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Abstract

Open-source software (OSS) development is leading trends in the software market. OSS teams occupied with knowledge-intensive tasks are confronted with role-related issues. Team-level role dynamics (i.e., role ambiguity and role conflict) which manifest whether information about roles (e.g., expected responsibilities, behaviours, and outcomes) perceived by members are clarified and coherent, affect team performance. Information about roles can be considered clues for expertise recognition and location, which strengthens members' reliable understandings about others' knowledge and work cooperation. Namely, it may influence transactive memory system (TMS), a group work pattern based on cognitive labour division. Although prior studies have proposed that role-related constructs (e.g., role identification, and role conflict) influence team cognitions (e.g., TMS) and team performance, the relationships between role dynamics, TMS and team performance are still unclear. This study intends to explore the affective and cognitive mechanism through which role dynamics influence TMS under various boundary conditions (i.e., instrumental and expressive communication), and provides a further understanding about how to enhance team performance within the mechanism. An empirical study sampling from OSS communities like SourceForge and GitHub will be conducted to verify our hypotheses. Our research intends to offer theoretical and managerial implications about role concerns in OSS teams.

Keywords: Open-source software (OSS), Role dynamics, Role ambiguity, Role conflict, Transactive Memory System (TMS), Team performance, Instrumental communication, Expressive communication

1 INTRODUCTION

Open-source software (OSS), a software that allows anyone to use, modify and contribute the source codes without paying license fees, has absorbed much attention (Bonaccorsi & Rossi 2006). OSS communities like SourceForge and GitHub provide platforms to developers to exchange experiences, coordinate projects and search for like-minded partners. Wherein, developers are organized in a core-periphery form. The core contains core developers and project leaders, coupled with co-developers and active users in a wider circle to offer technical aids voluntarily (Crowston & Howison 2006). OSS developers in core teams, accounted for roughly 20% in communities, make appropriately 80% of codes contribution and are less likely to leave the projects (Yamashita et al. 2015). In this study, we regard the core OSS development teams (hereinafter known as OSS teams,) as the research object.

Software development teams are faced with coordination problems due to different ways of allocating subtasks, like design, development, and test, to members (Amrit & Van Hillegersberg 2008). For members, incurring differentiated responsibilities means being placed to various positions and roles. Zhu et al. (2006) presented roles like project manager, analyst, designer, and programmer are needed in the software development process, and role-based software engineering is useful for virtual development teams. However, each OSS team member often takes on multiple roles based on volunteerism rather than strict assignment may lead to confusion about members' roles (Jensen & Scacchi 2005). These contradictory arguments indicate that role issues in OSS teams are noteworthy to research. According to the theory of role dynamics (Kahn et al. 1964), work-related expectation ambiguity and conflicts may cause individuals' role stresses, including role ambiguity (RA; the opponent of "role clarity") and role conflict (RC). Software development is a complex non-routine knowledge work that considers expertise as the most important resource (Faraj & Sproull 2000). Chen et al. (2013) insisted that transactive memory systems (TMS) is an useful cognitive mechanism for distributed teams to coordinate members' expertise because it offers an unspoken assumption about members' knowledge domains. Using developer mailing list is an important characteristic of OSS teams to form TMS. Here, we question how role dynamics affect TMS in the context of OSS teams.

Prior research shows that role dynamics negatively affect team performance via some cognitive states or activities, like team efficacy (Leo et al. 2015), team learning (Savelsbergh et al. 2012), and information acquisition (Deeter-Schmelz 1997). However, their associations with team cognitive system has been rarely researched. TMS contains meta-memory (i.e., "who knows what" and "who knows who") which is fostered on the base of statements about roles and responsibilities of members (Jackson 2011; Wegner 1987; Yuan et al. 2005). TMS can be promoted by role identification during the role compilation phase of team development (Pearsall et al. 2010). However, how role dynamics affect TMS remains unclear. In terms of the effect on team performance, although cognitive responses to role dynamics are worthy to be studies, extant research in role dynamics overwhelmingly focuses on individuals' affective and behavioural responses, like job dissatisfaction (Faucett et al. 2013), burnout (Crane & Iwanicki 1986), and propensity to leave (Verville & Halingten 2003), with little attention paid on the combination of affective and cognitive mechanism. Furthermore, Van Sell et al. (1981) argued that communication frequency can moderate the relationship between role dynamics and role incumbents' responses. Here, we adopt instrumental and expressive communication to respectively manifest the cognitive and affective functions of communication as a contextual factor. The moderating effect of communication on the links between role dynamics and TMS will also be probed.

