

Journal of the Association for Information Systems

JAIS

Special Issue

The Effects of Extrinsic Motivations and Satisfaction in Open Source Software Development

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Abstract

As a new phenomenon in the software industry, Open Source Software (OSS) development has attracted a high level of research interest. Examining what motivates participants in OSS projects and how to enhance the effects of motivations has received increased attention in recent years. This study is prompted by the significant but detail-lacking examination of differential effects of various types of extrinsic motivations on participants' task effort in OSS projects and their interaction effects with participants' psychological states. Drawing upon self-determination theory, we establish four types of extrinsic motivations in OSS communities (i.e., external, introjected, identified, and integrated motivation) and investigate how these types affect task effort differently. Also, integrating self-determination theory with affective event theory, we study how satisfaction of needs for competence, autonomy, and relatedness moderates the relationships between extrinsic motivations and task effort. The research model is largely supported by data from 250 participants in various OSS projects. Theoretical contribution and practical implications are discussed.

Keywords: open source software development, motivation, task effort, satisfaction of needs

* Michael Wade was the accepting senior editor. This article was submitted on 26th October 2009 and went through two revisions.

Volume 11, Special Issue, pp.784-808, December 2010

The Effects of Extrinsic Motivations and Satisfaction in Open Source Software Development

1. Introduction

Recent decades have witnessed the success of Open Source Software (OSS) development (von Krogh and von Hippel 2006; Fitzgerald 2006). Major companies such as IBM, Oracle, and HP, as well as large venture capitalists, are investing generously in the communities that develop OSS (Gallivan 2001). In the meantime, researchers and practitioners have begun asking questions about how and why this practice can succeed without the same control mechanisms as commercially-produced software (e.g., Crowston and Scozzi 2002; Feller and Fitzgerald 2002; Lee and Cole 2003; Ljungberg 2000; Colazo and Fang 2010). Since the viability and sustainability of OSS communities largely rely on individuals' discretionary contributions, studying the antecedents of participants' effort, and investigating how to enhance the effects of these drives, are of great significance (Franke and von Hippel 2003; Hars and Ou 2002; Hertel et al. 2003; Kuk 2006; Lakhani, et al. 2002; Lerner and Tirole 2002; von Hippel and von Krogh 2003).

Indeed, there is a plethora of studies identifying factors that may lead individuals to participate in OSS projects. Specifically, research has found that reasons to participate include enjoyment in helping others improve software, enjoyment in tackling complex programming problems, improving programming skills, gaining financial benefits, signaling competence to potential employers, improving future job prospects, gaining recognition from peers, enhancing reputation in the field, and identifying with the project teams (Hars and Ou 2002; Lakhani and Wolf 2005; Krishnamurthy 2006; Bagozzi and Dholakia 2006; Bonaccorsi, et al. 2006; Roberts et al. 2006; Shah 2006; Ke and Zhang 2009). Researchers generally categorize different motivations as either intrinsic or extrinsic (Krishnamurth 2006; Ke and Zhang 2009), except the works by Roberts et al. (2006) and Li et al. (2006) who classify motivations into types other than intrinsic and extrinsic. Intrinsic motivation refers to the psychological force arising from the individual's innate needs (Deci 1975), meaning that a person with intrinsic motivation volitionally performs a task or activity for the pleasure, satisfaction, and interest derived from the task itself (Deci and Ryan 1985). In contrast, extrinsic motivation is defined as the motivation that comes from outside the individual (Porter and Lawler 1968), meaning that, typically, an individual with an extrinsic motivation performs a task or activity in order to gain rewards or to avoid punishment.

However, according to self-determination theory (SDT), extrinsic motivations fall along a continuum anchored by controlled and autonomous regulations. Accordingly, extrinsic motivations range from external to integrated motivation, yielding four types: external, introjected, identified, and integrated motivation (Gagne and Deci 2005; Ryan and Deci 2000; Deci and Ryan 2000). Compared with classifying motivation as either intrinsic or extrinsic, the continuum proposed by SDT offers insights into the nuances of extrinsic motivation. In particular, the continuum allows us to better categorize motivating factors identified by the literature and examine how different types of motivations, especially extrinsic motivations, differentially affect OSS participation (Li et al. 2006; Roberts et al. 2006). Such research would provide guidelines for OSS project leaders to retain and energize participants. Some motivations may greatly affect participation behavior, whereas others may not be as salient (Roberts et al. 2006). With an understanding of the effects of different types of motivations, OSS project leaders may be able to design mechanisms focusing on enhancing salient motivating factors to mobilize participants' effort.

In addition, the research findings of prior OSS motivation studies are mixed. For instance, Roberts et al. (2006) found that need for software has negative effects on OSS participation, while Shah (2006) and Hertel et al. (2003) revealed that it drives individuals to participate. Also, Lakhani and Wolf (2005) indicated that reputation seeking has no significant effects, whereas Roberts et al. (2006) suggested that it leads to above-average contribution levels. The inconsistent findings across different studies motivate us to investigate potential moderating effects. Specifically, we propose satisfaction of psychological needs as a moderator for the relationships between motivations and participation.

According to SDT, in the process of person-environment interaction, an individual's satisfaction of psychological needs for competence, autonomy, and relatedness makes the individual experience

positive affect, in addition to feeling a sense of wellness (Deci and Ryan 2000; Ryan and Deci 2000; Gagne and Deci 2005). On the other hand, Affective Emotion Theory (AET) contends that positive affect has an impact on the underlying influencing process of motivations (e.g., Weiss and Cropanzano 1996; Erez and Isen 2002; Isen et al. 1988; George and Brief 1996; Spreitzer 1995). In particular, positive affect may influence the behavioral outcomes of motivations through individuals' expectancy and utility judgments (Forgas 1985; Isen 2000; Kahn and Isen 1993). That is, positive affect may enhance individuals' expectations that their effort will lead to positive outcomes and make individuals more favorably evaluate the outcomes, which, in turn, lead individuals to expend a larger amount of effort (Klein et al. 1999; Locke and Latham 2004). Indeed, a substantial body of social psychological research has shown that positive affect encourages the enactment of discretionary behavior such as contributing to OSS projects (e.g., Isen and Baron 1991; Erez and Isen 2002; Wegge et al. 2006; Brief and Weiss 2002). Therefore, examining the moderating effects of satisfaction of needs would allow a study on motivations in OSS communities to provide more insights.

Integrating SDT and AET, we develop our research model to illustrate the inter-relationships among the four types of extrinsic motivations, satisfaction of psychological needs, and task effort in OSS projects. The reasons for focusing on extrinsic motivations will be provided in detail in the next section. Specifically, we propose that the effects of extrinsic motivations on task effort increase as regulation becomes more autonomous. That is, among the four types of extrinsic motivations, integrated regulation, with the most autonomous regulation, would have the largest effect on task effort; while external motivation, with the most controlled regulation, would have the smallest effect. In addition, we contend that satisfaction of needs for competence, autonomy, and relatedness moderates the relationships between people's extrinsic motivations and task effort. Examining the relative significance of different types of extrinsic motivations and the possible moderating effects of satisfaction of needs makes the current study distinct from the work by Li et al. (2006), which also assesses the effects of a full spectrum of extrinsic motivations. The research model is largely supported by data collected from 250 OSS project participants.

2. Theoretical Background and the Research Model

Motivation theories are widely used to study human behavior and performance (Locke and Latham, 2004). There are many definitions of motivation in the extant literature. For example, Atkinson defined motivation as "the contemporary (immediate) influence on direction, vigor and persistence of action" (Atkinson, 1964, p.2), while Locke and Latham (2004) defined motivation as "internal factors that impel action and the external factors that can act as inducements to action" (Locke and Latham 2004, p. 388). These definitions are principally concerned with factors or events that energize, channel, and sustain human behaviors over time and eventually lead to task performance and psychological well-being (Steers et al. 2004).

