CORA Cork Open Research Archive
Cartlann Taighde Oscailte Chorcaí

Title	Uncovering the periphery: a qualitative survey of episodic volunteering in free/libre and open source software communities
Authors	Barcomb, Ann;Kaufmann, Andreas;Riehle, Dirk;Stol, Klaas-Jan;Fitzgerald, Brian
Publication date	2018-10-01
Original Citation	Barcomb, A., Kaufmann, A., Riehle, D., Stol, K. J. and Fitzgerald, B. (2020) 'Uncovering the Periphery: A Qualitative Survey of Episodic Volunteering in Free/Libre and Open Source Software Communities', IEEE Transactions on Software Engineering, 46(9), pp. 962-980.
Type of publication	Article (peer-reviewed)
Link to publisher's version	https://ieeexplore.ieee.org/document/8477174 - 10.1109/TSE.2018.2872713
Rights	This work is licensed under a Creative Commons Attribution 3.0 License. For more information, see http://creativecommons.org/licenses/by/3.0/ - http://creativecommons.org/licenses/by/3.0/
Download date	2026-10-30 00:53:41
Item downloaded from	https://hdl.handle.net/10468/7207

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Uncovering the Periphery: A Qualitative Survey of Episodic Volunteering in Free/Libre and Open Source Software Communities

Ann Barcomb, Andreas Kaufmann, Dirk Riehle, Klaas-Jan Stol, and Brian Fitzgerald

Abstract—Free/Libre and Open Source Software (FLOSS) communities are composed, in part, of volunteers, many of whom contribute infrequently. However, these infrequent volunteers contribute to the sustainability of FLOSS projects, and should ideally be encouraged to continue participating, even if they cannot be persuaded to contribute regularly. Infrequent contributions are part of a trend which has been widely observed in other sectors of volunteering, where it has been termed "episodic volunteering" (EV). Previous FLOSS research has focused on the Onion model, differentiating core and peripheral developers, with the latter considered as a homogeneous group. We argue this is too simplistic, given the size of the periphery group and the myriad of valuable activities they perform beyond coding. Our exploratory qualitative survey of 13 FLOSS communities investigated what episodic volunteering looks like in a FLOSS context. EV is widespread in FLOSS communities, although not specifically managed. We suggest several recommendations for managing EV based on a framework drawn from the volunteering literature. Also, episodic volunteers make a wide range of value-added contributions other than code, and they should neither be expected nor coerced into becoming habitual volunteers.

Index Terms—Community management, episodic volunteering, free software, open source software, peripheral developer

1 Introduction

Free/Libre and Open Source Software (FLOSS) projects are playing an increasingly important role in the software industry. Since the term "Open Source" was coined, FLOSS has become a critical asset to many firms. FLOSS products are not only used as essential parts of firms' infrastructure (e.g., Apache webserver), but firms now strategically engage with FLOSS projects on a large scale [1], [2]. This increased dependency on FLOSS projects has important consequences for how firms engage with FLOSS communities. Although most FLOSS projects are small [3], it is big projects which attract companies [4]. In such communities, the perceptions of the community and the retention of its members are critical to the project's long-term sustainability [5]. Clearly, in order to ensure long-term sustainability of their product offering, firms must manage the dependency on FLOSS projects by understanding the projects' communities.

Traditionally, the FLOSS literature characterizes contributors based on the quantity of their outputs or formal role in the community. The Onion model (see Fig. 1) [6], [7] divides participants into categories, or *layers*, based on the quantity of their contributions. *Core developer* generally describes the most prolific developers who collectively contribute 80 percent of the source code, but it is sometimes used as a synonym for *committer*, a person who has the authority to incorporate changes directly into the main development branch [8], [9]. Contributors who are not part of the core are called *associate* [10], *co-developers* [11], or *peripheral developers* [12].

Most research on FLOSS projects has focused on core developers, which can be justified by the fact that core developers make the most significant contributions in terms of lines of code. The number of top contributors reported can vary significantly, but they tend to be relatively few in number [13]. Some reported examples are 15 or fewer people [8], less than 25 percent of contributors [14], approximately 20 percent of contributors [15], and less than 10 percent of contributors [16]. Regardless of the exact size of the core, the range of examples makes it clear that top contributors make up the minority in projects with many contributors.

While the strong focus on long-term and core developers (e.g., [17]) can be justified when looking at the quantity of contributions, the periphery actually represents a large proportion of FLOSS communities, but has not been studied in any great detail. We do know that peripheral developers are associated with a number of significant benefits: for example a high level of innovation potential, improving

- *A. Barcomb is with the Open Source Research Group, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen 91058, Germany, and also with the Lero, Irish Software Research Centre, University of Limerick, Limerick V94 T9PX, Ireland. E-mail: ann@barcomb.org.*
- *A. Kaufmann and D. Riehle are with the Open Source Research Group, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen 91058, Germany. E-mail: andreas.kaufmann@fau.de, dirk@riehle.org.*
- *K.-J. Stol is with the Lero, Irish Software Research Centre, University College Cork, Cork T12 K8AF, Ireland. E-mail: k.stol@ucc.ie.*
- *B. Fitzgerald is with the Lero, Irish Software Research Centre, University of Limerick, Limerick V94 T9PX, Ireland. E-mail: bf@lero.ie.*

Manuscript received 25 Mar. 2018; revised 18 Sept. 2018; accepted 19 Sept. 2018. Date of publication 1 Oct. 2018; date of current version 17 Sept. 2020. (Corresponding author: Ann Barcomb.)
Recommended for acceptance by J. C. Carver.
Digital Object Identifier no. 10.1109/TSE.2018.2872713

This work is licensed under a Creative Commons Attribution 3.0 License. For more information, see http://creativecommons.org/licenses/by/3.0/

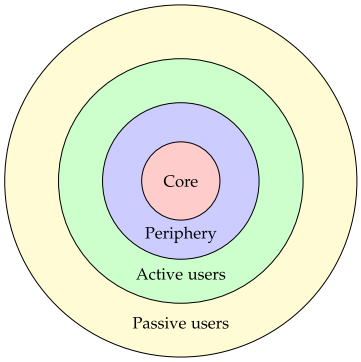


Fig. 1. The onion model of FLOSS engagement adapted from [7].

software quality, and developing new features [18], [19], [20], [21], [22]. Furthermore, peripheral developers come with extensive external social networks that are important for the sustainability of FLOSS projects [23].

Although one-off peripheral contributors are widespread [24], there are also those who continue to participate and form long-lasting relationships with the project, contributing to its longevity [25], [26]. Recent attempts to disambiguate the periphery have considered the frequency of participation rather than the division of tasks within the community [24], [27], which is precisely how we propose to distinguish contributors. To examine the factors and practices of continuing engagement among peripheral contributors, we draw on the general volunteering literature, and adopt the concept of *Episodic Volunteering* (EV). EV is a form of 'new' or 'reflexive' volunteering. In reflexive volunteering, participation depends on personal preferences rather than a sense of communal obligation [28], [29], [30]. This is in contrast to the collective style of volunteering, where volunteering is considered an integral part of community life [30]. EV is marked by short-term, erratic, and conditional participation [31], [32], ranging from one-off contributions to infrequent or short-term engagement. EV thus explicitly includes returning, emotionally committed contributors who nonetheless participate infrequently. Episodic volunteers are distinguished from *habitual volunteers*, whose contributions are "continuous or successive" [33]. There are varying definitions for the boundary between episodic and habitual (e.g., [34], [35]), but in this paper we define habitual as either frequent (10 or more substantial contributions in a year) or of a sustained duration (two or more contributions of any size in a month, for six consecutive months).

Unlike the peripheral developer in the Onion model, EV describes individuals on the basis of their contributions, irrespective of the activity of the community as a whole. The EV literature suggests that most organizations are ill-prepared to manage episodic volunteers because their administration is based on traditional best practices for volunteer management [36], which assume habitual engagement. Identifying practices for engaging episodic volunteers and incorporating their work is therefore of keen interest.

Another key challenge in the EV literature is volunteer retention. Retention refers to episodic volunteers returning to the same cause multiple times to volunteer again. This does not suggest these volunteers become habitual. For example, a volunteer who contributes two times a year for a decade would be an episodic volunteer, albeit a long-term one, due to the low frequency of contributions. Retention is desired because returning volunteers require less orientation and training than newcomers [37].

Although FLOSS communities now incorporate significant numbers of paid developers [38], these are rarely employees of a FLOSS community or foundation, but are typically hired by external companies. Thus FLOSS communities cannot use traditional incentives to influence the developer, but must instead rely on the same mechanisms which are used to manage volunteers [39], [40]. As FLOSS project management becomes less ad-hoc and more professional [2], it more closely resembles other large non-profit organizations, where volunteer management is handled by paid staff members [41]. Paid staff members and contributors who are paid directly by the firm or foundation to fix bugs or develop features cannot be considered volunteers.

We observe a number of shortcomings in the FLOSS literature. First, the dichotomous distinction between core developers on the one hand and peripheral developers on the other is too simplistic. The periphery has mostly been considered a homogeneous group of participants—a "black box"—while in actual fact, the periphery consists of many different types of contributors with different contribution patterns. There is a fundamental difference between one-off contributors and returning contributors in terms of contribution sizes and patch acceptance rates [27], and between long-term and short-term participants in terms of motivations [42]. Second, as a consequence of the dichotomous distinction between core and periphery, most research has focused on the core, ignoring the contributions made by peripheral contributors. However, by definition, the periphery represents a much larger proportion of people in FLOSS communities. In order to better leverage the potential of this group of contributors, we need to develop a greater understanding of these contributors. Third, much of the research on participation in FLOSS has focused on software development, ignoring the many other activities which contribute to software releases or to sustaining the community, such as translation, and the organization of conferences [43]. These non-code-centric activities are extremely important for the well-being of a project [43].

Given these shortcomings, our goal is to develop a better understanding of the episodic volunteering phenomenon in FLOSS projects. Specifically, our study had two primary objectives:

1) Describe how retention in FLOSS episodic volunteers relates to five concepts associated with EV retention;
2) Identify the current state of practices for EV retention used in FLOSS communities.

In our study, we conducted a qualitative survey spanning 13 different FLOSS communities. Among other findings, we observe that:

- EV is widespread among FLOSS communities, and episodic volunteers are engaged in many different tasks;
- FLOSS communities are not currently focused on EV retention or using management practices more compatible with EV; and

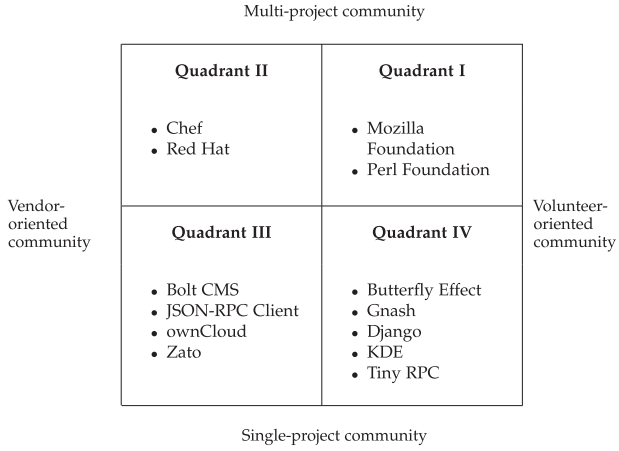


Fig. 2. Selected FLOSS communities.

- Contributor motivation, social norms, psychological sense of community, satisfaction, and community commitment are relevant factors in EV retention, which can be used to propose practices for managing the retention of episodic volunteers.

2 Terminology

Since FLOSS projects were first studied in the late 1990s, there have been a number of significant developments in how FLOSS communities have evolved. Early studies of the FLOSS phenomenon made a distinction between *core* and *peripheral* developers. Even today, many studies use this dichotomy to characterize FLOSS community members [44].

Our research examines FLOSS communities as a type of volunteer organization (henceforth called 'organization'). Communities can be organized around an individual project, a foundation, or a vendor (see Fig. 2 for examples). Crowston et al. [45] describe FLOSS as an example of a self-organizing, distributed team, where participants contribute to FLOSS projects as one of many activities, and can be viewed as volunteers, even if they are remunerated. Traditional volunteering does not preclude online, distributed volunteering [46], and FLOSS is sometimes given as an example of this type of volunteering. Yet FLOSS communities are, surprisingly, rarely viewed as volunteer organizations. Therefore, we contrast this alternative view of FLOSS communities as volunteer organizations with the traditional view that distinguishes between peripheral and core developers (see Table 1).

