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What makes a good contributor? Understanding contributor behavior within large Free/Open Source Software projects – A socialization perspective

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ABSTRACT

Attracting new contributors is a necessary but not a sufficient condition, to ensure the survival and long-term success of Free/Open Source Software (FOSS) projects. The well-being of a FOSS project depends on the turning of project newcomers into 'good contributors' that is to say into individuals that substantially contribute to the project - but also that perform citizenship behaviors that protect and nurture its community. This study is a mixed-methods investigation of the socialization factors that influence contributor performance in large FOSS projects. A qualitative research component resulted into the development of a FOSS socialization framework as well as into the identification of key FOSS project citizenship behaviors. A conceptual model was then developed and empirically examined with 367 contributors from 12 large FOSS projects. The model hypothesizes the mediating effect of two proximal socialization variables, social identification and social integration, between FOSS newcomer socialization factors and contributor performance (conceptualized as task performance and community citizenship behaviors). The results demonstrate the influence of social identification and social integration in predicting contributor performance, as well as the importance of key socialization factors that are: task segregation, task purposefulness, interaction intensity, and supportiveness. Theoretical and practical implications are discussed.

Introduction

The prominence garnered by Free/Open Source Software (FOSS) development along with the software industry's transformation it has engendered (Morgan and Finnegan, 2014), are unquestionable testaments of the overall attractiveness and success of FOSS development as a viable alternative to the conventional proprietary model of producing software (Daniel and Stewart, 2016; Sacks, 2015). While firms are more and more aware of the business value that can be derived from Free/Open Source Software (Marsan et al., 2012; Morgan and Finnegan, 2014; von Krogh and Spaeth, 2007), they have also realized that managing the use and development of FOSS can be a critical factor towards firm success (Dahlander and Magnusson, 2005; Gulati et al., 2012). A key feature that differentiates FOSS projects from traditional proprietary software projects is the reliance on an active and dedicated community consisting of talented individuals whose skills tap into a wide

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spectrum of software-related domains. The leveraging of such communities by firms has been shown to lead to substantial economic and organizational benefits (Chesbrough, 2007; Morgan et al., 2013).

Despite the success of the overall FOSS movement, research has demonstrated that FOSS projects are characterized by high project abandonment rates (Stewart et al., 2006), a lack of new developers' enrolment (Hahn et al., 2008) and a lack of sustained participation (Fang and Neufeld, 2009), altogether seriously endangering their survival, long-term success, and sustainability. Ensuring the continuing enrolment of newcomers is not, in and of itself, a guarantee that new members will perform well and help to sustain their FOSS communities. A FOSS community that attracts a large number of new contributors from which a majority does not successfully or satisfactorily carry out project tasks may not prosper in the long run and may even disappear. In addition, one of the key factors for maintaining the strength of FOSS communities concerns the manifestation of citizenship behaviors among contributors, behaviors such as sharing and helping (Kuk, 2006; Wu et al., 2007). If such citizenship behaviors begin to fade, the survival of the community may be seriously jeopardized.

FOSS communities have traditionally believed that access to the source code repository and to the interaction logs (such as mailing lists or forums) was sufficient for prospective contributors to attain a necessary level of performance, and engage in citizenship behaviors. FOSS communities are becoming aware that joining a FOSS project is characterized by (often important) entry obstacles that pertain to the specificity and complexity of development practices. Unless more is done, their sustainability is endangered. Adopting a wide range of strategies, they have launched various initiatives to attract new participants (e.g. creating newcomer sub-communities, running formal mentoring programs, implementing formal joining processes, etc.) but also to ensure that appropriate contributor behaviors are generated from new contributors.

Moreover, a unique feature that characterizes FOSS project engagement is that the experience through which an individual goes during the socialization phase is unique to each individual. As a result, it is not enough for FOSS communities to make sure socialization resources and initiatives are available for potential newcomers. Communities need to identify the practices that generate behaviors which are aligned with a project's values and goals. As a result, the overarching research question guiding this study is: *What socialization factors influence contributor performance in FOSS communities?*

To date there has been no careful scientific investigation of the effectiveness of such initiatives. There is then a need for FOSS communities and academic researchers to collaborate in order to help communities design appropriate socialization practices that generate satisfactory contributor behaviors. Drawing upon theories of socialization and citizenship behaviors from organizational behavior research, this research is an 'embedded' mixed-methods research design (Creswell and Plano, 2011; Venkatesh et al., 2016). The first stage consisted of conducting a qualitative research component which objective was twofold: to identify the important aspects that characterize the socialization experience of FOSS project newcomers, and to delineate the various instances of citizenship behaviors that are specific to the FOSS community context. The second step involved the development of a socialization model that hypothesizes the mediating effect of two proximal socialization variables, social identification and social integration, between FOSS newcomer socialization (captured as six distinct constructs) and contributor performance, conceptualized as task performance and community citizenship behaviors. The model was tested through an online survey involving 367 contributors from 12 large FOSS projects.

The rest of this paper is organized as follows. A review of the literature constituting the theoretical foundations of this study is first provided. We then explain how our research model was developed by integrating results from the literature as well as from a prior qualitative research component. After having described the implemented methodology, the data analysis and results are presented, followed by a discussion of the key findings, limitations, as well as implications for both research and practice.

Theoretical background

Towards a dynamic community-centered view of FOSS projects

FOSS practices started attracting the attention of IS researchers when they realized that a totally different software development methodology could engender high quality software with the potential of transforming the entire software industry (Morgan and Finnegan, 2014; Sacks, 2015). Ensuring the long-term success and sustainability of FOSS projects has become a critical concern for a number of organizations that derive strategic value from the use of FOSS (Chengalur-Smith et al., 2010; Marsan et al., 2012). The social structure of FOSS projects have been recurrently depicted as an 'onion-like' model with contributors ranging from passive users, active users, co-developers, to core developers within which are included project initiator and release coordinator and often project and community managers (Crowston and Howison, 2005; Jensen and Scacchi, 2007). The widespread acceptance of the onion-like model has acted as a theoretical converging lens orienting most FOSS research efforts towards the technical side of FOSS project development. As a result, a number of research projects adopted a techno-centric approach to assess contributor participation through programming-related measures such as the number of lines of code written in a project's source code, number of commits (AlMarzouq et al., 2015; Colazo, 2014; Colazo and Fang, 2010), or software downloads (Peng et al., 2013).

However, the static nature of the onion-like model is limited in its capacity to capture the mechanisms that govern the FOSS project reality as it was shown that the core group of a FOSS project does not persist for long periods of time; new generations take the lead over after a certain amount of time (Herraiz et al., 2006). Moreover, the onion model tends to assume that a new contributor, starting as a user, has to work his way through all layers of the onion model in order to reach the core

developer level. Research has demonstrated the limited predictive power of the model by emphasizing the absence of any typical project joining patterns (Herraiz et al., 2006) or role migration and advancement processes that are theorized by the model. Thus, the widespread view of FOSS project organization tends to fail at explaining how the FOSS production system is sustained and reproduced over time. Adopting a socialization perspective is a complementary strategy that can help better apprehend the dynamic nature of FOSS projects (Di Tullio and Devan, 2008; Fang and Neufeld, 2009; Qureshi and Fang, 2010).

Furthermore, adopting a software code-centric approach is only legitimate for projects of small size or else for those that are close to the initiation phase during which, in general, only developers are involved. The omission of non-programming and non-technical contributions appears questionable when a FOSS project grows to the point that the project gains the support of an active community that takes part in every aspect of the project (Fang and Neufeld, 2009). In such cases, individuals may be assigned one or several roles and may be in charge of various tasks that may go well beyond bug reporting, patch submission, or simply writing code. Some FOSS research efforts have identified the presence of a wide set of tasks such as quality assurance roles, source code versioning roles (e.g. CVS manager, CVS committer, etc.), project planning, usability, licensing, and marketing roles (Jensen and Scacchi, 2007). To date, large FOSS communities try to involve more and more contributors into documentation and translation tasks, graphical and other artistic tasks, and even project promotion and advocacy.

Theoretical boundaries: FOSS community-organization hybrids

The term 'FOSS project' shall be taken as an umbrella term since the extensive variation between the different FOSS development initiatives prevents from making any generalizations about the way projects work (Carillo and Bernard, 2015). FOSS projects significantly differ along a variety of attributes. For instance, FOSS project size ranges from one to several thousand contributors; the way a handful of programmers work on a software project cannot be similar to the way a community of thousands of individuals collaborate on a project involving a much broader spectrum of tasks such as marketing, design, or licensing. Similarly, project complexity can vary from simple utilities such as a password manager or a plain text editor to much more modular projects like operating systems or programming platforms. As a result, the many nuances of the FOSS reality make the delimitation of the theoretical boundaries of the IT artifact under investigation, particularly critical (Orlikowski and Iacono, 2001).

This article focuses on *large* and *complex* FOSS projects. *Complex* projects encompass operating systems, desktop environments, or programming platforms, all characterized by a high level of modularity. The term *large* characterizes the population of contributors instead of the software artifact itself. Moreover, large and complex FOSS projects rely on a population of contributors that function in a rather structured and organized manner that contradict the implications of the traditional chaotic bazaar-view (Raymond, 1999). As mentioned by Fitzgerald (2006), the FOSS software production process, from the planning to the implementation phase, relies more on more on procedures that are used in conventional IT organizations that produce and maintain software, suggesting the presence of some degree of organization and authority. Besides, a majority of large and complex FOSS projects now rely on either non-for-profit organizations (also called 'foundations') and/or corporate sponsors that take an active role in determining the goals and direction of the projects. Finally, the commonly accepted view about the peripheral participation of newcomers that assumes that socialization entirely depends on newcomer motivation and initiatives is another inaccurate belief in the case of large FOSS projects (Fang and Neufeld, 2009; Jensen and Scacchi, 2007). Indeed, a number of projects now rely on organized joining processes and more and more events and formal programs are being run to attract and help integrate newcomers. FOSS communities have created subcommunities of newcomers that create more collective socialization experiences such as KernelNewbies for the Linux Kernel project or GNOME Love. Formal mentoring programs such as the Google Summer of Code (which has brought together between 2005 and 2015, more than 10,000 participants and mentors from more than 100 countries) have also been developed for the same reason. Other communities such as the Debian and the Gentoo projects, specifically recommend that new members perform a pre-defined series of peripheral tasks before engaging into more complex project work.

As a result, large and complex FOSS projects are neither 'bazaars' nor conventional organizations but rather lay in a spectrum between 'bazaar-like' entities and organizations (Di Tullio and Staples, 2013; Peng et al., 2013). The dual nature (organization and community) of large and complex FOSS projects strongly compromises the strict applicability of traditional organizational research as well research on digitally-enabled communities when investigating issues related to socialization, contribution, and individual performance.

As a conclusion, the socialization phenomenon in the context of this study is characterized by a combination of aspects pertaining to both organizations and online communities, but also unique characteristics that pertain to the specificities of the production mode and the nature of the good that is produced (highly complex and modular software artifacts released under FOSS licenses).

FOSS socialization

Research addressing how individuals new to a FOSS community are progressively socialized into the community is scarce (Ducheneaut, 2005). Past FOSS research investigated socialization-related notions such as community joining and member specialization during the creation of a FOSS project (von Krogh, 2003), the different project joining processes between

volunteers and paid contributors (Herraiz et al., 2006), temporal socialization trajectories (Qureshi and Fang, 2010), and lateral authority mechanisms (Dahlander and O'Mahony, 2011). The FOSS socialization process has been explained as the extent of correspondence between the personal meanings of individual contributors and the community's shared meanings (Di Tullio and Devan, 2008). FOSS community contributor integration and participation was also conceptualized as a form of legitimate peripheral participation characterized by an iterative process of situated learning (with "thinking" and "doing" activities), and identity construction through community recognition (identity-regulation) and self-perception (identity-work) (Fang and Neufeld, 2009). Criticizing the simplistic view which treats FOSS communities as static entities rather than dynamic ones, Ducheneaut (2005) viewed socialization into a FOSS project as a combination of an individual learning and a political process.

FOSS socialization research has been overall exploratory in nature, mostly using qualitative research strategies and relying on a small number of individuals (usually in a single FOSS project). This approach had the merit of providing some in-depth understanding about the rather unexplored area of human behavior in the FOSS socialization context. However, focusing on a single community and a limited number of subjects constrains the development of a broader and more generalizable comprehension of the phenomenon. There is a gap between understanding the inner socialization mechanisms in a few instances of socialization experience, and providing recommendations to FOSS communities to facilitate the effective integration of newcomers. Furthermore, archival data from FOSS project artifacts such as code repository and mailing lists were used in most cases. This raises the issue that researchers drew conclusions only based on the data that was available on the project platforms, thus limiting the scope of their conclusions. Indeed, interactions through emails, community forums, the various IRC channels, or phone calls (even physical meetings, etc.) were simply omitted when testing the various hypotheses derived by the authors despite the potential importance of such interactions. This paper implements a more global and confirmatory approach addressing an individuals' entire socialization experience and relying on primary data. It thus provides a more encompassing view of the phenomenon that also allows predictions.

Modelling socialization in organizations

Organizational socialization has a long history in academic research particularly in the fields of applied psychology, sociology, and management. In an organizational context, socialization has been characterized as the transformation from outsider to participating and effective insider (Feldman, 1976). Socialization has been understood as the process through which individuals acquire knowledge about and adjust to their work context (Van Maanen and Schein, 1979) but also as "the process of learning the behaviors and attitudes necessary for assuming a role in an organization" (Morrison, 1993a, p. 173). Van Maanen and Schein's path-breaking conceptual socialization typology has received strong support in academic research for the last 30 years. The model is still widely used in current research works (Benzinger, 2016; Song et al., 2015). Their study offered a theoretical explanation about how six distinct socialization techniques used by organizations have an influence on the role orientation of new employees. According to their theory, newcomers respond to their roles differently because the socialization tactics that are used have an influence on how information is received (Jones, 1986). However, researchers have mostly relied on the later advancements developed by Jones (1986) who refined Van Maanen and Schein's dimensions and regrouped them into broader categories. Jones argued for the existence of three broader factors:

- Context tactics (collective vs. individual and formal vs. informal): Learning task requirements as part of a group and having formal training before starting the actual job.
- Content tactics (sequential vs. random and fixed vs. variable): Clear stages exist for training, and there is a clear timetable for role adjustment.
- Social tactics (serial vs. disjuncture and investiture vs. divestiture): Receiving positive feedback and identity affirmation from organizational insiders and having a trusted insider to guide them within the organization.

Furthermore, socialization research has investigated the organizational adjustment phenomenon by either examining variables that are more "proximal" to the employee adjustment process or aspects that are more global (or "distal") indicators of newcomer adjustment (Saks et al., 2007). Socialization research relies on the assumption that the socialization methods employed by organizations (e.g. orientation programs, socialization tactics, proactive tactics, mentoring) have an impact on immediate or "proximal" socialization outcomes (e.g. task mastery, social integration, or person–organization fit). Proximal outcomes have in turn, an influence on distal (or longer-term) outcomes such as job satisfaction, organizational citizenship behavior, job performance, or turnover (Johns and Saks, 2001).

FOSS citizenship behaviors

FOSS research relying on either a project- or a community-based perspective when studying contribution/performance in FOSS projects, has developed several performance categorizations covering different contribution types. Fang and Neufeld (2009) empirically assessed participation through the lens of legitimate peripheral participation theory, differentiating conceptual contributions (advising others) from practical contributions (improving the code). Dahlander and O'Mahony (2011) studied the phenomenon of lateral progression within FOSS communities, considering project interactions as technical contributions, technical communication, and coordination work. Previous FOSS research has highlighted the importance

of helping and sharing behaviors in FOSS communities (Subramanyam and Xia, 2008; Wu et al., 2007). Other authors have investigated FOSS communities using a knowledge exchange and sharing perspective (Xu et al., 2009) and have thus considered the notion of contribution from a community-wide perspective. This approach seems to acknowledge the existence and relevance of certain contributor behaviors which, while not comprising direct software contributions, nevertheless are beneficial to the FOSS community. There is thus a research gap to identify those extra behaviors but also to examine the factors that engender them.