In the literature, many theories have been put forth to explain an individual's motivation (Kanfer 1991; Pinder 1998). For example, Vroom (1964) presented the first systematic formulation of expectancy theory, and Locke and Latham (1990) proposed a theory of goal setting that links goal specificity, goal difficulty, and goal commitment to enhanced task performance. Most of the existing motivation theories make meaningful contributions to our understanding of what is obviously a complex process. However, these motivation theories treat motivation as a unitary concept that varies in amount rather than kind (Meyer, et al. 2004). In other words, the total motivation a person has is treated as a single variable that provides the basis for making predictions. As such, these theories focus on the amount of total motivation a person has for a task, as opposed to the types of motivation used in making predictions. Even theories such as Porter and Lawler's (1968) that distinguish intrinsic motivation and extrinsic motivation consider them to be additive, with total motivation being the critical motivational predictor (Meyer, et al. 2004).

In contrast, SDT contends that motivation is not a unitary or bipolar construct (Deci and Ryan 2000; Ryan and Deci 2000). Instead, based on the degree of regulation internalized (i.e., the extent to which the regulation is autonomous), motivation is a spectrum consisting of external, introjected, identified,

integrated, and intrinsic motivation (Deci and Ryan 2000; Gagne and Deci 2005; Ryan and Deci 2000). When an individual acts with external motivation, he or she has the intention of obtaining a desired consequence or avoiding an undesired one. As such, he or she is energized into action only when the action is instrumental to those ends. With an introjected motivation, the regulation has been taken in by an individual but has not been accepted as his or her own. It is a relatively controlled form of regulation in which behaviors are performed to avoid guilt or anxiety, or to attain ego enhancements such as pride (Deci and Ryan 1995). In contrast, with an identified regulation, a person feels greater freedom and volition because the behavior is more congruent with his or her personal goals and identity. Thus, the action is accepted or owned as personally important. Integrated regulation is the most autonomous form of extrinsic motivation. It occurs when regulations are fully assimilated to the self. Intrinsic motivation refers to the motivation to engage in a behavior primarily for its own sake, because the behavior itself is engaging, interesting, or in some way satisfying.

Previous research has found a number of factors motivating individuals to participate in OSS projects (e.g., Franke and von Hippel 2003; Hars and Ou 2002; Hertel et al. 2003; Bagozzi and Dholakia 2006; Bonaccorsi et al. 2006; Roberts et al. 2006; Shah 2006; Stewart and Gosain 2006). For example, Roberts et al. (2006) found that status motivation led to above-average contribution levels, whereas Hars and Ou (2002) found that participants are motivated by possible improvement of job prospect and identification with the project group. These motivating factors were investigated largely in isolation from each other in different studies. To accumulate, evaluate, and refine what we learn, we must consolidate the findings with a theoretical framework. In particular, the underlying influencing mechanisms vary across types of motivation (Deci and Ryan 2000). Investigating the effects of different motivations in a single model would provide new insight into how to increase participation by energizing individuals in the most effective way.

To summarize the many motivating factors identified by previous studies in a unified model, we categorize them into motivation types as shown in Table 1. According to SDT, motivation falls into a spectrum anchored by the locus of regulations. Specifically, motivation can be categorized into external, introjected, identified, integrated, and intrinsic motivation (Gagne and Deci 2005; Ryan and Deci 2000). Accordingly, we identify factors that are related with possible tangible rewards as external motivation due to their external locus of regulation. We classify factors manifesting ego involvement as introjected motivation, as the nature of their regulation is controlled. We regard less controlled regulation factors, those that are of personal importance, as identified motivation. Also, we classify factors pertaining to personal values and beliefs as integrated motivation, as the regulation is autonomous. In contrast, factors reflecting an individual's enjoyment of the task—as they are self-determined—are categorized as intrinsic motivation.

In this study, we choose to focus on extrinsic motivation rather than intrinsic motivation due to two reasons. First, intrinsic motivation has been relatively well-studied in the literature and has been firmly established as a key driver of OSS participation (Shah 2006; Ke and Zhang 2009). In contrast, our understanding of the effects of extrinsic motivations in the OSS context, especially different types of extrinsic motivations, remains rather limited. Second, intrinsically motivated behaviors are based on an individual's self-determination and need to feel competent (Deci 1975; Deci and Ryan 1985), not on reinforcements from the environment, because the activity itself is rewarding (Deci 1975; Deci and Ryan 2000). This implies that there is relatively limited room for OSS project leaders to affect the process of intrinsic motivation. In contrast, extrinsically motivated behaviors focus on rewards outside the individual and, thus, are not self-sustainable. As such, the results of this study may provide OSS project leaders the opportunity to enhance extrinsic motivations and affect their influence (Deci and Ryan 2000). Hence, focusing on extrinsic motivations in OSS communities can extend our current knowledge and provide meaningful guidance for OSS project management.

Table 1. Mapping of Motivation in OSS Communities to SDT Motivation Spectrum

| Motivations in OSS Communities | Motivation Type |
|--|------------------------|
| To make a profit by selling the software one day (Lakhani and Wolf 2005) To gain financial benefits (Hertel et al. 2003) To improve my future job prospects (Bates et al. 2002; Ghosh et al. 2002; Hars and Ou 2001) To signal my capability to potential employers (Lerner and Tirole 2004) | External Motivation |
| To gain recognition from peers (Ghosh et al. 2002; Roberts et al. 2006; Lakhani and Wolf 2005) To show off my great work (Krishnamurthy 2006) To enhance my reputation in the community (Roberts et al. 2006) | Introjected Motivation |
| Identifying with the development team (Hars and Ou 2002; Bagozzi and Dholakia 2006; Ke and Zhang 2009; Qureshi and Fang 2011) To develop code needed for work and/or non-work (Shah 2006; Lakhani and Wolf 2005; Roberts et al. 2006) Identity construction in OSS communities (Fang and Neufeld 2009) | Identified Motivation |
| Believing that source code should be open (Stewart et al. 2006; Bagozzi and Dholakia 2006) Feeling personal obligation to contribute to OSS (Lakahani and Wolf 2005) Disliking proprietary software and desiring a different development model (Lakahani and Wolf 2005) | Integrated Motivation |
| To be intellectually stimulated (Lakhani and Wolf 2005) To enjoy working on a given project (Bates et al. 2002; Shah 2006; Hars and Ou 2001) To help others improve the software (Hars and Ou 2002) | Intrinsic Motivation |

According to SDT, motivation reflects an individual's intention to act, and energizes and sustains individual behavior over time (Deci and Ryan 2000). As such, task effort has been shown to be positively influenced by motivation (Ke and Zhang, 2009; Shah 2006). Task effort (Kanfer 1991; Locke and Latham 1990) has three dimensions: direction, intensity, and persistence (Kanfer 1991). Direction is about an individual's behavioral choices, in other words, what this individual does. Intensity measures how hard an individual works, that is, the amount of effort expended on the task. Persistence refers to an individual's commitment to the task, and is comprised of two components: time commitment and task persistence in face of difficulties. In this study, we focus only on effort intensity and persistence for two reasons. First, individuals may participate in multiple OSS projects,

and we are interested in the projects to which participants dedicate most of their effort. Second, effort intensity and persistence constitute the essence of working hard over time (Brown and Leigh 1996). In contrast, direction is not an indication of hard work over time, and thus, was disregarded in our study.

