Peer Impressions in Open Source Organizations: A Survey

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Abstract

In virtual organizations, such as Open Source Software (OSS) communities, we expect that the impressions members have about each other play an important role in fostering effective collaboration. However, there is little empirical evidence about how peer impressions form and change in virtual organizations. This paper reports the results from a survey designed to understand the peer impression formation process among OSS participants in terms of perceived expertise, trustworthiness, productivity, experiences collaborating, and other factors that make collaboration easy or difficult. While the majority of survey respondents reported positive experiences, a non-trivial fraction had negative experiences. In particular, volunteer participants were more likely to report negative experiences than participants who were paid. The results showed that factors related to a person’s project contribution (e.g., quality and understandability of committed codes, important design related decisions, and critical fixes made) were more important than factors related to work style or personal traits. Although OSS participants are very task focused, the respondents believed that meeting their peers in person is beneficial for forming peer impressions. Having an appropriate impression of one’s OSS peers is crucial, but the impression formation process is complicated and different from the process in traditional organizations.

Keywords: Open source software, OSS, impression formation, virtual teams

1. Introduction

Many expert developers devote a significant amount of effort to Open Source Software (OSS) projects. Because many of those participants are not directly compensated, their participation must be motivated by other factors. Previous empirical research found that OSS participants are
motivated by the prospects of enhancing their reputation and by being identified with a particular OSS community. According to Raymond (1999): “The ‘utility function’ Linux hackers are maximizing is not classically economic, but is the intangible of their own ego satisfaction and reputation among other hackers.” Reputation among one’s peers is the only available measure of competitive success (Raymond, 1998) and the main source of power (Evans and Wolf, 2005) in OSS communities. Furthermore, the participants’ desire to maintain a good reputation among their peers is a major motivation for voluntarily devoting effort to an OSS project (Gutwin et al., 2004). The level of dedication a participant has for the OSS project is strongly related to peer recognition (Xu and Jones, 2010). Therefore, gaining and maintaining reputation is a key factor in keeping an OSS project on track (Markus et al., 2000). When a participant is well recognized within the OSS community, his or her peers regard the participant’s project related opinions more carefully (Gacek and Arief, 2004).

Because gaining peer recognition is a major motivation for OSS participants and it influences OSS projects greatly, it is important to understand the peer recognition process within OSS communities. We define **peer recognition** as: **the acknowledgement of a person's merits or status by his or her peers.** Before a person can acknowledge the merits or status of a peer s/he must be aware of those merits or status. Therefore, it is important to understand how peers form opinions of each other in OSS communities. There is a large body of research on peer recognition in the Psychology literature, where researchers use the term “impression formation” to describe the same concept. According to Kenny (1994), **peer impression** is “the judgements that a person, called the perceiver, makes about another person, called the target, where the target is a real person”. The formation of interpersonal impression primarily depends upon how well the perceiver is acquainted with the target and upon the personality traits of those two individuals. Similarly, Moore (2007) defined impression formation as: “the process by which individuals perceive, organize, and ultimately integrate information to form unified and coherent situated impressions of others”.

Generally, members of OSS communities are geographically distributed, rarely or never meet face-to-face (FTF), and collaborate using text-based tools over the Internet, i.e. Computer-Mediated-Communication (CMC) (Guadagno and Cialdini, 2005; Jarvenpaa and Leidner, 1998). Research has shown a marked difference between FTF and CMC regardless of the purpose. Specifically, McKenna and Bargh (2000) propose four domains in which social interaction via CMC differs from other more conventional interaction media: relative anonymity, reduced importance of physical appearance, attenuation of physical distance, and greater control over the time and pace of interactions. Due to those differences, the impression formation process between OSS participants is different than the impression formation process between co-located project participants. However, there is a lack of knowledge about the impression formation between the participants of OSS projects (Marlow et al., 2013).

To better understand the formation and evolution of peer impressions in distributed OSS teams, we surveyed a broad spectrum of OSS participants to discover: 1) how different forms of peer impressions develop in OSS communities, 2) the factors that affect the impression formation process, 3) how peer impressions evolve, and 4) the opinions of OSS participants about those peer impressions. In this study, we primarily focused on five dimensions of peer impressions: 1) productivity, 2) competency, 3) easy or difficult to work with, 4) perceived expertise, and 5) trustworthiness.

The remainder of the paper is organized as follows. Section 2 presents the research questions and hypotheses for the survey. Section 3 describes the survey design. Section 4 explains the data analysis process. Section 5 discusses the respondent demographics. Section 6 presents the
results relative to the research questions and hypotheses. Section 7 explains the threats to validity of the survey. Finally, Section 8 concludes the paper.

2. Research Questions and Hypotheses

Our study of the literature on reputation, communication and collaboration in OSS communities, identified eight important topics that can provide insight into the peer impression process in OSS communities. For five of those topics, the literature presented enough evidence to pose definite hypotheses. For the other three topics, we simply pose research questions, which may lead to hypotheses for future study. This section provides a brief discussion of the literature to motivate each of the five hypotheses and three research questions.