Katz's (1964) works have significantly influenced social scientists in conceptualizing individual performance within organizations. Katz stated that in addition to being induced to enter and remain within the system, individuals must successfully perform two types of behavior. First, they must carry out their role assignments in a dependable fashion. Second, they must manifest innovative and spontaneous activities in achieving organizational objectives which go beyond role specifications. In the early 1980s, the term 'organizational citizenship behavior' (OCB) was adopted for Katz' category of extra-role behavior (Bateman and Organ, 1983). The first wave of OCB-related research relied on the operationalization introduced by Organ (1988) who proposed five distinct dimensions that characterize the construct: altruism, conscientiousness, civic virtue, sportsmanship, and courtesy. Later, Organ subsequently expanded this model to include two other dimensions: peacekeeping and cheerleading (Organ, 1990). However, later empirical research (MacKenzie et al., 1991; Podsakoff et al., 2009) found difficulty in clearly distinguishing altruism, courtesy, peacekeeping, and cheerleading (suggesting they all belong to an overall helping dimension) thus raising serious concern about the nature and dimensionality of the OCB construct.

A more acknowledged conceptualization of organizational citizenship behaviors was developed by Williams and Anderson (1991) . The authors organize OCBs into categories on the basis of the target or direction of the behavior. In particular, they distinguish behaviors that are directed toward the benefit of other individuals (or OCB-I), and behaviors directed toward the benefit of the organization (called OCB-O). All of Organ's OCB dimensions can be captured by Williams and Anderson's conceptual scheme. Altruism, courtesy, peacekeeping, and cheerleading tap into the OCB-I category whereas conscientiousness, civic virtue and sportsmanship are captured in the OCB-O dimension (Podsakoff et al., 2009).

One of the key benefits of Williams and Anderson's (1991) model is that it is broad enough to encompass additional OCB-I/OCB-O dimensions that have been introduced in other works such as interpersonal helping (Graham, 1991) and interpersonal facilitation for OCB-I and organizational loyalty (Graham, 1991) or voice behavior (Lepine and Van Dyne, 1998) for OCB-O. Another advantage of Williams and Anderson's view towards OCB, is that it is able to include other types of citizenship behaviors that are specific to the context under study. Behaviors that pertain to the unique way FOSS communities function may qualify for being instances of citizenship behaviors directed towards individuals or else towards the project and its community.

Methodological implications

The nature and specificities of large and complex FOSS projects severely question the appropriateness of solely relying on a static and code-centric view. Adopting a socialization perspective provides a more encompassing understanding of the inner mechanisms that ensure the success and sustainability of projects. The socialization literature has demonstrated the importance of proximal socialization factors in explaining distal outcomes. This suggests that in the FOSS community context, socialization factors may have an influence on contributor behavior through the mediation of FOSS-specific proximal outcomes. Therefore, Van Maanen and Schein (1979)'s socialization model and its revision by Jones (1986) provide valuable insights towards grasping the various facets of an individual's FOSS community newcomer experience. The direct applicability of Van Maanen and Schein's socialization theory is questionable due to important differences between traditional organizational contexts and large and complex FOSS communities. Moreover, large and complex FOSS projects presuppose the existence and continuous support of an active community of individuals contributing to the software projects (Fang and Neufeld, 2009). FOSS project success seems to strongly depend on the well-being of FOSS communities which is in turned closely tied to certain non-code related behaviors that help nurture and protect communities. The literature review has highlighted a need for FOSS researchers to re-conceptualize contribution behavior by adopting a broader view about tasks that are performed within FOSS communities. Drawing insights from Katz (1964)'s works about individual behavioral requirements in organizations, it suggests to consider the two complementary notions of task performance and community citizenship behaviors.

Overall, the review of the literature led to the emergence of two unanswered subsequent research questions:

- What are the different instances of citizenship behavior in the FOSS community context?
- What are the key factors that characterize the socialization experience of newcomers in FOSS communities?

It thus appeared necessary to adopt a research design that would embrace the complexity of the FOSS socialization and citizenship phenomena. The social sciences have for long recommended the use of multi-methodology interventions when investigating phenomena that are inherently complex and multidimensional (Landry and Banville, 1992; Mingers, 2001; Tashakkori and Teddlie, 1998). Two decades ago, the "knights of change" of the IS discipline (Landry and Banville, 1992, p. 78) started advocating methodological pluralism, striving to keep the IS field away from the historical paradigm wars of the social sciences (Tashakkori and Teddlie, 1998). In this research, it appeared that a unique qualitative or else quantitative research design was ineffective to fully apprehend the research problem (Creswell and Plano, 2011). Indeed, the over-

arching research question calls for adopting a positivist view as it implies, in its wording, the use of a confirmatory approach allowing predictions. Meanwhile, the scarcity of research and inherent complexity of both FOSS community newcomer socialization and community citizenship behaviors implied the need to collect qualitative evidence.

In conclusion, a mixed methods research design was thus implemented (Mingers and Brocklesby, 1997; Teddlie and Tashakkori, 2009). This choice also contributes to answering the urgent need for relying more on mixed-methods approaches when conducting IS research (Venkatesh et al., 2013, 2016). The literature recommends to examine two main research design factors, implementation of data collection and priority, to help determine the most appropriate mixed-methods design (Creswell and Plano, 2011; Teddlie and Tashakkori, 2009). This study belongs to the QUAL-QUANT embedded design category (Creswell and Plano, 2011; Teddlie and Tashakkori, 2009; Venkatesh et al., 2016) since it is based on collecting qualitative data to answer two subsidiary research questions within a largely quantitative study that in turn aims at explaining an overarching research question.

A qualitative investigation about FOSS socialization and citizenship behaviors

The overall goal of this phase of the research was threefold. First, it was intended to delineate the key factors that categorize newcomer socialization in the context of large and complex FOSS projects. Second, the notion of community citizenship behavior, inherited from the organizational citizenship behavior literature, had to be examined in the FOSS community context to identify the citizenship behaviors that are critical to the functioning and sustainability of large and complex FOSS projects. Finally, the results of the preliminary were expected to help provide a basis for the generation of context-tailored measurement items that were used during the second phase of this mixed-methods research project.

Data collection and analysis

Eleven semi-structured interviews were conducted with FOSS experts who had experience in FOSS contribution and community management (9 men and 2 women). The experience of the interviewees as FOSS contributors ranged from several years to more than 15 years. Seven out of the eleven interviewees had some direct experience in terms of newcomer management within the communities in which they had been involved. All 7 mentioned having mentored community newcomers to some extent and 6 of them had taken part in organizing and managing community programs dedicated to attracting and engaging newcomers. Five participants contributed to FOSS communities as project managers and 2 individuals had experience as FOSS community managers (which was their main occupation). The interviewees contributed to a wide array of FOSS projects: Debian, Gentoo, GIMP, Gnome, KDE, Maemo, Mahara, Meebo, OpenHatch, Redrap, Ubuntu, Wordpress, and Yorba. Detailed demographics about the respondents are provided in the appendix section.

In addition to asking open-ended questions aiming at discovering the many facets characterizing both FOSS socialization and citizenship phenomena, Van Maanen and Schein's socialization framework as well as Organ's OCB dimensions were used as theoretical lenses to investigate both issues. The first stage of data analysis consisted of open coding. Then, the transcripts were scrutinized for similarities or differences and then grouped into clusters of conceptual units (axial coding). After several rounds of revision during the axial coding phase, the interview data were entirely recoded manually by the researchers using the final codes.[1] Further details about the sampling strategy, interview procedure, and coding techniques are provided in Appendices B and C.

Results

The analysis of the collected qualitative data allowed the identification of six distinct aspects that characterize newcomer socialization in large and complex FOSS projects. Two factors are related to the tasks performed by community newcomers (task segregation and task purposefulness), two factors pertain to interactions with other community members (interaction intensity and mentoring), and the last two (supportiveness and joining structuredness) characterize the interactions between newcomers and the community itself. Each of these factors is a separate facet of the experience through which an individual has to go through to become a project contributor. Table 1 summarizes the conceptual definition associated with each of the identified socialization aspects (sample quotes are provided in Appendix D).

The interviewees clearly confirmed the existence of two complementary aspects of an individual's contribution behavior. First, a person is good for the community based on his or her direct contributions to the project (technical or non-technical) by carrying out project tasks. Second, the interviewees highlighted another set of behaviors, independent of project-related tasks, which constitute a social ability to contribute to the well-being of communities. The analysis also allowed to identify two sets of behaviors pertaining to CCB-I (FOSS Community Citizenship Behaviors oriented towards the benefits of other individuals) and CCB-P (FOSS Community Citizenship Behaviors oriented towards the benefits of the project and its community) behaviors, in line with the OCB stream of research. Table 2 summarizes the various types of behaviors having been

[1] More details about the implemented methodology and the results can also be found in the appendix section and in the conference papers (Carillo et al., 2014a, 2014b).

Table 1
FOSS Socialization Factors – Conceptual definitions.

Task	
Task Segregation (TS)	The degree to which a newcomer has performed tasks that are specifically tailored for newcomers.
Task Purposefulness (TP)	The degree to which the sequence of tasks performed by a newcomer has been purposefully selected by the newcomer in order to learn how to become a contributor.
Individuals	
Interaction Intensity (IN)	The degree to which a newcomer is actively engaged with other newcomers and community members while learning how to become a project contributor.
Mentoring (ME)	The degree to which a newcomer has been taken under the wing of one or more experienced members while learning how to become a project contributor.
Community	
Joining Structuredness (JS)	The degree to which a newcomer has to adhere to a step-by-stepwise joining process in order to become a community contributor.
Supportiveness (SU)	The degree to which a newcomer has perceived a community to be supportive while learning how to become a project contributor.

Table 2
FOSS citizenship behaviors (supporting evidence from literature).

CCB Instances	Supporting OCB literature
CCB-I behaviors (FOSS community citizenship behaviors oriented towards the benefits of other individuals)	
Helping and assisting other community members	Altruism (Organ, 1988, 1990; Smith et al., 1983), interpersonal helping (Graham, 1991; Moorman and Blakely, 1995), helping co-workers (George and Brief, 1992; George and Jones, 1997)
Helping to prevent project problems to occur for other members	Courtesy (Organ, 1988, 1990), interpersonal conscientiousness (Coleman and Borman, 2000)
Treating others with respect	Courtesy (Alge et al., 2006; Niehoff and Moorman, 1993)
Maintaining a positive attitude	Helping co-workers (George and Brief, 1992; George and Jones, 1997), social participation (Van Dyne et al., 1994)
Facilitating member conflicts	Peacekeeping (Organ, 1988, 1990)
CCB-P behaviors (FOSS community citizenship behaviors oriented towards the benefits of the project and its community)	
Contributing with the best interest for the community	Loyalty (Graham, 1991), endorsing, supporting, and defending organizational objectives (Borman and Motowidlo, 1997), spreading goodwill (George and Brief, 1992; George and Jones, 1997), loyal boosterism (Moorman and Blakely, 1995)
Complying to the community behavioral rules	Conscientiousness (Chen et al., 1998; Niehoff and Moorman, 1993; Organ, 1988), OCB-O (Williams and Anderson, 1991)
Keeping the community informed about one's work and progress	Conscientiousness (Organ, 1988), following organizational rules and procedures (Borman and Motowidlo, 1997), obedience (Van Dyne et al., 1994), generalized compliance (Konovsky and Organ, 1996; Smith et al., 1983), OCB-O (Williams and Anderson, 1991)
Keeping project resources to a good standard	Protecting company resources (Farh et al., 1997), OCB-O (Yang et al., 2007), obedience (Van Dyne et al., 1994)
Exercising civic responsibility	Civic virtue (Graham, 1986; MacKenzie et al., 1991, 1993; Niehoff and Moorman, 1993; Organ, 1988; Podsakoff et al., 1990)
Responsible involvement in project decisions	Making constructive suggestions (George and Brief, 1992; George and Jones, 1997), civic virtue (Podsakoff et al., 1997; Vanyperen et al., 1999), identification with the organization (Farh et al., 1997), OCB-O (Yang et al., 2007)
Promoting the project to potential contributors and to the outside world	Organizational loyalty (Farh et al., 1997; Graham, 1991), loyal boostering (Moorman and Blakely, 1995), spreading goodwill (George and Brief, 1992; George and Jones, 1997)

identified during the analysis of the data along with theoretical evidence provided by the OCB literature. Sample quotes are provided in Appendix D.

Research model and hypotheses

FOSS contributor performance

Drawing insights from the seminal works from Katz (Katz, 1964; Katz and Khan, 1966) and the ongoing stream of research they engendered, this research conceptualizes individual performance in large and complex FOSS projects through two constructs. *Task performance* is defined as the *extent to which an individual carries out project tasks by meeting some minimal level of performance defined by the FOSS community to which he/she belongs* (Katz, 1964; O'Reilly and Chatman, 1986; Williams and Anderson, 1991). The second dependent variable, *community citizenship behaviors* (or CCB) is defined as *behaviors that are discretionary, not directly or explicitly recognized by the formal reward system of the community and that in the aggregate promote the effective functioning of the community* (Organ, 1988). Following Williams and Anderson (1991), the CCB construct used in this research is conceptualized as a second-order construct whose dimensions are: CCB-I (comprised

citizenship behaviors directed towards the benefit of individuals), and CCB-P (citizenship behaviors directed towards the benefit of the project). The conceptual model is summarized in Fig. 1.

Proximal FOSS socialization outcomes

According to the organizational socialization literature, social identification plays an important role in capturing how organizational newcomers are concerned with building a situational definition (Ashforth and Mael, 1989). Van Maanen and Schein (1979) argued that conceptions of the self are learned by interpreting the responses of others in situated social interactions. Furthermore, social identification was identified as one of the influential proximal outcomes of organizational socialization (Saks and Ashforth, 1997b), having an impact on distal outcomes such as job performance or OCB. *Social identification* is defined as *the extent to which one identifies with a FOSS community, leading to viewing the community's successes and failures as one's own* (Mael and Ashforth, 1992).

One of the critical challenges for newcomers is to become successfully integrated into their work group (Fisher, 1986). The socialization literature has introduced the notion of social integration as one of the important proximal outcomes of employee socialization. Von Hippel and Von Krogh (2003) emphasized the importance of studying the notion of social integration when studying FOSS participation. In this research, social integration is defined as *the extent to which an individual perceives himself/herself to be trusted and accepted by the other FOSS community contributors* (Feldman, 1981).

Effects of task-related socialization factors

In order to help newcomers learn how to contribute, FOSS communities often tailor certain tasks specifically for newcomers or at least tag project tasks that newcomers are able to perform. In the GNOME community for instance, certain bug reports are marked with the "gnome-love" keyword and are recommended for project newcomers. Other examples include the Debian project having a set of manuals for new contributors or the KDE project providing dedicated tutorials. FOSS projects expect that such tasks specifically designed for newcomers will help new contributors learn about the project and thus perform better. As a result, the following hypotheses were derived:

$H_{1a,b}$. Task segregation will be positively associated with (a) task performance, (b) community citizenship behavior.

FOSS project newcomers are free to perform tasks of their own choice. They are free to get started with submitting a patch which is expected to be handled by experienced contributors, or write an entire section in the documentation about a particularly complex module of the project. However, a newcomer may decide to purposefully perform a set of tasks that would help him or her learn about a project, gradually increasing the complexity level or else undertaking tasks from complementary parts of a software project. In addition, FOSS projects often recommend that newcomers perform tasks in a certain order which is judged to facilitate project learning. For instance, the Mozilla developer platform provides a precise set of steps to follow in order to learn how to contribute to the Mozilla codebase. As a consequence, structuring tasks in a way that optimizes learning seems to be expected to increase newcomer performance. The following hypotheses were generated:

$H_{2a,b}$. Task purposefulness will be positively associated with (a) task performance, (b) community citizenship behavior.