Definition. Although there is significant overlap between habitual volunteers and core contributors on one hand, and between episodic volunteers and peripheral contributors on the other hand, there are several differences between them. First, the terms derived from the volunteering literature refer to the *duration* and *frequency* of an individual's participation, whereas the traditional terms describe the quantity of contributions as a proportion of the total contributions.

Nature of Participants. Second, with an increasing involvement of companies in FLOSS communities, contributors may include paid contributors, who can be difficult to distinguish from volunteers [38]. The definition of 'volunteer' can actually be blurry in both the volunteering and FLOSS contexts. In FLOSS communities, paid developers are not usually employed by the community they contribute to, but by a company which offers their labor in expectation of economic benefit. From the perspective of the community, they may be indistinguishable from volunteers. Likewise, in traditional volunteer organizations, it is not always clear whether people motivated by employer pressure, mandatory national service, court-mandated service, or résumé building should be considered volunteers [29], [47], [48], yet it is not always possible for an organization to separate compulsory participation from volunteering. Participation without monetary reward, which is the cornerstone of most definitions of volunteering, is not always part of how the term is used in practice, as some volunteer programs may offer stipends [47]. For these reasons, in our alternative view using the habitual/episodic lens of volunteers, community managers cannot distinguish paid developers from 'true' volunteers. Hence, we use the term 'volunteer' in the broadest sense, to mean a participant engaged in *any* form of FLOSS contribution, but *not* directly employed or sponsored by the FLOSS foundation or vendor for the project to which they contribute.

Nature of Contributions. Finally, non-code contributors are frequently excluded from analysis of FLOSS communities [43]. Describing activities observed in the Drupal community, Rozas [49] listed 10 categories of contributions: source code, documentation, translation, design, support, evangelizing, mentoring, community management, events, and economic support. Nonetheless, evidence for the Onion model comes primarily from activities which automatically create digital records, such as code submissions, bug reports, and mailing list comments. Also, the term 'core' is often followed by 'developer' rather than the more inclusive

TABLE 1
Comparison of Core/Periphery Lens versus Habitual/Episodic Lens in FLOSS Communities

	Core / Peripheral lens	Habitual / Episodic lens
Common Definition	*Core* developers are the participants who contribute approximately 80 percent of the code. *Peripheral* developers are the remaining participants who contribute about 20 percent of the code.	*Habitual* volunteers make continuous or successive contributions. *Episodic* volunteers contribute infrequently and/or for a short duration.
Nature of Participants	Considers both volunteer participants and paid developers, either employed by a company or sponsored for a specified set of tasks.	Considers all participants who are not directly employed or sponsored by the FLOSS foundation or FLOSS vendor for the project they contribute to.
Nature of Contributions	Typically used to describe software contributions, sometimes used to describe other electronically documented activities such as mailing list discussion.	All types of activities done within the community, including code, documentation, translation, design, support, evangelizing, mentoring, community management, events, and economic support.

'participant' or 'contributor' (e.g., [8], [50], [51]), emphasizing the importance that is given to code contributions. By contrast, EV encompasses all activities which can be performed by volunteers. Thus, this study seeks go beyond the code-centric focus in the FLOSS literature.

3 Background and Motivation

3.1 Limitations of the Onion Model

Despite its widespread adoption, the Onion model has a number of limitations. One issue is that the most common definition of 'core' requires measuring activity and setting a threshold. Counting commits does not consider the role a person has within the community. While developers who contribute significantly tend to be more central in their community's communication network, some prolific developers work independently, and it is also possible for a person to be more engaged in coordination or code review than development [52]. Social network centrality has been proposed as a more accurate way of representing a developer's position in the community [53], [54]. We also observe that centrality addresses the question of the participant's role in the community, but does not describe the attributes of individuals, whose feelings and perceptions about their participation may differ from what can be observed. Intentions and self-perception are critical when it comes to predicting a person's intention to continue [55].

A second issue is that the core-periphery structure divides developers into categories based on an arbitrary threshold, when a continuous measure of 'core-ness' may more clearly reflect small differences between participants [56].

A third limitation is that the Onion model has only been validated in the context of contributions which can be readily mined—that is, code submissions, bug reports and mailing lists—and has not been evaluated to determine if it also describes other types of activities within FLOSS communities [43]. The core-periphery structure has been shown to be suboptimal in companies for the tasks of globally distributed activities such as support [57] and R&D [58]; therefore it is possible that non-coding activities in FLOSS communities do not follow the core-periphery pattern found in code contributions. For example, some communities have very hierarchical communication structures [59]. The core-periphery structure is not even guaranteed within software development in all FLOSS communities. While many FLOSS communities are controlled by a core of about 20 percent of contributors [22], in FLOSS communities focused on innovating and advancing the state of the art, the decision-making may be more strongly hierarchical [6]: Geldenhuys [16] found many smaller projects were significantly less egalitarian than the average, with the number of top contributors as low as 3.1 percent.

A fourth shortcoming is that the Onion model presents a snapshot of a single point in time, and therefore does not reflect how participants may change roles [60]. For example, reviewers in the OpenStack project often move back and forth between core and periphery status [61].

3.2 The Importance of Episodic Contributors

We found a number of studies which suggest that FLOSS contributor behavior can be interpreted as episodic. Table 2 summarizes these studies. Each example shows distinct evidence of infrequent or short-term contributions; e.g., if 3,975 bug reports were made by 3,060 contributors, the median number of reports made per person is one.

The periphery is important to FLOSS projects [21], [26], [44]. As the periphery is largely episodic, we suggest that episodic participation is also important for FLOSS projects. A number of benefits has been attributed to the periphery. Peripheral developers can facilitate innovation and improve the quality and diffusion of knowledge, often providing critical input into solving technical problems [18], [19], [21], [23], [78], [79]. People who initially contribute peripherally may also grow into core roles, helping to sustain the project by replacing developers who leave [21], [79], [80], [81], [82]. Their commits include not only high-quality bug fixes [83], peripheral contributors are especially interested in implementing functionally novel features [18], [19], [79]. In a study of popular projects on GitHub, Pinto et al. [24] found that 30 percent of one-off contributors' commits fixed bugs, while 19 percent added features and 9 percent refactored code. When peripheral developers do not implement new features, their suggestions and reports can often result in the identification of bugs [8], [20] or trigger significant new development [18], [22], [84]. Lastly, peripheral developers engage in citizenship behaviors, such as policing adherence to community rules—which reduces friction and conflict—and identifying legal issues such as copyright infringement [21].

4 A Framework for Studying Episodic Volunteering in FLOSS

In this section we draw on the volunteering literature to derive an analytical framework comprising five key concepts associated with attraction and retention of volunteers [85]. The entire volunteer process can be considered at the *agency*, *social system*, or *individual* level [86]. We focus on *individual* level concepts which are correlated with intention to remain among episodic volunteers [87]. These concepts are, for the most part, not novel in FLOSS. Indeed, it is precisely because of the similarities between volunteering and FLOSS contexts that we expect the EV concept to apply to FLOSS. The advantage of using these well-defined concepts from models of episodic volunteering is that it offers a systematic approach to considering factors affecting the retention of individual episodic volunteers. Furthermore, this approach allows the utility of practices to be explained through an understanding of the constructs related to retention among FLOSS episodic volunteers.

4.1 Contributor Motivation

Volunteers have a variety of motivations for their contributions, and their motivations have been extensively studied. Episodic volunteers in traditional volunteer organizations may have self-oriented motives, such as self-esteem, enjoyment, obtaining tax benefits and networking, or they may have other-oriented motives, such as the promotion of a cause and a sense of duty [88], [89], [90], [91]. It has been proposed that EV exists along a spectrum, from people who participate spontaneously, to those who repeatedly participate, albeit episodically [37]. Handy et al. [92] found long-term episodic volunteers and habitual volunteers are more likely than infrequent episodic volunteers to have altruistic motives, but are

TABLE 2
Evidence of Episodic Contributions Among FLOSS Contributors

Study	Year	Project	Findings
Dempsey et al. [62]	1999	Linux kernel	Only 13 contributors made 10 or more commits, with the majority making one or two.
Moon and Sproull [63]	2000	Linux kernel	84%, or 10,925, of contributors posted 10 or fewer messages on the linux-kernel mailing list.
Lerner and Tirole [64]	2002	Sendmail	The majority of participants were students who made one or two submissions.
Koch and Schneider [65]	2002	GNOME	78% of people made only one bug report.
Mockus et al. [8]	2002	Apache web server	A total of 3,975 bug reports were made by 3,060 contributors.
Nakakoji et al. [6]	2002	GNUWingnut, Linux support, SRA-PostgreSQL, and Jun	The contribution of peripheral developers is described as "irregular, and the period of involvement is short and sporadic." Such developers are common in utility-oriented FLOSS which doesn't have an independent community associated with it, such as the Linux system excluding the kernel.
Crowston et al. [66]	2003	–	An analysis of bug reports from 122 large projects hosted on SourceForge showed that while some people have many interactions, most have only a few. Decentralized social networks tend to have more developers contributing bug reports.
Lee and Cole [67]	2003	Linux kernel	Between 1995 and 2000, over 14,500 people sent at least one email to the mailing list. On average, each person sent 14 emails in five years.
Ye and Kishida [68]	2003	GIMP	There were 111 peripheral developers, described as having irregular, sporadic contributions. 92 contributors made 1-2 commits during the period observed, and 502 people sent only one email to the mailing list between 1999–2002.
Dinh-Trong and Bieman [14]	2005	FreeBSD	A total of 16,115 bug reports were made by an estimated 6,082 people, of whom 3,370 reported one bug, 1,875 reported two bugs, and 447 reported three.
Ducheneaut [69]	2005	Python	Of 284 people who joined by posting a message during the course of a year, 136 posted a single message and never returned. 256 did not make a commit in this period. After one-off participants were excluded, the median number of messages posted was 3.
Christley and Madey [70]	2007	–	In a study of projects hosted on SourceForge, 40% of people were observed to sometimes fill the role of software users by checking out the code but not contributing, and at other times to contribute.
Kagdi et al. [71]	2008	KOffice	24 developers contributed 2–10 commits apiece.
Singh and Twidale [72]	2008	Mozilla Firefox	In a sample of 100 threads on bulletin boards offering technical support, 40% of participants posted only one message, and another 45% posted 2–5 messages.
Davies et al. [73]	2010	Debian	Most of almost 54,000 bug reporters submitted only one or two reports.
Zhou and Mockus [74]	2012	Mozilla and GNOME	At least 70% of contributors have only one interaction with the project.
Ma et al. [75]	2013	JBossAS, Apache Geronimo, and JOnAS	Some developers took several months off between commits. The median commit interval for inactive committers was 2.4 days, compared to 0.08 days for active committers. 75% of commits made by inactive committers occurred with a gap of no more than 200 days.
Zhou and Mockus [17]	2015	Mozilla and GNOME	One developer, who is in the top 90% of contributors in the GNOME project, helped with an average of 3 bugs a year and declined to be described as a "long term contributor."
Pinto et al. [24]	2016	–	In a study of 320 mature, non-trivial projects hosted on GitHub, 30% of one-off contributors fixed bugs; 19% of one-off contributors added features; and 9% refactored code.
Palyart et al. [76]	2017	User projects linked to Maven and RubyGems	In more popular components, developers of the user project are less likely to get involved in the component project and the shorter the involvement will be. For component projects with more than 30 user projects, newcomers only contribute for a few days.
Silva et al. [77]	2017	GSoC projects	19% of students participating in Google Summer of Code (GSoC), a 3-month program, only had code merged during this period, not before or after.

equally likely to have self-oriented motives. However, Hyde et al. [87] reported that people with self-oriented motives and altruistic motives were equally represented among newcomers and long-term episodic volunteers, highlighting the importance of studying EV in different contexts.

The motivations of FLOSS contributors, both intrinsic and extrinsic, were summarized by von Krogh et al. [93]. Some motivations could be described as self-oriented, as in the joy of working with a specific team [94], or expected future career benefits [95]. Examples of other-oriented motives have also been observed: altruistic values [96] and supporting the community [97]. Extrinsic motives do not predict long-term, frequent participation, either in general [6], [26], [42], [98], or in peripheral contributions in particular [79].

