. First, we focus on 16 VCoPs for healthcare professionals hosted by the same platform; specifically, we analyse all the data available on the platform at the time of data collection. The 16 analysed communities are representative of a range of different healthcare topics, sometimes pretty different, such as HIV prevention or global surgery. Moreover, the platform is targeted toward a variety of audiences, with participants sometimes carrying out very different jobs in the healthcare context (e.g. nurses, physicians, accountants) across different countries. Even if the problem of differences between communities is partially solved by the use of multilevel regression models (which also show a rather low intraclass

correlation coefficient), we encourage future research on a larger number of online communities operating in knowledge-intensive sectors other than healthcare. Moreover, the inclusion of more control variables, such as individual traits (e.g. age, location, personality and Web literacy) or professional characteristics of members (e.g. domain knowledge, experience, job, organization and formal role), could help verify and generalise our findings.

Finally, although as compared to other researches on VCoPs adopting mainly SNA variables (Zaphiris and Sarwar, 2006; Pfeil and Zaphiris, 2009; Stewart and Abidi, 2012; Nistor et al., 2014), our analysis has been enriched by content and interaction metrics, we do not consider more qualitative aspects such as the evolution of specific discussion topics. Therefore, in line with Malinen (2015), we suggest further research to combine both qualitative and quantitative approaches.

Note

1. available at: www.galaxyadvisors.com/products/

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