Effects of individuals-related socialization factors

Socialization research has emphasized the importance of sense-making (information and feedback seeking) when studying employee socialization (Ashford and Black, 1996). Early works demonstrated that information-seeking efforts towards co-workers were linked to newcomers' commitment (Louis et al., 1983) while the literature has highlighted some overlap between the affective dimension of social identity and the notion of affective commitment (Bergami and Bagozzi, 2000). Information acquisition from supervisors and coworkers was shown to positively affect attitudinal socialization outcomes such as commitment and feelings of adjustment (Ostroff and Kozlowski, 1992). A meta-analysis of 70 socialization studies revealed that information seeking had an impact on organizational commitment (Bauer et al., 2007). Robert Kraut and colleagues' works about socialization in virtual communities conclude that by using collective socialization tactics, new members are more likely to become more committed to the community (Kraut et al., 2011), thus increasing their sense of identification with it. As a consequence, the following hypothesis was derived:

H_{3a}. Interaction intensity will be positively associated with social identification.

Some empirical evidence was found in the literature to suggest a relationship between the extent to which a newcomer interacts with individuals and the person's perception towards his or her integration within a group or an organization. For instance, an investigation of the influence of socialization tactics on newcomer turnover by embedding newcomers into the organization concluded that collective tactics were positively related to on-the-job embeddedness (Allen, 2006). Morrison (1993a, 1993b) showed that information seeking and feedback seeking were related to social integration in a sample of newly recruited staff accountants. The delineation between the inquiry mode of information-seeking versus monitoring

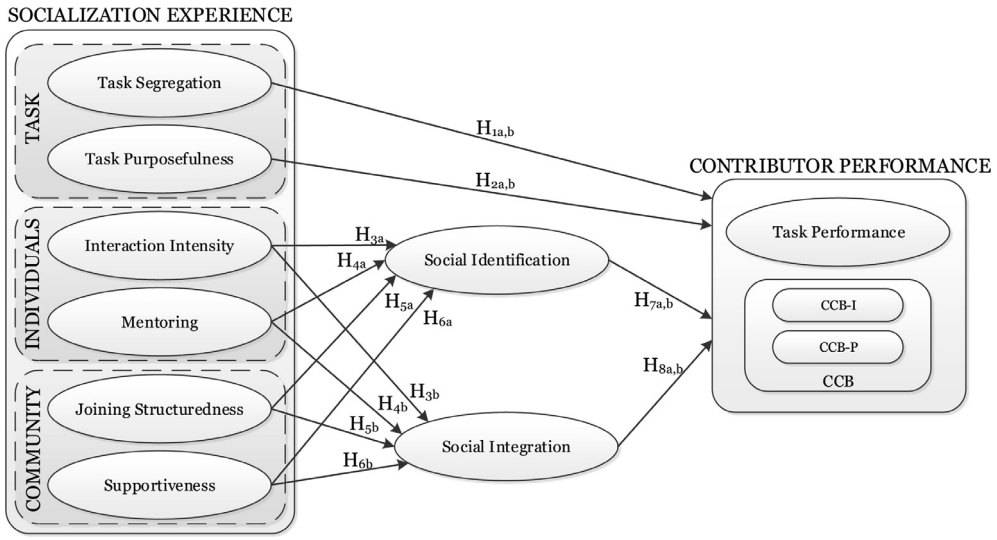

Fig. 1. Conceptual model.

(Ashford and Cummings, 1983) is particularly important in the FOSS context. Newcomers have various communication means to interact with community members in order to ask for socialization-related information, such as general or newcomer-dedicated IRC channels, mailing lists, forums, or even direct emails.

H_{3b}. Interaction intensity will be positively associated with social integration.

Mentoring has a long tradition in organizational behavior research. In their seminal work about mentoring relationships in organizational settings, Kram and Isabella (1985) identified psychosocial support as one of the two main functions played by a mentor. The authors explained that psychosocial support concerns the interpersonal aspects of the mentor-mentee relationship that enhance an individual's sense of competence and identification to an organization. It can then be argued that a mentor-mentee relationship may have an influence on the degree to which a newcomer relates to an organization or a FOSS community and identifies with it. Mentoring programs being more and more spread in FOSS projects (such as the Google Summer of Code), the following hypothesis was derived:

H_{4a}. Mentoring will be positively associated with social identification.

Studying mentor-mentee relationships, Kram and Isabella (1985) identified the relevance of career-related support, which characterizes how a mentee may benefit from the experience and influence of a mentor. Career-related support functions include actions from the mentor related to the mentee's human capital enhancement providing opportunities to create links to important individuals in the organization (Kammeyer-Mueller and Judge, 2008). Aspects of career-related support include sponsorship, exposure and visibility (Allen et al., 2004). Within the FOSS community context, a mentor may thus help a newcomer become integrated in the community by introducing the person to other community members, including influential ones. This aspect of mentoring relationship was clearly emphasized by the interview respondents during the qualitative phase of this research.

H_{4b}. Mentoring will be positively associated with social integration.

Effects of community-related socialization factors

Trice and Beyer (1984) were among the first scholars to study rites and ceremonies in the organizational context and investigated their influence on the notions of commitment and social identity. Early studies from Van Maanen (1975) showed that the ritualized socialization of policemen engendered a stronger commitment from the recruits. In the online community context, Kraut et al. (2011) reflected on the various means to keep newcomers engaged and pointed out that "barriers and initiation rituals that cause newcomers to suffer a little before joining a group should increase their eventual commitment" (p. 22). Furthermore, early works on FOSS socialization determined that the socialization process is punctuated by specific rites of passage (Ducheneaut, 2005). The author concluded that placing obstacles on the path of a newcomer's socialization experience functions as trials and rites that play an important role in the development of the individual's identity, in turn ensuring a good fit with the project.

In line with Lave and Wenger (1991), such rites of passage help newcomers become more visible to established contributors as the associated learning process contributes to identity construction. It then suggests that a formal and structured joining process in FOSS communities tend to develop a higher sense of identification to the community.

H_{5a}. Joining structuredness will be positively associated with social identification.

Actions in organizations and other social entities have often a dual significance (Islam and Zyphur, 2009). First, actions have a tangible characteristic that pertains to the instrumental nature of actions: to gain profits, to get a promotion, or reach other calculated goals (Trice et al., 1969). Second, actions often have a symbolic nature that transcribes the culture of a social entity and that plays a role in helping individuals become integrated into larger social entities (Trice et al., 1969). The reliance of formal joining processes in FOSS communities can be seen as instances of rites. For instance, sponsorship mechanisms are rather common practices in FOSS projects (e.g. Debian or Gentoo). As a result, this suggests the hypothesis that one of the goals of formal joining processes in FOSS communities is to facilitate the integration of recruits by connecting them to other community members. One's sense of being socially integrated in a FOSS community should be affected when taking part in a joining process that involves the interaction with other community members (and especially experienced ones).

H_{5b}. Joining structuredness will be positively associated with social integration.

Allen and Meyer (1990) verified the significance of the positive relationship between socialization investiture tactics (defined as tactics based on confirming the entering identity of the recruit) and organizational commitment; the notion of commitment tapping into the affective dimension of social identity. Person-organization fit and organizational commitment were both found to be affected by investiture tactics (Cooper-Thomas et al., 2004). Simosi (2010) demonstrated the role of investiture-divestiture tactics as a moderator in the relationship between newcomers' task-related information acquisition and organizational affective commitment. In sum, the literature suggests that identification with a FOSS community by a newcomer would be positively influenced by the degree of support exerted by the embedding social entity.

H_{6a}. Supportiveness will be positively associated with social identification.

Individuals who perceive the support from their organization are more likely to feel as valued and trusted organizational members (Stamper and Masterson, 2002). However, both in the organizational behavior and FOSS literatures, the evidence concerning the influence of organizational/community support on social integration is limited. For instance, a study investigated the relationship between perceived organizational support on social integration from a sample of 167 newcomers in a leading insurance organization in China, failed to find a statistically significant relationship (Chen and Eldridge, 2011). In the context of the Wikipedia encyclopedia, Carillo and Okoli (2011) investigated, among other group factors, the effect of organizational support on member support (conceptualized as the activities related to the ways individuals are embedded within a group through relations among group members). The authors did not find any significant relationship. This research aims to provide additional insights to clarify the above mentioned conflicting results.

H_{6b}. Supportiveness will be positively associated with social integration.

Effects of social identification and social integration

Social identity was found to influence individual productivity within groups (Worchel et al., 1998). The impact of social identity on individual participation has also been investigated in the context of online communities. Social identity was found to have a direct impact on overall online community participation (Liu and Iyer, 2007) or else through the mediation of participation desires and "we-intentions" (Bagozzi et al., 2007; Dholakia et al., 2004). In FOSS research, social identity was also found to influence the behavior and performance of community members in Linux user-groups intentions to participate in the user-groups which in turn was found to have an impact on participation (Bagozzi et al., 2007). Social identity was also found to have a direct and indirect impact through the mediation of effort intensity on contributor task performance (Ke and Zhang, 2009). A study empirically verified how adherence to components of the FOSS ideology impacts effectiveness in FOSS teams (Stewart and Gosain, 2006).

$H_{7a,b}$. Social identification will be positively associated with (a) task performance, (b) community citizenship behavior.

Von Hippel and Von Krogh (2003) developed the view that FOSS is a compound development model that comprises both elements of the private investment and the collective action models. The authors emphasized the importance of studying the notion of social integration in the FOSS context, seen as a means for FOSS communities to ensure that members sustain their

participation in a project. Drawing insights from Bauer et al.'s work (2007), Kraut et al. (2011) also suggest the importance of social acceptance when dealing with online community newcomers to influence their performance level. It may therefore be hypothesized that social integration in FOSS communities plays a role in influencing contributor performance:

$H_{8a,b}$. Social integration will be positively associated with (a) task performance, (b) community citizenship behavior.

Methodology

Data collection

The conceptual model was tested through a full-scale online survey involving 12 large FOSS projects: Debian, Fedora, FreeBSD, Gentoo, KDE, GNOME, Mozilla, NetBSD, openSUSE, Ubuntu, and Wikimedia/MediaWiki. It was important to determine appropriate survey participation conditions that would ensure that respondents had clear recollections of their socialization into their respective project but also that the effect of their socialization phase had not faded out entirely. After several rounds of discussion with experienced FOSS contributors, it was decided to include individuals who had joined within the last 3 years and had been active within the last six months. In total, 1137 individuals accessed the online survey and a total of 367 people completed the entire survey giving a completion rate of about 32%.

The sample was composed of a vast majority of males (88.9%) with 281 men for 35 women (Table 3 summarizes the main survey respondent demographics). The most represented FOSS project was Debian with 66 respondents followed by GNOME (42), KDE (39), and Fedora (39). A large majority of respondents were less than 35 years old (257 individuals) with a total of 94 respondents being between 21 and 25 years old. Forty-nine percent of the respondents had no previous FOSS experience when they joined the FOSS project about which they reported in their survey responses, while 20% had more than 3 years of experience (the rest of the respondents reported FOSS experience between 0 and 3 years).

The time it took for respondents to become established contributors was evenly spread out ranging from less than a month to more than a year (the highest frequency being between 1 and 3 months, with 88 individuals). Further details about the survey respondents (including contribution types) are provided in Appendix E.

Measurement development and item generation

The first phase of the quantitative component of this research involved the design and validation of a survey questionnaire instrument to test the theoretical model. The measurement items of the socialization constructs were newly generated using an inductive approach based on the scope of the conceptual definition of each construct as well as results from the interview findings (Hinkin, 1998). The measurement scales of social identification and social integration were derived respectively from Mael and Ashforth (1992) and Wanberg and Kammeyer-Mueller (2000). The operationalization of task performance and CCB was inspired from past literature (e.g. Williams and Anderson, 1991) but also strongly reliant of the results of the qualitative component of the research project. The initial item pool consisted in 48 socialization items (eight for each construct) and 35 performance-related items (7 for task performance, 11 for CCB-I, and 17 for CCB-P). The item generation phase was conducted during sessions involving the main researchers and three other IS researchers.

A panel of four experts was then conducted to provide assistance during questionnaire development and assess content validity. This phase resulted into rephrasing and refining some of the measurement items. Then, two rounds of card sorting[2] were performed (one open and one closed), following Moore and Benbasat's (1991) guidelines, allowing to have an initial 'qualitative' assessment of both construct convergent and discriminant validity. The procedure resulted into the rephrasing of some of the items, while the most problematic items were simply discarded.

Pretests and pilot study

After having created an online survey using a PHP-based FOSS online survey application, two rounds of pretest were conducted (the first one involving 5 IS academics and 5 IS PhD students and the other one with 15 experienced FOSS contributors). Finally, a pilot study involving 2 FOSS communities, Perl and LibreOffice (for a total of 41 participants) helped further appraise and refine the instrument items and scale measures. The analyses of the pilot study data confirmed that the question items exhibited adequate reliability, as well as convergent and discriminant validity. We excluded the pretest and pilot study participants from our subsequent study. By the end of the measurement development process (including item generation, the expert panel, the two card-sorting rounds, the two pretests, and the pilot study), the final questionnaire consisted of 29 socialization items and 22 performance-related items (4 for task performance, 10 for CCB-I, and 8 for CCB-P). The social identification and social integration scales were slightly fine-tuned to the context of this study.

[2] The first round (open card sorting) involved four participants: a male IS Senior Lecturer and a female PhD candidate that had a good understanding of FOSS and software development, and two male FOSS contributors (one very experienced and the other with several years of experience). The second round (closed card sorting) was conducted with four other judges: a female IS Senior Lecturer and a male IS Associate Professor, and two male FOSS contributors with several years of experience in FOSS.

Table 3
Survey respondent demographics.

Demog. criteria/FOSS project		1	2	3	4	5	6	7	8	9	10	11	12	Total
Age	*20 or younger*	1	2	2		9	10	3	1	1		12	2	42
	21–25	15	13	1	3	14	15	11	3	4	3	9	3	94
	26–30	15	13	6	6	8	6		2	5	3	5	2	71
	31–35	16	7	5		5	3	3	1	3	4	1	2	50
	36–40	9	2	1		3	1	2	3		4	3	1	29
	41–45	4	1	1	2	1	1		2	2	1	2	1	18
	46–50	5	1	3										9
	51 or older				1	1	1		1	1				5
Educ. background	*PhD*	8	2		1	1	2		2	1	1	2		20
	Master's degree	29	11	6	4	5	4	5	3	3	4	3	2	79
	Postgraduate certificate or diploma	3	2	4		5	3		2	3	4	5	1	32
	Undergraduate degree	12	13	4	3	15	10	7	1	4	6	8	4	87
	Postsecondary certificate or diploma	4	4	2	1	6	3	3	2			5		30
	Secondary or high school graduate	7	7	2	3	9	15	3	3	4		6	3	62
	None			1		1						2	1	5
	Other	2						1		1		1		5
Past FOSS experience	*No experience*	30	15	6	6	22	28	10	2	9	7	21	5	161
	Less than 6 months	4	5	2	3	9	2	1	1		1	5		33
	Between 6 months and 1 year	4	3			4	4	3	1	1		1	1	22
	Between 1 year and 2 years	1	3	5		4	1	2		2	3	3		24
	Between 2 years and 3 years	4	5		1	1	4	2	1	1		1		20
	More than 3 years	23	8	7	2	2		2	9	3	4	1	6	67
Newcomer socialization length	*Less than 1 month*	5	11	3		10	4	4	6	2		3		48
	Between 1 month and 3 months	13	10	5	1	17	17	7	4	2	3	8	3	88
	Between 3 months and 6 months	20	10	5	6	7	3	5	2	7	5	5	6	81
	Between 6 months and 1 year	13	5	1	1	3	9	3	2	4	2	10	2	57
	More than 1 year	14	3	6	4	4	6	1		1	5	6	1	51
Total respondents		66	39	20	12	42	39	20	14	16	15	32	12	327

FOSS projects: 1- Debian/2- Fedora/3- FreeBSD/4- Gentoo/5- GNOME/6- KDE/7- Mozilla/8- NetBSD/9- OpenSUSE/10- Python/11- Ubuntu/12- Wikimedia.