In OSS contexts, each of the four types of extrinsic motivations should lead to task effort. In particular, external motivation (the type with the least autonomous regulation) drives an individual to work hard so as to get expected rewards such as better career opportunities and potential financial benefits (Roberts et al. 2006; Ke and Zhang 2009). This is especially so when rewards are performance-contingent, which is often the case in OSS projects, since the individual must strive for participation outcomes required by the reward system. As such, the individual would choose to expend effort on the tasks in the project to satisfy the reward contingency (Ryan and Deci 2000). Although Ke and Zhang (2009) found that external motivation has no significant effect on effort intensity, we investigate its effect on task effort, because we conceptualize task effort as a construct of multi-dimensions, i.e., time commitment, task persistence, and effort intensity. Furthermore, the positive relationship between external motivation and task effort in OSS communities is generally supported by other empirical studies (e.g., Franke and von Hippel 2003; Roberts et al. 2006). Hence, we have the following hypothesis:

H1a: *An individual's external motivation positively relates to task effort expended in the OSS project.*

With introjected motivation, an individual is pursuing recognition among peers and is looking for a degree of ego-enhancement from the OSS project. According to Raymond (1999), the sought-after status in OSS communities is determined by the participant's contribution. To showcase his or her ability, and to attain high status in the project, the individual with introjected motivation expends effort on the project. Indeed, the positive relationship between introjected motivation and task effort has gained empirical support from previous studies (e.g., Roberts et al. 2006; Krishnamurthy 2006; Lakhani and Wolf 2005). Thus, we hypothesize the following:

H1b: *An individual's introjected motivation positively relates to task effort expended in the OSS project.*

With an identified motivation, an individual consciously values the collective goal of the OSS project and perceives it as his or her own (Bagozzi and Dholakia 2006; Ryan and Deci 2000). The internalization of regulatory control and identification with the project group's values leads the individual to gain a sense of emotional involvement (Ellemers et al. 1999; Allen and Meyer 1996). In particular, the individual is energized to work hard on solving problems and helping others in the group, which is characterized as an affective commitment to the project (Bergami and Bagozzi 2000; Allen and Meyer 1996). This notion has gained empirical support from prior research conducted in the OSS context (e.g., Bagozzi and Dholakia 2006; Fang and Neufeld 2009; Hars and Ou 2002). As such, we propose the following hypothesis:

H1c: *An individual's identified motivation positively relates to task effort expended in the OSS project.*

Integrated motivation is reflected by an individual's conviction in the ideology of the OSS movement (Stewart and Gosain 2006). With a personal endorsement of the ideology, the individual regards tasks in the OSS project as meaningful and significant. Also, the individual perceives expending effort on the project as rewarding and worthwhile (Ke and Zhang 2009). Therefore, integrated motivation has a positive impact on task effort expended by the individual in the OSS project (Lakahani and Wolf 2005; Bagozzi and Dholakia 2006). Hence, we have the following hypothesis:

H1d: *An individual's integrated motivation positively relates to task effort expended in the OSS project.*

According to SDT, both the amount of motivation and the type of motivation will affect behavioral outcomes such as task effort (Deci and Ryan 2000). The regulatory styles of the four types of extrinsic motivation are ordered along the dimension of self-determination, and the four types of extrinsic motivation form a simplex-like pattern in which the motivation types that are closer on the regulatory style dimension are more strongly correlated (Grolnick et al. 1991). In addition, the extent to which the regulation is self-determined reflects how fully the activity is endorsed by the self and, thus, is in accord with abiding values and interests. Specifically, external motivation is the most heteronomous form of motivation, introjected motivation reflects partial assimilation of external controls, identified motivation reflects a personal valuing of the task or activity, and integrated motivation reflects that the task or activity is both personally valued and well synthesized with the totality of one's values and beliefs (Ryan and Deci 2000).

It is established that the more self-determined the regulatory style and the more closely the extrinsic motivation approximates intrinsic motivation, the more an individual carries out the activity with greater effort and persistence (Deci and Ryan 2000; Green-Demers et al. 1997). Many empirical studies support that motivations of different regulatory styles have differential effects on task effort and performance (e.g., Hayamizu 1997; Yamauchi and Tanaka 1998; Williams and Deci 1996; Sheldon and Kasser 1998). For example, Sheldon and Elliot (1998) found that compared with more controlled motivations, more self-determined motivations for performing an activity are associated with more task effort on the activity and better performance.

We expect that this logic can be extended to the current research context. When an individual is motivated by external motivation, he or she participates in the OSS project depending on the continuous presence of the rewards. The individual may quit working on the project once the tangible benefit is gained (Shah 2006), or may choose not to work on difficult tasks due to unfavorable cost-benefit analysis (Bonaccorsi and Rossi 2006). In contrast, an individual with a more self-determined regulatory motivation, such as integrated motivation, will persistently and consistently work on the OSS project (Stewart and Gosain 2006; Fang and Neufeld 2009). Indeed, Stewart and Gosain (2006) found that adherence to OSS ideology helps project teams to retain participants. Similarly, Bagozzi and Dholakia (2006) found that ideology conviction influenced participants' social identity and motivated them to expend great effort in OSS projects. Based on the theory and existing empirical findings, we expect that a participant's integrated motivation will have the largest effect on task effort in OSS projects, identified motivation will have the second largest effect, introjected will have the third largest, and external motivation will have the least. Thus, we hypothesize the following:

H2: *The effects of various types of extrinsic motivation on task effort increase along the continuum anchored by controlled and autonomous regulation.*

SDT further proposes that individuals have three innate psychological needs: competence, autonomy, and relatedness (Deci and Ryan 2000; Ryan and Deci 2000). The need for competence represents an individual's desire to achieve success through one's own efforts, and to take personal responsibility and credit for outcomes. Need for autonomy refers to the desire to be self-determining or self-initiating. Need for relatedness is the desire for a sense of mutual respect and reliance with others (Gagne and Deci 2005; Ryan and Deci 2000). According to SDT, each of these three needs is necessary for psychological health, whereby none can be neglected without significant negative consequences (Deci and Ryan 2000). Conversely, satisfaction of these needs enhances well-being, allowing people to experience positive affect (Reis et al. 2008; Ryan and Deci 2000). Further, SDT suggests that satisfaction of psychological needs is the antecedent of intrinsic motivation and facilitates the internalization of extrinsic motivation (Deci and Ryan 2000). For instance, when needs are thwarted, individuals tend to develop external or introjected motivation (Deci and Ryan 2000).

Recent theoretical and empirical advances in psychology and neurobiology make it clear that an understanding of the effects of motivation must take an individual's affect into account (Seo et al. 2006). Specifically, AET suggests that the level of pleasant (or unpleasant) emotion, caused by the satisfaction of (or unmet) innate psychological needs afforded by the environment, will have an impact on the influencing process of motivation, especially the motivation for the enactment of

discretionary behavior (Weiss and Cropanzano 1996; Wegge et al. 2006). For instance, Isen and Baron (1991) found that positive affect generally encourages the conduct of helping behavior and cooperation. Similarly, George (1991) found that positive affect leads to altruism on the job and customer service.

Positive affect may influence the behavioral outcome of motivation through both expectancy and utility judgments (Forgas 1985; 2001; Isen 2000; Kahn and Isen 1993). Expectancy judgment refers to evaluating the likelihood of certain actions leading to expected outcomes, while utility judgment is concerned with the attractiveness of the outcomes (Vroom 1964). According to expectancy theory, an individual decides whether to take on a task and how much effort to expend on it based on these two judgments (Vroom 1964). With positive affect, individuals are better able to see the connections between relatable concepts and, thus, see a link between their effort and possible performance (Erez and Isen 2002). Also, positive affect makes individuals evaluate things more favorably and, thus, is a major determinant of the valence of outcomes (Weiss et al. 1999). Therefore, positive affect reinforces the effects of motivation on task effort (Seo et al. 2004; Erez and Isen 2002). Indeed, the interaction effect of positive affect and motivation on performing discretionary behavior (i.e., task effort) has gained consistent empirical support (e.g., Lee and Allen 2002; Erez and Isen 2002; Forgas and George 2001; Loewenstein et al. 2001).

Viewing participation in and contributions to OSS projects as discretionary behavior, the notion of AET can be applied to the current research context. That is, the process in which motivation influences behavioral outcomes (i.e., task effort) in OSS projects is affected by positive affect (Weiss and Cropanzano 1996; Lee and Allen 2002; Deci and Ryan 2000). Integrating AET and SDT, we suggest that whether or not a participant experiences satisfaction of needs for competence, autonomy, and relatedness may influence how extrinsic motivation energizes the individual to expend task effort.