Although there is some disagreement in the EV literature, the wealth of FLOSS literature on the subject of motivation provides the expected context for FLOSS EV. We expect our findings to be consistent with the general volunteering

literature and FLOSS literature, and to provide support for viewing FLOSS as a form of volunteering. Furthermore, because motives are a factor primarily affecting new volunteers [85], we expect our respondents to propose practices aimed at newcomers to support EV contributor motivation. Reducing barriers to entry, especially technical ones, is recommended to promote socially-motivated individuals [99], so we anticipate community managers will recommend good documentation, contributor dashboards, and easy workspace setup [26], [100], [101]. *We expect to observe FLOSS episodic volunteers with intrinsic motivations and altruistic feelings to have more intention of remaining, and for practices associated with contributor motivation to be aimed at newcomers.*

4.2 Social Norms

Social norms comprise the support or pressure from others to volunteer [86], [87]. Episodic volunteers in traditional volunteer organizations who are more concerned about social norms are more likely to be retained [87] in cases where the cause is viewed positively [86]. Among habitual volunteers, social norms are most significant for novice volunteers who have not acquired community commitment [85], but even long-term episodic volunteers remain influenced by social norms [87]. Episodic volunteers are more likely than habitual volunteers to participate out of a sense of civic duty, and are more likely to respond to invitations to participate [89].

FLOSS contributions have not been considered in depth in the context of social norms. Studies have considered the effect of cultural factors (e.g., [102]) and of firms' culture (e.g., [39]) on participation. The effect of environment on FLOSS contributors' participation has not been widely studied.

The EV literature is clear that social norms are a particularly important concept for episodic volunteers. We expect social norms to be important to FLOSS episodic volunteers and believe that EV may be instrumental in illuminating this hitherto unstudied concept because social norms are more significant for episodic than habitual volunteers. Due to the lack of study on social norms, we do not expect FLOSS community managers to be deliberately utilizing practices associated with social norms to retain episodic volunteers. In summary, *we expect social norms to be important, but to be under-appreciated by FLOSS community managers.*

4.3 Psychological Sense of Community

The concept of psychological sense of community describes the feelings of efficacy, responsibility and support that a person experiences from belonging to a group [86]. The concept need not refer to a geographically constrained group, but can instead describe a distributed community with shared objectives and common values [103]. It is distinguished from community commitment (discussed later), which occurs when a person comes to identify as a member of the community and as a volunteer.

Psychological sense of community is an important concept in the retention of volunteers in traditional volunteer organizations [103], [104], and it has been speculated that it is relevant to the retention of long-term episodic volunteers [90]. However, the literature on EV is inconclusive. Hyde et al. [87] did not find a link between psychological sense of community and the retention of volunteers, but their study used a physical definition of community which the authors described as a possible limitation.

FLOSS contributors, both core and peripheral, experience a psychological sense of community, with—depending on the study—as few as 30 percent or as many as 83 percent of participants claiming they felt affinity for the community [20], [55], [96]. Even one-off contributors tend to have a positive impression of the projects to which they contribute [26]. Contributors who derive pleasure from working in the community have increased intentions to continue to participate [42], [55].

FLOSS and general volunteering literature has taken a broader view of community and has established a connection with retention. We expect the FLOSS case to affirm the relevance of a psychological sense of community to EV which is currently lacking. FLOSS communities will likely employ practices to increase the psychological sense of community, such as formal mentoring structures, guided introductory sessions, reining in aggressive community members, and valuing all types of contributions [105], [106]. To summarize, *we expect FLOSS episodic volunteers who feel a psychological sense of community to have an intention to remain, and FLOSS communities to be using welcoming practices to appeal to a psychological sense of community.*

4.4 Satisfaction

Satisfaction describes the match between an individual's motivations and the benefits delivered by the volunteering activity [107], and is the result of the experiences the volunteer has with the volunteer work and community [104].

In traditional volunteering organizations, satisfaction predicts intention to continue volunteering in the short term, but is not a predictor of long-term intentions [85]. Episodic volunteers might also experience diminished expectations of satisfaction over time [33], but it is also possible that satisfaction is associated with intention to remain regardless of tenure [87]. Hustinx et al. [89] found no differences in satisfaction between episodic and habitual contributors, but did not consider the duration of service.

In a survey of nearly 150 developers, Wu et al. found that satisfaction was the single best predictor of intention to remain among FLOSS contributors [108].

The literature on general volunteering, EV and FLOSS all agree that satisfaction is an important concept in retention, but disagree about its relationship to participation tenure. Because FLOSS literature which did not distinguish between episodic and habitual contributors nonetheless found that satisfaction was extremely important, we expect that our study will support the view that satisfaction matters in all stages of EV. *We anticipate that satisfaction will be important for FLOSS episodic volunteers, regardless of how long they have been participating. We expect that community managers will be employing practices related to satisfaction.*

4.5 Community Commitment

As volunteers participate in a community, they can develop a strong commitment to the community. In such cases, a person's identify becomes linked with the community, and people identify as being part of the community [109], [110]. This in turn can encourage role identity, where the participant identifies as a volunteer. Both role identity and community

commitment are good predictors of a volunteer's intention to continue contributing to a community [85].

Episodic volunteers in traditional volunteer organizations can demonstrate increased attachment when they feel that they are a part of something bigger than themselves [111]. Community commitment—measured by loyalty to the community, willingness to exert effort on behalf of the community, and acceptance of the community's values—influences experienced episodic volunteers' intention to remain within the community [87], [112]. Commitment in the form of financial contributions is most common among habitual volunteers, then long-term episodic volunteers, and finally short-term episodic volunteers [92].

Among FLOSS contributors, factors that affect sustained participation include: positive community experiences; association with the beliefs and values of FLOSS; and seeing oneself as a FLOSS developer [55], [98]. Adherence to cooperative norms, passion and a 'sense of community' are present among peripheral contributors [20], [21].

To account for differences between habitual and episodic contributors, *we expect to find community commitment is relevant to sustained FLOSS episodic participation, but somewhat less than has been previously observed among FLOSS contributors. We expect to find FLOSS communities using techniques such as predictable cycles to help episodic volunteers return.*

4.6 Identifying Practices for Managing EV

The constructs presented in Sections 4.1, 4.2, 4.3, 4.4, and 4.5 together form a framework that is related to EV retention. This, combined with the relevant FLOSS literature as well as the general volunteering literature, allows us to make predictions about the ways in which FLOSS episodic volunteers are similar to, or different from, other episodic volunteers or FLOSS habitual volunteers. Community managers are generally concerned with understanding how to acquire and retain participants, both of which are necessary for a project to survive [113]. Developing such insights is essential in order to formulate strategies that FLOSS communities can employ to encourage episodic volunteers to return.

Incorporating infrequent contributors presents challenges to communities. One concern is to balance the cost and time involved in recruiting volunteers on one hand [79], [114] and the work they contribute on the other hand. This problem has also been observed in the general volunteering sector [37]. In other words, there is an inherent tension in balancing the positives and negatives associated with the flow of resources in and out of an online community [115]. The EV literature suggests it may be necessary to modify processes to account for the short durations involved [29], [31], [36], [37].

The literature on EV suggests that organizations can strategically examine their volunteering in order to identify what work needs to be done, how it might be done by more people volunteering fewer hours, and how a larger number of people can be motivated [37]. One way in which this might be done is the 'volunteer scenario' approach promoted by Meijs and Brudney [116], wherein volunteer assets, volunteer availability, and potential assignments are listed in order to find suitable matches. Episodic volunteers with low availability and low assets are best suited to tasks which require little cognitive effort, are quickly completed, have a narrow focus, require little up-front investment, can be broken into small parts, do not require skilled labor, or currently disrupt the work of habitual volunteers [37], [116], [117]. Several of these characteristics were also identified as appropriate for one-off contributors in the FLOSS literature [100]. Episodic volunteers can also be specialists, with high assets but limited opportunity to contribute their skills. A lawyer specializing in copyright law would be an example of a specialist episodic volunteer in a FLOSS context. For such volunteers, the EV literature recommends ensuring that they are able to practice their specialist skills without being exposed to organizational details [88], [116].

In our research, we examine what practices, if any, are currently being employed in FLOSS communities with the intention of managing EV. We also investigate how existing EV practices might be adapted to a FLOSS context, and how existing FLOSS practices might be re-imagined with episodic volunteers in mind.

5 Research Method

The goal of our study is to develop a better understanding of episodic volunteers in FLOSS communities. We consider how FLOSS episodic volunteers differ or are similar to habitual FLOSS volunteers and episodic volunteers in the general volunteering sector, and what practices might be used to retain FLOSS episodic volunteers or to help them be more effective. We do this by considering the vast periphery in terms of the characteristics of tenure and patterns of participation. In particular, we expand our research to encompass non-code contributions, in order to create a broader picture of episodic participation in FLOSS communities.

We conducted a qualitative survey [118], [119] in order to investigate the episodic volunteering phenomenon in FLOSS communities [120]. Two reasons prompted this choice. First, we wanted to examine all types of participants, not just code contributors. Archival methods such as code repository mining could bias the study by encouraging the inclusion a higher proportion of code contributors. Second, EV has not yet been studied in a FLOSS context, and is not well understood in general [90], making an exploratory study more appropriate for laying the groundwork of how the EV concept can be applied to FLOSS communities. The qualitative survey was conducted through interviews.

5.1 Participant Selection

Our research relies on theoretical sampling: purposive, non-probabilistic samples which are typically small, as a single observation is sufficient for inclusion in the coding system [121], [122]. Researchers identify both key informants with access to important information, and a *"wide range of types of informants"* who have experienced the circumstances relevant to the research topic [123]. We selected community managers as key informants on community relationships [124] because they interact with many contributors and play a key role within their respective communities.

To select appropriate informants, we chose criteria which would relate to the research objective and cover a wide breadth of differences [125] between projects. We identified two dimensions which together span four quadrants; for each we sought both community managers and episodic

volunteers. Fig. 2 shows these quadrants, along with the communities we included in our study.

The first dimension is the size of the community. Size of community or organization is commonly used as a dimension in studies of this type (e.g., [126]). Differences in project size might affect how episodic volunteering is incorporated in the project. For example, episodic volunteers might experience increased difficulty engaging with larger projects, because larger codebases might present a barrier to newcomers [127]. Conversely, larger projects have successfully socialized more members [69] and might have more processes in place, including ones for episodic volunteers. We operationalize size as a multi-/single project distinction. In multi-project communities, participants often identify with the larger community, seeing themselves—for example—as part of the *Mozilla* community as opposed to the *Mozilla Thunderbird* community. In single project communities, the project might still be part of a foundational umbrella, such as *GNU*, but the participants talk of being part of the *Gnash* project. Within the single project category, we considered both very small projects with only a handful of participants (e.g., Butterfly Effect), as well as larger projects (e.g., KDE).

The second dimension is whether the community is *vendor-oriented* or *volunteer-oriented*. In the vendor-oriented category, we consider both consortia of vendors which play a major role in project direction, and single-vendor commercial open source projects *"owned by a single firm that derives a direct and significant revenue stream from the software"* [128]. The community category contains projects which are non-commercially managed, either formally or through an informal community process.

Involvement of vendors is reflected in many aspects of FLOSS projects, such as choice of license, level of activity, maturity, and the extent to which unsolicited contributions are accepted [2], [4], [128], [129]. In light of the acknowledged changes to FLOSS project structures wrought by industry involvement we felt this difference might be reflected in the treatment of episodic volunteers. By including highly commercial projects and extremely non-commercial projects, as well as larger and smaller projects, we intended to capture the full range of EV behavior in FLOSS projects.

Quadrant I consists of multi-project, community-oriented communities. These are foundations with multiple, loosely coupled projects.

- *The Mozilla Foundation* is a 501(c)(3) charitable organization and manages a number of projects such as Firefox and Rhino. Non-code contributors often identify with geographic or functional groups rather than projects.
- *The Perl Foundation* advances the Perl 5 and Perl 6 programming languages. It coordinates the efforts of numerous grassroots groups such as Perl Mongers.

Quadrant II contains multi-project vendor-oriented communities. These are communities with a commercial focus organized by companies with a wide range of projects.

- *Chef* is a company focused on software relating to configuration and management of servers. Chef has three open source projects, Chef, InSpec, and Habitat. It has approximately 500 employees.
- *Red Hat* is a company with approximately 7,300 employees and multiple FLOSS communities around projects such as Fedora Linux. It has employee and volunteer community managers.

Quadrant III contains vendor-oriented single projects: companies with one major offering.

- *Bolt CMS* is a content management tool. Development is led by Two Kings, which provides commercial support.
- *JSON-RPC Client* is a generic library for the JSON-RPC API. There are multiple implementations. Our interviewee was speaking of one which was developed in-house and then released by the employer as open source.
- *ownCloud* has one major offering, client-server software for creating file hosting services. ownCloud has about 200 employees and about 350 additional contributors. The ownCloud data was collected prior to the Nextcloud fork.
- *Zato* is an enterprise service bus platform designed for building systems in the cloud. Zato's business model is based on providing professional support services.

Quadrant IV consists of community-oriented single project communities. These may be foundations or informal communities with either one or a few tightly coupled projects.