Results

PLS was chosen to analyze the survey data because of the exploratory nature of the research project, the complexity of the structural model, as well as because a number of constructs had been newly designed (not guaranteeing the normality of the collected data) (Chin et al., 2003; Marcoulides et al., 2009).

Measurement model

Common method bias

Prior to analyzing the data, it was important to ensure that common method bias (CMB) was not an issue since all measures were self-reported. First, Harman's one-factor (or single-factor) test was used in this research (Podsakoff et al., 2003). An EFA with un-rotated solution was run, resulting in a 12-factor solution in which each factor corresponded to a construct in the model or a CCB dimension (accounting for 70% of the total variance). Meanwhile, the covariance explained by a forced one-factor solution was found to be 26.49%. Therefore, these results argued that common method bias was not a threat to the validity of the findings (Liang et al., 2007).

We also conducted the latent common method factor analysis following Podsakoff et al. (2003) adapted to PLS analysis by Liang et al. (2007) (See detailed results in Appendix F). The results were conclusive as only nearly none of the method factor loadings were significant while the average indicator variance caused by the substantive constructs was much larger than the average variance explained by the method factor larger (with a ratio above 130:1; a ratio much larger than the recommended threshold suggested by Liang et al., 2007). Considering the low magnitude and absence of significance of the method variance, we could confidently conclude that CMB was not a concern in this study.

Non-response bias

The dataset was also tested for non-response bias in order to ensure that the sample data adequately reflected the population under study (Lewis et al., 2005). Two subsamples consisting of the first and last five responses for each FOSS project, were generated. The two subsamples of 60 responses (12 times 5 responses) each were then compared using a two-tailed *t*-test at 5% significance level. Out of the 68 measurement items, only 3 (IN4, JS3, and IDE2) presented some degree of statistical difference between the two groups. A close look at the two subsamples did not reveal any significant differences between the respondent profiles.

Exploratory factor analyses

The novelty of the socialization constructs as well as the CCB dimensions argued for performing a particularly thorough examination of both convergent and discriminant validity. As a consequence, it was decided to perform exploratory factor analyses for both the socialization constructs and CCB (and its subsequent dimensions). Two separate rounds of analyses were conducted since the socialization constructs and CCB corresponded to different causal stages of the conceptual model (Straub et al., 2004).

Concerning the six socialization constructs, the EFA fully satisfied the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's tests (KMO = 0.907 and Bartlett's Test p = 0.000). The factor solution resulted in 6 distinct factors (see Appendix G for the detailed results), each corresponding to a socialization construct (using a factor loading threshold of 0.50 and a cross-loading threshold of 0.40, as recommended by the literature, e.g. Hair et al., 2009). All items but one (IN5, see details in appendix G) provided satisfactory results.

Dimensionality of CCB

No study was found during the review of the literature that examined the OCB concept in the FOSS community context. There was thus no empirical evidence about the dimensionality of FOSS CCB. This research integrated the past OCB literature to introduce two CCB dimensions: CCB-I and CCB-P. The rationale behind the conceptualization was essentially theoretical. Extra caution was then employed when investigating the dimensionality of the CCB second-order construct. Some preliminary results provided during factor analyses performed during the pilot study started raising skepticism about the 2-dimension structure of the CCB construct; the analyses rather leading to a 3-factor structure. Our doubt was confirmed during the full-scale survey. EFA simulations were conducted by including all CCB items as well as the task performance ones, using Oblique-Oblimin rotation. Both Kaiser-Meyer-Olkin (KMO) and Bartlett's tests were fully satisfactory (KMO = 0.855 and Bartlett's Test p = 0.000). The EFA resulted into 4 factors: three for CCB and one for task performance. Only one item (CCB-I6, see Appendix H) was discarded due to unsatisfactory EFA and CFA loadings/cross-loadings.

Various EFAs were conducted through different analysis strategies; they all converged towards the same conclusion that CCB in the particular context of FOSS communities was found to consist of three distinct behavioral dimensions: CCB-I (or citizenship behaviors directed towards the benefit of individuals) consisted of helping behaviors towards other contributors, CCB-P (or citizenship behaviors directed towards the benefit of the project) related to notions around compliance or adherence to the behavioral rules, norms, and objectives of a FOSS project, and CCB-C (or citizenship behaviors directed towards the benefit of the overall community). The last dimension was found to be comprised of a set of behaviors that support the interests of the overall community, such as the promotion of the community to the outside world and to potential new contributors.

Other tests

All the measurement scales of the model provided internal consistency scores above 0.70 (Cronbach's alpha coefficients and composite reliability). Individual item reliability was evaluated by examining the loadings of the measurement items with their respective construct (Hulland, 1999), using a loading threshold of 0.707. However, researchers have encouraged careful consideration of items displaying loadings between 0.5 and 0.7, which may or may not be discarded based on several criteria (Hair et al., 2011a, 2011b). Recent PLS analysis best practices (Hair et al., 2011a, 2011b; Ringle et al., 2012) recommend retaining an item whose loading is between 0.5 and 0.7 only when the composite reliability of the corresponding construct substantially decreases when the item is discarded as well as when the content validity of the construct is affected by omitting the item. Six items had loadings between 0.5 and 0.7 resulting to dropping one joining structuredness item and retaining the other ones. Indeed, the loadings of each retained item were very close to the 0.7 threshold, and the composite reliability of the constructs was negatively affected by the removal of any of the items.

Construct convergent validity was evaluated for each construct by looking at Average Extracted Variance (or AVE), with a threshold value of 0.50 (Wetzels, 2009). The AVE of all constructs as well as the CCB dimensions were all above the set threshold. The measurement scales of both social identification and social integration provided satisfactory psychometric properties (See Appendix I). Finally, construct discriminant validity was evaluated through two measures: the Fornell–Larcker criterion (Fornell and Larcker, 1981) and item cross-loadings. For both tests, the results were entirely satisfactory (details about the item loadings and cross-loadings are provided in Table 4 and Appendices G and I).

Structural model evaluation

Overall, the exogenous variables (socialization variables, social identification, and social integration) explained 29% of the variance of task performance while they explained about 44% of the variance of CCB. Moreover, researchers using PLS have been encouraged to assess model predictive relevance using Stone's (1974) and Geisser's (1975) cross-validated redundancy measure Q2 (Henseler et al., 2009; Ringle et al., 2012). The Q2 scores of task performance and CCB were both positive (0.16 and 0.17, see Appendix K for all Q2 values), providing positive evidence for the predictive ability of the model.

Furthermore, the literature has been recently urging the use of a global goodness-of-fit (GoF) criterion to evaluate the quality of a model in PLS (Tenenhaus et al., 2005). The model was found to have a GoF of 0.433 indicating a high or 'large' quality model. Indeed, Wetzels (2009) recommends to use GoF baseline values of $GoF_{small} = 0.1$, $GoF_{medium} = 0.25$, and $GoF_{large} = 0.36$.

Table 4
Internal consistency, discriminant validity and construct/dimension correlations.*

Const/Dim.	CR	Alpha	TS	TP	IN	ME	JS	SU	IDE	INT	PERF	CCB-I	CCB-P	CCB-C
TS	0.922	0.939	**0.869**											
TP	0.849	0.899	0.444	**0.830**										
IN	0.822	0.882	0.362	0.386	**0.807**									
ME	0.905	0.930	0.279	0.305	0.464	**0.853**								
JS	0.874	0.853	0.202	0.243	0.029	0.267	**0.738**							
SU	0.917	0.938	0.366	0.426	0.511	0.564	0.258	**0.867**						
IDE	0.825	0.872	0.262	0.368	0.380	0.348	0.102	0.446	**0.729**					
INT	0.897	0.928	0.234	0.338	0.484	0.452	0.209	0.695	0.477	**0.807**				
PERF	0.805	0.874	0.251	0.399	0.239	0.290	0.228	0.400	0.308	0.461	**0.797**			
CCB-I	0.883	0.914	0.290	0.344	0.376	0.223	0.054	0.371	0.475	0.430	0.370	**0.825**		
CCB-P	0.884	0.910	0.237	0.352	0.242	0.228	0.141	0.387	0.400	0.486	0.455	0.424	**0.768**	
CCB-C	0.871	0.908	0.258	0.276	0.255	0.151	0.035	0.165	0.484	0.256	0.228	0.427	0.464	**0.815**

* Diagonal elements are square roots of the Average Variance Extracted.

Table 5
Results.

Hypothesis	Path coefficient	Standard Error	T-stat	Sig. (2-tailed)	Effect size f^2	Predictive relevance q^2
H1a : TS - > PER	0.061	0.0408	1.2704			
H1b : TS - > CCB	**0.107**	0.0402	2.6705	$p < 0.01$	**0.02**	**0.01**
H2a : TP- > PER	**0.247**	0.0689	3.582	$p < 0.001$	**0.06**	**0.02**
H2b : TP- > CCB	**0.136**	0.0527	2.5784	$p < 0.01$	**0.02**	**0.01**
H3a : IN- > IDE	**0.194**	0.073	2.6543	$p < 0.01$	**0.03**	**0.01**
H3b : IN- > INT	**0.170**	0.0557	3.048	$p < 0.01$	**0.04**	**0.02**
H4a : ME- > IDE	0.092	0.0617	1.3669			
H4b : ME- > INT	0.052	0.038	0.9437			
H5a : JS- > IDE	-0.046	0.0352	0.5956			
H5b : JS- > INT	0.048	0.0339	0.9634			
H6a : SU- > IDE	**0.303**	0.0719	4.2213	$p < 0.001$	**0.07**	**0.04**
H6b : SU- > INT	**0.581**	0.0498	11.6693	$p < 0.001$	**0.40**	**0.19**
H7a : IDE- > PER	0.057	0.0408	0.7345			
H7b : IDE- > CCB	**0.388**	0.0554	7.0057	$p < 0.001$	**0.19**	**0.05**
H8a : INT- > PER	**0.348**	0.0582	6.0209	$p < 0.001$	**0.07**	**0.06**
H8b : INT- > CCB	**0.241**	0.0545	4.4213	$p < 0.001$	**0.11**	**0.02**

Besides, recent reviews of PLS analyses in social sciences research (Hair et al., 2011a, 2011b; Ringle et al., 2012) have criticized the lack of consideration of a model's predictive capability and the absence of assessment of the paths' effect size. In response to such claim, both f2 effect sizes and q2 predictive relevance coefficients were calculated for each hypothesized path. Following recommendations from Cohen (Cohen, 1988), baseline values of 0.02, 0.15, and 0.35 corresponding to *small*, *medium*, *large* levels, were used to assess both effect size and predictive relevance (Henseler et al., 2009). Table 5 provides the path coefficients, the f^2, and q^2 scores (see Appendix J for further details).

Ten out of the sixteen hypotheses were supported (see Fig. 2 and Table 5) with six path coefficients above 0.20, two being close, and the last two being between 0.10 and 0.15. Social identification was found to have a significant impact on CCB (0.39, $p < 0.001$) while social integration was found to have a significant influence on both task performance (0.35, $p < 0.001$) and CCB (0.24, $p < 0.001$).

The effect size and predictive relevance indices provided additional support for the associated hypotheses. Task segregation was found to significantly influence task performance (0.11, $p < 0.001$) while task purposefulness positively impacted task performance (0.25, $p < 0.001$) and CCB (0.14, $p < 0.01$). As a result, the hypotheses TS → CCB, TP → PERF, and TP → CCB were supported, even though some of the paths should be interpreted with caution (the path coefficients being below 0.2).

Interaction intensity, mentoring, joining structuredness, and supportiveness were found to explain 24% of the variance of social identification and about 51% of the variance of social integration. Both constructs were found to have positive Q^2 scores (0.12 and 0.34), providing further evidence concerning the explanatory power of the exogenous latent variables. Social identification was found to be significantly affected by supportiveness (0.30 with $p < 0.001$) and interaction intensity (0.19 with $p < 0.01$). The effect size and predictive relevance scores provided additional evidence supporting the associated hypotheses. The results showed that the same constructs, supportiveness (0.58 with $p < 0.001$) and interaction intensity (0.17 with $p < 0.01$) were positively associated with social integration. Neither mentoring nor joining structuredness was found to have any significant influence on social identification or social integration.

Robustneness checks (see Appendix L for details) provided supplementary confidence towards the results. The CCB construct being operationalized as a second-order construct, the measurement of CCB using Lohmöller's (1989) "Hierarchical

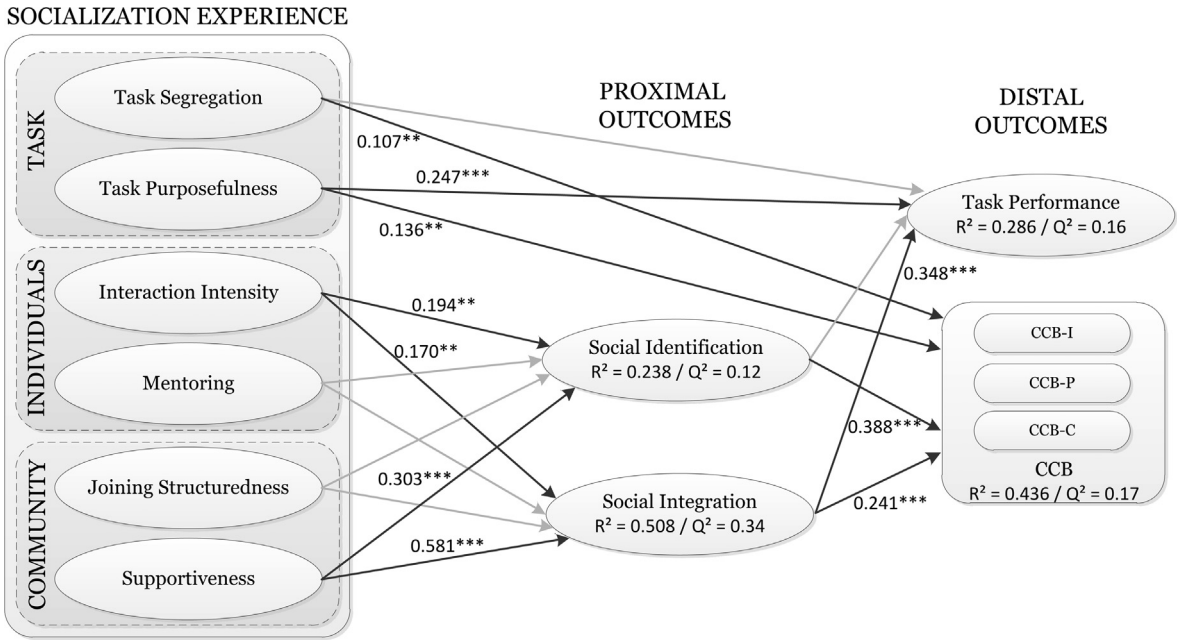

Fig. 2. Structural model evaluation.

Component Model Repeated Indicators Approach" and the Two-Step approach (Croteau and Bergeron, 2001) resulted into nearly identical results.

Supplemental analyses were also run to determine whether the data supported the posited full mediation of the effects of the four socialization constructs (individuals- and community-related factors) on task performance and CCB by social identification and social integration. Consequently, an alternative model including all direct and indirect paths was tested. The results confirmed the full mediating effect of the two proximal socialization variables (see Appendix L).