In particular, an OSS project may satisfy individuals' needs for competence, autonomy, and relatedness. The project group may continuously improve the software and constantly share knowledge (Heckman et al. 2006; Fitzgerald 2006). Also, individuals may receive responsive replies from peers on problems encountered or feedback on the quality of finished tasks. Thus, the project could provide a channel to satisfy the need for competence. In addition, the project may give participants the freedom to choose what and how to contribute (Crowston and Scozzi 2002; Kuk 2006; Lee and Cole 2003) and involve them in the decision-making process. Therefore, individuals may experience satisfaction of the need for autonomy (Hars and Ou 2002; von Krough and von Hippel 2006). Furthermore, the project may build strong ties among participants, nurturing affective and cognitive trust, and thus, support the individuals' needs for relatedness (Bagozzi and Dholakia 2006; Stewart and Gosain 2006). Satisfaction of needs would make individuals experience positive affect and, thus, have more favorable expectancy and utility judgments for expending effort on the project. Hence, we expect that, given the same level of extrinsic motivation, the level of satisfaction of needs will have positive effects on task effort.

H3a: *Satisfaction of an individual's needs strengthens the relationship between the individual's external motivation and task effort.*

H3b: *Satisfaction of an individual's needs strengthens the relationship between the individual's introjected motivation and task effort.*

H3c: *Satisfaction of an individual's needs strengthens the relationship between the individual's identified motivation and task effort.*

H3d: *Satisfaction of an individual's needs strengthens the relationship between the individual's integrated motivation and task effort.*

Figure 1 summarizes the Hypotheses 1a-1d, and 3a-3d.

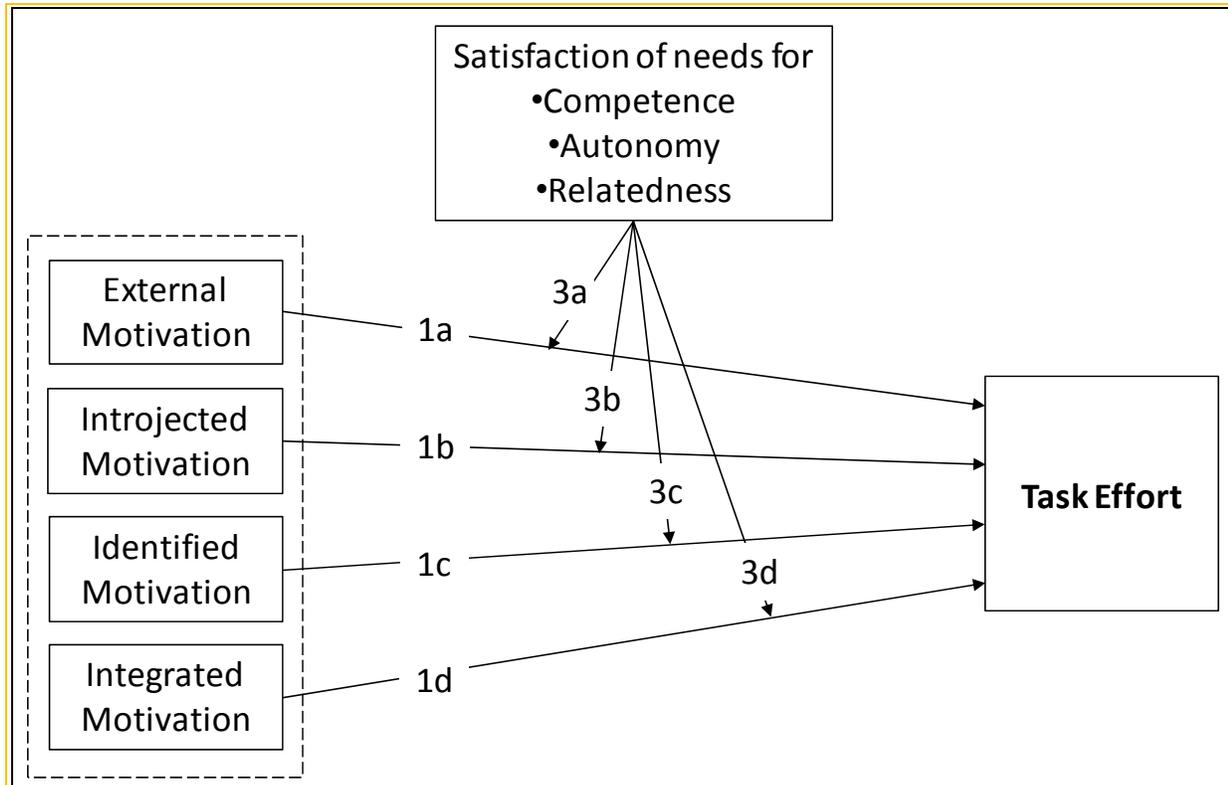


Figure 1. Research Model

3. Research Methodology

3.1 Data Collection

To test our research model, we conducted a survey to collect data from OSS project participants. We randomly selected discussion forums hosted by sourceforge.net (an Open Source applications and software directory) and other forums for OSS projects such as MySQL and OpenOffice. From each discussion forum, we extracted email addresses of its participants and combined these into a list of 10,002 people. From this list, we randomly selected 2,000 respondents to be included in our study, sending out invitations to fill out our questionnaire posted on SurveyMonkey.com (an online survey service provider). With SurveyMonkey's email invitation collectors, we were able to create unique links, with each link tied to a specific email address. Applying this feature allowed us track who had responded to our survey and to ensure that the survey was completed by the target respondents. We sent reminders in each of the following two weeks encouraging respondents to complete our survey. A total of 250 people responded to our invitations, resulting in a response rate of 12.5 percent. Twenty of the 250 were disregarded for analysis due to various data inconsistency and incompleteness problems. The entire survey took about 15 minutes to complete (we should note that elements of it were designed to also capture data regarding a larger project). Participants were asked to first identify and describe a particular OSS project on which they recently expended most effort, and then to answer the questionnaire based on their motivations and feelings toward that specific project. The questionnaire was designed to suit different types of participants, such as developers and users, since the success of an OSS project relies on the contributions made by all types of individuals. For example, users test the software, report bugs, and comment on its features. Such information and ideas are valuable for developers to further improve the software. The demographic data of the respondents are shown in Table 2.

Table 2. Sample Demography and Their Participation in the OSS Projects

| | Category | Frequency | Percent |
|---|---|-----------|---------|
| | | (n=230) | |
| Gender | Female | 8 | 4% |
| | Male | 198 | 96% |
| Age | 18-21 years old | 17 | 8% |
| | 22-25 years old | 34 | 16% |
| | 26-30 years old | 50 | 24% |
| | 31-35 years old | 33 | 16% |
| | 36-40 years old | 25 | 12% |
| | 40-50 years old | 31 | 15% |
| | 51 and above | 20 | 10% |
| Education | High school or below | 15 | 7% |
| | Two years college | 24 | 11% |
| | Bachelor Degree | 86 | 41% |
| | Master Degree and above | 85 | 40% |
| Claimed Role Played in the OSS Project (including multiple roles by a same participant) | User of the product of this project (use the code as it is) | 80 | 34% |
| | Core developer of this project | 112 | 48% |
| | Peripheral developers (bug reporting and fixing) | 82 | 35% |
| | Translator | 31 | 13% |
| | User Experience/User Interface Expert | 35 | 15% |
| | User of application(s) that that are built on the product of this project | 41 | 18% |
| | Other | 31 | 13% |
| Software Product Type (including multiple types) | Operating System (for example, Linux) | 22 | 9% |
| | Database Management System (for example, My SQL) | 15 | 6% |
| | Development Platform (for example, Eclipse) | 32 | 14% |
| | Server-side application (for example, Apache) | 31 | 13% |
| | Office application (for example, OpenOffice) | 18 | 8% |
| | Domain specific application (for example, education, entertainment) | 82 | 35% |
| | Others | 99 | 42% |
| Compensation from OSS projects | Yes as salary | 30 | 13% |
| | Yes as bonus | 3 | 1% |
| | Yes as side income | 11 | 5% |
| | No | 184 | 81% |
| Project Size (#people in the immediate group) | 0-10 people | 176 | 87% |
| | 11-30 people | 20 | 10% |
| | 31-99 people | 5 | 2% |
| | 100 + people | 1 | 0% |

3.2 Measures of the Constructs

We adapted the measurement items in our questionnaire from existing validated and well-tested scales in the extant literature, previously demonstrating good validity and reliability. In the questionnaire, extrinsic motivation, dimensions of satisfaction of needs (i.e., satisfaction of needs for competence, autonomy, and relatedness), and dimensions of task effort (i.e., time commitment, task persistence, and effort intensity) were treated as reflective variables, since all observed indicators were caused by the underlying common dimension or construct of interest (Bagozzi and Fornell, 1982; Fornell and Bookstein, 1982). The higher-order construct, satisfaction of needs, was a formative construct with the three dimensions. All first-order constructs were measured with 5-point Likert scales, ranging from “strongly disagree” to “strongly agree.” We also provided the choice of “not applicable” for these variables.