2.1. Experiences working with other participants

The ‘craftsmanship model’ states that the pure joy of developing software is a major motivation for OSS participants (Raymond, 1998). Studies have identified the most important reasons why developers contribute to OSS projects to be: enjoyment, learning benefits (Hars and Ou, 2002; Lakhani and Wolf, 2005), and positive experiences from participation (Xu and Jones, 2010). Conversely, if an OSS participant’s experiences are continually negative, he or she will eventually leave the project (Von Krogh et al., 2003). Therefore, we expect that participants in successful OSS projects will have positive experiences. Even so, it is likely that some OSS participants will have negative experiences. To better understand impression formation, it is important to understand the OSS participants’ experiences working with their peers and what factors affect those experiences. Therefore, we pose the following research question:

\[ RQ1: \] What positive and negative experiences do OSS participants have while working with their peers?

2.2. Perceived Expertise

An OSS community member gains reputation primarily based upon his or her consistent high quality contributions (Raymond, 1998). Most OSS activities are highly knowledge-intensive and require a certain level of expertise (Von Krogh et al., 2003). Therefore, an OSS participant displays expertise through his or her contributions to the project. The impression that people have about another person’s expertise affects whether they trust that person’s opinions (Moorman et al., 1993). This finding is true both on and off line (Cialdini, 2009; Guadagno and Cialdini, 2005). The interaction between perceived expertise and interpersonal interaction leads to the following hypothesis:

\[ H1: \] An OSS participant considers his or her impression of a peer’s expertise an important factor affecting their interactions with that peer.

2.3. Trust

Psychological research has demonstrated the importance of trust in establishing online relationships (Green, 2007). Similarly, research on team performance suggests that a virtual team needs a solid foundation of mutual trust to enable effective collaboration (Jarvenpaa and Leidner, 1998; Holton, 2001; Peters and Manz, 2007). Virtual teams cannot be effective without trust, because individual members are not willing to take the risk that a team member will act in his or her own self-interest, rather than the interest of the team (Zand, 1972). Because OSS teams are a prime example of virtual, online communities, we can hypothesize the following:
**H2**: An OSS participant considers his or her level of trust of a peer important when interacting with that peer.

### 2.4. Losing Mutual Trust

OSS participants are quite diverse relative to age, race, nationality, and educational background (Ghosh et al., 2002; Lakhani and Wolf, 2005). The participants also have diverse skills and interests. The diversity often causes conflicts (Jensen and Scacchi, 2005), which may result in lost trust. Again, one participant may be very enthusiastic but not as competent as another participant. Hence, his/her repeated failures may cause the project owners to lose confidence in him/her. There may be other reasons that OSS participants lose mutual trust. Because the literature did not provide enough evidence to hypothesize the most important factors, this research question seeks to identify those factors.

**RQ2**: Which factors influence OSS participants to lose trust in their peers?

### 2.5. Meeting in Person

Most OSS community members are geographically distributed, rarely or never meet in person, and coordinate primarily via text-based communication tools (e.g., mailing list, Internet Relay Chat (IRC), repositories, and wikis). Because those communication tools cannot capture facial expressions and body language, it may be difficult to understand and interpret the tone of the communication (Peters and Manz, 2007). In addition, research has shown that virtual teams who use FTF meetings for team building and solving complex issues were more effective than teams that did not use FTF meetings (Maznevski and Chudoba, 2000).

OSS participants often meet each other at conferences (e.g., ApacheCon, EclipseCon, PyCon, and MySQL AB conference). Crowston et al. (2007) interviewed OSS participants at five OSS conferences to understand the impact of FTF meetings. The results indicated that meeting in person helps build social ties among developers, which in turn facilitates better interactions. More specifically, one interviewee mentioned that s/he felt more connected to other participants after meeting with them the first time. Another interviewee mentioned that s/he was more comfortable sending other participants email after meeting them (Crowston et al., 2007). These results are similar to results reported in the psychology literature that social cues (such as a little biographical information about a virtual colleague) facilitate the formation of positive impressions (Tanis and Postmes, 2003). The apparent difference between people who interact FTF compared with those who do not leads us to pose the following hypothesis:

**H3**: When OSS participants meet in person, their impressions of each other improve.

### 2.6. Belief about Peers’ Impressions

Participation in OSS projects is highly visible because most of the activities occur via the Internet. OSS repositories and mailing list archives are open for public viewing. This visibility allows members of the community to monitor the performance and behavior of each community member. Members are generally aware of which members do good work and which members violate the community norms (Markus et al., 2000). This transparency should allow community members to form an accurate opinion of their peers’ abilities. To maintain awareness between project members, OSS projects use mailing lists, IRC channels, and commit logs (Gutwin et al., 2004). OSS project hosting sites (i.e. GitHub, LaunchPad, and SourceForge) provide participants with dashboards and activity feeds to help them track project plans and other members’ contributions (Treude and Storey, 2010). Thus, we can hypothesize that:
H4: OSS participants believe that their peers have an accurate impression of their abilities.