- *The Butterfly Effect* is a game where the player combines mechanical systems and objects to accomplish tasks. It has fewer than ten contributors.
- *Gnash* is a media player for playing Adobe Flash files. It currently has about half a dozen contributors.
- *Django* is a web framework which is maintained by the Django Software Foundation. It has over 1,500 code contributors.
- *KDE* is a foundation with one key project, Plasma, the KDE window manager. It is large and well-known as a strong community project, and over half of the contributors are volunteers [130].
- *Tiny RPC* is a framework for handling remote procedure calls in the Python programming language. It has a handful of contributors.

Community managers were drawn from four communities (Red Hat, Mozilla, ownCloud and KDE), representing the four quadrants created by the two dimensions described above. Community managers were recruited through a combination of personal contacts, recommendations from contacts within the communities, and mailing list advertisement. In communities which have both staff and volunteer community managers, we interviewed at least one of each. Three community managers were employees of their respective foundations or companies (CM_3, CM_5, CM_8), and one was an former employee (CM_9).

Identifying episodic volunteers can be challenging, as community managers can rarely identify them except in retrospect, and our decision to avoid a code-centric approach meant that we could not identify potential candidates from digital records. Additionally, episodic volunteers are often unable to devote time to participate in research [88]. We therefore relied on self-selection of episodic volunteers. In a parallel study about motivations of episodic contributors,

TABLE 3
Interviewed Community Managers (CM) and Episodic Volunteers (EV)

ID	Community	Activity/Area
CM_1	KDE	Governance .
CM_2	KDE	Translation
CM_3	Red Hat	Open standards
CM_4	Red Hat	Technical
CM_5	ownCloud	Overall
CM_6	Mozilla	Administration
CM_7	Mozilla	Technical
CM_8	Mozilla	Education
CM_9	Mozilla	Operations
CM_{10}	Mozilla	Overall
CM_{11}	Mozilla	Governance
EV_1	Mozilla	Events
EV_2	Mozilla	Bug report
EV_2	Gnash	Coding
EV_3	Perl	Coding, evangelism
EV_4	Chef	Coding
EV_5	Perl	Coding, translation, events
EV_6	Butterfly Effect	Translation, testing
EV_7	Bolt CMS	Design
EV_8	Zato	Bug report
EV_8	TinyRPC	Coding
EV_8	JSON–RPC	Coding
EV_9	Django	Events

we conducted a survey where we made an open call for participants on social media, mailing lists, and at a number of conferences, including *Mozfest* and *FOSDEM*. We used survey participants' self-identification as volunteers, episodic participants, and reported hours of participation in order to determine eligibility for the current study. We contacted all participants who both met the criteria and expressed a willingness to participate in further research. Nine people agreed to be interviewed. In the case of code contributors, we compared the number of commits with the self-reported hours and found no incongruity. Consequently, the episodic volunteers represent a number of different FLOSS communities, but our interviews with episodic volunteers represent every quadrant of Fig. 2. Seven of our interviewees were not paid contributors, while two (EV_4, EV_8) contributed both paid and unpaid contributions.

5.2 Data Collection and Analysis

We interviewed people representing 13 different communities and supplemented the interviews with content from community websites and mailing lists.

We first conducted semi-structured interviews with community managers. Interviews were divided into six sections, two of which covered a respondent's position in the community. The remaining four sections contained 24 main questions covering perceptions of volunteering, types of EV, prevalence of EV, and management of EV. Subquestions were asked if a response to an initial question did not cover topics of interest. Appendix A, which can be found on the Computer Society Digital Library at http://doi.ieeecomputersociety.org/10.1109/TSE.2018.2872713, contains an interview guide for these interviews. The interviews were conducted in-person (2), by phone (8), and through email (1).

Following the interviews with community managers, we proceeded with the interviews with episodic volunteers. The interview contained 17 questions in sections about EV behavior, motives and intentions, experiences, practices related to EV, and volunteering identity. Subquestions were used when responses did not address topics of interest. An interview guide for the interview can be found in Appendix B, available in the online supplemental material. The interviews were conducted in-person (1) and by phone (8). We found that on average, the episodic volunteers we interviewed participated in two FLOSS projects episodically, and contributed habitually to another project. This finding is consistent with previous research, which showed that a distinct minority of infrequent contributors participate in only one project [26]. The respondents had contributed as episodic volunteers to their communities anywhere from one to 15 years, with an average of 6.4 years.

Table 3 summarizes the interviewees. We use 'CM' to denote community managers and 'EV' for episodic volunteers. The participants provided sufficiently similar descriptions of their experiences, suggesting data saturation was achieved. Furthermore, our set of participants represented a wide range of communities as well as community managers and volunteers, thus providing different perspective on the subject. All codes were discovered in the first 14 interviews.

In order to triangulate across data sources [131], we also collected supplemental data, consisting of 50 documents in the form of public interviews, web pages, and mailing list threads. Supplemental material was found by a web search for the community name plus one of the following terms: 'casual contributors,' 'drive-by,' 'casual commit,' 'one-time.' In addition we included the code of conduct (where available) and the contributor landing page. These documents were used to look for implicit bias against EV, and to confirm the presence or absence of practices described by community managers. All data was collected between Autumn 2014 and Spring 2017. All but one interview were recorded and transcribed; detailed notes were taken for the interview which was not recorded. All transcriptions were reviewed by the lead author and corrected as required. Transcripts and notes were sent to the participants to allow them to review and modify as they saw fit.

Theoretical thematic analysis was performed on the transcripts, notes, and supplemental material, available online, using computer-assisted qualitative data analysis tools. In theoretical thematic analysis, the research question drives theme selection, and a literature review precedes the analysis [132]. Focusing on the objectives of the study can help make sense of qualitative data by drawing attention to the characteristics relevant to the question [133], which in theoretical thematic analysis are identified in part by the themes present in the literature [132].

A codebook was created iteratively by two authors, using the format described by Guest et al. [125]. Each code consists of a name (top-level group, sub-group, and code), a short definition, a long definition, descriptions of when it should be used, descriptions of when it should not be used, and an example of the application of the code taken from the data.

In our analysis, one author coded eight interviews representing two communities, as well as the associated supplemental material, available online. A second author then coded the same interviews and a selection of the other documents. Coding discrepancies were discussed and the codebook was revised accordingly. The initial coder coded an additional three interviews, then the first 11 interviews were coded by a distributed coding team. The codebook was further refined, after which we coded the remaining interviews.

6 Results

In this section, we present our findings about EV in a FLOSS context using the framework introduced in Section 4.

6.1 Contributor Motivation

We expected to observe FLOSS episodic volunteers with intrinsic motivations and altruistic feelings to have more intention of remaining, and for practices associated with contributor motivation to be aimed at newcomers.

Our findings were consistent with our prediction. The relationship between contributor motives and retention is well grounded. Both community managers and episodic volunteers described people who were participating out of a need to improve the software as having less intention to continue, while enjoyment was given as a reason to continue:

> *If they are very hardcore coders, they'll fix the security bug or patch up some translation and then they leave, because they have their own commitments. —CM_{10}*

A Perl contributor (EV_5) commented that involvement lessened, but that *"the interest moved me to contribute to the language itself."* Another developer described the shift from habitual paid contributions to EV contributions:

> *As paid staff, it was part of my job. I could carve out as much time as I needed. Now, it's all in my personal time. So, there's a conflict between my day job, my family life, and trying to fit in time to volunteer as well. —CM_9*

The episodic volunteers who described their intentions to quit once they no longer had a need for the software also described other projects where they were motivated by having fun, and intended to remain. The motive therefore is an attribute of the person and project relationship, rather than existing entirely within the person in relation to all FLOSS projects. One episodic volunteer explained this distinction:

> *Mostly I'm motivated by work but every once in a while, there have been cases where I was so interested in the project because it was a really nice solution. —EV_4*

Neither community managers nor episodic volunteers were able to think of any current practices being employed specifically for the retention of episodic volunteers. However, they were able to suggest several practices which they believed would be effective at retaining episodic volunteers. One participant explained:

> *Some of the granular tasks within the Mozilla community are really great for episodic volunteers because there are so many of them. So, designing a certain thing, or writing code to patch a certain bug, or any tasks that are broken up and very specific. —CM_8*

An understanding of contributor motivations helps explain why these practices were proposed.

- People with intrinsic social or entertainment motives are more likely to remain in the community, and are discouraged by technical challenges. Making the onboarding process easier facilitates joining. Barriers to entry can be reduced by accepting contributions through a standardized interface (e.g., GitHub), which reduces the need to learn project-specific tools [134]; good documentation; a task-finding dashboard which enables episodic volunteers to identify appropriate tasks; a supportive portal (e.g., FLOSSCoach [135]); and creating an easily instantiated workspace, for instance by creating a Docker container containing all dependencies.
- Events can help newcomers overcome technical challenges, and address the interests of people who are socially motivated. Communities can offer guided introductory experiences such as *Google Summer of Code*.
- Episodic volunteers with social motives can be encouraged by providing opportunities for interaction and developing relationships (e.g., IRC or Slack), and regular, local low-key meetups such as Perl Mongers. In addition to central platforms, communication platforms in different regions allow for greater social interaction in different languages. Such platforms should not only allow newcomers to have their questions answered, but should also provide space for them to discuss their experiences.

6.2 Social Norms

We expected social norms to be important, consistent with EV literature, but to be under-appreciated by FLOSS community managers. Our findings were consistent with expectations, but we also found that episodic volunteers *themselves* may underestimate the effect of social norms. The picture which initially emerged from our intake questionnaire was that episodic volunteers did not see a link between their environment and their participation. Episodic volunteers disagreed that it was important to friends and relatives that they continue volunteering. However, in the interview data we found evidence of the role of social norms. Several episodic volunteers stated that they had initially started volunteering in response to an invitation from someone they knew. Invitation was the most common method of recruitment among (but not exclusive to) non-code contributors. One episodic volunteer described the recruitment experience:

> *It was a personal connection. I have event planning experience and my partner was involved in conference organizing and needed help, so I offered. —EV_9*

Another participant (EV_1) responded that the combination of interest and available time helped to accept the invitation: *"So it was interest, the fact that I had spare time, that I knew the organizer. Also, it was local."*

This finding has two interesting implications. First, it shows that FLOSS episodic volunteers, in common with other episodic volunteers, are influenced by invitation. Second, it suggests two reasons this effect has not been observed

previously: the classic measures for social norms do not reflect how FLOSS participants think about themselves in relation to their communities, and previous research has looked primarily at code contributions. A community manager described the importance of non-code contributions:

> *Everyone's contribution is unique. Somebody can have one patch but 50 events are hosted and two speeches given. Somebody can have one 150 patches submitted, 0 events hosted, maybe 5 speeches given. —CM_7*

None of the FLOSS communities we studied was making deliberate use of social norms to recruit episodic volunteers. Based on the experiences of the episodic volunteers we interviewed, we propose the practice of encouraging existing contributors to talk to family and friends about involvement. If communities can communicate the value of FLOSS more widely, more participants might be encouraged to invite others to join. Communities could make it easier for contributors to talk about their participation by providing simple information for sharing. As one episodic volunteer explained, non-code contributors can be invited to join, given appropriate opportunities:

> *My friend has zero talent as a programmer but is really really good at writing documentation. That's the kind of people who want [non-coding opportunities]...One mistake is that we put everybody on the bucket as software developers but it's greyer than that. —EV_5*

6.3 Psychological Sense of Community

We expected to observe FLOSS episodic volunteers who feel a psychological sense of community to have an intention to remain, and for FLOSS communities to use welcoming practices to appeal to a psychological sense of community.

We found that the only practice being specifically employed for EV was associated with a psychological sense of community. Additionally, this sense of community appeared to be more common among *long-term* episodic volunteers.