In particular, we measured external motivation and introjected motivation with items adapted from Amabile et al. (1994). The instrument for identified motivation was adapted from Bergami and Bazoggi (2000) and Allen and Meyer (1996). We measured integrated motivation with items adapted from Becker et al. (1996) and time commitment, task persistence, and effort intensity with items adapted from Yeo and Neal (2004). In addition, we adapted the measurement items for satisfaction of needs for competence, autonomy, and relatedness from Deci et al. (2001) and Spreitzer (1995). All these measurement items are listed in Appendix A. Table 3 shows the descriptive statistics of the variables. For the three control variables, we converted direct answers for project size, role played, and project experience into discrete categorical values.

Table 3. Descriptive Statistics for Variables

| Construct | Mean | Standard Deviation |
|---------------------------------------|------|--------------------|
| External Motivation | 3.12 | 1.43 |
| Introjected Motivation | 3.18 | 1.03 |
| Identified Motivation | 3.90 | 0.96 |
| Integrated motivation | 3.72 | 0.78 |
| Time Commitment | 3.23 | 1.08 |
| Task Persistence | 3.86 | 0.82 |
| Effort Intensity | 3.96 | 0.80 |
| Satisfaction of Needs for Competence | 4.20 | 0.73 |
| Satisfaction of Needs for Autonomy | 4.40 | 0.76 |
| Satisfaction of Needs for Relatedness | 4.13 | 0.80 |

3.3 Common Method Bias

As all data were perceptual and collected from a single source at one point in the time, common method bias was a concern, such as the threat of social desirability (Podsakoff et al. 2003). We examined the possibility of common method bias with the Harman's one-factor test (Podsakoff and Organ, 1986). According to this technique, common method bias may exist when a general construct accounts for the majority of the covariance in the measure scores. We conducted both principal components analysis (Carr et al. 2007) and principal axis factoring analysis (Costello and Osborne 2005). They both showed that there were six constructs with eigenvalues greater than 1.0. Specifically, the results of principal components analysis indicated that the six constructs accounted for 66.47 percent of the variance, while the first construct only accounted for 25.34 percent of the variance.

Similarly, the results of principal axis factoring analysis revealed that the six constructs and the first construct accounted for 57.98 percent and 23.08 percent of the variance, respectively. As such, the results of these two methods were consistent and both demonstrated that common-method bias was unlikely to be an issue for this study. We describe the details of the common method bias test in Appendix B.

4. Data Analyses and Results

There were two stages for data analyses. In the first stage, we assessed the reliability and construct validity of the reflective variables using confirmatory factor analysis. In the second stage, we conducted multi-regression analyses with SPSS to examine the differential effects of various types of extrinsic motivation and the moderating effects of satisfaction of needs for competence, autonomy, and relatedness. In the analysis, we treated both task effort and satisfaction of needs as second-order constructs with three first-order construct components. Specifically, three components for task effort are time commitment, task persistence, and effort intensity, and the three components for satisfaction of needs are satisfaction of needs for competence, for autonomy, and for relatedness.

4.1 Measurement model

We used convergent validity and discriminant validity to examine the measurement scales (Hair et al. 1998). Convergent validity was assessed by (1) reliability of items, (2) composite reliability of constructs, and (3) average variance extracted (AVE) (Fornell et al. 1981). We assessed reliability of items using each item's loading on its corresponding construct and Cronbach's alpha for each construct. Confirmatory factor analysis shows that the loadings of all measurement items of variables (the shaded values in Table 5) were higher than the benchmark of 0.7 (Barclay et al. 1995; Chin 1998). Also, as shown in Table 4, each construct's Cronbach's alpha was greater than the benchmark value of 0.7. In addition, Table 4 shows the composite reliability (CR) of each construct. It is recommended that CR should be .70 or higher, which is satisfied by all constructs. AVE measures the amount of variance that a construct captures from its indicators relative to the amount due to measurement error (Chin 1998). It is recommended that it should exceed .50. Table 4 shows the AVEs of all constructs exceeded .50. Hence, all three conditions for convergent validity are met.

We assessed discriminant validity between constructs using Fornell and Larcker's recommendation that the square root of the AVE for each construct should exceed the correlations between itself and all the other constructs (Chin 1998; Fornell et al. 1981). In Table 4, the shaded numbers on the diagonals are the square root of the AVEs. Off-diagonal elements are the correlations among constructs. All diagonal numbers are greater than the corresponding off-diagonal ones, indicating satisfactory discriminant validity of all the constructs.

Another criterion for discriminant validity is that no measurement item should load more highly on any construct other than the construct it intends to measure (Chin 1998). Based on the guideline from Gefen et al. (2005), the difference between the loading on the supposed construct and the loading on other constructs should be more than .10. An examination of loadings and cross-factor loadings (Table 5) shows that all items satisfied this guideline.

In addition, as shown in Table 4, three inter-construct correlations (the correlation between Identified Motivation and Satisfaction of Need for Relatedness, between Time Commitment and Task Persistence and between Task Persistence and Effort Intensity) are over the value of 0.60. This indicates that multicollinearity might be a potential problem for this research (Grewal et al. 2004). To detect multicollinearity, we assessed the Variance Inflation Factors (VIFs) and Tolerance values of the constructs. Generally, the common rule of thumb for the presence of multicollinearity is that VIFs are higher than 10 or Tolerance values are less than 0.1 (Mason et al. 1991). In this analysis, the results show that the highest VIF was 2.182, and the lowest tolerance value was 0.458. This indicates that multicollinearity is not a serious issue.

Table 4. Internal Consistency and Discriminant Validity of Constructs

| Constructs | Cronbach's alpha | Composite Reliability | AVE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|------------------|-----------------------|------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 1 External Motivation | 0.82 | 0.90 | 0.74 | 0.86 | | | | | | | | | |
| 2 Introjected Motivation | 0.74 | 0.85 | 0.66 | 0.55** | 0.81 | | | | | | | | |
| 3 Identified Motivation | 0.79 | 0.88 | 0.71 | 0.05 | 0.21** | 0.84 | | | | | | | |
| 4 Integrated motivation | 0.66 | 0.82 | 0.60 | -0.07 | -0.07 | 0.18** | 0.77 | | | | | | |
| 5 Time Commitment | 0.81 | 0.89 | 0.73 | 0.17** | 0.29** | 0.42** | -0.05 | 0.86 | | | | | |
| 6 Task Persistence | 0.83 | 0.90 | 0.75 | 0.13* | 0.23** | 0.40** | -0.12 | 0.62** | 0.86 | | | | |
| 7 Effort Intensity | 0.79 | 0.88 | 0.71 | 0.06 | 0.15* | 0.41** | 0.00 | 0.51** | 0.62** | 0.84 | | | |
| 8 Satisfaction of Need for Competence | 0.83 | 0.90 | 0.75 | 0.13* | 0.22** | 0.25** | -0.08 | 0.43** | 0.41** | 0.37** | 0.87 | | |
| 9 Satisfaction of Need for Autonomy | 0.86 | 0.92 | 0.78 | -0.15* | -0.05 | 0.25** | 0.13 | 0.08 | 0.17* | 0.15* | 0.42** | 0.89 | |
| 10 Satisfaction of Need for Relatedness | 0.82 | 0.90 | 0.74 | 0.18** | 0.29** | 0.68** | 0.16* | 0.36** | 0.33** | 0.33** | 0.23** | 0.23** | 0.86 |