2.7. Judging Peer Productivity

Raymond (1998) states that OSS communities have a ‘gift culture’ by saying that “… social status is determined not by what you control but by what you give away”. An OSS community member’s contributions determine his or her identification and reputation in the community (Roberts et al., 2006). Moreover, due to the virtual nature of OSS collaboration, the differences in online vs. FTF communication (McKenna and Bargh, 2000), and the ease with which contributions can be monitored, we believe that project contributions are the most reasonable way to judge a peer. To test this belief, we hypothesize:

H5: OSS participants consider contributions of a peer to the project as the most important factor when evaluating the productivity or competency of that peer.

2.8. Judging a Peer as Easy or Difficult to Work With

Multiple factors can affect whether someone believes working with a particular peer is easy or difficult. Factors related to individual characteristics may include: creativity, responsibility, honesty, and use of negative words (e.g., swear words, insults, or racial remarks). Because virtual community members are very task focused (Guadagno and Cialdini, 2002), an OSS participant may also judge a peer based upon the quality of his or her work. For example, in OSS communities, a participant may judge a peer by his or her code. The literature provided no conclusions about which particular factor(s) might be more important for judging whether working with a peer would be easy or difficult. Therefore, to identify these factors, we posed the following question:

RQ3: What factors affect whether working with a peer on an OSS project will be easy or difficult?

3. Survey Design

To investigate the hypotheses and question posed in Section 2, we designed an online survey about communication, collaboration, peer evaluation and conflict resolution between OSS participants. Using our varied expertise (i.e. Software Engineering and Psychology), we worked together to develop a set of 20 questions, of which eight used a 5-point scale, four used multiple-choice answers, and the remaining eight used open-ended answers. For the multiple choice and 5-point scale questions, we drew the answer choices from the OSS literature (Gallivan, 2001; Hertel et al., 2003; Raymond, 1998; Roberts et al., 2006; Stewart and Gosain, 2006; Xu and Jones, 2010), our own experiences, discussions in OSS community forums and examination of OSS mailing lists. This paper describes the results of the 15 questions that most directly relate to our hypotheses and questions. Appendix A provides a copy of the survey.

To distribute the survey, we identified 50 successful OSS communities (i.e. at least 50,000 downloads) that had active development communities and used development mailing lists for collaboration. Mailing lists are a critical communication tool for OSS communities (e.g., python-dev for the Python project). Because each active developer subscribes to the development mailing list, these mailing lists reach the appropriate survey population. To ensure that our survey request email was distributed to the list, we contacted the list administrators to obtain access/instructions
for sending the survey request. In the survey request email, we specified that only recipients who were actively participating in OSS projects should consider responding to the survey. We subscribed to the mailing lists to verify that the survey request was sent out. Our survey request was posted to 48 of the 50 mailing lists during the second week of June 2011. We sent a reminder email to each list one week after the first email. When the rate of responses slowed, approximately two weeks later, we closed the survey. Overall, 115 developers responded.

4. Data Analysis

The survey produced three types of data. For the multiple choice questions (nominal data) and the 5-point scale questions (ordinal data), we used the non-parametric Chi-square and Mann-Whitney U tests, respectively. Both tests are robust and do not require normally-distributed data. We used the standard alpha value of .05 for judging significance. For the open-ended questions, we followed a systematic qualitative data analysis process to generate nominal data that could be analyzed with the Chi-square test. Each author had his/her own role in data analysis. First, Bassett extracted the general theme associated with each response. Next, Carver and Hochstein, with Software Engineering expertise, and Guadagno and McCallum, with Psychology expertise, analyzed these themes to develop an agreed-upon coding scheme for each question.

Using these coding schemes, Bosu and Bassett worked independently to code the responses. After coding, they examined their results to identify any discrepancies. They discussed those discrepancies and were able to resolve most of them. For the small number of discrepancies they could not resolve, Carver provided the tie-breaking vote after listening to the competing rationales.

5. Respondent Demographics

This section characterizes the sample based on responses to five questions to help readers properly interpret the applicability of the results.

5.1. OSS Projects Represented

The respondents indicated their primary OSS project. Although we sent the survey to the mailing lists of 48 OSS projects, the respondents listed 67 unique projects as their primary projects (Table 1). The reason 67 projects were represented in our sample could be because 74% of the respondents indicated that they worked on multiple OSS projects. A participant who is a minor contributor on one of the 48 projects solicited could also be a major contributor to another OSS project. In addition, OSS participants may subscribe to the email lists of other popular OSS projects simply to stay informed about the latest development activities within that community. The survey instructed the respondents to answer the remaining questions based on their experiences on their primary project.