In this study, adopting the Input-Process-Output (IPO) model, we concentrate on the effect of OSS teams' role dynamics on team performance through TMS, which is contingent upon instrumental and expressive communication. Herein, role dynamics are team inputs (Vincent 2010). TMS, as a team cognitive process or an emergent state, is the "process" portion (Zhong et al. 2012). The IPO model deems that team factors (inputs) are translated by team interactions (processes) into team-shared results (outcomes) (McGrath 1984). In summary, we address the following questions: 1) How do role

dynamics affect TMS from cognitive and affective mechanism, and then influence team performance? 2) How do instrumental and expressive communication moderate the effect of role dynamics on TMS?

2 THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Theory of Role Dynamics

Role theory argues that role is a set of expectations about behaviours applied to a position by this role incumbent and related senders who can be focal role incumbent' supervisors, clients, co-workers and subordinates (Van Sell et al. 1981). The theory of Role Dynamics (Kahn et al. 1964) proposed the term RA and RC. Previous scholars also mentioned them as "role perceptions" (Beauchamp & Bray 2001; Esper et al. 2008), because their degrees are perceived by individuals and mainly measured by self-report method in research. Kahn et al. (1964) used role episode model to demonstrate the cyclical interactions between role senders and incumbents in terms of perceiving long-term changeable work demands (Mellalieu & Juniper 2006). Wherein, role dynamics emerge. Role senders evaluate a focal person's ability by observing his/her behaviours or outcomes and then expect the latter's responsibilities. Subsequently, the focal role incumbent experiences these expectations and provides feedbacks (affective, cognitive, or behavioural responses, e.g., anxiety and work involvement) to role senders. In short, RA indicates that these expectations are not clearly perceived by role incumbents, whereas RC signifies the level of incongruence in expectations from multiple sources including role senders and focal role incumbents per se (Rizzo et al. 1970). The relationships between role senders and incumbents may be reciprocal in causality over several time periods (Van Sell et al. 1981), which means a role incumbent (sender) can also be a role sender (incumbent) to others.

Team-level role dynamics, manifesting a characteristic of team structure, are embedded in the social context of a team and are perceived and processed by members in a similar way (Pearsall et al. 2009). They are the average and composite constructs of individuals' role perceptions (Savelsbergh et al. 2012). Team RA is negatively associated with team efficacy (Leo et al. 2015), team coordination (Savelsbergh et al. 2012), team information acquisition (Deeter-Schmelz 1997), team satisfaction (Carbonell & Rodriguez-Escudero 2013), and team performance (Savelsbergh et al. 2012). Similarly, team RC hinders desirable team outcomes in the aspects of team learning, coordinating, and task performing (Leo et al. 2015; Lynn & Kalay 2015; Savelsbergh et al. 2012). Additionally, RA and RC can be regarded as typical hindrance stressors to which employees tend to negatively respond from the affective, cognitive, and behavioural aspects (Pearsall et al. 2009). The authors empirically stated that teams faced with hindrance stressors may obtain higher psychological withdraw, less transactive memory, and worse team performance. RA and RC perceived by information system professional are antecedents of burnout (Sethi et al. 1999). They trigger the negative psychological states of software development team members, which can explain the variance in individuals' job satisfaction (Pedrycz et al. 2011). Role dynamics of OSS team members, as the immediate socialization outcomes, can convey the effect of socialization tactics on job performance (Carillo et al. 2014).

2.2 Transactive Memory System

A transactive memory system (TMS), aiming at encoding, storing, and retrieving knowledge from different knowledge domains (Wegner 1987,1995), is composed by individuals' memory systems and related interactive processes (Wegner 1987; Yuan et al. 2005). The interactive processes contain information encoding/updating, allocation, and retrieval (Jackson 2011; Yuan et al. 2005). Meta-knowledge that indwells in individuals' memory system is fundamental to TMS formation. Some informational cues (e.g., departmental responsibilities, formal group memberships, and role titles) facilitate the identification of meta-knowledge providers (Jackson 2011; Wegner et al. 1991).