Discussion

This research has high strategic significance as the extensive impact of the overall FOSS movement on the economy and our society (von Krogh and Spaeth, 2007) has become a critical concern for the strategic information systems literature (Galliers et al., 2012). This research is somehow unusual in FOSS research, in that it gathered data from a relatively large number of different projects (twelve projects for the main survey and another two projects for the development and validation of the questionnaire instrument); past FOSS research works have tended to focus on single projects. The approach adopted in this research improves the generalizability and validity of the findings within the theoretical boundaries set in this research: large and complex FOSS projects. Despite a substantial body of knowledge on FOSS community practices, FOSS socialization research has lacked well-grounded theoretical investigations. The organizational socialization literature contains a wealth of results, a number of which were applied in the derivation of the FOSS-specific socialization models featured in this study. Previous FOSS socialization research had suffered from: a lack of strong theoretical underpinnings encompassing the complexity of large and complex FOSS projects, the use of archival data drawn from project repositories, as well as a tendency to rely on single projects, thus compromising the generalizability of the findings.

Key findings

The final conclusions of this research project are summarized in Table 6. Overall, this research adopts a QUAL-QUAN embedded mixed-methods approach to investigate the influence of FOSS newcomer socialization experience on contributor behavior. In the initial qualitative research component, this project developed a socialization framework consisting of six distinct factors. Two factors are related to the tasks performed by community newcomers (task segregation and task purposefulness), two factors pertain to interactions with other community members (interaction intensity and mentoring), and the last two (supportiveness and joining structuredness) characterize the interactions between a newcomer and the community itself. Then, key FOSS community citizenship behaviors were identified. The quantitative phase of the research project involved the development and validation of a conceptual model through a web-based survey involving 12 large and complex FOSS projects. Overall, this research has provided empirical evidence about the causal link that exists between newcomer socialization and performance. About 29% of the variance in task performance was explained by the hypothesized paths, while the model explained 44% of the variance in CCB. The GoF score, with a value of 0.433, indicating good predictive power of the model.

Table 6
Final conclusions.

Hypothesis	Path coefficient	Sig. (2-tailed)	Effect size f^2	Predictive relevance q^2	Conclusion
H1a : TS- > PER					Not supported
H1b : TS- > CCB	+	**	Small		**Partially supported**
H2a : TP- > PER	++	***	Small	Small	**Supported**
H2b : TP- > CCB	+	**	Small		**Partially supported**
H3a : IN- > IDE	++	**	Small		**Supported**
H3b : IN- > INT	+	**	Small	Small	**Partially supported**
H4a : ME- > IDE					Not supported
H4b : ME- > INT					Not supported
H5a : JS- > IDE					Not supported
H5b : JS- > INT					Not supported
H6a : SU- > IDE	+++	***	Small	Small	**Supported**
H6b : SU- > INT	+++	***	Large	Medium	**Supported**
H7a : IDE- > PER					Not supported
H7b : IDE- > CCB	+++	***	Medium	Small	**Supported**
H8a : INT- > PER	+++	***	Small	Small	**Supported**
H8b : INT- > CCB	++	***	Small	Small	**Supported**

Task performance was found to be predicted by social integration, confirming its impact on distal socialization outcomes (Kammeyer-Mueller and Wanberg, 2003), and task purposefulness. The integration of newcomers within FOSS communities is then proven to be of high importance when trying to have project newcomers become better achievers in terms of direct project contributions. This finding responds to von Hippel and von Krogh's request (2003) to provide empirical evidence about the importance of social integration in enabling sustained participation. The results also suggest that even though individuals in FOSS communities are generally free to perform any task they want, the structuring of tasks in a way that optimizes learning is expected to increase newcomer performance. FOSS communities should then encourage their newcomers to perform project tasks following a logic that supports their learning about the project. In addition, dedicated resources shall provide guidance to newcomers about the order and types of tasks that shall be performed. Both results together have important implications about the limited effectiveness of the conventional view that assumes that FOSS newcomer socialization shall be a self-initiated peripheral participation process in which individuals must work their way towards a project's center (Fang and Neufeld, 2009). This research indicates that FOSS socialization shall rather be a community-supported process aiming at integrating newcomers within projects and along which newcomers shall be suggested the nature and sequence of tasks to be performed.

This research also identified four predictors of CCB: task purposefulness, task segregation, social identification, and social integration. First, this suggests that if community managers and project leaders want newcomers to become *good* community citizens, they shall start with providing them newcomer-dedicated tasks structured in a way that optimizes learning. It also contributes to the socialization research sub-stream that emphasizes the importance of newcomer learning (Ashforth et al., 2007) which shall be placed "at the heart of any organizational socialization model" (Cooper-Thomas and Anderson, 2005, p. 117). Combined with its effect on task performance, the strong positive impact of social integration on CCB echoes considerations about the crucial importance of social integration in retaining FOSS contributors (von Hippel and Von Krogh, 2003) but also the integration of newcomers in digitally enabled communities (Kraut et al., 2011). This provides additional evidence about the crucial need to turn newcomer socialization into a community-driven process tailored in a way that promotes the integration of newcomers. FOSS practitioners must be aware that generating a sense of social integration among newcomers is doubly important as it helps individuals to become better achievers but also better citizens; ensuring the success and sustainability of projects. Developing a sense of identification with a FOSS community was also found to engender the manifestation of citizen-like behaviors from its new contributors. The finding suggests that FOSS communities should aim at influencing each new member's socialization experience in an attempt to nurture such feelings of identification. As a consequence, FOSS community managers and project leaders must place the generation of a sense of social integration and social identification (together explaining nearly half the variance of CCB) at the center of their socialization initiatives. This result extends past socialization research that has seen social integration and social identification among the most important socialization proximal outcomes (Bauer et al., 2007; Chan, 2006; Chan and Schmitt, 2000).

Out of the six socialization factors introduced in this research, interaction intensity and supportiveness, were found to have a significant impact on both of social integration (explaining 51% of the construct's variance) and social identification (24%). First, the two findings together emphasize the importance of the social side of socialization experience, which encompasses both the interactions with community members as well as the support provided by a community to a newcomer. This is consistent with past socialization literature that demonstrated the influence of the extent to which a newcomer interacts with individuals on the person's perception towards his or her integration within a group or an organization (Morrison, 1993a). This also echoes past research that determined that organizational support plays a role in satisfying individuals' needs for self-esteem, affiliation, emotional support, and approval (Eisenberger et al., 1998). Second, the results are aligned with past socialization studies that demonstrated the positive impact of investiture tactics on on-the-job embeddedness and social acceptance thus suggesting that the positive support provided by an organization helps increase the integration of newcomers (Allen, 2006; Simosi, 2010).

Second, considering the central role played by social integration and social identification in turning FOSS project newcomers into *good* contributors (task performance and CCB), the results provide insightful indications about how FOSS projects shall tailor socialization initiatives that generate both types of feelings. Implementing community-driven socialization processes thus also implies the need for FOSS communities to deploy means to locate, identify, and follow new contributors throughout their socialization experience. One the one hand, recurrently interacting with newcomers and expressing the support of the community can be engrained into the norms of FOSS projects (that are often embodied into a project's code of conduct). Indeed, FOSS norms, beliefs, and values support the predictability of behaviors that are beneficial to FOSS projects (Stewart and Gosain, 2006). On the other hand, the conclusions suggest that FOSS projects shall monitor the progression of newcomers and allocate dedicated project contributors to accompany newcomers throughout their socialization experience. Overall, this finding contributes to the socialization literature as the effect of social support on socialization outcomes has been largely ignored (Chen and Eldridge, 2011).

Furthermore, the impact of task-related factors on the two performance-related dependent variables imply the important role played by newcomer learning. It thus suggests that investigating the importance of learning-related proximal socialization factors such as task mastery or self-efficacy (Kammeyer-Mueller and Wanberg, 2003; Saks and Gruman, 2011) could help capture some of the unexplained variance of task performance and CCB. Socialization experience length as well as FOSS contribution experience (before joining a given project) could also help explore the existence of potential moderating effects.

Finally, the absence of support about the importance of mentoring and joining structuredness deserves further investigation as the results are counter-intuitive. One could argue that mentoring is not necessarily 'good mentoring' and that instead of adopting a dichotomous view towards the existence of a mentoring relationship, capturing aspects pertaining to the nature and type of such relationship may help investigate the issue further. For instance, assessing mentoring interaction frequency could provide additional insights. Distinguishing formal from informal mentoring relationships could also help gain a deeper understanding. Indeed, while certain respondents took part to formal mentoring programs such as the Google Summer of Code (during which participants perceive a remuneration), others were taken under the wing of an experienced contributor in a more spontaneous manner. Past research on mentoring determined that the relationship between mentoring and affective commitment (a notion overlapping with social identification) was moderated by the 'supervisory versus nonsupervisory' condition of mentorship (Payne and Huffman, 2005). Informal mentorship was also found to have more favorable outcomes (such as career-related support and salary) than formal one (Chao et al., 1992). This raises concern about the effectiveness of formal FOSS mentoring programs such as the Google Summer of Code and call for future research efforts. Regarding joining structuredness, it is likely that aspects such as respondent type (e.g. 'no experience' versus 'experimented' individuals) or overall socialization length could play a role in explaining the lack of significant results.

Limitations

The limitations of this study include those common to quantitative survey research and others particular to this research project. The conceptualization of socialization adopted in this research, has obvious organizational connotations and thus assumes the presence of a minimum of structural and hierarchical features. The hypothetical application of the findings to 'smaller' FOSS projects shall then be considered very carefully as it breaches the validity boundaries of this research.

The data used to test the hypotheses are cross-sectional, which means that causality is only inferred, not proven. Future research studies may extend this research by adopting a complementary approach such as longitudinal studies that inherently lead to stronger causal conclusions. Survey research is characterized by potential challenges such as measurement error, sampling error, internal validity error, and statistical conclusion error (Straub, 1989). This research attempted to mitigate these errors through the use of commonly accepted methods such as judgment rounds, card sorting procedures, and a pilot test to develop the survey instrument. Nevertheless, while mitigated, these sources of error cannot be entirely eliminated.

Limitations exist about the implemented measurement strategy. For instance, participants were asked to assess various aspects of their socialization experience within a given community based on the recollection of past perceptions (up to three years back) but also at one particular point of time and without regard to differences in time. This view is overall simplistic since socialization is a collection of actions and interactions that occur at different times, and thus perceptions are bound to vary through time. A similar point can be made about using a 'snapshot measure' of contributor behavior. A contributor can be a good community citizen for a certain period of time and then be a "bad citizen" for the rest of the time. This research has also done its best to mitigate the inherent social desirability risk of performance-based measures but it cannot be said that a social desirability bias was totally absent from the responses provided by the participants.

Finally, this research relied on the use of a self-selecting sample consisting of individuals whose socialization experience resulted into a 'positive' outcome since they eventually became project contributors. In other words, the sample did not include individuals who left a project while being in the socialization phase. This is a limitation inherent to the methodology implemented in this research.

Contributions and implications for research

The first theoretical contribution of this research resides in the theorization of the social entity under investigation: large and complex FOSS projects. Moving away from the outdated bazaar-view, this research conceptualizes large and complex FOSS projects as organization-community hybrids which function is the commons-based peer production of highly modular

software artifacts. In such projects, contributing involves a variety of tasks that go well beyond coding. The FOSS socialization framework developed in this research provides an extension to Van Maanen and Schein (1979) and Jones (1986) socialization models in the specific context of large and complex FOSS projects. The development of a FOSS socialization framework and the associated measurement of the six socialization variables provide a deeper understanding of the experience through which a FOSS project newcomer goes. The sub-categorization of socialization factors into task, individuals, and community-related factors also helps in gaining insights about the various dimensions that characterize FOSS socialization. The development and validation of this study's model extends the body of knowledge of socialization theories in virtual environments. The model comprises a theoretical tool that can be used by researchers to study the FOSS socialization phenomenon in a given FOSS community or a set of communities.

The theoretical particularities of the social entities under investigation also led to re-investigate the notion of individual performance in the context of large and complex FOSS projects in light of the organizational behavior literature. Performance was then conceptualized into two distinct but complementary constructs: task performance and community citizenship behavior. This view contributes to the FOSS research body of knowledge by introducing a community-level view of performance. Furthermore, this research contributes to the OCB body of knowledge by extending the notion of citizenship behaviors to non-organizational and virtual social contexts. This research highlights the particularities of FOSS organization-community hybrids by showing that unlike the two-dimensional OCB structure which has been shown to apply to traditional organizations, CCB is characterized by a 3-dimension structure that consists of: CCB-I (citizenship behaviors directed towards the benefit of individuals), CCB-P (citizenship behaviors directed towards the benefit of the software project), and CCB-C (citizenship behaviors directed towards the community).

This research has helped to address a significant literature gap in both FOSS as well as broader organizational behavior research concerning the relationship between socialization and citizenship behaviors. Finally, this research contributes to the current discussion on the use of multi-methods in Information Systems research. Eminent IS scholars have urged the need for IS researchers to conduct research that rely on the use of mixed methods (Venkatesh et al., 2013, 2016).

This research has opened new research avenues and suggested areas for further research along three main areas of development: extending the current model, reexamining and/or validating the constructs and their associated measurement scales; and finally assessing the applicability of the conceptual model in different but related contexts.

The socialization framework developed in this research unveils new possibilities for studying socialization in FOSS communities. First, the framework and its associated measurement can be used to assess newcomer socialization in other FOSS communities (other than the 12 + 2 communities which took part in this study). It can also be used in the case of smaller FOSS projects so as to assess its applicability to other FOSS contexts. Second, this research has left room for other important socialization factors that could be discovered through the collection of additional qualitative data. The sub-categorization into task, individuals, and community factors introduced in this research acknowledges the possible existence of other factors and leaves room for further refinements of the framework.

The results which emerged from the analysis of the survey data concerning the non-relevance of mentoring are somewhat surprising, since the qualitative phase of this research concluded that mentoring was important. Further research should investigate further the potential role of mentoring when inducing FOSS newcomers; the measurement of the mentoring construct in particular should be re-examined in order to confirm or infirm the results found in this study.

Some further research could be conducted in order to identify other possible predictors of both social identification and social integration in the FOSS socialization context, since the socialization variables accounted for respectively 24% and 51% of the variance of the two proximal socialization variables. Individual factors (such as intrinsic/extrinsic motivation) or project-related factors (such as license type, license restrictiveness, or project size) that have been shown by past FOSS research to influence FOSS project participation could be investigated. Another possibility could be in importing constructs from well-acknowledged attitude-theoretic models in IS models such as the theory of planned behavior (Ajzen, 1991) or the theory of reasoned action (Ajzen and Fishbein, 1980). Initial studies along these lines have been undertaken in past FOSS research. For example, Bagozzi and Dholakia (2006) found that attitudes and perceived behavioral control had both a significant positive impact on participation intentions in the case of Linux user groups.

Furthermore, this research suggests the possibility of uncovering proximal socialization outcomes, since the model explained respectively 29% and 44% of the variance of task performance and community citizenship behaviors. Consequently, the socialization literature could be consulted in order to find other potential factors such as perceived fit (Saks et al., 2007), self-efficacy (Bauer et al., 2007), task mastery (Kammeyer-Mueller and Wanberg, 2003), or role conflict (Ashforth et al., 1997). The socialization tradition also provides an array of distal outcomes that could be worth investigating in relation to the socialization framework developed in this research. The investigation of socialization distal outcomes such as intentions to remain, turnover, satisfaction, or commitment (Bauer et al., 2007; Gruman et al., 2006; Saks and Ashforth, 1997a; Saks et al., 2007) could provide additional insights into the FOSS socialization phenomenon.