5.2. Project Role(s) of the Respondents

Figure 1 shows the percentage of respondents who perform various roles (note that a respondent can perform multiple roles and in fact 90% of the respondents reported multiple roles). Most respondents (80%) perform some type of maintenance activities (e.g., fixing bugs, maintaining infrastructure, package maintenance, bug triage, or general maintenance). About 75% of the respondents perform development activities (e.g., adding new features, committing codes
Table 1: Respondents’ primary OSS project

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Figure 1: Roles of the respondents

or module integration). About 50% of the respondents performed various other roles (e.g., reporting bugs, participating in discussions, consultancy, system administration, and conducting webcasts).

5.3. Voluntary vs. Paid-Participation

Many popular OSS projects are sponsored by commercial organizations (e.g., Google sponsors Chromium and Android). Some employees of these sponsoring companies contribute to the OSS project as part of their job. We call these participants paid participants. We call the participants who are not paid to contribute volunteer participants. Because paid participants may have different motivating factors than volunteer participants, we expect their behavior may differ. Interestingly, the sample was comprised of approximately the same number of each type of participant (52% volunteer participants and 48% paid). Using this even distribution we analyze any differences in responses between the two participant types in Section 6.

5.4. Distribution of Participants across Organizations

Most respondents (71%) indicated that their projects were highly distributed, i.e. contained contributors from more than five organizations. Conversely, only 13% of the respondents indicated that the projects were co-located, i.e. all participants came from the same organization. The remainder of the respondents (16%) indicated that their projects were distributed across two to five organizations.
6. Results

This section describes the analysis for each of the five hypotheses and three research question described in Section 2. In addition to analyzing each hypothesis or question in isolation, we also analyzed whether being a paid or volunteer participant affected the results. Where the effect was present, we report the results.

6.1. RQ1: Experiences working with other participants

Using the qualitative analysis approach described in Section 4, we split the responses into: Positive Experiences (65 responses, 61%) and Negative Experiences (41 responses, 39%). We then further divided the responses into sub-groups as shown in Figure 2 (note that the total is greater than 100% because each respondent may have provided multiple answers). Overall, the majority of respondents had positive experiences working with their peers, as evidenced by the fact that the two most common codes are positive ones, and all but one of the negative codes appear near the bottom of the distribution. The respondents found their peers to be knowledgeable, respectful, and fun to work with. One respondent commented that:

“There’s folks that are really good at what they do and are a lot of fun to work with.”

Other respondents found collaboration with other participants to be an enjoyable and valuable learning experience. As one respondent put it:

“Most developers have a quite different set of skills and technological background; this also allows me to learn new things as I contribute to the project.”

It is important to examine the negative experiences in more detail to help OSS communities take effective measures to eliminate or reduce the negative experiences. The most common
reason for a negative experience was difficulties in collaboration and poor management, typically manifested as difficulty receiving a timely response (9%). Some respondents were frustrated by the bureaucratic decision-making process that made it difficult to obtain a timely and favorable decision about their proposed development directions. Some respondents (about 8%) had good experiences with the majority of the community but had problems getting along with a few people. For example, one respondent stated:

“Generally, the other developers have been attentive to the many problems that I have brought to their notice though there has been one developer who has been over-sensitive to criticism and at times somewhat non-cooperative and aggressive.”

Some participants may even leave a project due to the bad behavior of a peer. As another respondent noted:

“I was very happy working in the group for many years but decided to leave due to the addition of one new developer who was argumentative, short and generally nasty to users who asked rather basic or dumb questions. I didn't see why I should spend my free time working on a project with such [a rude person].”

Some respondents (about 8%) found it very difficult to get involved with the community due to: lack of mentors, delayed response from project leaders, and a steep learning curve. For example, one respondent said,

“The process of getting involved is a bit tricky - they're very open folks, but getting into somewhere I can assist is difficult because of an incredibly steep learning curve.”

As many OSS projects have participants separated by thousands of miles and multiple time zones, some respondents (about 4%) mentioned that time-zone difference and distance were a hindrance to collaborating. If there is a large difference between two participants’ time-zones, it is difficult to collaborate synchronously, which can lead to slower resolution of problems. Large geographical distances may result in peers never meeting each other FTF to observe physical cues, which can lead to misunderstood emails and other textual communication. A few respondents (about 2%) also observed conflicts between OSS participants resulting from differences in opinions and clashes of personalities. Although the respondents reported some negative experiences, the overall tones of the responses indicated that the respondents found working with peers to be a positive experience. The following response provides a good summary of the overall experiences of the respondents:

“We're from a wide variety of backgrounds and professions, and therefore bring different perspectives to the project's issues. This can be both good and bad, but usually the good outweighs the bad.”