We found that some community managers were dubious about the psychological sense of community felt by episodic volunteers because they perceived episodic participation as a sign of lower interest. For example, one community manager (CM_2) commented that *"Episodic volunteers haven't found their spot, and don't know whether that's the pathway they want to continue."* The majority of episodic volunteers, however, did claim an affinity for the communities they participated in, but some also clearly opposed this description of participation, stating that they merely worked toward a common goal:

> *I'm very much code-driven, I'm not looking for acquaintances. But it happens that I have contacts for longer period outside the project I'm working on. —EV_8*

Both attitudes were present among long-term and short-term episodic volunteers, but it was more common for short-term episodic volunteers to reject descriptions involving family, friends, and belonging. Those episodic volunteers who did see themselves as similar to other members of their communities cited this as a reason to continue participating. One community member (CM_6) described this as a *"kind of a community, extended family, it may sound cheesy but it is true."*

In comparing themselves to the community, the value of inclusivity came up multiple times as a reason for feeling affinity. Our interviewees spoke of geographic, gender, sexual orientation, and ability as types of diversity which were welcomed in their communities, engendering feelings of support and similarity. One contrasted it positively to the gruffness historically present in many FLOSS communities:

> *I asked questions that were beginner questions and I received an answer like "Oh. You're [expletive] stupid."... Today, I really can't see the new generation standing for that.... Now it's more like a real community. —EV_5*

The only practice that we observed which focused on episodic volunteering relied on the construct of psychological sense of community. Mozilla has been engaging in episodic collaborations with other non-profit organizations to promote values such as openness and efficacy among people who had not previously seen themselves as similar to FLOSS volunteers. A community manager described it:

> *Hive Learning Network in New York has 40 organizational partners, everyone from the Natural Museum of History to the Brooklyn Public Library to small organizations in the Bronx that teach kids how to make their own radio programs. So it's really all different levels of institutions that participate in that network. —CM_8*

Based on our findings about psychological sense of community and its effect on episodic volunteers, we recommend that FLOSS communities consider these existing practices in light of their potential to enhance episodic participation:

- Episodic volunteers who feel accepted by the community have an intention to remain. Use codes of conduct to detail appropriate communication so that potential volunteers can determine in advance if they will be welcomed by the community.
- Encourage episodic volunteers to feel similar to other members of the community. Highlight the different activities available, not simply the code-based ones, for instance through collaboration with non-FLOSS organizations with similar values. Recognizing all contributors is another way of encouraging episodic volunteers to develop an affinity toward the group.
- When episodic volunteers feel a psychological sense of community, stimulating it by hosting events and issuing a personal invitation can encourage them to return.

6.4 Satisfaction

We anticipated that satisfaction is important for FLOSS episodic volunteers, regardless of how long they have been participating. We expected that community managers would be using practices related to satisfaction to encourage EV.

Our findings matched expectations regarding the relevance of satisfaction to EV in FLOSS, but FLOSS community managers are not deliberately encouraging satisfaction in order to promote EV retention. A satisfying experience was one of the primary reasons given by community managers for long-term episodic contributions. Many episodic volunteers also spoke of satisfaction. Feeling appreciated, enjoying

the work, helping others, and the community were the most common reasons for satisfaction. One participant described it well:

> *The people I interacted with were very supportive, they gave good feedback on patches and the company sent me a card for contributing. So I was very pleased. —EV_4*

This observation was shared by a community manager (CM_5): *"people stay because it is fun, it is interesting and stimulating, and they have good time with other people."*

By adapting a recommendation from the EV literature, we suggest that communities can increase satisfaction among episodic volunteers by making them feel appreciated through thanking all contributors. A common method of thanking contributors is to list names in a 'credits' file, but non-code contributors are commonly overlooked, especially if the process is automated. Thus, FLOSS communities should consider tracking all types of contributions. Mozilla has attempted to do this with Project Baloo and Open Badges. Some of our interviewees were concerned that this would be time-consuming and risk alienating people who were overlooked. Others proposed simply encouraging people to self-publicize their contributions to the community:

> *whether the contribution is small or big so you can [tell us]—for example you can go to our Facebook page or mailing list and someone shares "I did that, I contributed to this," and we encourage them. —CM_{11}*

Another recommendation we adapted from the EV literature is intended to utilize existing satisfaction, and is enabled by the previous practice. Asking previous contributors for help, sparingly, in an individual's area of specialization and in a way which shows respect for that person's time and acknowledgement of their expertise, is a practice to which episodic volunteers said they would largely respond positively:

> *I guess it feels good, that people will notice you and invite you for such an event. I think it's all about how you feel eventually to be appreciated. —EV_7*

Asking for help can also be a way of making a person feel appreciated for their previous efforts, increasing satisfaction. One volunteer (EV_9) commented that being asked implied appreciation, and that *"one of the most important things about volunteering is feeling appreciated."*

6.5 Community Commitment

We expected to find that community commitment is relevant to sustained FLOSS episodic participation, but somewhat less than has been previously observed among FLOSS contributors. We expected to find FLOSS communities using techniques such as predictable cycles to help episodic volunteers return.

Our findings were largely in agreement with expectations. FLOSS episodic volunteers expressed community commitment in two ways: toward their community and its goals, and toward FLOSS as a social movement. Regardless of tenure, episodic volunteers frequently described themselves as sharing values of their communities. One community manager (CM_7) described this attitude *"to make things better"* as Mozilla's mission. Another (EV_4) felt that *"it's good to be able to contribute to those things; they make the world a better place."*

One interesting observation was that people who *talk* about their FLOSS involvement were also strongly inclined to *continue* participating. The importance of talking about the community was recognized by some community managers. One community manager (CM_3) suggested this signaled community membership: *"If you are using the software and you are telling other people about it, that makes you part of that community."* Another community manager (CM_7) suggested an initial 'push' can help to enthuse contributors: *"We just have to push someone to give their first public speech and then they usually don't stop contributing."*

Some community managers believed that episodic volunteers were less committed to the community and impatient for success. While it was true that some episodic volunteers—typically those with personal benefit motives—did not express community commitment, most episodic volunteers considered themselves committed and part of the community, and intended to continue volunteering episodically. Family and work commitments were the primary limitations preventing habitual volunteering.

The connection to the community does not always persist. Over time, interests can shift, leading to less commitment to the community. Outgrowing the community was recognized as a reason for departure by both community managers and episodic volunteers. One community manager commented:

> *Of course I think it's important to keep people around to retain them in the community, but I think of the community as a big learning environment. So people come, grow within the community. They also outgrow the community and move on to other stuff. —CM_2*

When volunteers are committed to the community but lack the time to participate habitually, the community manager should focus on techniques to encourage bounce-back. Two practices that were already in place in a number of communities, but not used in the context of episodic volunteering, were time-based releases and general calls for participation based on need. A community manager described the episodic participation of task-focused contributors:

> *We also have the sort of individual volunteers who pop up only when we have something that needs to be designed. They only care about doing design work.—CM_8*

Community managers described increased participation in the period preceding a release, as well as difficulty in retaining episodic volunteers with an unpredictable schedule. Activities without a schedule can struggle to retain contributors, according to a community manager:

> *I'm absolutely losing volunteers in the community IT side because there's nothing keeping people involved because it's too 'bursty' in nature. —CM_9*

However, episodic volunteers were not universally in favor of regular releases. Some felt that it added obligation and pressure. Time-based releases were more popular with episodic volunteers working on large projects than small ones. This was the only observation where we found a distinct difference between the small and large communities.

Michlmayr et al. [136] provide some additional suggestions for assessing a project's suitability for time-based releases.

Requests for participation at times when extra help was required were effective for many community managers. Episodic volunteers who were open to calls for participation often subscribed to mailing lists, Twitter, or Facebook groups, while those less engaged tended not to subscribe to these channels. To summarize:

- Utilize long-term episodic volunteers with strong community commitment to talk about your community in ways that can encourage others to join. They could be asked to speak with their friends (Section 6.2), to arrange collaborations with other communities they are involved with (Section 6.3), or to speak at other, unrelated events. Communities could support the last activity with outlines for proposed talks.
- Predictability can allow episodic volunteers to align their availability with assignments. If time-based releases and other cyclical processes are appropriate for the community, they can be a tool to encourage episodic volunteers to return.
- Making a public announcement on a dedicated channel when additional volunteers are needed for a specific task can alert committed episodic volunteers.

6.6 Episodic Volunteering in FLOSS

Our study demonstrates that all five concepts related to the retention of episodic volunteers in general volunteering can also be observed in FLOSS. Our research goal was to better understand the EV phenomenon in a FLOSS context. We therefore also offer a general description of the current state of EV in FLOSS.

First, episodic volunteering in FLOSS is widespread, as in other types of volunteer work. EV was observed in every type of FLOSS community work we examined, from evangelism to event organization to documentation to support. Code contributions, for example, were considered especially appropriate for episodic volunteers, contrary to the view that software development has a high barrier to entry [101] and does not lend itself to small contributions. Translation was another type of contribution which was singled out by a number of community managers. However, the responses concerning this activity were mixed. In larger projects, translation requires consistency which in turn requires familiarity with style guides, whereas in small communities it is more ad-hoc and therefore suitable for episodic volunteers.

However, despite the presence of episodic volunteers, FLOSS community managers were often not aware of how prevalent EV is. This is not surprising, since new episodic volunteers are difficult to distinguish from other newcomers, except in retrospect [88]. Furthermore, a community which is not strategically engaging with episodic volunteering reduces its sensitivity to noticing this type of volunteer. Community managers were more likely to notice EV retention when it involved people with specialist skills who returned.

FLOSS community managers would, in general, prefer to have habitual volunteers and some preferred to think of episodic volunteers as future habitual volunteers. However, this is not always a realistic expectation. Neulinger et al. [22] noted, *"Due to their private, preferential or personal issues, people spend different amounts of time and effort for an [FL]OSS project."* One participant described this sentiment as follows:

> *[Involvement] really goes from very low to very high from time to time. So actually, this time I was in a very low mood, like doing it last year because I have personal troubles. Now things are fine, so I participated again. —EV_5*

Many participants simply have no intention to become more deeply involved, and their eventual participation can be predicted from their initial activities [17], [26]. Others are already involved in a number of projects and would prefer to be involved in more [137], which of course limits the amount of time available. The EV literature advises against assuming that episodic volunteers can be transformed into habitual volunteers, noting that volunteers may not be a good fit for the organization, or may feel that they lack the time or ability to honor a regular commitment [29], [47]. The episodic volunteers we spoke to seemed to confirm that they were content as episodic volunteers. Most were already contributing habitually to other projects, and did not see an opportunity to increase their participation in the communities where they contributed episodically. Sometimes, the choice of which project received the most attention was almost arbitrary, but friction—difficulty in contributing or feeling the contribution was not valued—was a factor in reducing participation when personal factors were not involved:

> *There was a bug report that I submitted and for what I assume is the decision of one or two guys, this bug report has not been addressed after years actually. If Mozilla were to be more helpful for users, I think that would encourage people to contribute more. —EV_2*

Perhaps for these two reasons (the preference for habitual volunteers and the invisibility of non-specialist EV), none of the community managers we spoke to were pursuing specific strategies to manage episodic volunteers, although all acknowledged the presence of episodic volunteers in their communities. Likewise, none of the episodic volunteers were aware of any practices in their communities specifically aimed at retaining episodic volunteers. FLOSS communities could thus better manage EV with a dedicated strategy. The practices recommended by our participants are, for the most part, in widespread use, but our interviewees indicated that they would be particularly useful if applied to EV. A community manager summed up the current strategy:

> *We don't have a volunteer recruitment strategy that says this is how you do it. We have more best practices and we have mentorship within the community itself for people who want to do that kind of recruitment. —CM_8*

Table 4 summarizes our findings and includes a set of recommendations derived from considering the relationship between existing FLOSS practices mentioned by our interviewees as affecting episodic participation and what is known of EV.

7 Limitations of the Study

Guba [138] proposed a set of criteria to gauge the limitations of qualitative studies. Four aspects of trustworthiness are credibility, transferability, dependability, and confirmability.