Contributions and implications for strategic IS research

This research has implications for the 'strategic FOSS' body of research (as opposed to 'operational' FOSS) that investigates the use of FOSS software and processes by firms to create business value (Morgan and Finnegan, 2014) and gain competitive advantage (Bonaccorsi et al., 2006a, 2006b). Whether businesses rely on strategic FOSS to create and capture value from using FOSS artifacts (Chengalur-Smith et al., 2010) or else from the communities and commons-based peer production pro-

cesses that surround FOSS (Morgan and Finnegan, 2014), companies that want to adopt strategic FOSS have no choice but to engage and collaborate with FOSS communities (Dahlander and Magnusson, 2005; Morgan and Finnegan, 2014). By showing that participation in FOSS projects goes beyond writing lines of code, this research provides a finer understanding about what collaboration means in the FOSS context: contributing to software artifacts but also performing citizenship behaviors. Furthermore, past research has determined that firms using FOSS rely on business models that are calibrated according to their openness towards FOSS (Bonaccorsi et al., 2006a, 2006b), leading to three distinct firm–community relationship types namely symbiotic, commensalistic, and parasitic (Dahlander and Magnusson, 2005). This research suggests that engaging into symbiotic relationships with FOSS projects (and commensalistic to a lesser extent) implies that companies need to specifically act in a way that nurtures and protects communities. To do so, the results of this research identify the means by which a company's employees can get accepted and engrained within communities. Further investigation is needed to help firms calibrate how they shall engage with FOSS communities by determining the optimal balance of code contribution/citizenship behaviors based on firm-community relationship type and FOSS-based business model.

Commercial companies often join forces with FOSS communities to implement the FOSS development model as a global sourcing strategy (also called opensourcing), an approach that necessitates the growing of a global FOSS community around a company's products (Ågerfalk and Fitzgerald, 2008). This research highlights the crucial importance for firms to ensure the presence of citizen contributors and to facilitate the manifestation of citizenship behaviors. The results identify specific means and mechanisms to engender such behaviors. Further research efforts are needed to investigate the development of citizenship behaviors in opensourcing initiatives from a longitudinal perspective while research shall determine concrete outcomes and metrics that demonstrate the benefits of engendering citizenship behaviors.

Past FOSS research has often focused on the positive effects of network connections on project success (Peng et al., 2013; Singh and Phelps, 2013) while a recent research stream has been calling for a more nuanced view that ascertains the existence of factors that moderate the positive impact of network connections such as developers' attention to focal projects (Daniel and Stewart, 2016). This research sheds some new light on the investigation of the FOSS project's network/project success relationship by suggesting the potential influence of citizenship in moderating such relationship. Future research efforts shall explore the FOSS citizenship phenomenon from a network perspective to provide further insights.

Finally, this research contributes to the research stream that investigates how firms implement strategies that rely on online communities to create business value and gain competitive advantage. Implications can be derived in the context of open innovation (Chesbrough, 2007), crowdsourcing (Majchrzak and Malhotra, 2013) or user communities (Di Gangi and Wasko, 2009). This research implies that more attention shall be paid by firms to allocate employees that engage in behaviors that aim at maintaining communities into a sound and healthy state. Further research efforts shall aim at extending the operationalization and measurement of citizenship behaviors to such related contexts.

Implications for practice

This research project addresses two important issues faced by large FOSS projects. On the one hand, it will help FOSS communities in understanding the socialization factors that contribute to the successful socialization of new members. The results of this research thus help communities to tailor effective socialization initiatives that are likely to generate contributor behaviors which support the values and sustainability of the communities. For instance, this study has demonstrated the direct and indirect influence of task purposefulness on individual performance. This finding encourages FOSS community managers to determine sequences of tasks that optimize project learning and strongly encourage newcomers to perform them. This research has demonstrated that such guidance would enhance significantly the contributions provided by a "socialized" newcomer.

On the other hand, in spite of the importance of citizenship behaviors to ensure the survival of a community, this study's investigation of the individual factors that lead to citizenship behaviors is new in FOSS research. The finer understanding of participation and performance provided in this research will also benefit communities in helping them to understand more thoroughly how individuals contribute. This research clearly demonstrates the importance of performance-related behaviors to go well beyond the common idea that contributing to a FOSS project is only about writing code. The results provided in this research help FOSS communities to realize that three overall types of citizenship-like behavior benefit a community: behaviors aiming at helping individuals, those directed toward the direct benefit of the software project, and also those targeted towards the benefit of the overall community. The identification of such behaviors will help FOSS communities to evaluate a contributor' level of performance more objectively, and can also help identify and support the individuals that contribute heavily to the functioning and sustainability of a given community even though their code contribution is limited or even non-existent.

This research will also benefit FOSS participants themselves by providing them indications about the practices into which they should engage when joining a new FOSS community. For instance, this research strongly encourages newcomers to engage with as many project contributors as possible when learning about a FOSS project. Such behavior helps become 'better' contributors by developing both the feeling of being accepted by the community and the sense of identification to this community. Finally, this research indirectly contributes to our understanding of virtual communities more generally. Both, socialization and contribution behavior have some overlapping aspects with FOSS communities. The findings may be to some extent extrapolated to the domain of other virtual communities.

Conclusion

This research provides a significant message to the strategic IS audience by contributing to advance our knowledge on a complex IS development method: the Free/Open Source Software model; a pregnant area of the 'strategies for IS issues' sub-stream of research (Gable, 2010). Moreover, by providing insights to software firms who want to either adopt the open source production model as a source of competitive advantage (Bonaccorsi et al., 2006a, 2006b), or else to implement the FOSS development model as a global sourcing strategy (Ågerfalk and Fitzgerald, 2008), the results tap into the 'strategic use of IS' dimension of the strategic IS literature (Gable, 2010). This paper also sheds some light on the implementation by firms of strategies and business models that are based on engaging and collaborating with online communities such as open innovation, crowdsourcing, peer production, or user communities. It emphasizes the need to adopt a community-centric approach that places the health and well-being of communities at the core of the debate.

FOSS keeps playing a leading role in "a wave of profound, radical change that is sweeping through the IT world" (Marsan et al., 2012, p. 258). The rate of organizational adoption of FOSS technologies has not ceased increasing (Nagy et al., 2010) with organizations implementing more and more FOSS-based operating systems, middleware solutions, browsers, and database solutions (Chengalur-Smith et al., 2010), all being highly complex modular software projects relying on large diversified communities of contributors. Ensuring the long-term success and sustainability of such breed of FOSS projects is then critical to the software industry landscape (Jaisingh et al., 2008; Jiang and Sarkar, 2009) as well as to all organizations which derive strategic value from the use of FOSS (Morgan and Finnegan, 2014). This research shows that adopting a community-centered and dynamic view of FOSS projects, through the use of a socialization perspective, helps better apprehend how FOSS production systems are sustained and reproduced over time.

Appendix A. Qualitative investigation – Interview demographics

Participant	Gender	Education	Occupation	Nb. FOSS projects	Contribution type	FOSS experience
1	M	Postsecondary certificate	School principal	2	Non-technical contributor, user	Several years
2	M	Master's	PhD candidate	4	Non-technical contributor, user	5 years
3	M	Bachelor's	Senior software developer	4	Project manager, maintainer, in charge of newcomer programme, social event participant	9 years
4	M	Bachelor's	IT security analyst	1	Technical contributor, user	More than 15 years
5	M	2 master's	Not-for-profit org. administrator	2	Maintainer, technical contributor, social event organizer and participant, newcomer management, mentor	13 years
6	M	Unfinished bachelor's	Web designer	1	Former project manager, project outreach	4 years
7	M	Master's	Freelance FOSS community consultant	5	Technical contributor, board member, project manager, release manager, community manager, mentor, social event organizer and participant	13 years
8	F	Master's	Community manager	1	Community manager, social event participant, mentoring programme administrator, technical contributor	8 years
9	F	Master's	Software engineer	1	Paid project contributor, mentoring programme administrator	7 years
10	M	Not mentioned	Freelance documentation consultant	1	Technical and non-technical contributor, project manager, board member	10 years
11	M	PhD	IT industry analyst	3	Project manager, technical contributor, mentor, project outreach, desktop manager, mentoring programme administrator, social event participant	10 years

Appendix B. Qualitative data collection procedure

B.1. Sampling

In this research, two sampling strategies were combined when identifying and selecting potential interviewees. In a first phase, an invitation to participate to the research project was sent on a mailing list which is followed by FOSS practitioners in New Zealand. Four individuals responded favorably to the invitation. During the numerous informal conversations the researchers had with FOSS practitioners, it was often mentioned that researchers involved in FOSS research rarely 'give back' to FOSS communities by sharing and disseminating their results outside the academic sphere. This perspective is particularly important, as interactions among FOSS practitioners are frequently governed by "gift-giving" mechanisms (Bergquist and Ljungberg, 2001). By not contributing back to FOSS communities, some previous researchers have thus broken the moral contract that had been established with the research subjects when they agreed to take part in a research project. As a result, researchers are now struggling to gain the support and cooperation of FOSS practitioners when conducting research. A way of counteracting this tendency and gaining the trust of potential participants is by being referred by FOSS project members with high status and reputation. This is the strategy that was adopted for identifying and recruiting respondents for this phase of the research.

Initially, five interviews were planned. However, preliminary coding of the interview data revealed that in spite of the overall validity of Van Maanen and Schein's approach towards socialization, at a deeper level of the theory, some conceptual and operational changes had to be undertaken on the original constructs. The interviews also showed that FOSS community citizenship behaviors are a complex phenomenon, confirming the validity of most of the five types of citizenship behaviors: altruism, conscientiousness, civic virtue, and courtesy but they also revealed new forms of citizenship behaviors that pertain specifically to the FOSS context. Six additional interviews were therefore conducted (a total of 11 interviews were conducted altogether).

The second phase employed a theoretically motivated purposeful sampling method in selecting interview participants. The four individuals who took part in the first interview phase were asked to identify individuals who had some solid experience as FOSS contributors and expertise in FOSS community management. It was also crucial that respondents had a good understanding of FOSS community newcomer experience. These individuals were then invited by email to take part to this research project. Seven individuals agreed to participate and were thus interviewed. Since the analysis of the interview data revealed that theoretical saturation had been reached after the eleven interviews, it was decided not to conduct any additional interviews.

B.2. Interview procedure

Each interview lasted between 60 and 90 min and was conducted by the researchers. The interview protocol consisted of the following:

1. Brief presentation of the research project.
2. Background information about the interviewee (educational background, occupation, FOSS experience).
3. Interviewee's newcomer experience(s).
4. Reflection about the various aspects that characterize one's newcomer experience in the FOSS context.
5. Exploration of the applicability and relevance of Van Maanen and Schein's theoretical view of socialization.
6. Interviewee's contributions in FOSS projects.
7. Reflection about what a 'good' contributor is and assessment of the relevance of the conceptualization of contribution behavior introduced in this research project (assignment performance and citizenship behavior).
8. Reflection about the meaning of citizenship behavior in the FOSS context and its different manifestations.
9. Applicability and relevance of Organ's theoretical view of organizational citizenship behavior.

In addition to the questions present in the interview protocol, the researchers were able to raise specific questions, informed by the literature review, which related to important emerging topics during the interviews. The interview data were transcribed using a transcribing software that allowed easy manipulation of the interview sound recordings.

Appendix C. Qualitative data analysis procedure

In this research, Miles and Huberman (1994)'s data analysis strategy was followed considering that the authors' recommendations are well acknowledged in qualitative research. The authors called their approach 'transcendental realism' and suggested that data analysis shall be conducted along three concurrent streams of activities that constantly interact throughout the analysis: data reduction, data display, and conclusion drawing and verification. Strauss and Corbin (2015)'s two-phase coding strategy involving open coding and axial coding, was used for the data reduction phase. This decision was motivated by the 'grounded theory' flavor of the overall approach implemented during that phase of the research since the goal was to unveil key dimensions that characterize FOSS socialization and CCB.

C.1. Open coding

Van Maanen and Schein's socialization framework as well as Organ's OCB dimensions were used as theoretical lenses to investigate FOSS socialization and community citizenship behavior. The initial set of codes used during open coding was comprised of van Maanen and Schein's socialization dimensions as well as Jones' subcategorization. Three codes represented context, content, and social aspects, each aspect being sub-divided into the two associated dimensions from van Maanen and Schein. Similarly, CCB codes consisted of the five OCB dimensions from Organ. In addition, some 'descriptive codes' were used in the beginning of the analysis following Miles and Huberman's recommendations to help capture information about the cases. Finally, new codes emerged while the data was being analyzed. Each new code was added to the initial set of codes (see coding examples). For instance, the notion of mentoring clearly appeared as an important issue when discussing FOSS socialization as interviewees highlighted its practice at both informal and formal levels. The code SOCIALIZATION/SOCIAL/MENTORING was then added. Similarly, the careful analysis of the data identified being friendly and advocating projects as potential instances of citizenship behavior in the FOSS context. The codes CONTRIBUTION/CCB/FRIENDLINESS and CONTRIBUTION/CCB/ADVOCACY were then created.

C.2. Axial coding

At the end of the open coding phase, a careful examination of the codes allowed to generate axial codes along five distinct scenarios. A first type of axial code resulted in strictly reusing the open code along with its properties since the code appeared to capture an important concept. For instance the code 'INFORM PROJECT' defined as 'keeping the community informed about one's work and progress' was retained since the code generated during open coding captured well the concept having been identified by the researchers. A second category of axial codes consisted of retaining the code label determined during open coding. However, the scope of the definition was extended as it appeared that the initial definition was too narrow in the sense that it excluded important related aspects that could be all grouped under a same umbrella code. During the open coding phase, the researchers had identified CONTRIBUTION/CCB/MAINTENANCE as an instance of CCB behavior defined as 'performing maintenance tasks'. However, the initial definition was code-centric and excluded other types of tedious tasks that were also found to be valuable for the interviewees. As a result, the code CONTRIBUTION/CCB/MAINTENANCE was retained but its associated definition was reworded: 'keeping project resources to a good standard'. Some open codes were discarded during axial coding since the interviewees clearly indicated their irrelevance in the FOSS context. This was the case for the code SOCIALIZATION/CONTENT/FIXED for instance, as all interviewees acknowledged that the notion of timetable was foreign in FOSS projects. The same issue arose with the code CONTRIBUTION/CCB/SPORTSMANSHIP. Most interviewees noted that the idea of tolerating difficult work conditions without complaining had nothing to do with FOSS development since contributors usually manage their own commitment level. The re-examination of some open codes resulted in modifying the scope and label of some initial codes. This happened for some of the socialization characteristics that were identified while thoroughly examining the associated open codes. The open code CONTRIBUTION/CCB/ALTRUISM resulted into creating the axial code CONTRIBUTION/CCB/INTERPERSONAL HELP because helping other contributors had indeed been shown to be an important instance of CCB behavior; but the altruistic motivation governing helping actions was found to have been seriously questioned by a number of interviewees. Finally, the last category of axial codes consisted of merging certain open codes. CONTRIBUTION/CCB/BEING NICE, CONTRIBUTION/CCB/CODE OF CONDUCT COMPLIANCE, and some aspects of CONTRIBUTION/CCB/CONSCIENTIOUSNESS were merged into the axial code CONTRIBUTION/CCB/CULTURE COMPLIANCE to capture behaviors that relate to 'behaving in a way that complies with the behavioral norms of a community'. Open and axial coding samples are provided below.

C.3. Open coding - coding examples

Coding sample - Initial codes
SOCIALIZATION/CONTENT/SEQUENTIAL *. . .that precise path is probably the only way into a very technical group where source code is the important thing. So, your ability to submit a good bug report is your understanding of the computer. Once you've shown that, you can submit a good patch which is leaved on the service of it because you've shown that you understand the computer so the patch is probably valid. And then the next step in is a patch for a non-bug, a feature patch. It probably wouldn't be looked as a feature unless you've already shown that you don't break code when you submitting fixes.*
CONTRIBUTION/CCB/ALTRUISM *Some people believe that helping a new contributor is not an altruistic thing but instead it is a desperate act of self-promotion in order to gain a new contributor. So, it is radically not altruistic. If I can pay this person in kindness, then I buy a new contributor, and my project will have doubled in contributors because I am the only person right now.*

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Coding sample - New codes

SOCIALIZATION/SOCIAL/MENTORING

The other thing that there is more formal programs, there is of course the Summer of Code which people have to connect mentors to new contributors in a project. That's quite active. I had my own informal mentoring network and learnt what was going on and who is who. I think it does happen a lot.