Figure 3 shows that the ratio of positive to negative experiences working with peers was significantly dependent upon whether the respondent was a paid or volunteer participant ($\chi^2_{1,106} = 3.559, p = .05$). In addition, Figure 4 shows that specific types of experiences were reported with different frequencies by the two types of participants. Some experiences were more common among paid participants while others were more common among volunteer participants. Of those experiences, the only one that was significant was the frequency with which participants found their peers to be competent or dedicated ($\chi^2_{1,106} = 4.771, p = .029$).
6.2. H1: Impact of Perceived Expertise on Peer Interactions

Figure 5 shows that 56% of the respondents considered their impression of the level of expertise of a peer as a very important or extremely important factor during interaction with that peer. The median and the mode of the ratings were “4 - Very Important”. This positively skewed distribution is significantly different from uniform ($\chi^2_{112} = 70.468, p < .001$). This result supports Hypothesis 1. This result is also consistent with previous literature on virtual teams. Potter et al. (2000) highlighted the need for expertise as the primary reason that virtual collaborations form. Peters and Manz (2007) and Kayworth and Leidner (2000) indicated that expertise is an important factor for virtual team performance. Because OSS communities are virtual teams (Gallivan, 2001), perception of peer expertise should be an important factor affecting collaborating.

6.3. H2: Impact of Trust on Peer Interaction

Figure 5 shows that 63% of the respondents considered their level of trust in a peer to be either very important or extremely important during interaction with that peer. The mode and median of
The ratings was “4 - Very Important”. This positively skewed distribution is significantly different from uniform ($\chi^2_{4,112} = 54.125, p < .001$). This result supports Hypothesis 2.

This result may be related to the importance of mutual trust in OSS communities found in the literature. Collaborative development efforts, such as those in OSS communities, cannot be effective without mutual trust. Because contributions to the OSS project from different participants have to work together without conflict, value of one participant's contribution depends, in part, upon the efforts and contributions of the others (Stewart and Gosain, 2006). A developer also needs to trust that the project administrators will give appropriate credit for his or her contribution. Low levels of trust can result in higher developer turnover (Von Krogh et al., 2003). Other researchers have found that mutual trust between team members positively affects the productivity of OSS projects (Xu and Jones, 2010; Stewart and Gosain, 2006; Lane et al., 2004). The importance of trust was also validated in a recent study that showed that before accepting a code change, OSS project owners form an opinion about the trustworthiness of a code author based on information in the author’s profile (Marlow et al., 2013).

6.4. RQ2: Losing trust in a peer

We asked the respondents to indicate which of the following 11 factors caused them to lose confidence in a peer (Appendix A-Q14). Post-hoc, during the analysis process, we grouped the 11 factors as follows:

1. **Coding-related factors**: Poor quality code, buggy features, introducing critical bugs, and codes violate design integrity;

2. **Professional factors**: Contributing code not consistent with project goals, trying to sabotage project reputation, contributing to a rival project, and consistently missing deadlines; and

3. **Interpersonal factors**: Telling lies, irresponsible behavior, and using negative words in forums.

As shown in Figure 6, the **Coding-related** factors were the top causes for losing trust in a peer, followed by most of the **Interpersonal** factors.

To further understand trust, we asked whether it was possible for a peer to regain trust once confidence had been lost and why or why not (Appendix A-Q15). Of the 80 respondents who
answered this question, 68 (85%) believed it was possible to regain lost trust, 7 (8%) believed it was not possible to regain lost trust and the remainder had not experienced lost trust.

Of those who said it was possible to regain trust, 77% stated that regaining trust is only possible through work. In addition, 16% stated that effective communication is required to regain trust. A peer who has lost trust has to admit the fault, reverse the action that resulted in lost trust (if possible), demonstrate commitment to the community, and produce quality work. Some respondents said that regaining trust is very difficult and takes a long time.

6.5. H3: Effect of Meeting in Person on Peer Impression

The qualitative analysis of the 87 responses to the question about the effects of meeting a peer in person (Appendix A-Q11) resulted in the four responses shown in Figure 7. The respondents overwhelmingly viewed meeting in person to have a positive impact on peer impression (71% vs. 11%). This result supports Hypothesis 3 and the findings from Crowston et al. (2007). The following quotes help describe some of the reasons for the positive responses. First, many respondents mentioned that meeting in person helps to humanize the peer. For example:

“Meeting a person in real life allows one to identify with them as an individual and develop a rapport (or not!). Until then they are merely a name, and one’s impression of them is solely based upon the words they have written in communications (mail, IRC) and in code (patches, commits). I have found that such meetings are generally beneficial.”

Second, many respondents mentioned that meeting in person improved communication because they could better understand the messages. As one respondent said,

“We have a meeting every year, and it can make a lot of difference to later be able to “hear” what their emails say as if they were speaking. For example, one person 12
turned out to be a very funny person in real life, but did not always understand that their jokes do not go over well in written form. Having met them, it was easier to understand when they’re joking, and so get less upset when they say something supposedly funny.”

Another respondent said,

“It makes further communication and interaction easier. I’ve dealt with more people that I haven’t met and our interactions are perfectly fine, but the ones I’ve met in person are a bit more loose.”

Third, some respondents mentioned that after meeting in person they felt a stronger sense of association and were able to assume a positive intent from email communications. As one respondent said,

“I’ve found that people (including myself) tend to do a better job of assuming positive intent from people that they’ve met in person.”