Gauging dimensions widely accepted by transactive memory literature are: specialization, credibility, and coordination (Akgun et al. 2005; Lewis et al. 2005; Zhang et al. 2007; Zhong et al. 2012). Specialization refers to members' ability to specifically remember task-related knowledge from various expertise domains (Moreland & Myaskovsky 2000; Namho et al. 2015). Credibility reflects the belief pertaining to the accuracy and reliability of teammates' expertise (Akgun et al. 2005; Zhong et al. 2012). Coordination means members' ability in effectively utilizing knowledge and achieving tasks in a collective fashion (Lewis 2003; Li & Huang 2013). In brief, a well-developed TMS is maintained when a group of people who have specific expertise and cognition-based trust can coordinate to achieve collective tasks (Tang et al. 2015).

By regarding teammates as external knowledge stores and interacting, members use TMS to decrease memory redundancy and to save cognition capacity (Li & Huang 2013; Robertson et al. 2013). Hence, higher team effectiveness can be achieved (Hewitt & Roberts 2015). Scholars have suggested that TMS promotes task performance (e.g., Akgun et al. 2005; Choi et al. 2010; Zhong et al. 2012). Moreover, some researchers also presented the factors influencing the TMS formation, such as team familiarity (Lewis 2004), member proximity (Akgun et al. 2005), team training (Liang et al. 1995) and communication (Tang 2015). Roles as a type of relation interactions, coordinate organizational TMS (Peltokorpi 2014). A meta-analysis emphasized that, "imposed knowledge structure" and "acute stress" that respectively represent team-level and contextual inputs, are two main TMS antecedents (Ren & Argote 2011). Role information, as the informative ensembles that form the foundation of expertise location, can be considered a type of imposed knowledge structure.

3 RESEARCH MODEL AND HYPOTHESES

We develop a theoretical model and related hypotheses based on the literature review (see Figure 2). In our assumptions, TMS is affected by role dynamics, and can positively affect team performance. The model also intends to test the moderating effect of instrumental and expressive communication.

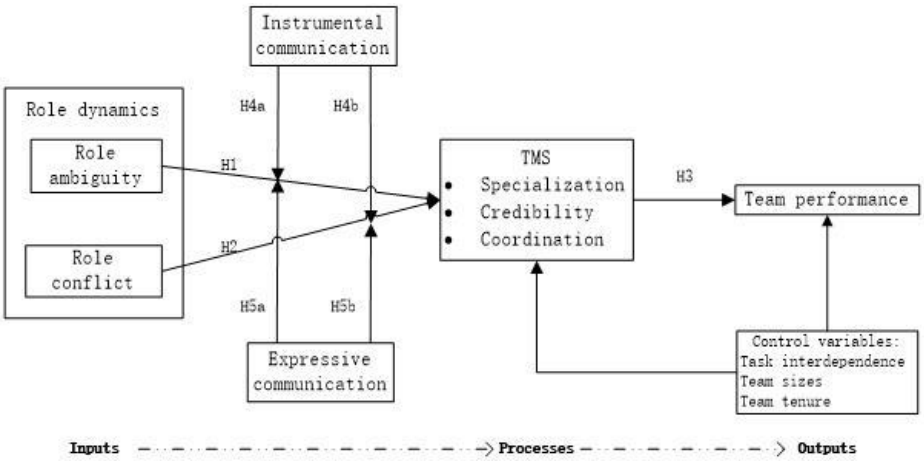

Figure 2. Research model

3.1 Role Dynamics and TMS

Stewart and Stasser (1995) argued that "member's roles provide clues to their access to unshared information" (p. 620) that exclusively resides in the minds of experts. For example, an OSS developer who enacts the role of database designer is believed to be competent in database architecture techniques. Team RA implicitly implies that, all members believe the instructions and expectations for the assigned roles of teammates and themselves are unclear (Verville & Halingten 2003). Virtual OSS team members may be affected cognitively. As role senders, members may find it difficult to

preliminarily judge the knowledge and skills of unfamiliar teammates without clear observation of what their teammates are working on in the collaboration platform (e.g., Confluence). By contrast, if RA is low, it seems true that developers who perfectly and timely achieve coding of software modules that they are responsible for are capable of enacting assigned roles and can be tagged as experts for the role-related domains. Members, from the position of role incumbents, tend to perceive higher RA when they aren't provided a fine-grained role statement. In this situation, members may feel confused about their own authorities, goals, objectives and responsibilities. Furthermore, they cannot competently draw up effective work schedules with an undimmed vision of what should be done (Rizzo et al. 1970). Cognitively, they feel lower self-efficacy to be responsible for what are attributed to them (Beauchamp & Bray 2001), leading to less effort and persistence to fulfil and present their capabilities. Given this, it is less likely for their teammates to notice their actual expertise to form a meta-knowledge for TMS.