TABLE 4
Summary of Study Findings and Recommendations for Practice

Construct	Findings	Recommendations
Contributor Motivation	Episodic volunteers with intrinsic motives are more likely to intend to remain, compared to episodic volunteers with extrinsic motives	1) Lower barriers to entry through: • Accepting contributions directly through GitHub • Good documentation • Task–finding dashboard • Simple workspace 2) Offer guided introductory events to help newcomers get started and to introduce the social element 3) Provide opportunities for social interactions, such as: • Interactive sites, including localized options • Hosting local meetups
Social Norms	Although FLOSS episodic volunteers were unlikely to see their participation as influenced by social norms, personal invitation was a common form of recruitment, especially among non-code contributors	4) Encourage existing volunteers to talk about their FLOSS involvement by: • Highlighting the benefits of advocating broadly • Providing digestible information for sharing
Psychological Sense of Community	Psychological sense of community is more common among long-termparticipants; A policy of inclusion was a commonly mentioned reason for feeling welcomedin the community.	5) Use a code of conduct to express the community's intentions, allowingpotential episodic volunteers to determine their similarity to thecommunity 6) Give potential episodic volunteers the opportunity to identifyalignment with the community through awareness of non-coding activities: • Collaborate with organizations with a different focus but sharedvalues • Recognize all forms of contribution 7) Re-enforce the psychological sense of community by: • Hosting local events • Issuing personal invitations to episodic volunteers
Satisfaction	Satisfaction was most commonly cited as a reason to remain; Episodic volunteers derive satisfaction from knowing that theirwork is used, enjoying the work itself, and feeling appreciated.	8) Encourage satisfaction by increasing feelings of appreciation, byrecognizing all contributors and their areas of expertise 9) Being aware of episodic volunteers' areas of expertise and requestingtheir assistance, sparingly, can: • Make episodic volunteers feel appreciated • Encourage episodic volunteers to return to the community
Community Commitment	Episodic volunteers who talk about their involvement are more inclined to continue participating; Long-term episodic volunteers often have community commitment; Community commitment is less common among episodic volunteers with extrinsic motives.	10) Encourage long-term episodic volunteers to talk about the community to strengthen their commitment to the community and: • To utilize Social Norms to recruit friends/family • To recruit from similar organizations through Psychological Sense of Community 11) Consider time-based releases for large projects to allow episodicvolunteers to plan their return 12) Use opt-in platforms to broadcast calls for participation forspecific tasks to encourage episodic volunteers to return
Episodic volunteering	EV is widespread in FLOSS, but FLOSS communities are not strategically engaging with episodic volunteers; FLOSS episodic volunteers are often habitual volunteers in other communities.	13) Evaluate volunteer assets, volunteer availability, and potential assignments to find opportunities for EV

Credibility can be assessed through data triangulation, where multiple data sources are used to observe if similar patterns are present [131]. Although our study was an interview study, we examined more than 50 documents from web pages and mailing lists describing practices within FLOSS communities to confirm our participants' understanding of how EV is being managed in FLOSS. Another concern with credibility is misrepresentation by participants. Our study included interviews with episodic volunteers who were identified by their self-reported average hours of contribution per

month over the last year. We were able to confirm the contributions of half of the participants. Furthermore, underreporting is more common when the activity is condemned [139]. Self-reporting is viewed as a reliable indicator for hours worked, especially when a longer period of time is considered [140]. Another way of establishing credibility is through member checks, where members of the group being studied are given an opportunity to review the findings [138]. An early draft of this paper was sent to all participants. We also presented the preliminary findings of this study in talks at three FLOSS conferences, and published a report in a popular practitioner journal. This is a form of 'venting,' whereby a study's results are presented and discussed with professional colleagues [141]. The response to our results was very positive.

Transferability can be established through purposive sampling. If the results demonstrate an essential similarity between two contexts, and the contexts differ along key dimensions, it is expected that the findings will also apply to other, related situations [138]. In Section 5, we described our interview selection. Regardless of whether we spoke to community managers or episodic volunteers in a single community, or to participants in communities which varied by size and governance, our findings were remarkably similar. Therefore we can reasonably expect that our understanding of EV describes the situation in many FLOSS communities.

Dependability can be improved by establishing an audit trail. In addition to retaining all the original data sources, along with a record of how they were collected, we maintained a codebook [125]. Different iterations of the codebook were retained, making it possible to reconstruct the development of a single code through the coding process.

In order to ensure confirmability of our study we employed investigator triangulation, which is a method of ensuring neutrality [131]. Our codebook was developed iteratively through collaboration between two of the authors, reducing the possibility of subjectivity [142]. We also attempted to avoid a common source of bias in FLOSS studies by deliberately seeking out participants who are engaged in non-code activities, in order to present a more balanced picture of FLOSS communities.

The practices we propose follow logically from the EV constructs in a FLOSS context, but unless communities introduce these practices as part of a deliberate strategy of managing EV, it remains difficult to demonstrate their effectiveness with episodic volunteers. In order to fully benefit, communities will need to consider the impact of practices on EV, contemplate a specific EV strategy, and explore the options for utilizing social norms.

Little is known about EV in general volunteering, and in FLOSS there is still much to learn about the periphery and the relevance of the EV model to the FLOSS context. Our research cannot be generalized to all FLOSS communities, although our interviews were selected to examine many different types of FLOSS communities and show the same patterns regardless of project type.

8 Conclusion

Our research goal was to develop a better understanding of the concept of episodic volunteers in a FLOSS context. A summary of our findings appears in Table 4.

Our work demonstrates that the five concepts related to the retention of episodic volunteers in general—contributor motivation, social norms, psychological sense of community, satisfaction and community commitment—are applicable to FLOSS, and EV is widespread in FLOSS. By applying the concept of EV from the general volunteering literature, we identified new facets of peripheral contribution, which were not predicted by the existing FLOSS literature. Future research could extend our exploratory study by confirming a link between the proposed concepts and FLOSS EV retention.

Examining all types of contributions allowed us to see social norms as a potential factor in the decision to participate in FLOSS communities. Future research could explore the effect of invitation on FLOSS participation, to determine to what extent it is a factor in volunteers' decisions.

Looking at EV as a volunteering phenomenon allowed us to see that code contributions are, as recent studies on one-off participation have highlighted, perhaps distinctly suited for episodic volunteering. At the same time, our investigation showed that communities are not really thinking of the constraints of episodic volunteering, and are not addressing EV strategically. Given the observed prevalence of EV, and the limitations to volunteers becoming habitual, the effective incorporation of episodic volunteers may become an important competency in FLOSS project sustainability.

Neither community managers nor episodic volunteers felt that FLOSS communities were utilizing practices specifically for EV. Many practices we recommended—such as time-based releases—are widely used, and are thought to have an effect on episodic participations. These effects are accidental, rather than a result of systematic analysis. Community managers who are interested in adapting to EV can analyze practices in terms of their potential impact on episodic volunteers by using the framework we presented. Future work might explore the strategies FLOSS communities use to improve the retention and utilization of episodic volunteers, metrics for measuring EV engagement, and measuring the effect of practices on EV. The fact that the episodic volunteers we interviewed also contributed to a number of other communities raises the intriguing possibility of studying EV by considering the interrelatedness of an individual's contributions across multiple projects.

Although FLOSS episodic volunteers have significant similarities with FLOSS contributors taken as a group, the EV concept allowed for new insights:

- EV is widespread in FLOSS communities, and episodic volunteers can be found participating in a wide variety of activities.
- There are currently no significant differences in how episodic versus habitual volunteers are managed, across FLOSS communities. Communities are not specifically addressing EV, with the exception of a few initiatives to collaborate with other communities.
- FLOSS episodic volunteers are likely to be recruited by friends, especially if they are non-code contributors.
- FLOSS episodic volunteers who talk about their participation are more likely to intend to remain in the community.

At the same time, our work shows that the general volunteering literature is largely applicable to the FLOSS context,

and that the EV concept can be used to more fully understand some of the observed differences between the FLOSS literature and the general volunteering literature.

Our findings were largely consistent across communities, with the biggest observed difference pertaining to whether or not translations should be done by episodic volunteers. Given the breadth of communities we examined, we believe this represents an accurate snapshot of EV in FLOSS.

A better understanding of the phenomenon of EV in FLOSS communities is important as it recognizes a distinct group of contributors who can help to sustain FLOSS communities. Thus far, the FLOSS literature has not considered this type of contributor, and we believe this study provides a foundation for future studies, and contributes to our understanding of FLOSS communities in general.

Acknowledgments

This work was supported, in part, by Science Foundation Ireland grants 13/RC/2094 and 15/SIRG/3293.

References

[1] B. Lundell, B. Lings, and E. Lindqvist, "Perceptions and uptake of open source in Swedish organisations," *IFIP Int. Conf. Open Source Syst.*, vol. 203, pp. 155–163, 2006.

[2] B. Fitzgerald, "The transformation of open source software," *MIS Quart.*, vol. 30, no. 3, pp. 587–598, 2006.

[3] S. Krishnamurthy, "Cave or community? An empirical examination of 100 mature open source projects," *First Monday*, vol. 7, 2002.

[4] A. Bonaccorsi, D. Lorenzi, M. Merito, and C. Rossi, "Business firms' engagement in community projects. Empirical evidence and further developments of the research," in *Proc. Workshop Emerging Trends FLOSS Res. Develop.*, 2007, pp. 13–17.

[5] J. Gamalielsson and B. Lundell, "Sustainability of open source software communities beyond a fork: How and why has the Libreoffice project evolved?," *J. Syst. Softw.*, vol. 89, pp. 128–145, 2014.

[6] K. Nakakoji, Y. Yamamoto, Y. Nishinaka, K. Kishida, and Y. Ye, "Evolution patterns of open-source software systems and communities," in *Proc. ACM Int. Workshop Principles Softw. Evolution*, 2002, pp. 76–85.

[7] K. Crowston, H. Annabi, J. Howison, and C. Masango, "Effective work practices for software engineering: Free/libre open source software development," in *Proc. ACM Workshop Interdisciplinary Softw. Eng. Res.*, 2004, pp. 18–26.

[8] A. Mockus, R. T. Fielding, and J. D. Herbsleb, "Two case studies of open source software development: Apache and Mozilla," *ACM Trans. Softw. Eng. Methodology*, vol. 11, no. 3, pp. 309–346, 2002.

[9] W. Maass, "Inside an open source software community: Empirical analysis on individual and group level," in *Proc. Workshop Open Source Softw. Eng.*, 2004, pp. 64–70.

[10] L. Yu and S. Ramaswamy, "Mining CVS repositories to understand open-source project developer roles," in *Proc. IEEE Int. Workshop Mining Softw. Repositories*, 2007, pp. 8–12.

[11] K. Crowston and J. Howison, "The social structure of free and open source software development," *First Monday*, vol. 10, no. 2, 2005.

[12] W. Zhang and J. Storck, "Peripheral members in online communities," *Proc. Americas Conf. Inf. Syst.*, 2001, pp. 586–593.

[13] R. A. Ghosh and V. V. Prakash, "The Orbiten free software survey," *First Monday*, vol. 5, no. 7, 2000.

[14] T. T. Dinh-Trong and J. M. Bieman, "The FreeBSD project: A replication case study of open source development," *IEEE Trans. Softw. Eng.*, vol. 31, no. 6, pp. 481–494, Jun. 2005.

[15] M. Goeminne and T. Mens, "A comparison of identity merge algorithms for software repositories," *Sci. Comput. Program.*, vol. 78, no. 8, pp. 971–986, 2013.

[16] J. Geldenhuys, "Finding the core developers.," in *Proc. IEEE EUROMICRO Conf. Softw. Eng. Adv. Appl.*, 2010, pp. 447–450.

[17] M. Zhou and A. Mockus, "Who will stay in the FLOSS community? Modeling participants initial behavior," *IEEE Trans. Softw. Eng.*, vol. 41, no. 1, pp. 82–99, Jan. 2015.

[18] K. R. Lakhani, "The core and the periphery in distributed and self-organizing innovation systems," PhD thesis, Dept. Sloan School Manage., Massachusetts Inst. Technol., Cambridge, MA, USA, 2006.

[19] A. Capiluppi and M. Michlmayr, "From the cathedral to the bazaar: An empirical study of the lifecycle of volunteer community projects," in *Proc. Int. Conf. Open Source Develop. Adoption Innovation*, 2007, pp. 31–44.

[20] H. Masmoudi, M. den Besten, C. De Loupy, and J.-M. Dalle, "Peeling the onion," in *Proc. IFIP Int. Conf. Open Source Syst.*, 2009, pp. 284–297.

[21] F. Rullani and S. Haefliger, "The periphery on stage: The intra-organizational dynamics in online communities of creation," *Res. Policy*, vol. 42, no. 4, pp. 941–953, 2013.

[22] K. Neulinger, A. Hannemann, R. Klamma, and M. Jarke, "A longitudinal study of community-oriented open source software development," in *Proc. Int. Conf. Adv. Inf. Syst. Eng.*, 2016, pp. 509–523.

[23] J. Wang, "Survival factors for free open source software projects: A multi-stage perspective," *Eur. Manage. J.*, vol. 30, no. 4, pp. 352–371, 2012.

[24] G. Pinto, I. Steinmacher, and M. Aurélio Gerosa, "More common than you think: An in-depth study of casual contributors," in *Proc. Int. Conf. Softw. Anal. Evolution Reeng.*, vol. 1, pp. 112–123, 2016.

[25] A. Iriberri and G. Leroy, "A life-cycle perspective on online community success," *ACM Comput. Surveys*, vol. 41, no. 2, 2009, Art. no. 11.

[26] A. Lee, J. C. Carver, and A. Bosu, "Understanding the impressions, motivations, and barriers of one time code contributors to FLOSS projects: A survey," in *Proc. Int. Conf. Softw. Eng.*, 2017, pp. 187–197.

[27] A. Lee and J. C. Carver, "Are one-time contributors different? A comparison to core and periphery developers in FLOSS repositories," in *Proc. ACM/IEEE Int. Symp. Empirical Softw. Eng. Meas.*, 2017, pp. 1–10.