Figure 8 illustrates that the effects of meeting a teammate in person were significantly different depending on the type of participant ($\chi^2_{3, 87} = 9.18, p = .027$). Two key observations emerge from this data. First, approximately 20% of the volunteer participants answered “Don’t know/Have not met anyone,” compared with only 2% of the paid participants. Second, 80% of the paid participants answered “Yes / Certainly,” compared with only 60% of the volunteer participants.

To better understand this result, we hypothesized that the paid participants would be more likely to work in the same office as other project members (who were likely also paid by the same organization to participate in the project). This co-location should help facilitate in person interactions. However, when we tested this hypothesis, we found no significant relationship between participant type and project distribution (Section 5.4).

Therefore, we hypothesize an alternate explanation for this result. Companies that pay employees to participate in OSS projects also pay for those participants to attend project meetings and conferences, providing more opportunities to meet their peers in person. Conversely, a volunteer participant will typically have to pay his or her own expenses to attend project meetings.
or conferences. Volunteers are likely able to attend fewer conferences and project meetings than paid participants. Moreover, small scale or unsuccessful OSS projects, whose members tend to be volunteers, might not be able to arrange a conference at all. For these reasons, paid participants likely have more opportunities than volunteers to meet their peers. The survey data supports this conclusion as it shows that it is more common for volunteer participants to never meet any peers in person. Approximately 20% of the volunteer participants said that they have never met anyone in person, compared with only 2% of the paid participants. Because the paid participants meet their peers in person more frequently, more of them have a basis upon which to state that meeting in person affected their impression of their peers. We plan to test this hypothesis more specifically in future surveys.

6.6. H4: Accuracy of Peer Impression

The qualitative analysis of the 88 responses to Appendix A-Q10 resulted in four categories of answers. Figure 9 shows that 55% of the respondents believed their peers have an accurate impression of their abilities, 33% were unsure, but leaning positive, and only 13% believed that their peers do not have an accurate impression of their abilities. These results support Hypothesis 4.

Some specific quotes from the responses help to explain this result. Many respondents mentioned that because in OSS communities everything is archived and open, participants who maintain regular collaboration with the community can easily get a sense of a participant’s ability. For example, one respondent said,

“Yes. A lot of the communication happens in the open *and* is archived in public places. The openness of discussions means not only that a lot of people can see what is going on, but also that everyone is on the same boat regarding what happened, what was discussed, what conclusions we reached, and what we are currently doing.”

Some respondents mentioned that the collaborative development process is helpful for building peer impressions. For example, one respondent said,

“Yes. Code reviews are a daily metric.”

Conversely, some of the reasons given for inaccurate impressions include: not being able to spend enough time and not being able to use full capabilities. As one respondent said,

“Probably not. There has never been a need to use my full capability. I just contribute in areas that are productive, and leave areas that I could work in when there are other bodies who can do that work.”
Surprisingly, whether a participant was paid or volunteer did not affect whether he/she thinks his/her peers have an accurate view of his/her abilities. We expected that more paid participants would think their peers (who may be co-located in the same company) have an accurate view of them than the volunteers (who are distributed and may never meet) would. We will investigate this result further in future studies.

6.7. H5: Effect of Project Contributions on Opinions about Productivity and Competency

We asked the respondents to rate the importance, on a 5-point scale, of the following 13 factors for judging whether a peer is productive or competent (Appendix A-Q8)

1. **Work style**: creativity, accuracy, response time and efficiency;

2. **Historical factors**: A peer’s handle (i.e. screen name or loginId), background and online profile; and

3. **Project Contribution factors**: Quality and understandability of committed code, quality and quantity of comments, critical fixes made, important design decisions made, informal written communication and other work produced.

Figure 10 shows the 13 factors sorted in increasing order according to the proportion of the top two ratings (Extremely important and Very important). The median for each factor can be identified by observing which category the 50% line crosses through.

The **Historical** factors appear at the top of the chart, indicating that the respondents found these factors to have relatively low importance for judging a peer to be productive. Next, three of the four **Work style** factors appear, indicating moderate importance of these factors. The fourth **Work Style** factor, *accuracy* is the second most important factor overall. Finally, the **Project Contribution** factors appear at the bottom of the chart, indicating them to be the most important overall. Even though *accuracy* is a **Work Style** factor, it could also have been considered a **Project Contribution** factor because accuracy affects the quality of a participant’s contribution. These results suggest that overall, OSS participants consider **Project Contribution** to be more important than **Work Style** or **Historical** factors for judging the productivity or competency of a peer. These results support Hypothesis 5.

![Figure 10: Importance ratings of the factors to decide a peer as productive or competent](image-url)
This result supports the findings of Marlow et al. (2013) that general coding ability, project relevant skills, and interaction style are the most important factors for forming impressions about the competency of a peer. The participants mentioned the use of various cues to form impressions, such as: amount of activity, frequency of commits, length of contribution, languages used, and discussion threads.