The influence of RA on TMS can also be explained by changes in the attitudes of role senders and incumbents. When team RA is high, role senders hesitate to trust the team's ability in solving problems, which implies that they are less likely to trust focal persons' personal knowledge (Leo et al. 2015). Correspondingly, they may less frequently and openly communicate with others (Lynn & Kalay 2015). In turn, they will loss the benefits of role clarity in terms of expediting teammates' expertise recognition and information acquisition without duplicating efforts to ascertain who knows what and who does what (Deeter-Schmelz 1997). Affectively, role incumbents may be more anxious, fear and hostile when working (Rizzo et al. 1970). They are less motivated to involve in jobs (Bauer et al. 2007) and to spare work effort (Caillier 2014) for achieving their task segments. Teams with high level of RA may be tortured by coordination losses, because the "interactive capacity to perform toward a common and valued goal in a coordinated manner" will be undermined (Savelsbergh et al. 2012, p. 6) and role incumbent will be less concerned about group coordination (Verville & Halingten 2003), even show propensity to leave the team (Bauer et al. 2007). A team with high RA is assumed to perform worse in specialization, credibility, and coordination of TMS. Therefore, we hypothesize:

H1. Role ambiguity is negatively associated with the level of TMS.

Team RC refers to the incongruent expectations within a team towards individuals' ability and performance (Leo et al. 2015). As a role sender, from the perspective of regarding others' roles as the expertise tags, team RC perceived by a team member is equivalent to his/her belief that others are almost suffering incongruent and incompatible expectations of responsibilities for vested positions. For example, when other developers have to enact roles that surpasses their knowledge boundaries, this role sender may consider role assignment is inappropriate (i.e., low person-role fit) (DeRue & Morgeson 2007)), and may feel confused when matching defined role requirements with actual role occupants. For another instance, if role incumbents are assigned to be both code developers and testers simultaneously, which means they enact multiple roles that pursue different or incompatible targets, the expertise information that is manifested by their work patterns is too complicated to identify (Jones 1993). This role sender may be confounded to locate experts for specific problems (Savelsbergh et al. 2012). Role information loses its functionality of being a reliable expertise cue to figure out "who knows what" exactly. From the stance of role incumbents, RC is a type of hindrance stressor that triggers withdrawal behaviours, which means members faced with high RC will abandon attempts to improve the situation and instead to separate themselves from tasks (Pearsall et al. 2009). Cognitively, RC leads role incumbents to quit in learning about teammates' roles and expertise domains as well as demonstrating their expertise by involving in team tasks. Fixing to habitual routines hinders teammates to jointly contribute personal efforts. Given this, members can not co-ordinately use mutual knowledge to achieve collective goals (Tang 2015).

Team members, as role incumbents, may be anxious, tense and dissatisfied after bearing multiple incompatible expectations or undertaking tasks beyond their capabilities (Kahn et al. 1964). Other affective effects of RC include less workers' commitment to organizations (Anton 2009), which restricts people's work contribution to task performing. Role incumbents may feel frustrated by their inability to successfully complete tasks due to RC. These negative emotions may easily impact their

teammates who are role senders (Pearsall et al. 2009). Negative emotions impede members' information retrieval and allocation, which harms the TMS development (Huang 2009). Team RC can be considered a source of employees' stress (Jackson & Schuler 1985). Moreover, members perceiving high RC show less trust in those who impose role pressure on them. The less harmonious personal relationship decreases frequent interaction (Rizzo et al. 1970), which reduces exchange of understandings about mutual expertise domains. It also jeopardizes their corresponding coordination of utilizing cognitively reliable expertise that has been distributed to various teammates. All in all, high level of RC may damage specification, credibility, and coordination. Thus, we hypothesize:

H2. Role conflict is negatively associated with the level of TMS.