Table 5. Cross Loading of Measurement Items to Latent Variables

| | External Motivation | Introjected Motivation | Identified Motivation | Integrated Motivation | Time Commitment | Task Persistence | Effort Intensity | Sat. of Need for Competence | Autonomy | Relatedness |
|-----------|---------------------|------------------------|-----------------------|-----------------------|-----------------|------------------|------------------|-----------------------------|----------|-------------|
| EXT_M_1 | 0.86 | 0.36 | -0.05 | -0.07 | 0.08 | 0.06 | 0.00 | 0.10 | -0.12 | 0.09 |
| EXT_M_2 | 0.90 | 0.52 | 0.09 | -0.02 | 0.21 | 0.15 | 0.07 | 0.12 | -0.17 | 0.21 |
| EXT_M_4 | 0.82 | 0.57 | 0.10 | -0.10 | 0.16 | 0.15 | 0.10 | 0.13 | -0.11 | 0.19 |
| INJ_EM_1 | 0.50 | 0.80 | 0.17 | -0.03 | 0.25 | 0.21 | 0.09 | 0.22 | 0.00 | 0.26 |
| INJ_EM_2 | 0.52 | 0.85 | 0.22 | -0.08 | 0.27 | 0.25 | 0.18 | 0.16 | -0.09 | 0.30 |
| INJ_EM_3 | 0.34 | 0.78 | 0.13 | -0.05 | 0.20 | 0.10 | 0.09 | 0.18 | -0.02 | 0.15 |
| IND_EM_6 | 0.04 | 0.16 | 0.75 | 0.05 | 0.27 | 0.28 | 0.29 | 0.19 | 0.22 | 0.50 |
| IND_EM_7 | 0.06 | 0.21 | 0.89 | 0.21 | 0.39 | 0.38 | 0.37 | 0.25 | 0.23 | 0.58 |
| IND_EM_8 | 0.04 | 0.17 | 0.87 | 0.18 | 0.40 | 0.34 | 0.38 | 0.20 | 0.18 | 0.63 |
| INT_EM_1 | -0.14 | -0.18 | 0.04 | 0.72 | -0.10 | -0.13 | -0.07 | -0.10 | 0.17 | 0.08 |
| INT_EM_2 | -0.01 | 0.00 | 0.17 | 0.79 | -0.09 | -0.15 | -0.08 | -0.12 | 0.07 | 0.14 |
| INT_EM_3 | -0.01 | 0.03 | 0.22 | 0.80 | 0.07 | 0.02 | 0.15 | 0.05 | 0.05 | 0.15 |
| TIME_CM1 | 0.14 | 0.23 | 0.33 | -0.02 | 0.87 | 0.51 | 0.49 | 0.34 | 0.01 | 0.30 |
| TIME_CM2 | 0.09 | 0.22 | 0.35 | -0.03 | 0.90 | 0.54 | 0.44 | 0.37 | 0.09 | 0.34 |
| TIME_CM3 | 0.20 | 0.30 | 0.39 | -0.09 | 0.79 | 0.51 | 0.39 | 0.39 | 0.12 | 0.27 |
| TASK_PST1 | 0.17 | 0.22 | 0.34 | -0.12 | 0.60 | 0.89 | 0.50 | 0.37 | 0.20 | 0.33 |
| TASK_PST2 | 0.13 | 0.22 | 0.37 | -0.07 | 0.51 | 0.90 | 0.51 | 0.36 | 0.10 | 0.28 |
| TASK_PST3 | 0.03 | 0.15 | 0.33 | -0.11 | 0.46 | 0.80 | 0.60 | 0.32 | 0.13 | 0.23 |
| EFF_3 | 0.08 | 0.09 | 0.33 | -0.02 | 0.48 | 0.50 | 0.85 | 0.31 | 0.05 | 0.25 |
| EFF_4 | 0.00 | 0.13 | 0.37 | -0.05 | 0.44 | 0.53 | 0.80 | 0.34 | 0.19 | 0.35 |
| EFF_5 | 0.07 | 0.17 | 0.34 | 0.06 | 0.39 | 0.54 | 0.88 | 0.28 | 0.16 | 0.24 |
| CMP1 | 0.04 | 0.13 | 0.29 | -0.07 | 0.33 | 0.35 | 0.28 | 0.85 | 0.43 | 0.23 |
| CMP2 | 0.09 | 0.17 | 0.23 | -0.09 | 0.36 | 0.34 | 0.35 | 0.88 | 0.37 | 0.18 |
| CMP3 | 0.21 | 0.27 | 0.15 | -0.04 | 0.42 | 0.36 | 0.31 | 0.86 | 0.31 | 0.18 |
| AUTO1 | -0.04 | 0.02 | 0.22 | 0.14 | 0.14 | 0.17 | 0.15 | 0.46 | 0.87 | 0.25 |
| AUTO2 | -0.14 | -0.02 | 0.21 | 0.11 | 0.10 | 0.15 | 0.13 | 0.42 | 0.92 | 0.18 |
| AUTO3 | -0.22 | -0.12 | 0.22 | 0.09 | -0.02 | 0.12 | 0.13 | 0.24 | 0.86 | 0.18 |
| REL1 | 0.16 | 0.27 | 0.64 | 0.13 | 0.40 | 0.37 | 0.35 | 0.28 | 0.23 | 0.86 |
| REL3 | 0.12 | 0.21 | 0.56 | 0.23 | 0.24 | 0.26 | 0.25 | 0.14 | 0.21 | 0.88 |
| REL4 | 0.19 | 0.26 | 0.56 | 0.06 | 0.28 | 0.22 | 0.25 | 0.17 | 0.16 | 0.84 |

4.2 Hypotheses Testing

We conducted a series of three multi-regressions. Model 1 has only control variables as the antecedents of task effort. Model 2 has the control variables and all the extrinsic motivations as the antecedents. Model 3 incorporates all the above variables and the moderator (satisfaction of needs for competence, autonomy, and relatedness). As Table 6 shows, Model 2 provides significantly higher variances explained (R square = 0.339) than Model 1, with an F-value of 16.29 ($p < 0.01$); while Model

3 provides significantly higher variances explained (R square = 0.406) than the other two models. The F-value for the comparison between Model 2 and Model 3 is 12.38 (p<0.01). Collectively, these models provide evidence on testing the various hypotheses.

Table 6. Multi-Regression Analyses Results

| | Model 1 | | | Model 2 | | | Model 3 | | |
|-------------------------------|-------------|---------|-------|---------------|---------------|--------------|---------------|---------------|--------------|
| | Coefficient | t-value | Sig. | Coefficient | t-value | Sig. | Coefficient | t-value | Sig. |
| Project Size | 0.025 | 1.642 | 0.102 | 0.025 | 1.902 | 0.058 | 0.013 | 0.985 | 0.326 |
| Role in Project | 0.041 | 1.149 | 0.252 | 0.010 | 0.324 | 0.746 | 0.015 | 0.503 | 0.615 |
| Experience with Project | 0.017 | 1.781 | 0.076 | 0.023 | 2.856 | 0.005 | 0.022 | 2.917 | 0.004 |
| External Motivation (EXT) | | | | 0.013 | 0.365 | 0.716 | 0.028 | 0.833 | 0.406 |
| Introjected Motivation (INJ) | | | | 0.106 | 2.103 | 0.037 | 0.062 | 1.240 | 0.216 |
| Identified Motivation (IND) | | | | 0.376 | 8.201 | 0.000 | 0.286 | 5.530 | 0.000 |
| Integrated Motivation (INT) | | | | -0.141 | -2.568 | 0.011 | -0.158 | -2.984 | 0.003 |
| Satisfaction of Need (SANEED) | | | | | | | 0.310 | 3.422 | 0.001 |
| EXT*SANEED | | | | | | | -0.172 | -2.623 | 0.009 |
| INJ*SANEED | | | | | | | 0.224 | 2.678 | 0.008 |
| IND*SANEED | | | | | | | 0.009 | 0.117 | 0.907 |
| INT*SANEED | | | | | | | 0.203 | 2.170 | 0.031 |
| R Square | 0.069 | | | 0.339 | | | 0.406 | | |
| Adjusted R2 | 0.057 | | | 0.318 | | | 0.374 | | |
| F | 5.59** | | | 16.29** | | | 12.38** | | |

Note: * p < 0.05; ** p < 0.01; SANEED means Satisfaction of Needs

Model 2's results indicate that two control variables, project size and experience with the project, have positive effects on task effort. Also, the results of Model 2 show that the link between external motivation and task effort is not significant (b = 0.013, p>0.70). As such, Hypothesis 1a on the positive effect of external motivation on task effort is not supported. In addition, Model 2's results indicate that the path coefficients for the links between introjected and task effort (b = 0.106, p<0.05) and between identified motivation and task effort (b = 0.376, p<0.001) are positive and significant. Thus, Hypothesis 1b and 1c, on the positive effects of introjected and identified motivation, respectively, are supported. Furthermore, the results show that the path coefficient of the link between integrated motivation and task effort is significant (b = -0.141, p<0.05) but negative.