CONTRIBUTION/CCB/FRIENDLINESS

Other kinds of good contributors for a community have been people who just hang out on the IRC channels and are friendly I have only participated in projects where the expectations are to be friendly with people.

CONTRIBUTION/CCB/ADVOCACY

Somebody advocating the project outside, that could be perhaps an aspect of citizenship. Somebody who is promoting the project to the business world, even to his friends, that could be one aspect.

C.4. Axial coding - coding examples

CASE 1: Open code retained as final axial code

Open/Axial code = CONTRIBUTION/CCB/INFORM PROJECT

I think it should be actively encouraged to put your hand up and say "I am doing too much work, help!"

CASE 2: Label of open code is retained but scope is modified/extended

Open code = CONTRIBUTION/CCB/MAINTENANCE

A lot of the really good contributors are people that clean up other people's messes. For example merging bug reports that are duplicates, cleaning up code . . .

Axial code = CONTRIBUTION/CCB/MAINTENANCE

I think it is a good one because there is not many people that would volunteer to do these things necessarily. That's actually a really good way to get started because people like you a lot more if you do the things that nobody wants to do.

CASE 3: Open code is not relevant, code is discarded

Open code = SOCIALIZATION/CONTENT/FIXED

Basically, absolutely not. Those projects have no sort of timetable for new contributors especially because the sort of high watermark for a project to make somebody go to the next stage of power in your project, say commit access, or maybe read access to the primary mailing list, or write access to the bug tracker is very subjective.

CASE 4: Open code label and scope are modified (notions are related)

Open code = SOCIALIZATION/CONTEXT/INVESTITURE

If somebody comes in with a lot of skills, we love it. They get some instant reputation especially if they are known in other open source communities already. If somebody comes in without skills, we are not hostile but we are not afraid to tell them "You need to go and learn this, come back and you will be able to contribute". Until you learn these things, you will not be able to contribute in a meaningful way.

Axial code = SOCIALIZATION/COMMUNITY/SUPPORTIVENESS

That depends a lot on the community members. In #PROJECT_NAME# we are very supportive. We are trying to at least support in spirit. I think #PROJECT_NAME# on the whole is supportive.

CASE 5: Several open codes are combined into one axial code

Open code = CONTRIBUTION/CCB/BEING NICE

When I say nice here, I mostly mean treats people in accordance with the community expectations for how people are to be treated

Open code = CONTRIBUTION/CCB/CONSCIENCIOUSNESS

We have a lot of unwritten technical rules, how things are supposed to work that would take years to pick up. But the social rules are much easier to pick up. You learn them from the most active or respected people posting on the lists.

Open code = CONTRIBUTION/CCB/CODE OF CONDUCT COMPLIANCE

To be a good contributor, you have to make contributions and comply with the code of conduct.

Axial code = CONTRIBUTION/CCB/CULTURE COMPLIANCE
Because there are always roadblocks and hurdles, you are walking into a culture that you don't know where people know each other, it takes some effort to get into that. I think it takes a fair amount of effort on both sides.

C.5. Data display & conclusion drawing and verification

The use of qualitative data analysis software allowed the researchers to generate reports that summarized the coded data per code and per participant. The reports were automatically generated by the software and provided a visual display of the coded data that helped in revising the preliminary codes as well as identifying emerging ones. The reports generated by NVivo 9 can be seen as variations of the data matrix data displays recommended by Miles and Huberman (1994) when analyzing data after axial coding.

To answer the need to rely on criteria that are specific to qualitative research, Guba (1981) developed a model to assess the trustworthiness of qualitative studies. This research relied on Guba's model.

C.5.1. Truth value

Once data analysis was completed, interview respondents as well as experienced FOSS contributors were informally consulted to assess the confidence level associated with the quality of the results. They all strongly acknowledged the pertinence of the results for both the socialization framework and the CCB aspects that were identified.

C.5.2. Applicability

This was assessed when the researchers contacted experienced FOSS contributors who did not take part to the interviews and who were contributors to FOSS communities that were not represented such as Perl, LibreOffice, or Mozilla. A lot of support and encouragements were provided to the researchers.

C.5.3. Consistency

Coding samples during both the open coding and axial coding phases were regularly sent to the supervising staff to ensure the quality of the coding procedure. In addition, the collected data was entirely recoded manually at the end of axial coding to assess the stability of the results. Overall, the outcome was highly satisfactory as with a few exceptions, the results were nearly identical.

C.5.4. Neutrality

Guba recommends the use of an audit strategy that consists of involving an external auditor from the beginning of the research in order to follow through the sequence of events and the decisions that were made along the process. IS researchers, experts in FOSS and external to the research project, played that role as the researchers constantly informed them of the course of actions that was undertaken.

Appendix D. Qualitative investigation – Sample quotes (socialization factors and citizenship behaviors)

D.1. FOSS socialization factors

FOSS socialization factors
Task Segregation (TS) - the degree to which a newcomer has performed tasks that are specifically tailored for newcomers.
"Yes, I would say that one kind of training is tutorials for new contributors … One thing that we do is that we run weekend workshops that teach students how to contribute to open source". *"There are junior jobs that people can look at. There are really simple bugs, really simple tasks.*"
Task Purposefulness (TP) - the degree to which the sequence of tasks performed by a newcomer has been purposefully selected by the newcomer in order to learn how to become a contributor.
"For example, there is a list of potential project where you can start, categorized by difficulty level, by prerequisite you have to be coming with, with mentors available to talk to about them." *"Basically, you start with some bugs that are small that are agreed on that you can work with and also connect with the people who can help you with that bug.*" *"Your ability to submit a good bug report is your understanding of the computer. Once you've shown that, you can submit a good patch which is leaved on the service of it because you've shown that you understand the computer so the patch is*

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FOSS socialization factors

probably valid. And then the next step in is a patch for a non-bug, a feature patch. It probably wouldn't be looked as a feature unless you've already shown that you don't break code when you submitting fixes."
"People don't have to be filing bugs before a year in [project name] before they start working on fixing a bug. They can jump in and learn the technology for a particular project, look at its code and fix a small bug. You can find things that are more narrow in scope, yes."

Interaction Intensity (IN) - the degree to which a newcomer is actively engaged with other newcomers and community members while learning how to become a project contributor.

"There is also a full beginner forum, for beginners, staffed by moderators who are tolerant enough to answer the dumb questions. That's probably the most formal beginner stuff in [project name]."
"It absolutely happens with the Google Summer of Code and the [programme name]."

Mentoring (ME) - the degree to which a newcomer has been taken under the wing of one or more experienced members while learning how to become a project contributor.

"Yes, there is a lot of you see somebody on the forums or the mailing lists who is struggling, and after a couple of interchanges of email, you end up exchanging personal messages like in IRC, Twitter, or Google Chat. From there, you develop a little relationship with somebody."
"You cannot get a new developer bug filed if you do not have a sponsor or a mentor. Because the mentor is the person who files the bug for you."
"When we file a new developer bug, there is always at least one mentor for that bug. The person who says 'if this new recruit is going to be working on X then I already work on X so I am bringing them on to teach them exactly how X works and how it is maintained".

Joining Structuredness (JS) - the degree to which a newcomer has to adhere to a step-by-stepwise joining process in order to become a community contributor.

"So it is very easy to get commit access to our repository for example. If you have two or three merge requests then someone will likely say 'you should get a commit account, we will advocate that for you' then you have it."
"It is almost always by gut feeling, if you are sensitive to this person, you will do something for him."
"You can't become a developer before going through this process. You can till put a patch on Bugzilla, you can still post to the mailing list. Your ability to commit code yourself is not existent."

Supportiveness (SU) - the degree to which a newcomer has perceived a community to be supportive while learning how to become a project contributor.

"Some communities are supportive and other communities are not."
"I think it varies a lot. There are communities that are a little bit friendlier to newcomers. I think it depends, it really depends on who is a member, what sort of members you can expect in your community."
"You don't know. It will depend. The [project name] community is big. It's several hundred people. In certain projects, you will have a really outstanding experience. In some others, people may go away saying 'That guy is an asshole'."
"Some people are supportive in communities and some people somehow don't receive the support from supportive communities."

D.2. Community citizenship behaviors (CCB)

Community-citizenship behaviors directed towards individuals (CCB-I)

Helping and assisting other community members

"It is important that contributors do help each other and act as a big family."
"I don't think it is possible to become a community member without having some kind of empathy for the other people in that community and be helping them."
"If people come to you and they need help, you should not turn them away.

Helping to prevent project problems to occur for other members

"You do have to be self-aware of what you are going to do. Because everybody can change everything, you need to make sure that what you are changing, you have to think about it. You cannot just change some major stuff before thinking before."

Community-citizenship behaviors directed towards individuals (CCB-I)

"Especially when you have something with a lot of dependencies like a Linux distribution and multiple layers of packages depending on others, you don't want to make a change to a library then break everything that uses the library. You have to be thinking through what is going to be the effect of this."

Treating others with respect

"When I say nice here, I mostly mean treats people in accordance with the community expectations for how people are to be treated".

"I think it is important that to be a good citizen that you get on well with the community, that you get on well with the other people."

Maintaining a positive attitude

"You don't have to smile at people to be nice, you just have to be respectful and effective."

"If you have somebody, ever y time, when you say 'open source' he would say 'No, it's free software'. Ever y time you say Linux, they say 'No, it's GNU/Linux'. This is continuous belligerent behavior. Then, I would say that's being a bad community citizen because you are making the general ambiance of the project less agreeable."

Facilitating member conflicts

"There might be geniuses and contribute great code, but the number of people that are scared away because of them has always been greater that what they contribute to the project."

"People would just be toxic to the community but they would just write great code and it kind of sucks. The community has to tell them to clean up their act or go away."

"I will now make sure I watch everything he posts. If he is being abusive, I'll immediately reply and say that's just #NAME#. This is what we think in general. And they will put in the extra work to cover up . . . to sort of smooth over the damage, to fix the damage he is creating over here."

Community-citizenship behaviors directed towards the project (CCB-P)

Contributing with the best interest for the community

"I think that a good contributor is somebody who can come in and not just do stuff in the project but also do stuff in that context of those shared goals, culture, and priorities."

"First, they have to understand what the community wants and you have to be backing the overall goal where there is one. And where there isn't an explicit one, you have to be backing the current implicit goal of the community otherwise your contribution is not a good one."

Complying to the community behavioral rules

"We have a code of conduct that actually lays down some of our community rules. It is very important especially for long-term community members who are the role models that you comply to our community standards."

"To be a good contributor, you have to make contributions and comply with the code of conduct."

Keeping the community informed about one's work and progress

"I think it is vitally important to communicate what you will and will not do, and when."

"If you are saying you'll do something by January 31 and then you don't, this is important but it is even more important to say that you can't and let people know about that."

Keeping project resources to a good standard

"I have great admiration for community members who find an interest in thankless tasks, and this is very important."

"A lot of the really good contributors are people that clean up other people's messes. For example merging bug reports that are duplicates, cleaning up code . . ."

Exercising civic responsibility

"You don't necessarily need to know every detail happening in every team. But it is important to know kind of the big picture, the big announcements, how things are going, how things are changing."

"It is important to know what is going on and to actually make an informal effort there as well."

Responsible involvement in project decisions

"It is the person who, when there is a group decision he does not agree with, will say "I don't agree with it, here is why" but he will let it drop afterwards."

"I think that people do need to voice their opinion and be heard, but sometimes you have to let things go."

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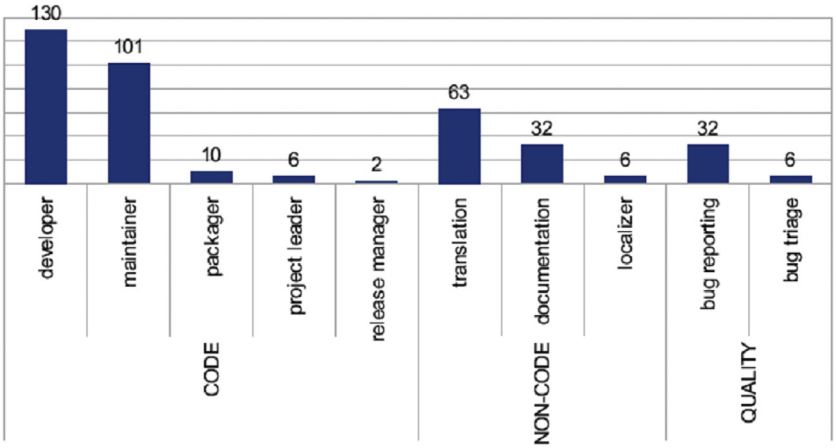
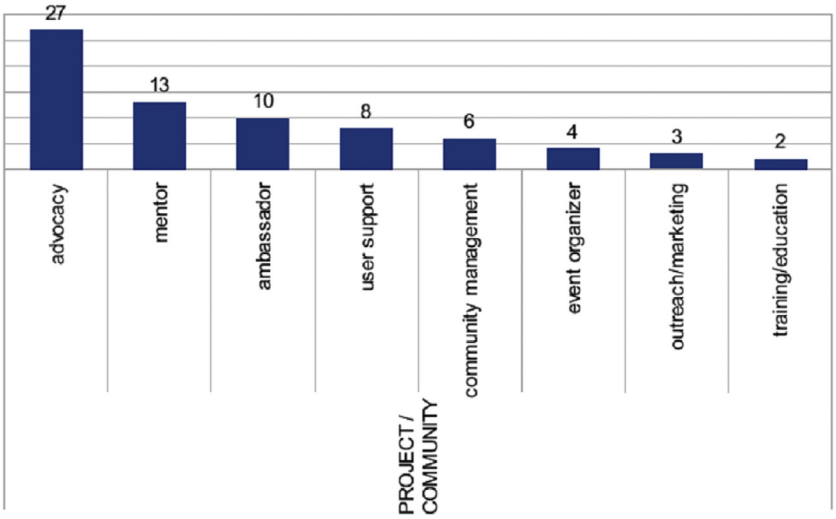
Community-citizenship behaviors directed towards the project (CCB-P)
Promoting the project to potential contributors and to the outside world *"If you are a true passionate citizen then naturally you will be talking about the project in good terms and spread your passion to other people, promoting it to others."* *(about FOSS community citizens) "Somebody who represents the project well to new community members and outside of the community, to tell the project especially to the commercial world because you often to deal with organizations who want to make money as well."*

Appendix E. Survey respondent demographics/participation type

The survey participants were asked to indicate the different types of tasks and roles they performed in their respective FOSS projects. Their responses could be categorized into two main types of tasks: direct contributions to the software artifact, and contributions to the overall project and its community. Among the direct contributions, three sub-groups could be distinguished: code-related (e.g. developers, maintainers, etc.), non-code-related (e.g. documentation, translation, etc.), and quality assurance (e.g. bug reporting, bug triage, etc.) tasks. Project/community contributions involved tasks such as mentoring, community advocacy, or event organization.