[28] M. Nunn, "Building the bridge from episodic volunteerism to social capital," *Fletcher Forum World Affairs*, vol. 24, pp. 115–127, 2000.

[29] R. D. Safrit and M. V. Merrill, "Management implications of contemporary trends in volunteerism in the United States and Canada," *J. Volunteer Admin.*, vol. 20, no. 2, pp. 12–23, 2002.

[30] L. Hustinx and F. Lammertyn, "Collective and reflexive styles of volunteering: A sociological modernization perspective," *Voluntas: Int. J. Voluntary Nonprofit Organizations*, vol. 14, no. 2, pp. 167–187, 2003.

[31] N. Macduff, "Societal changes and the rise of the episodic volunteer," *Emerging Areas Volunteering*, vol. 1, no. 2, pp. 49–61, 2005.

[32] F. Tang, N. Morrow-Howell, and E. Choi, "Why do older adult volunteers stop volunteering?," *Ageing Soc.*, vol. 30, no. 5, pp. 859–878, 2010.

[33] D. A. Harrison, "Volunteer motivation and attendance decisions: Competitive theory testing in multiple samples from a homeless shelter," *J. Appl. Psychology*, vol. 80, no. 3, pp. 371–385, 1995.

[34] D. H. Smith, R. A. Stebbins, and M. A. Dover, *A Dictionary of Nonprofit Terms and Concepts*. Bloomington, IN, USA: Indiana Univ. Press, 2006.

[35] N. Macduff, F. E. Netting, and M. K. O'Connor, "Multiple ways of coordinating volunteers with differing styles of service," *J. Community Practice*, vol. 17, no. 4, pp. 400–423, 2009.

[36] M. A. Hager, "Toward emergent strategy in volunteer administration," *Int. J. Volunteer Admin.*, vol. 29, no. 3, pp. 13–22, 2013.

[37] R. A. Cnaan and F. Handy, "Towards understanding episodic volunteering," *Vrijwillige Inzet Onderzocht*, vol. 2, no. 1, pp. 29–35, 2005.

[38] D. Riehle, P. Riemer, C. Kolassa, and M. Schmidt, "Paid versus volunteer work in open source," in *Proc. 47th Hawaii Int. Conf. Syst. Sci.*, 2014, pp. 3286–3295.

[39] L. Dahlander and M. G. Magnusson, "Relationships between open source software companies and communities: Observations from Nordic firms," *Res. Policy*, vol. 34, no. 4, pp. 481–493, 2005.

[40] P. J. Ågerfalk and B. Fitzgerald, "Outsourcing to an unknown workforce: Exploring opensourcing as a global sourcing strategy," *MIS Quart.*, vol. 32, pp. 385–409, 2008.

[41] M. A. Hager and J. L. Brudney, *Volunteer Management Capacity in America's Charities and Congregations: A Briefing Report*. Washington, D.C., USA: The Urban Institute, 2004.

[42] S. K. Shah, "Motivation, governance, and the viability of hybrid forms in open source software development," *Manage. Sci.*, vol. 52, no. 7, pp. 1000–1014, 2006.

[43] K. Carillo, S. Huff, and B. Chawner, "What makes a good contributor? Understanding contributor behavior within large free/open source software projects—A socialization perspective," *J. Strategic Inf. Syst.*, vol. 26, pp. 322–359, 2017.

[44] K. Crowston and I. Shamshurin, "Core-periphery communication and the success of free/libre open source software projects," *J. Internet Serv. Appl.*, vol. 8, no. 1, pp. 10–21, 2017.

[45] K. Crowston, K. Wei, J. Howison, and A. Wiggins, "Free/libre open-source software development: What we know and what we do not know," *ACM Comput. Surveys*, vol. 44, no. 2, 2012, Art. no. 7.

[46] J. Cravens, "Involving international online volunteers: Factors for success, organizational benefits, and new views of community," *Int. J. Volunteer Admin.*, vol. 24, no. 1, pp. 15–23, 2006.

[47] M. V. Merrill, "Global trends and the challenges for volunteering," *Int. J. Volunteer Admin.*, vol. 24, no. 1, pp. 9–14, 2006.

[48] F. Handy and J. L. Brudney, "When to use volunteer labor resources? An organizational analysis for nonprofit management," Tech. Rep., University of Pennsylvania School of Social Policy and Practice, 2007.

[49] D. Rozas, "Self-organisation in commons-based peer productiong, Drupal: "The drop is always moving"," PhD thesis, Univ. Surrey, 2017.

[50] K. Crowston, J. Howison, and H. Annabi, "Information systems success in free and open source software development: Theory and measures," *Softw. Process: Improvement Practice*, vol. 11, no. 2, pp. 123–148, 2006.

[51] K. Crowston, J. Howison, C. Masango, and U. Y. Eseryel, "The role of face-to-face meetings in technology-supported self-organizing distributed teams," *IEEE Trans. Prof. Commun.*, vol. 50, no. 3, pp. 185–203, Sep. 2007.

[52] M. Cataldo and J. D. Herbsleb, "Communication networks in geographically distributed software development," in *Proc. ACM Conf. Comput. Supported Cooperative Work*, 2008, pp. 579–588.

[53] J. Xu, Y. Gao, S. Christley, and G. Madey, "A topological analysis of the open souce software development community," in *Proc. 38th Annu. Hawaii Int. Conf. Syst. Sci.*, 2005, pp. 198a–198a.

[54] G. A. Oliva, F. W. Santana, K. C. de Oliveira, C. R. de Souza, and M. A. Gerosa, "Characterizing key developers: A case study with Apache Ant," in *Proc. Int. Conf. Collaboration Technol.*, 2012, pp. 97–112.

[55] R. P. Bagozzi and U. M. Dholakia, "Open source software user communities: A study of participation in Linux user groups," *Manage. Sci.*, vol. 52, no. 7, pp. 1099–1115, 2006.

[56] K. Crowston, K. Wei, Q. Li, and J. Howison, "Core and periphery in free/libre and open source software team communications," in *Proc. Annu. Hawaii Int. Conf. Syst. Sci.*, vol. 6, pp. 118–124, 2006.

[57] Y. Lu, P. V. Singh, and B. Sun, "Is core-periphery network good for knowledge sharing? A structural model of endogenous network formation on a crowdsourced customer support forum," *MIS Quart.*, vol. 41, pp. 607–628, 2016.

[58] P. Hinds and C. McGrath, "Structures that work: Social structure, work structure and coordination ease in geographically distributed teams," in *Proc. ACM Conf. Comput. Supported Cooperative Work*, 2006, pp. 343–352.

[59] C. De Souza, J. Froehlich, and P. Dourish, "Seeking the source: Software source code as a social and technical artifact," in *Proc. ACM SIGGROUP Conf. Supporting Group Work*, 2005, pp. 197–206.

[60] I. Herraiz, G. Robles, J. J. Amor, T. Romera, and J. M. González-Barahona, "The processes of joining in global distributed software projects," in *Proc. Int. Workshop Global Softw. Develop. Practitioner*, 2006, pp. 27–33.

[61] P. van Wesel, B. Lin, G. Robles, and A. Serebrenik, "Reviewing career paths of the OpenStack developers," in *Proc. IEEE Int. Conf. Softw. Maintenance Evolution*, 2017, pp. 544–548.

[62] B. J. Dempsey, D. Weiss, P. Jones, and J. Greenberg, "A quantitative profile of a community of open source Linux developers," Tech. Rep. TR-1999-05, Chapel Hill, School of Information and Library Science, University of North Carolina, 1999.

[63] J. Y. Moon and L. Sproull, "Essence of distributed work: The case of the Linux kernel," *First Monday*, vol. 5, no. 11, 2000.

[64] J. Lerner and J. Tirole, "Some simple economics of open source," *J. Ind. Econ.*, vol. 50, no. 2, pp. 197–234, 2002.

[65] S. Koch and G. Schneider, "Effort, co-operation and co-ordination in an open source software project: GNOME," *Inf. Syst. J.*, vol. 12, no. 1, pp. 27–42, 2002.

[66] K. Crowston and J. Howison, "The social structure of open source software development teams," Tech. Rep., Paper 123, The School of Information Studies Faculty Scholarship, 2003.

[67] G. K. Lee and R. E. Cole, "From a firm-based to a community-based model of knowledge creation: The case of the Linux kernel development," *Org. Sci.*, vol. 14, no. 6, pp. 633–649, 2003.

[68] Y. Ye and K. Kishida, "Toward an understanding of the motivation open source software developers," in *Proc. Int. Conf. Softw. Eng.*, 2003, pp. 419–429.

[69] N. Ducheneaut, "Socialization in an open source software community: A socio-technical analysis," *Comput. Supported Cooperative Work*, vol. 14, no. 4, pp. 323–368, 2005.

[70] S. Christley and G. Madey, "Global and temporal analysis of social positions at sourceforge.net," in *Proc. Int. Conf. Open Source Syst.*, 2007.

[71] H. Kagdi, M. Hammad, and J. I. Maletic, "Who can help me with this source code change?," in *Proc. IEEE Int. Conf. Softw. Maintenance*, 2008, pp. 157–166.

[72] V. Singh and M. B. Twidale, "The confusion of crowds: Non-dyadic help interactions," in *Proc. ACM Conf. Comput. Supported Cooperative Work*, 2008, pp. 699–702.

[73] J. Davies, H. Zhang, L. Nussbaum, and D. M. German, "Perspectives on bugs in the Debian bug tracking system," in *Proc. IEEE Work. Conf. Mining Softw. Repositories*, 2010, pp. 86–89.

[74] M. Zhou and A. Mockus, "What make long term contributors: Willingness and opportunity in OSS community," in *Proc. Int. Conf. Softw. Eng.*, 2012, pp. 518–528.

[75] Y. Ma, Y. Wu, and Y. Xu, "Dynamics of open-source software developer's commit behavior: An empirical investigation of Subversion," in *Proc. 29th Annu. ACM Symp. Appl. Comput.*, 2014, pp. 1171–1173.

[76] M. Palyart, G. C. Murphy, and V. Masrani, "A study of social interactions in open source component use," *IEEE Trans. Softw. Eng.*, 2017.

[77] J. D. O. Silva, I. S. Wiese, D. M. German, I. F. Steinmacher, and M. A. Gerosa, "How long and how much: What to expect from Summer of Code participants?," in *Proc. IEEE Int. Conf. Softw. Maintenance Evolution*, 2017, pp. 69–79.

[78] P. Setia, B. Rajagopalan, V. Sambamurthy, and R. Calantone, "How peripheral developers contribute to open-source software development," *Inf. Syst. Res.*, vol. 23, no. 1, pp. 144–163, 2012.

[79] R. Krishnamurthy, V. Jacob, S. Radhakrishnan, and K. Dogan, "Peripheral developer participation in open source projects: An empirical analysis," *ACM Trans. Manage. Inf. Syst.*, vol. 6, no. 4, pp. 14–45, 2016.

[80] G. Von Krogh, S. Spaeth, and K. R. Lakhani, "Community, joining, and specialization in open source software innovation: A case study," *Res. Policy*, vol. 32, no. 7, pp. 1217–1241, 2003.

[81] C. Amrit and J. Van Hillegersberg, "Exploring the impact of socio-technical core-periphery structures in open source software development," *J. Inf. Technol.*, vol. 25, no. 2, pp. 216–229, 2010.

[82] L. Dahlander and S. O'Mahony, "Progressing to the center: Coordinating project work," *Org. Sci.*, vol. 22, no. 4, pp. 961–979, 2011.

[83] M. Foucault, M. Palyart, X. Blanc, G. C. Murphy, and J.-R. Falleri, "Impact of developer turnover on quality in open-source software," in *Proc. ACM 10th Joint Meet. Found. Softw. Eng.*, 2015, pp. 829–841.

[84] H. Masmoudi, V. Fernandez, and L. Marrauld, "The organization of distributed problem-solving networks: Examining how core and periphery interact together to solve problems in Mozilla's community," in *Proc. Int. Conf. Eng. Technol. Innovation IEEE Int. Technol. Manage. Conf.*, 2013, pp. 1–10.

[85] F. Chacón, M. L. Vecina, and M. C. Dávila, "The three–stage model of volunteers' duration of service," *Social Behavior Personality: Int. J.*, vol. 35, no. 5, pp. 627–642, 2007.

[86] A. M. Omoto and M. Snyder, "Considerations of community: The context and process of volunteerism," *Amer. Behavioral Sci.*, vol. 45, no. 5, pp. 846–867, 2002.