3.2 TMS and Team Performance

For OSS development, a project performance is represented by coding achievement of a core team (Chen et al. 2013). TMS stimulates desirable team performance for following reasons. Firstly, TMS can provide sufficient knowledge resources to support task attainment. Specialization improves the ability of a team to readily find the needed knowledge from the most right developers who incur divided responsibilities such as coding diversified software modules (Faraj & Sproull 2000; He et al. 2007), which benefits team effectiveness. Additionally, it expedites the processes of knowledge retrieval and utilization by avoiding repetitive memorizing and reducing cognitive load of each member (Tiwana 2004; Von Krogh et al. 2003), which contributes to team efficiency. Furthermore, TMS inherently expects OSS members to hold mutual confidence in teammates' personal knowledge. Members' cognition-based trust on teammates can reduce mistakes related to work (Erdem & Ozen 2003) and boost task coordination (Kanawattanachai & Yoo 2007), which conduces to team performance. When members feel more relieved and comfortable to rely on others' knowledge to figure out task-related problems, they can spare empty personal cognitive efforts for other subtasks, and obtain high team effectiveness and efficiency. Lastly, TMS intrinsically requires members' actual action to co-ordinately leverage shared cognitions with few misunderstandings. During the process of forming TMS, members eventually reduce group response time by facilitating knowledge retrieval and develop a cooperative work pattern, to effectively perform tasks (Yuqing et al. 2006). Therefore, we argue that TMS facilitates team members to achieve tasks in a more effective and efficient manner, and hypothesize:

H3. Well-developed TMS enhances team performance.

3.3 Moderating Effect of Communication

Instrumental communication is used to accomplish task goals, characterized by specific content, format and context requirements. It is supported by specific forms and media (Thomas 2001; Thomas et al. 2001). OSS teams often use professional project tracking tools (e.g., JIRA) and knowledge collaborative softwares (e.g., Confluence and Yammer) to exchange information related to developing and modifying codes or reporting and fixing bugs. They also leverage mailing lists to view who have made what contributions for projects to deduce who knows what (Chen et al. 2013). If necessary, OSS team members can turn to any communication platforms that they jointly participate to send an instant message to any specific teammates to deepen understandings about them. Furthermore, OSS teams often conduct video conference to respond to members' work-related confusions. This instrumental communication facilitates knowledge distribution and uncertainty reduction, affecting members' cognitive orientation (Umphress et al. 2003) and is a cognitive support for task achievement of teams (Müller & Turner 2005).

For OSS team members, written documents explaining roles and instrumental communication tools are alternative channels to obtain information about others. According to media richness theory (Daft & Lengel 1986; Trevino et al. 1990), communication channels with various richness of information are differential in reducing equivocality and uncertainty embedded in communication content and aims. Instrumental communication via media like video conferences and emails are superior to written

documents due to richer information cues, faster feedback, higher personal focus, and more natural language utilization. Richer information about one's responsibilities is more likely to increase accuracy of locating team experts. Namely, when members conduct frequent instrumental communication with teammates, they have an additional source to form TMS and may less depend on understanding others' expertise from role information. Even though they suffer from high level of RA, they can also smoothly form a perception of who knows what. Moreover, after receiving instructions through frequent instrumental communication with teammates, role incumbents who confronted with RC may better understand how to enhance their own ability or where to search for others' knowledge to fulfil tasks. Similarly, role senders can better locate experts rather than keep disturbed by the problematic information about members' roles by which their teammates' expertise can not be reflected. Hence, instrumental communication is presumed to alleviate the negative effect of RC on the level of TMS.

H4a. Instrumental communication moderates the relationship between RA and TMS, such that the effect of RA on TMS is stronger when instrumental communication level is low within a team.

H4b. Instrumental communication moderates the relationship between RC and TMS, such that the effect of RC on TMS is stronger when instrumental communication level is low within a team.

Expressive communication is motivated by personal or social aims to share experiences, express agreement, or show humour (Thomas 2001; Thomas et al. 2001). It is a personal interaction outside of work, through which individuals get acquainted with teammates and then develop and maintain relationship with others (Malik 2013). Being affect-based, it changes or reinforces communicators' attitudes, norms, and values (Umphress et al. 2003). OSS team members are separated spatially and temporally, and mainly rely on computer-mediated (CM) social media tools, such as WeChat, Tencent QQ and Microblog, to interact personally. The more frequently members implement expressive communication, the higher mutual affective trust they may foster as a manifestation of enhancing social capital in teams (Thomas et al. 2001). Correspondingly, the indifferent and hostile interpersonal relationship can be eliminated, and a better level of team cohesion can be achieved, which promotes team maintenance and survival during the process of task performing. In this situation, it is less likely for OSS team members to readily leave the team merely because of dissatisfaction with work, co-workers, or team caused by role stress (e.g., RA and RC).