To test Hypothesis 2, we compared the path coefficients for the links between extrinsic motivation and task effort. Given that integrated motivation had negative effects on task effort, we left it out of the path comparison test. For the comparison between the links of external motivation – task effort and introjected motivation – task effort, the t-value is 22.94. The t-value for the comparison between the links of external motivation – task effort and identified motivation –task effort is 95.28. The t-value for the comparison between the links of introjected motivation – task effort and identified motivation – task effort is 60.25. All these t-values are significant at a 0.01 level and indicate that the differences in the effects of external, introjected, and identified motivation on task effort are significant. Thus, Hypothesis 2 on the increasingly larger effects of extrinsic motivation along the continuum of controlled and self-determined regulation is partially supported.

The results of Model 3 show that, when satisfaction of needs is incorporated in the model, the link between introjected motivation and task effort becomes insignificant (b = 0.062, p>0.20). Thus, the effects of introject motivation on task effort is insignificant. Also, the results of Model 3 indicate that the multiplication term of external motivation and satisfaction of needs (b = -0.172, p<0.01) is significant, but in the opposite direction than what was hypothesized. The multiplication term of

introjected motivation and satisfaction of needs ($b = 0.224, p < 0.01$) is significant and, thus, lends support to Hypothesis 3b on the positive moderating effect of satisfaction of needs on the link between introjected motivation and task effort. Also, the multiplication term of integrated motivation and satisfaction of needs ($b = 0.203, p < 0.05$) is significant. Thus, Hypothesis 3d on the positive moderating effect of satisfaction of needs on the association of integrated motivation and task effort is supported. In contrast, the results indicate that the interaction term of identified motivation and satisfaction of needs is not significant ($b = 0.009, p > 0.90$). Consequently, Hypothesis 3c on the moderating effect of satisfaction of needs on the association of identified motivation and task effort is not supported.

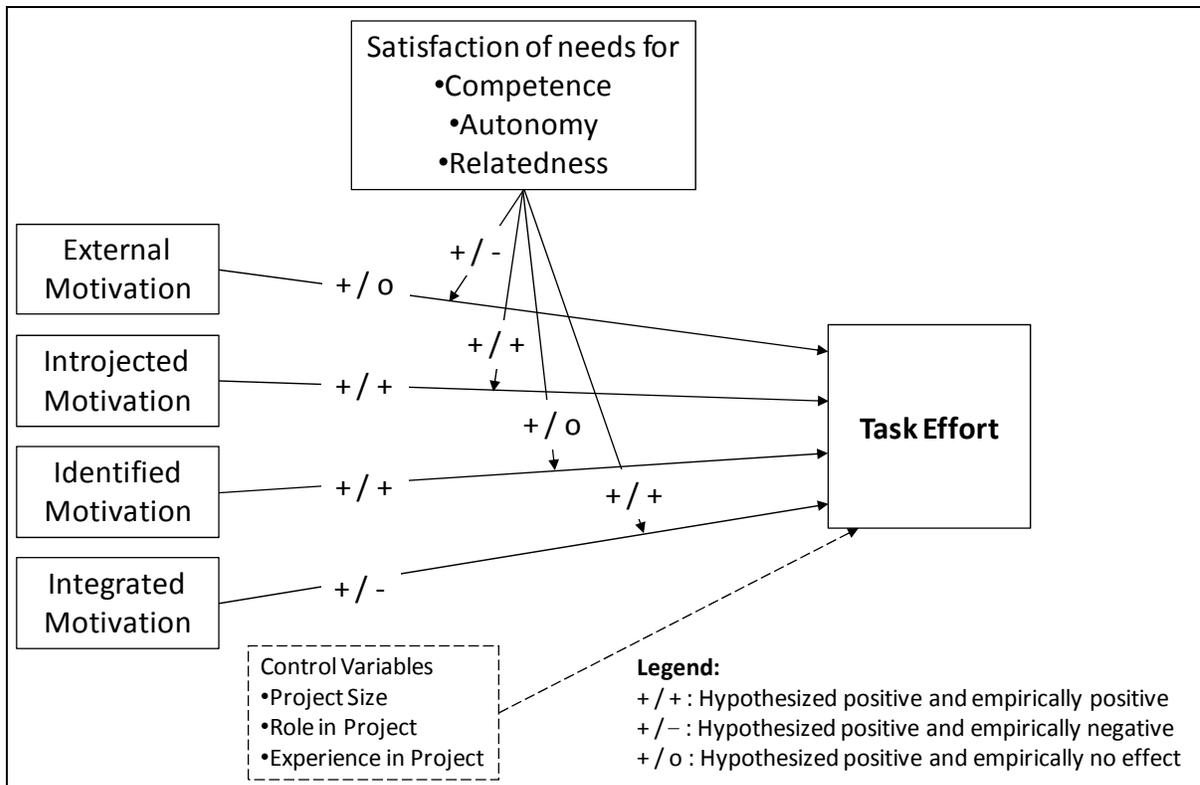


Figure 2. Hypotheses Testing Results

5. Discussions and Conclusion

The present study investigates varying effects of different types of extrinsic motivations, and the interaction effect of satisfaction of needs on task effort expended by participants in OSS projects. Specifically, instead of treating motivation as a unitary construct, we differentiate extrinsic motivation along the spectrum proposed by self-determination theory: external, introjected, identified, and integrated motivation (Deci and Ryan 2000; Ryan and Deci 2000). We assess how these different types of extrinsic motivations effects on task effort intensity are moderated by satisfaction of needs for competence, autonomy, and relatedness. Our research model is largely supported by the empirical data.

5.1 Limitations

It is important to understand this study's results and contributions in light of its two limitations. First, we collected data with a single source during one period of time. All the major constructs were measured by respondents' perceptions, which are subjective. In particular, there is no guarantee that respondents filled out our questionnaire with a particular project in mind, although we clearly asked them to do so at the beginning of the questionnaire. Future research should use more objective

measures from multiple sources. Ideally, future research should also collect data at multiple points of time. A longitudinal study may enrich research findings by offering additional information on the possible variations of the relationships between independent and dependent variables within a person across time, and how the fluctuations of satisfaction of needs moderate those relationships. Second, we collected data only from English-speaking OSS participants. OSS development, as a global phenomenon, involves individuals speaking various languages from diverse cultures. Future research should be conducted to verify the applicability of our research results to participants who speak different languages and are from different cultures.

5.2 Implications for Research

The present study has conceptual and theoretical implications for OSS research. Conceptually, this research investigates the nuances of extrinsic motivation. Few, if any, prior studies on motivation in OSS communities have categorized and empirically tested the spectrum of extrinsic motivation. Given that the type, in addition to the magnitude, of motivation makes a difference in its effects on energizing participants' efforts (Deci and Ryan 2000; Ryan and Deci 2000), this study categorizes the motivating factors identified by previous studies into four types of extrinsic motivation: external, introjected, identified, and integrated motivation. This conceptualization helps to enrich our understanding of the differential effects of different types of motivation on task effort in OSS projects (Roberts et al. 2006; Li et al. 2006).