The importance of Project Contribution factors is also not surprising. OSS communities are often described as ‘meritocracies’ (Fielding, 1999; Raymond, 1998; Schmidt and Porter, 2001) (the form of governance where responsibilities are assigned to individuals solely based upon their merits). Because committed code includes the author names, the quality and understandability of each participant’s code can be easily judged by his or her peers. Understandable code also helps to facilitate collaboration. Unsurprisingly, this factor was chosen as the most important factor.

Furthermore, OSS participants typically discuss important design decisions and critical bugs in mailing lists and in IRC. Therefore, all developers who subscribe to the list or participate in the IRC are able to judge the intellect of those developers that provide the solutions. Because the success and reputation of an OSS project are critically dependent upon developers making good design decisions and fixing critical bugs, those factors are very important for judging whether a peer is productive.

Figure 2 shows that approximately 19% of the respondents thought their peers were “competent or dedicated” (RQ1 - Section 6.1). Figure 11 shows that respondents who found their peers “competent or dedicated” gave significantly higher importance to the two most important factors in Figure 10, “Quality and understandability of code” (Mann-Whitney U=617.0, Z=-2.53, p=.011) and “Accuracy” (Mann-Whitney U=612.0, Z=-2.593, p=.01). Relative to the peer impression formation process, this result suggests that when a participant performs a significant task (e.g., developing a critical module) with quality, understandability and accuracy, his/her peers form a better impression.

6.8. RQ3: Factors affecting Ease or Difficulty of Working Together

The responses to Question 12 (Appendix A), shown in Figure 12, illustrate that the respondents viewed five of the six factors as very influential in judging how easy it is to work with a peer. Conversely, the responses to Question 13 (Appendix A), shown in Figure 13, illustrate how the respondents thought 10 of the 11 factors from RQ2 affected their judgement of how difficult
it was to work with a peer. In the same way as for RQ2, post-hoc we grouped these factors into three categories. Not surprisingly, the results are similar to those for RQ2. The Coding-Related factors were the top reasons for deciding it was difficult to work with a peer, followed by most of the Interpersonal Factors. As a group, the Professional Factors were the least influential. The similarity of the results for RQ2 and RQ3 suggests that OSS participants may start to lose confidence in a peer when they find it difficult to work with that peer. This hypothesis will be tested in future studies.

The fact that Coding-Related factors were the most important is not surprising. Because OSS participants generally collaborate at the code level, and often cannot have FTF meetings, understandable code is of utmost importance. Moreover, due to the lack of formal requirements and documentation in most OSS communities, the quality and understandability of source code is very important for effective collaboration and future maintenance. Therefore, OSS participants find it difficult to work with team members who write poor quality code that has bugs or violates design integrity.

One interesting observation from Figure 13 is that most of the respondents (70%) indicated that contributing to a rival project did not have a negative influence. It is possible that OSS participants consider working on a rival project to be advantageous by helping them become aware of the strong and weak features of the project. The experiences from rival projects may also help guide development directions.
7. Threats to Validity

As with any empirical study there are some threats to validity that need to be discussed. This section is organized around three common types of validity threats.

7.1. Internal validity

A threat to internal validity for our study is related to the selection of study participants. We sent the survey requests only to successful OSS project communities. Those communities might not be a good representation of the overall OSS world. Although we requested only active OSS participants to respond, we could not ensure this fact. However, we believe there was no motivation for inactive participants to respond to the survey because we did not offer any financial incentive. While analyzing the qualitative data, we suspected that four respondents may have answered the questions carelessly (i.e. they provided random texts in the open-ended responses). We excluded these responses from the analysis.

7.2. Construct validity

First, we selected the factors to include in various questions based on a reading of the literature and own personal experiences. The lists of factors may not be complete. To combat this threat, we provided respondents with an “Others (Please specify)” option. However, very few respondents selected the “Other” option. For those that did, no particular factor was mentioned frequently. Therefore, we believe this threat is not significant.

Second, we did not perform a formal validity analysis of the survey. Rather, we had the survey questions reviewed by survey and domain experts to ensure their understandability and to remove any potential bias. Because the results of the survey were largely consistent with findings from earlier studies, we do not believe this threat is serious.

7.3. External validity

We are not able to definitively establish that our sample is representative of the entire OSS population. While OSS communities vary a lot based on product, participant type, community structure, and governance, our sample represents a large number of OSS projects. Even though we did not take into account most of those factors, we do have confidence that our sample is representative. Of course, the results may not be applicable to all OSS communities.

8. Conclusion

This paper presents the results of a survey that explored the peer impression formation process in OSS communities. The results showed that the majority of survey respondents had positive experiences when collaborating with their peers. The respondents consider the perceived expertise and trustworthiness of their peers to be very important factors for interaction and impression formation. Although meeting a peer FTF is infrequent, those meetings can positively affect peer impression. Factors related to project contributions are the most important when forming an impression of whether a peer is productive and how easy or difficult it is to work with a peer.