Furthermore, through frequent expressive communication, team members have chances to pour out complaints about anything dissatisfies them within the team to their intimate teammates. In this manner, their negative emotions caused by RA and RC may be exhausted. Hence, the adverse affective effect of role stress on team members' job involvement can be mitigated. Due to lasting harmonious interpersonal relationships with teammates, members are increasingly strengthening the intentions to update knowledge, to recognize experts, to trust teammates' expertise, and to coordinate with teammates in leveraging knowledge. Namely, the development of TMS can be achieved, even though role stress exists but is restricted by frequent expressive communication. Thus, expressive communication is assumed to negatively moderate the effect of RA and RC on the level of TMS.

H5a. Expressive communication moderates the relationship between RA and TMS, such that the effect of RA on TMS is stronger when the expressive communication level is low within a team.

H5b. Expressive communication moderates the relationship between RC and TMS, such that the effect of RC on TMS is stronger when the expressive communication level is low within a team.

4 RESEARCH DESIGN

An exploratory cross-sectional design will be applicable to test our theoretical model. Survey is the main method to collect data. A popular Chinese professional survey website called Wenjuanxing (www.sojump.com) will be employed. We will select around 100 OSS development core teams who jointly undertake tasks like writing and modifying codes as our research samples. OSS communities such as SourceForge, GitHub and OSChina are our target sampling sources. For each potential OSS

team, we intend to get contacted with the developer(s) who publicly announce(s) email address in OSS communities, through whom we invite other members to conduct the survey.

All question items are adapted from extant literature. In detail, role dynamics measures derive from Rizzo et al. (1970), and will be adapted to reflect team-level RA and RC according to Savelsbergh et al. (2012). Items about TMS are based on the work of Lewis (2003). The measures of team performance come from Sawyer (2001) to reflect efficiency of teamwork and quality of outcomes. Instrumental and expressive communication are measured by items from Ding et al. (2015). The average frequency of communicating with others are required to be reported by respondents. Objective data about team performance will also be collected. As Crowston et al. (2004) argued, the output acceptable to those who receive or review it manifests team effectiveness. We adopt the number of high praise (e.g., "star" in Github) to objectively signify the quality of team work. Additionally, some team characteristics such as task interdependence (Zhang et al. 2007), team tenure, and team size (Zhong et al. 2012), are included in our model as control variables. SmartPLS and SPSS will be used to implement the confirmatory factor analysis (CFA), path analysis, and multiple regression analysis.

5 CONCLUSIONS AND EXPECTED CONTRIBUTIONS

Our study intends to explore the OSS team work by delineating how RA and RC influence the processes through which team members locate, trust and coordinate teammates' expertise, which in turn affect team performance. Furthermore, the situations where role dynamics or perceptions impact the TMS to different degrees are also investigated.

The current study is expected to have both theoretical and practical implications. We endeavour to contribute to previous research in three primary ways. First, following the contention that role identification behaviours (Pearsall et al. 2010), imposed knowledge structure and acute stress (Ren & Argote 2011) play a pivotal role in TMS development, we take a further step to link role dynamics or perceptions to the level of TMS affectively and cognitively. It can extend our understanding of the antecedents of TMS and add to Transactive Memory Theory. Second, by expanding the research context of role dynamics to include OSS teams and leveraging IPO model, we contribute to team performance literature by linking Role Theory and Transactive Memory Theory and delineating that team cognitive processes (TMS) can be an underlying intermediate mechanism between role dynamics and team performance. Unlike previous research that unscrambled role dynamics from the perspective of the affective, psychological and behavioural responses of individuals, we provide a more comprehensive lens by adding into the aspect of cognitions. Lastly, we investigate the impact of different potential moderators, namely, instrumental and expressive communication, on the relationship between role dynamics and TMS, which enhances our understanding of the boundary conditions.

This research also provides implications for practice. Our potential findings will conduce to role-related issues solving and knowledge collaborating for OSS teams. First, before distributed OSS teams actually implement projects, clear and congruent role definition and skill requirements should be ensured, coupled with the high level of match between job responsibilities and personal expertise. In this way, members understand who knows what and who does what accurately. Second, OSS team members can enhance the level of TMS by paying more attention to effective usage of CM communication within teams. Specifically, members can set a proper environment where role dynamics affect TMS by finding an episode of level of instrumental and expressive communication.

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