Specifically, the empirical findings of this study indicate that integrated motivation has negative, rather than positive, effects on effort expended on a specific project, although it is widely accepted that the ideology of the OSS movement motivates individuals to participate in OSS projects (e.g., Lakhani and Wolf 2005; Bagozzi and Dholakia 2006). This is in accord with Stewart and Gosain's findings (2006) that individuals, with their belief in open source, act as agents of social change and participate broadly rather than focus on a specific project. Also, the results show that external motivation has no significant effects on task effort. It may be due to the lack of internalization of regulation, according to SDT (Ryan and Deci 2000), that external motivation cannot lead an individual to *persistently* work on an OSS project. Hence, future OSS research should be cautious about the effects of external and integrated motivation.

In addition, we proposed and empirically examined that motivation with a higher degree of the self-determined regulation style would lead individuals to expend greater effort. Indeed, the results show that identified motivation is the most salient and motivating factor in OSS communities, followed by introjected motivation. Previous research has treated different extrinsic motivations equally and, thus, ignored their specific influencing mechanisms in OSS communities (e.g., Hertel et al. 2003; Lakhani and Wolf 2005). The present study highlights that an autonomous locus of regulation is important for an extrinsic motivation to truly motivate OSS participants. Future OSS research may explore the tactics that would help participants internalize the locus of regulation and eventually expend more effort on the OSS project.

Theoretically, the research extends the OSS participation research to incorporate the effects of satisfaction of psychological needs afforded by OSS projects. Given that there is no organizational control or formal remunerating systems in OSS communities, satisfying participants' psychological needs is expected to be even more important in guiding individuals' self-organization. Indeed, as indicated by our research findings, models with and without satisfaction of psychological needs provide different information about which types of extrinsic motivations are significant antecedents of task effort. In particular, modeling the satisfaction of psychological needs as a moderator, the present research helps to explain the mixed findings of previous studies on motivations in OSS communities (e.g., Roberts et al. 2006; Shah 2006; Hertel et al. 2003; Lakhani and Wolf 2005).

In the view that positive affect plays a critical role in leading to individual's volitional behaviors (Isen and Baron 1991; Erez and Isen 2002), how positive affect derived from an individual's interaction with the OSS project environment may help enhance individuals' effort warrants scrutiny. Hence, the current study opens up avenues for research investigating the confluence of motivation and

satisfaction of needs (and positive affect) in OSS communities. In particular, future OSS studies may link our research findings to their research context and examine how project-level characteristics, such as license choice, project governance, and organizational sponsorship (e.g., Colazo and Fang 2009; Lerner and Tirole 2005; Shah 2005; Stewart et al. 2006), may afford satisfaction of needs and, thereby, strengthen or weaken the effects of motivation.

5.3 Implications for Practice

This study also has significant practical implications. Specifically, OSS project leaders should be aware of the differential effects of various types of extrinsic motivation. As indicated by our research findings, external motivation is not effective for retaining participants in the project. In contrast, identified motivation has the greatest impact on effort expended. Hence, practitioners should realize that offering financial rewards may not be a good strategy to attract participants. Instead, project leaders should create an appropriate group atmosphere to help participants assimilate the group's values and identify with the project.

In addition, practitioners should be aware of the effects of satisfaction of psychological needs on how motivation energizes participants' efforts. In particular, our research suggests that satisfying participants' needs for competence, autonomy, and relatedness may strengthen the effects of extrinsic motivation on effort expended on a project. Currently, many project leaders assign tasks to participants based on their competence, which may have a negative impact on their satisfaction for autonomy. It may be more effective to have participants self-identify project tasks. Also, our findings have extended implications for project design. Modular design would make project tasks less time demanding and more achievable, which would better satisfy participants' needs for competence. Furthermore, project leaders should develop social networks that facilitate communication, coordination, and collaboration among participants. In particular, project leaders should nurture a favorable project environment to enhance participants' satisfaction of needs for relatedness.

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Appendix A. Measurement Items

External Motivation (Adapted from Amabile et al. [1994])

1. I am strongly motivated by the money I can earn through my participation in this OSS project.
2. I am keenly aware of the possible career promotion that may be brought by my participation in this OSS project.
3. I am keenly aware of the income goals I have for myself if I participate in this OSS project.

Introjected Motivation (Adapted from Amabile et al. [1994])

1. I am strongly motivated by the recognition I can earn from other people in this project.
2. I want other people to find out how good I really can be in software development/testing.
3. To me, success of participation in this project means doing better than other people.

Identified Motivation (Adapted from Bergami and Bagozzi [2000] and Allen and Meyer [1996])

1. I really feel as if this project's problems are my own.
2. This project group has a great deal of personal meaning for me.
3. I have a strong positive feeling toward this project group.

Integrated Motivation (Adapted from Becker et al. [1996])

1. If the values of the OSS group were different, I would not be as attached to it.
2. The reason I participate in this project is because of what it stands for, that is, its values.
3. My attachment to this group is primarily based on similarity of my values and those represented by this project.

Task Effort (Adapted from Yeo and Neal [2004])

Time Commitment

1. I work long hours in this project.
2. I devoted a large number of hours to this project.
3. Few of my peers in this project group put in more hours than I do.

Task Persistence

1. I persist in overcoming obstacles to complete tasks in this project.
2. I tackle difficult problems encountered in this project enthusiastically.
3. When facing a difficult task, I make every effort to complete it.

Effort Intensity

1. When there's a problem to be solved in this project, I devote all my energy to getting it done.
2. I work at my full capacity in all of my contribution to this project.
3. When I work on this project, I really exert myself to the fullest.

Satisfaction of Needs (Adapted from Deci et al. [2001] and Spreitzer [1995])

Competence

1. I feel very competent when I am working on this project.
2. In this project, I get many chances to show my capability.
3. When working on this project, I often feel very capable.

Autonomy

1. I feel like I can make a lot of inputs to deciding how I contribute to this project.
2. I feel like I can pretty much be myself when working on this project.
3. There are many opportunities for me to decide for myself what and how I participate in this project.

Relatedness

1. People in this project are pretty friendly towards me.
2. I really like the people working on this project.
3. I get along with people in this project.

Appendix B. Details of Common Method Bias Test

We examined the possibility of common method bias with the Harman's one-factor test (Podsakoff and Organ 2006). Before conducting Harman's one-factor test in two ways (i.e., principal components analysis and principal axis factoring), we checked the adequacy of sample size. Some researchers suggest that an effective factor analysis requires a sample size of 300 (Tabachnick and Fidell, 2001; Comrey and Lee, 1992). Given that our sample size was less than 300, we assessed the adequacy of sample size by using the Kaiser-Meyer-Olkin (KMO) measure (Kaiser, 1970; 1974). According to Field (2005), a value of KMO of 0.7 and above indicates that factor analysis would be adequate, regardless of sample size. The results showed that the value of KMO was 0.834. Thus, we moved on to conduct factor analysis.

We followed Carr et al. (2007) and entered all items into a principal components analysis with an oblique rotation (i.e., Direct Oblimin). The results showed that there were six constructs with eigenvalues greater than 1.0. These six constructs accounted for 66.47% of the variance, while the first construct only accounted for 25.34% of the variance. Given that principal components analysis does not distinguish between shared and unique variance in variables, we applied principal axis factoring suggested by Costello and Osborne (2005) to verify the validity of the results of principal components analysis. The results also indicated that there were six constructs with eigenvalues greater than 1.0. These six constructs and the first construct accounted for 57.98% and 23.08% of the variance, respectively. As such, the results of these two methods were consistent and both demonstrated that common-method bias was unlikely to be an issue for this study.

To further ensure common method bias was not a serious threat, we also compared the fit between the one-factor model and measurement model. The results showed that the one-factor model yielded a $\chi^2 = 3089.07$ and d.f. = 405, and the measurement model yielded a $\chi^2 = 611.78$ and d.f. = 360. Thus, the fit of the one-factor model was considerably worse ($p < .01$) than the fit of the measurement model. This indicated that common method bias is not a serious concern.

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