The Psychology literature suggests that impression formation depends on the familiarity with personal qualities. In OSS projects, participants are not aware of most of the personality traits of their peers. Therefore, OSS participants become very task-focused when they form impressions...
about a peer. The survey results indicated that the respondents placed the lowest emphasis on interpersonal factors and the highest emphasis on project contributions when forming impressions of their peers.

The introduction mentioned the four domains of CMC interaction (i.e. relative anonymity, reduced importance of physical appearance, attenuation of physical distance, and greater control over the time and pace of interactions) proposed by McKenna and Bargh (2000). The current survey results address two of those domains. We found that collaboration between OSS participants is relatively anonymous and they give the least importance to the background and profile of a peer. However, the results do not support reduced importance of physical appearance. Although OSS participants rarely meet their peers in person, this does not imply that they do not want to meet in person or that meeting in person does not benefit them. In fact, the results show that meeting in person improves communication by helping participants better understand the tone of a peer’s messages and helps to humanize their peers.

In this paper, we studied components of impression formation between OSS participants and found some evidences regarding how those components form and evolve. The results provide some insight into the impression formation process between OSS peers. Impression formation is different and complicated in virtual organizations like an OSS community compared with traditional organizations. Yet, OSS participants consider those impressions very important for communication and collaboration. Therefore, we believe peer impressions will also affect the outcomes of OSS projects. In the future, we plan to study how project outcomes are affected by peer impressions and how to improve the impression formation process in OSS organizations.

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References

Appendix A. Survey questions

Q1. What open source project are you most actively involved in?

Q2. What other open source project(s) have you actively worked on?
Q3. Please name or describe your roles on the open source project? (e.g., add new code, report bugs, fix bugs, maintain project infrastructure, make strategic decisions about direction of projects, etc...)

Q4. Please briefly provide your thoughts on the quality of the software.

Q5. Please briefly provide your thoughts about working with other developers on the project.

Q6. Do you contribute to the open source project during your regular job, or only in your spare time?
   - I contribute during my regular job (getting paid)
   - I only contribute in my spare time (volunteer)

Q7. How are the project contributors distributed?
   - Contributors are roughly evenly distributed across many (>= 5) different organizations
   - Most contributors come from a small number (< 5) of organizations
   - Most contributors are members of one organization

Q8. When deciding if a teammate is productive or competent, how important are each of the following factors? Please rate each factor on a 1-5 scale. (1= Not at all important, 2=Slightly important, 3=Moderately important, 4=Very important, 5=Extremely important)

   - Creativity
   - Accuracy
   - Response time
   - Efficiency
   - Their handle
   - Their background
   - Their online profile
   - Quality and understandability of the code committed to repository
   - Quality and quantity of comments in their code
   - Other work products produced (i.e. design documents, test cases)
   - Informal written communication (i.e. post to mailing lists, IRC chats)
   - Critical fixes
   - Important design decisions made
   - Others(Please specify) __________

Q9. Thinking about your interactions with your teammates, on a scale of 1-5 how important is each of the following factors? (1= Not at all important, 2=Slightly important, 3=Moderately important, 4=Very important, 5=Extremely important)

   - Your impression of their level of expertise
   - How much you trust them

Q10. Do you think your teammates have an accurate view of your abilities? Why or why not?

Q11. Does meeting a teammate in person affect your impression of them? Explain.
Q12. Think of a time when you found a teammate easy to work with. How important were the following factors in deciding that teammate was easy to work with? (1= Not at all important, 2=Slightly important, 3=Moderately important, 4=Very important, 5=Extremely important)

- Creative
- Responsible
- Good coding style
- Willing to accept challenges
- Developed good quality features
- Others (Please specify) _______

Q13. Think of a time when you found a teammate difficult to work with? Which factors influenced your decision? (1= Not at all influential, 2=Slightly influential, 3=Moderately influential, 4=Very influential, 5=Extremely influential)

- Telling lies
- Trying to avoid responsibilities
- Consistently missing deadlines
- Poor quality code
- Buggy features
- Codes violating design integrity
- Trying to sabotage project reputation
- Contributing to a rival project
- Using negative words in forums (e.g., swear words, insults, racial remarks etc.)
- Contributing code that is not consistent with project goals
- Others (Please specify) _______

Q14. Have you ever lost confidence in a teammate to the point where you would not trust their opinions (e.g., on design decisions), or the quality of their work products (e.g., code produced)? What factors that caused you to lose this confidence? (Please check all applicable)

☐ Telling lies
☐ Consistently missing deadlines
☐ Poor quality code
☐ Introducing critical bug
☐ Buggy features
☐ Code violates design integrity
☐ Trying to sabotage project reputation
☐ Contributing to a rival project
☐ Irresponsible behavior
☐ Using negative words in forums
☐ Contributing code that is not consistent with project goals

Q15. Is it possible for a teammate to regain trust once they have lost your confidence? If so, how?
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