[87] M. K. Hyde, J. Dunn, C. Bax, and S. K. Chambers, "Episodic volunteering and retention an integrated theoretical approach," *Nonprofit Voluntary Sector Quart.*, vol. 45, no. 1, pp. 45–63, 2016.

[88] L. M. Bryen and K. M. Madden, "Bounce-back of episodic volunteers: What makes episodic volunteers return? Working Paper No. CPNS 32," Tech. Rep., Queensland University of Technology, 2006.
[89] L. Hustinx, D. Haski-Leventhal, and F. Handy, "One of a kind? Comparing episodic and regular volunteers at the Philadelphia Ronald McDonald House," *Int. J. Volunteer Admin.*, vol. 25, no. 3, pp. 50–66, 2008.
[90] M. K. Hyde, J. Dunn, P. A. Scuffham, and S. K. Chambers, "A systematic review of episodic volunteering in public health and other contexts," *BMC Public Health*, vol. 14, no. 1, pp. 992–1008, 2014.
[91] J. Dunn, S. K. Chambers, and M. K. Hyde, "Systematic review of motives for episodic volunteering," *Int. J. Voluntary Nonprofit Organizations*, vol. 27, no. 1, pp. 425–464, 2016.
[92] F. Handy, N. Brodeur, and R. A. Cnaan, "Summer on the island: Episodic volunteering," *Voluntary Action*, vol. 7, no. 3, pp. 31–46, 2006.
[93] G. Von Krogh, S. Haefliger, S. Spaeth, and M. W. Wallin, "Carrots and rainbows: Motivation and social practice in open source software development," *MIS Quart.*, vol. 36, no. 2, pp. 649–676, 2012.
[94] K. R. Lakhani and R. G. Wolf, "Why hackers do what they do: Understanding motivation and effort in free/open source software projects," in *Perspectives on Free and Open Source Software*. Cambridge, MA, USA: MIT Press, 2005, pp. 3–22.
[95] J. Feller, B. Fitzgerald, W. Scacchi, and A. Sillitti, *Understanding Open Source Software Development*. London, U.K.: Addison-Wesley, 2002.
[96] A. Hars and S. Ou, "Working for free? Motivations of participating in open source projects," in *Proc. Annu. Hawaii Int. Conf. Syst. Sci.*, 2001, pp. 25–39.
[97] G. Hertel, S. Niedner, and S. Herrmann, "Motivation of software developers in open source projects: An internet-based survey of contributors to the Linux kernel," *Res. Policy*, vol. 32, no. 7, pp. 1159–1177, 2003.
[98] Y. Fang and D. Neufeld, "Understanding sustained participation in open source software projects," *J. Manage. Inf. Syst.*, vol. 25, no. 4, pp. 9–50, 2009.
[99] C. Hannebauer and V. Gruhn, "On the relationship between newcomer motivations and contribution barriers in open source projects," in *Proc. 13th Int. Symp. Open Collaboration*, 2017, Art. no. 2.
[100] R. Pham, L. Singer, and K. Schneider, "Building test suites in social coding sites by leveraging drive-by commits," in *Proc. Int. Conf. Softw. Eng.*, 2013, pp. 1209–1212.
[101] I. Steinmacher, I. S. Wiese, T. Conte, M. A. Gerosa, and D. Redmiles, "The hard life of open source software project newcomers," in *Proc. Int. Workshop Cooperative Human Aspects Softw. Eng.*, 2014, pp. 72–78.
[102] Y. Takhteyev and A. Hilts, "Investigating the geography of open source software through GitHub," U of Toronto, 2010.
[103] A. M. Omoto and A. M. Malsch, *Psychological Sense of Community: Conceptual Issues and Connections to Volunteerism-Related Activism*. Mahwah NJ, USA: Lawrence Erlbaum Associates Publishers, 2005, pp. 83–102.
[104] M. Snyder and A. M. Omoto, "Volunteerism: Social issues perspectives and social policy implications," *Social Issues Policy Rev.*, vol. 2, no. 1, pp. 1–36, 2008.
[105] D. Nafus, "'Patches don't have gender': What is not open in open source software," *New Media Soc.*, vol. 14, no. 4, pp. 669–683, 2012.
[106] B. Xu, Z. Xu, and D. Li, "Internet aggression in online communities: A contemporary deterrence perspective," *Inf. Syst. J.*, vol. 26, no. 6, pp. 641–667, 2016.
[107] E. G. Clary, M. Snyder, R. D. Ridge, J. Copeland, A. A. Stukas, J. Haugen, and P. Miene, "Understanding and assessing the motivations of volunteers: A functional approach.," *J. Personality Social Psychology*, vol. 74, no. 6, pp. 1516–1530, 1998.
[108] C.-G. Wu, J. H. Gerlach, and C. E. Young, "An empirical analysis of open source software developers' motivations and continuance intentions," *Inf. Manage.*, vol. 44, no. 3, pp. 253–262, 2007.
[109] R. T. Mowday, R. M. Steers, and L. W. Porter, "The measurement of organizational commitment," *J. Vocational Behavior*, vol. 14, no. 2, pp. 224–247, 1979.
[110] J. A. Grube and J. A. Piliavin, "Role identity, organizational experiences, and volunteer performance," *Personality Social Psychology Bulletin*, vol. 26, no. 9, pp. 1108–1119, 2000.
[111] K. Filo, D. C. Funk, D. O'Brien, et al., "The meaning behind attachment: Exploring camaraderie, cause, and competency at a charity sport event," *J. Sport Manage.*, vol. 23, no. 3, pp. 361–387, 2009.
[112] K. J. Stewart and S. Gosain, "The impact of ideology on effectiveness in open source software development teams," *MIS Quart.*, vol. 30, pp. 291–314, 2006.
[113] K. Crowston, H. Annabi, and J. Howison, "Defining open source software project success," in *Proc. Int. Conf. Inf. Syst.*, 2003, pp. 1–14.
[114] J. Bacon, *The Art of Community: Building the New Age of Participation*. Sebastopol, CA, USA: O'Reilly Media, 2012.
[115] S. Faraj, S. L. Jarvenpaa, and A. Majchrzak, "Knowledge collaboration in online communities," *Org. Sci.*, vol. 22, no. 5, pp. 1224–1239, 2011.
[116] L. Meijs and J. L. Brudney, "Winning volunteer scenarios," *Int. J. Volunteer Admin.*, vol. 24, no. 6, pp. 68–79, 2007.
[117] N. Macduff, "Episodic volunteers: Reality for the future," *Voluntary Action Leadership*, vol. Spring, pp. 15–17, 1990.
[118] H. Jansen, "The logic of qualitative survey research and its position in the field of social research methods," *Forum Qualitative Sozialforschung/Forum: Qualitative Social Res.*, vol. 11, 2010.
[119] C. Andersson and P. Runeson, "Verification and validation in industry-a qualitative survey on the state of practice," in *Proc. Int. Symp. Empirical Softw. Eng.*, 2002, pp. 37–47.
[120] M. D. Myers, "Qualitative research in information systems," *Manage. Inf. Syst. Quart.*, vol. 21, no. 2, pp. 241–242, 1997.
[121] M. B. Miles and A. M. Huberman, *Qualitative Data Analysis: An Expanded Sourcebook*. Newbury Park, CA, USA: Sage, 1994.
[122] J. Ritchie and J. Lewis, Eds., *Qualitative Research Practice: A Guide for Social Science Students and Researchers*. Newbury Park, CA, USA: Sage, 2013.
[123] N. Mays and C. Pope, "Qualitative research: Rigour and qualitative research," *BMJ*, vol. 311, no. 6997, pp. 109–112, 1995.
[124] J. Seidler, "On using informants: A technique for collecting quantitative data and controlling measurement error in organization analysis," *Amer. Sociol. Rev.*, vol. 39, pp. 816–831, 1974.
[125] G. Guest, A. Bunce, and L. Johnson, "How many interviews are enough? An experiment with data saturation and variability," *Field Methods*, vol. 18, no. 1, pp. 59–82, 2006.
[126] A. Filippova and H. Cho, "Mudslinging and manners: Unpacking conflict in free and open source software," in *Proc. ACM Conf. Comput. Supported Cooperative Work Social Comput.*, 2015, pp. 1393–1403.
[127] I. Steinmacher, M. G. Silva, and M. A. Gerosa, *Barriers Faced by Newcomers to Open Source Projects: A Systematic Review*. Berlin, Germany: Springer, 2014, pp. 153–163.
[128] D. Riehle, "The single-vendor commercial open course business model," *Inf. Syst. e-Bus. Manage.*, vol. 10, no. 1, pp. 5–17, 2012.
[129] J. West and S. Gallagher, "Challenges of open innovation: The paradox of firm investment in open-source software," *R&D Manage.*, vol. 36, no. 3, pp. 319–331, 2006.
[130] E. Berdou, "Managing the Bazaar: Commercialization and peripheral participation in mature, community-led Free/Open source software projects," PhD thesis, LSE, 2007.
[131] L. A. Guion, D. C. Diehl, and D. McDonald, "Triangulation: Establishing the validity of qualitative studies," Family Youth and Community Sciences, 2011.
[132] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Res. Psychology*, vol. 3, no. 2, pp. 77–101, 2006.
[133] C. B. Seaman, "Qualitative methods in empirical studies of software engineering," *IEEE Trans. Softw. Eng.*, vol. 25, no. 4, pp. 557–572, Jul./Aug. 1999.
[134] B. De Alwis and J. Sillito, "Why are software projects moving from centralized to decentralized version control systems?," in *Proc. ICSE Workshop Cooperative Human Aspects Softw. Eng.*, 2009, pp. 36–39.
[135] I. Steinmacher, T. U. Conte, C. Treude, and M. A. Gerosa, "Overcoming open source project entry barriers with a portal for newcomers," in *Proc. Int. Conf. Softw. Eng.*, 2016, pp. 273–284.
[136] M. Michlmayr, B. Fitzgerald, and K.-J. Stol, "Why and how should open source projects adopt time-based releases?," *IEEE Softw.*, vol. 32, no. 2, pp. 55–63, Mar./Apr. 2015.
[137] B. Vasilescu, K. Blincoe, Q. Xuan, C. Casalnuovo, D. Damian, P. Devanbu, and V. Filkov, "The sky is not the limit: Multitasking across GitHub projects," in *Proc. Int. Conf. Softw. Eng.*, 2016, pp. 994–1005.

[138] E. G. Guba, "Criteria for assessing the trustworthiness of naturalistic inquiries," *Educational Tech. Res. Develop.*, vol. 29, no. 2, pp. 75–91, 1981.
[139] P. E. Spector, "Method variance in organizational research: Truth or urban legend?," *Organizational Res. Methods*, vol. 9, no. 2, pp. 221–232, 2006.
[140] J. A. Jacobs, "Measuring time at work: Are self-reports accurate?," *Monthly Labor Rev.*, vol. 121, pp. 42–53, 1998.
[141] J. Goetz and D. LeCompte, *Ethnography and Qualitative Design in Educational Research*. New York, NY, USA: Academic, 1984.
[142] D. J. Hruschka, D. Schwartz, D. C. S. John, E. Picone-Decaro, R. A. Jenkins, and J. W. Carey, "Reliability in coding open-ended data: Lessons learned from HIV behavioral research," *Field Methods*, vol. 16, no. 3, pp. 307–331, 2004.



Ann Barcomb is a member of the Open Source Research Group, Friedrich-Alexander University Erlangen-Nürnberg and Lero–the Irish Software Research Centre. Throughout her career, she has been active in open source, in particular the Perl community.



Andreas Kaufmann is a researcher with the Department of Computer Science, Friedrich-Alexander University Erlangen-Nürnberg. His research interests include requirements engineering, domain modeling, and qualitative research methods using qualitative data analysis.



Dirk Riehle is a Professor of computer science at Friedrich-Alexander University. Riehle once led the Open Source Research Group at SAP Labs, Silicon Valley, and founded the Open Symposium (OpenSym). He was the lead architect of the first UML virtual machine. Prof. Riehle holds a Ph.D. in computer science from ETH Zürich, and blogs at http://dirkriehle.com.



Klaas-Jan Stol is a lecturer with the Department of Computer Science, University College Cork, an SFI principal investigator and a funded investigator with Lero—the Irish Software Research Centre. His research interests include research methodology, and contemporary software development approaches.



Brian Fitzgerald is director of Lero—the Irish Software Research Centre. He holds an endowed chair, the Frederick Krehbiel II chair in innovation in business and technology with the University of Limerick. His research interests include open source software, inner source, crowdsourcing, and agile methods.

▷ **For more information on this or any other computing topic, please visit our Digital Library at** www.computer.org/csdl.