Appendix F. Common method bias analysis

Construct/Dimension	Item	Substantive factor loading (R1)	$R1^2$	Common method factor loading (R2)	$R2^2$
Task segregation	TS1	0.902***	0.814	0.015	0.000
	TS2	0.838***	0.702	0.026	0.001
	TS3	0.912***	0.832	−0.026	0.001
	TS4	0.877***	0.769	0.030	0.001
	TS5	0.787***	0.619	−0.053	0.003
Task purposefulness	TP1	0.819***	0.671	−0.004	0.000
	TP2	0.784***	0.615	−0.014	0.000
	TP3	0.877***	0.769	−0.038	0.001
	TP4	0.826***	0.682	0.052	0.003
Interaction intensity	IN1	0.734***	0.539	0.007	0.000
	IN2	0.859***	0.738	−0.040	0.002
	IN3	0.767***	0.588	0.053	0.003
	IN4	0.841***	0.707	−0.019	0.000
Mentoring	ME1	0.892***	0.796	−0.003	0.000
	ME2	0.922***	0.850	−0.060	0.004
	ME3	0.815***	0.664	0.084*	0.007
	ME4	0.885***	0.783	−0.068	0.005
	ME5	0.722***	0.521	0.052	0.003
Joining structuredness	JS1	0.824***	0.679	−0.134**	0.018
	JS2	0.887***	0.787	0.045	0.002
	JS4	0.881***	0.776	0.067*	0.004
	JS5	0.860***	0.740	0.005	0.000
Supportiveness	SU1	0.889***	0.790	−0.005	0.000
	SU2	0.885***	0.783	0.068	0.005
	SU3	0.879***	0.773	−0.061	0.004
	SU4	0.951***	0.904	0.057	0.003
	SU5	0.696***	0.484	−0.053	0.003
Social identification	IDE1	0.864***	0.746	−0.193***	0.037
	IDE2	0.627***	0.393	0.018	0.000
	IDE3	0.603***	0.364	0.188**	0.035
	IDE4	0.726***	0.527	0.107	0.011
	IDE5	0.771***	0.594	0.035	0.001
	IDE6	0.833***	0.694	−0.185**	0.034

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Appendix F *(continued)*

Construct/Dimension	Item	Substantive factor loading (R1)	$R1^2$	Common method factor loading (R2)	$R2^2$
Social integration	INT1	0.815***	0.664	0.086	0.007
	INT2	0.850***	0.723	0.003	0.000
	INT3	0.966***	0.933	−0.123*	0.015
	INT4	0.843***	0.711	0.029	0.001
Task performance	PER1	0.891***	0.794	−0.04	0.002
	PER2	0.869***	0.755	0.006	0.000
	PER3	0.585***	0.342	0.135*	0.018
	PER4	0.839***	0.704	−0.077	0.006
CCB-I	CCB-I1	0.730***	0.533	0.098	0.010
	CCB-I2	0.814***	0.663	−0.018	0.000
	CCB-I3	0.827***	0.684	−0.004	0.000
	CCB-I4	0.878***	0.771	−0.012	0.000
	CCB-I5	0.880***	0.774	−0.06	0.004
CCB-P	CCB-I7	0.741***	0.549	−0.022	0.000
	CCB-I8	0.812***	0.659	−0.048	0.002
	CCB-I9	0.784***	0.615	−0.017	0.000
	CCB-I10	0.849***	0.721	−0.058	0.003
	CCB-P2	0.828***	0.686	0.002	0.000
	CCB-P3	0.759***	0.576	0.000	0.000
	CCB-P4	0.671***	0.450	0.144*	0.021
CCB-C	CCB-P1	0.638***	0.407	0.097	0.009
	CCB-P5	0.896***	0.803	−0.071	0.005
	CCB-P6	0.817***	0.667	0.002	0.000
	CCB-P7	0.890***	0.792	−0.054	0.003
	CCB-P8	0.840***	0.706	0.042	0.002
Average		0.820	0.679	0.000	0.005

Appendix G. Socialization factors

Construct		Item id	EFA						Mean	Std. dev.	Factor loading	Item
			Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6				
TASK	**Task Segregation**	TS1			0.892				4.22	1.94	0.92***	I have performed tasks that were specifically designed for newcomers
	α = 0.922	TS2			0.789				3.81	1.88	0.86***	I have undertaken tasks which are intended to turn new community members into project contributors
	CR = 0.939 AVE = 0.755	TS3			0.899				4.14	1.94	0.90***	I have been involved in tasks which I was clearly aware were designed for newcomers
		TS4			0.855				4.15	1.96	0.90***	I have carried out tasks designed by the community to help newcomers become project contributors
		TS5			0.805				3.30	1.74	0.75***	My contributions to this community have included tasks that were particularly suitable for newcomers
	Task Purposefulness α= 0.849	TP1				0.843			2.83	1.52	0.87***	The pattern of the sequence of tasks that I have chosen to undertake helped me gain an understanding of the project
	CR = 0.899 AVE = 690	TP2				0.703			2.87	1.56	0.82***	Almost every task that I have chosen to perform has expanded and built upon the knowledge gained from the preceding tasks
		TP3				0.815			3.15	1.67	0.78***	To learn how to become a contributor, I have selected jobs with gradually increasing complexity
		TP4				0.830			2.96	1.61	0.85***	The logical connection among the tasks I have opted to perform helped me gain an understanding of the project

Construct		Item id	EFA						Mean	Std. dev.	Factor loading	Item
			Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6				
Individuals	**Interaction Intensity**	IN1						0.684	2.44	1.60	0.75***	I have been active in the project communication channels (such as forums, mailing lists, or IRC channels) to help me learn about the project
	α = 0.822 CR = 0.882 AVE = 0.652	IN2						0.855	2.95	1.65	0.84***	I have been engaged with many other community members to gain project-related knowledge

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Appendix G *(continued)*

Construct		Item id	EFA						Mean	Std. dev.	Factor loading	Item
			Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6				
		IN3						0.726	2.47	1.47	0.82***	Interacting with a lot of other project members has helped me understand how to become a project contributor
		IN4						0.769	2.31	1.43	0.82***	Working with other people as a newcomer has contributed to my learning
		IN5						*0.458*	2.70	1.54		*DROPPED (EFA) The way I have learned to become a contributor in this project has been highly collaborative*
	Mentoring $\alpha = 0.905$ CR = 0.930 AVE = 0.726	ME1	0.896						2.04	1.29	0.76***	One or more experienced member(s) provided me with support and feedback when I was new to this community
		ME2	0.891						3.03	1.95	0.90***	One or more experienced member(s) took me under his/her wing while I was learning how to contribute to this project
		ME3	0.774						2.96	1.85	0.88***	I became a project contributor thanks to the mentoring of one or more experienced members
		ME4	0.834						2.58	1.66	0.87***	One or more experienced contributor(s) has been instrumental in helping me learn how to become a contributor to this project
		ME5	0.654						3.24	1.86	0.84***	I have been mentored by one or more experienced contributor(s)

Construct		Item id	EFA						Mean	Std. dev.	Factor loading	Item
			Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6				
Community	**Joining Structuredness** $\alpha = 0.874$ CR = 0.853 AVE = 0.562	JS1		0.777					2.78	1.90	0.74***	There was a clear set of steps I needed to follow in order to join this community
		JS2		0.640					3.56	1.94	0.55**	There was a formal course of action that I had to follow to join this community
		JS3		0.877					3.06	1.76	*0.36*	*DROPPED (CFA/loading) In this community, I had to go through several steps in order to become a project contributor*
		JS4		0.858					3.19	1.80	0.82***	The process I had to follow to join this community has been clearly structured

	JS5	0.839			3.32	1.84	0.83***	The process I undertook to join this community has clearly followed a defined pathway
Supportiveness $\alpha = 0.917$ CR = 0.938 AVE = 0.752	SU1			0.788	2.96	1.50	0.75***	Most community members that I have been in contact with have gone out of their way to help me become a contributor
	SU2			0.813	2.37	1.44	0.85***	I have been made to feel that my contributions are valuable in this project
	SU3			0.799	2.50	1.57	0.88***	This community is very supportive towards its newcomers
	SU4			0.859	2.95	1.66	0.93***	This community cared a lot about me when I was a newcomer
	SU5			0.547	2.58	1.52	0.91***	I have felt valued by the community even though I was a newcomer

EFA: Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.907/Bartlett's Test of Sphericity Approx. Sig = . 000

Appendix H. Task performance and CCB – Final measurement

Item Id	EFA				Mean	Std. dev.	Factor loading	Item
	Factor 1	Factor 2	Factor 3	Factor 4				
CCB-I $\alpha = 0.883$ CR = 0.914 AVE = 0.681	CCB-I1			0.845	2.23	1.30	0.84***	I lend a hand to members who express a need for help in project areas for which I am knowledgeable
	CCB-I2			0.740	2.78	1.42	0.81***	I go out of my way to help other community members with project-related problems
	CCB-I3			0.882	2.71	1.48	0.86***	I help community members who seek support from other members
	CCB-I4			0.782	2.54	1.35	0.78***	I redirect people who have a problem for which I do not know the answer to members who are in a position to help
	CCB-I5			0.829	2.15	1.22	0.82***	I assist newcomers in becoming familiar with the community
	CCB-I6			*0.401*	2.35	1.10		*DROPPED (EFA) I consult people who might be affected by my actions*

(*continued on next page*)

Appendix H *(continued)*

Item Id	EFA				Mean	Std. dev.	Factor loading	Item
	Factor 1	Factor 2	Factor 3	Factor 4				
CCB-P	CCB-I7	0.622			1.83	0.86	0.76***	I pay attention to how my actions and contributions will affect other members
α = 0.884	CCB-I8	0.768			1.71	0.87	0.80***	I try to avoid creating problems for other members when contributing to the project
CR = 0.910								
AVE = 0.590	CCB-I9	0.800			1.70	0.77	0.77***	I treat other community members with respect
	CCB-I10	0.796			1.55	0.67	0.71***	I maintain a positive attitude when interacting with other members
	CCB-P2	0.716			1.74	0.75	0.78***	I try to align my contributions with the shared goals of the project
	CCB-P3	0.789			1.63	0.74	0.81***	I behave in a way that is aligned with the shared values of this community
	CCB-P4	0.805			1.84	0.89	0.73***	I respect the behavioral rules of the community
CCB-C	CCB-P1		0.587		2.27	1.25	0.80***	I think about the whole community when contributing to the project
α = 0.871	CCB-P5		0.865		2.19	1.23	0.68***	I actively promote the achievements of the project's community
CR = 0.908	CCB-P6		0.823		1.82	0.99	0.86***	I spend time talking about the project to project outsiders
AVE = 0.664	CCB-P7		0.862		1.91	1.04	0.86***	I promote the project to potential users
	CCB-P8		0.825		2.33	1.33	0.87***	I encourage potential users to use the software produced by the community
Task Perf.	PER1			0.782	2.24	1.00	0.77***	My work in this project meets the quality that the community expects from its members
α = 0.805								
CR = 0.874	PER2			0.861	2.30	1.05	0.87***	My contributions meet the performance expectations from the community
AVE = 0.636	PER3			0.858	2.34	1.19	0.86***	I carry out assignments to meet the standard that is expected by the community
	PER4			0.632	2.27	1.00	0.67***	I adequately complete my project tasks in this community

EFA: Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.855/Bartlett's Test of Sphericity Sig = 0.000

Appendix I. Proximal socialization outcomes– Final measurement

Item Id		Mean	Std. dev.	Loading	Item
Social Identification (IDE)	IDE1	3.52	1.75	0.68***	When someone criticizes the community, it feels like a personal insult.
α = 0.825					
CR = 0.872	IDE2	2.31	1.33	0.64***	I am very interested in what outsiders think about the community.
AVE = 0.532					
Source: Mael and Ashforth (1992)	IDE3	2.35	1.54	0.76***	When I talk about this community, I usually say 'we' rather than 'they'.
	IDE4	2.66	1.59	0.82***	This community's successes are my successes.
	IDE5	2.72	1.45	0.81***	When someone praises this community, it feels like a personal compliment.
	IDE6	3.18	1.78	0.65***	If a story in the media criticized the community, I would feel embarrassed.
Social Integration (INT)	INT1	2.17	1.18	0.88***	In this community, members seem to accept me as one of them.
α = 0.897					
CR=0.928	INT2	2.21	1.19	0.87***	I get along with the project members I am in touch with very well.
AVE = 0.764					
Source: Wanberg and Kammeyer-Mueller (2000)	INT3	2.10	1.12	0.87***	I feel comfortable when interacting with other community members.
	INT4	2.12	1.12	0.88***	The community members I interact with respect me.

Appendix J. Cohen's (1988) pseudo F-test (f2 effect size)

Endogenous construct	Original R^2	Excluded exogenous construct											
		TS		TP		IN		SU		IDE		INT	
		R^2	f^2	R^2	f^2	R^2	f^2	R^2	f^2	R^2	f^2	R^2	f^2
Social identification	0.238					0.212	0.03	0.183	0.07				
Social integration	0.508					0.488	0.04	0.310	0.40				
Task performance	0.282			0.239	0.06							0.202	0.11
CCB	0.441	0.432	0.02	0.428	0.02					0.337	0.19	0.400	0.07

Appendix K. Predictive relevance (Q^2 and q^2)

Endogenous construct	Original Q^2	Excluded exogenous construct											
		TS		TP		IN		SU		IDE		INT	
		Q^2	q^2	Q^2	q^2	Q^2	q^2	Q^2	q^2	Q^2	q^2	Q^2	q^2
Social identification	0.12					0.11	0.01	0.08	0.04				
Social integration	0.34					0.32	0.02	0.21	0.19				
Task performance	0.16			0.14	0.02							0.11	0.06
CCB	0.17	0.16	0.01	0.16	0.01					0.13	0.05	0.15	0.02

Appendix L. Robustness checks

In this research, Lohmöller's (1989) "Hierarchical Component Model Repeated Indicators Approach" was used to compute the CCB scores (conceptualized as a reflective second-order construct). This widely used approach consists of repeating the manifest indicators of the associated lower order constructs (the three CCB dimensions) in the CCB second-order construct (Tenenhaus et al., 2005; Wetzels, 2009). The Two-Step approach is an alternative way provided by the literature to compute second-order construct scores. It was used in a subsequent analysis to assess the CCB scores and to verify the stability and consistency of the final results. The generated R2 coefficients for each of the endogenous variables were very close to the ones found when using a Repeated-Items approach. In addition, the path coefficients and significance levels were almost identical to the results provided when using the Repeated Indicators strategy. For instance, the PLS path analysis in the initial conceptual model using the Two-Step approach provided an R2 of 0.439 for CCB (with R2 = 0.441 when using the Repeated Items procedure).

Conceptual model			Alternative model (direct vs. Indirect paths)		
Endogenous variable	AVE	R^2	Endogenous variable	AVE	R^2
IDE	0.560	0.238	IDE	0.56	0.237
INT	0.763	0.507	INT	0.763	0.507
PER	0.636	0.282	PER	0.636	0.297
CCB	0.401	0.441	CCB	0.401	0.448
Average	0.518	0.362	Average	0.590	0.372
GoF	0.433		GoF	0.469	

Social integration was found to be significantly related to CCB with a path of 0.219 and a significance level of $p < 0.001$ (0.241 with $p < 0.001$ when using Repeated Items).

A significant path of 0.405 was also found between Social identification and CCB with a significance level of $p < 0.001$ (compared to 0.388 with $p < 0.001$ with the Repeated Items method). It is important to note that the path coefficient (and significance level) differences between the Repeated Items and Two-Step approaches were all of similar size for all the hypothesized relationships.

Supplemental analyses were also run to determine whether the data supported the posited full mediation of the effects of the four socialization constructs (individuals- and community-related factors) on task performance and CCB by social identification and social integration (Agarwal and Karahanna, 2000; Holmbeck, 1997; Wetzels, 2009). Consequently, an alternative model including all direct and indirect paths was tested. The results confirmed the full mediating effect of the two proximal socialization variables. First, the coefficient of determination of task performance and CCB was not much affected: from 0.282 to 0.297 for task performance and from 0.441 to 0.448 for CCB. The GoF index was also close (0.469 for the alternative model and 0.433 for the original model). More importantly, the PLS analysis did not result in any significant path coefficient for any of the direct paths associated with the four socialization variables. These results demonstrate that the relationships between interaction intensity and task performance/CCB, and between supportiveness and task performance/CCB, are fully mediated by social identification and social integration. No conclusion could be drawn for the two remaining variables, mentoring and joining structuredness, since no significant path was found in either the conceptual or the alternative models.

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