Motivations for Self-Assembling into Project Teams

Mengxiao Zhu, Yun Huang, Noshir S. Contractor

Department of Industrial Engineering and Management Sciences, Northwestern University, Evanston, USA

Email: mzhu, yun, nosh @northwestern.edu

Abstract

This study investigates the self-assembly mechanisms of ad hoc project teams using a bipartite network perspective. Individuals and projects are modeled as two types of nodes and team membership as relations between them. This approach enables us to investigate factors that impact voluntary team assembly at the individual, dyadic, and team levels simultaneously. Using Exponential Random Graph Models (ERGM/*p**), we study players' combat teams in a Massively Multiplayer Online Role-Playing Game (MMORPG) as a case of self-assembled project teams. Empirical results show that individuals are motivated to join ad hoc teams to complete difficult projects but not projects with long durations. We also found that individuals tend to collaborate with specific teammates who have complementary skills, those who have similar age or skill level, and those who are affiliated with the same organizational entity.

1 Introduction

People join teams to accomplish challenging projects and fulfill common goals. Advanced information and communication technologies enable collaboration across organizational, cultural and geographical boundaries (Beyene, Hinds, & Cramton, 2009; Hinds, Liu, & Lyon, 2011) and also reshape the way teams are assembled (Maznevski & Chudoba, 2000; Schiller & Mandviwalla, 2007). In contrast to traditional teams with appointed and relatively permanent members(Mintzberg, 1980), many teams today are ad hoc and self-assembled, i.e. people across all types of boundaries team up for specific projects and disband upon accomplishing the projects (Contractor, 2013). Some examples include inter-disciplinary and multi-institutional scientific collaboration teams (Acedo, Barroso, Casanueva, & Galán, 2006; Jones, Wuchty, & Uzzi, 2008), open source software development teams that collaborate over the Internet (Fong Boh, Slaughter, & Espinosa, 2007; Hahn, Moon, & Zhang, 2008; Huckman, Staats, & Upton, 2009), and teams in games, especially in Massively Multiplayer Online Role-playing Games (MMORPGs) (Reeves & Malone, 2007; Reeves, Malone, & O'Driscoll, 2008; D. Williams, Contractor, Poole, Srivastava, & Cai, 2011).

In the research literature on teams, these teams are often called “project teams,” which are usually “time-limited, draw members from different disciplines and functional units and produce one-time outputs” (Cohen & Bailey, 1997, p. 242). These teams are also referred to as *voluntary collaborative project teams* (VCPT’s) (Margolin, Ognyanova, Huang, Huang, & Contractor, 2012), *self-governing groups* (Hackman & Katz, 2010) or *project groups* (Sundstrom, McIntyre, Halfhill, & Richards, 2000). Some project teams are embedded in organizations and created by special management or assignments, while many others are formed voluntarily by individuals for specific projects, such as teams in GitHub (Dabbish, Stuart, Tsay, & Herbsleb, 2012) or Wikipedia (Keegan, Gergle, & Contractor, 2013). In these teams, instead of belonging to rigid formal teams, individuals have the freedom to make decisions on creating, maintaining, dissolving, and reconstituting team linkages (Hahn et al., 2008). Clearly ad hoc project teams are becoming increasingly prominent, especially enabled by online environments. The emergence of ad hoc project teams emphasizes the trend of virtual and decentralized organizations in contemporary society and raises new research questions on motivations for self-assembling into project teams.

While the studies referenced above focus on the processes and outcomes of project teams that are self-assembled, there is ironically very little understanding about the assembly of these teams. This despite the fact that scholars have proposed that team assembly can significantly influence the outcome of project teams (Cohen & Bailey, 1997; Mathieu, Maynard, Rapp, & Gilson, 2008). This study seeks to address this limitation by focusing on the assembly mechanisms used by self-assembled project teams.

Most prior studies that are most relevant to the assembly of teams focus on the relations between the team composition and the team effectiveness (Cohen & Bailey, 1997; Cummings & Kiesler, 2008). Past research on the motivations of project team assembly are limited by both methodology and data collection. These studies either model teams as simple aggregations of individuals (e.g., Ruef, Aldrich, & Carter, 2003) or as dyadic connections among individuals (e.g., Guimera, Uzzi, Spiro, & Amaral, 2005; Hahn et al., 2008). The aggregation approach considers teams as a composition of individual level and team level attributes; the dyadic approach takes a compilation perspective and emphasizes the patterns of individual attributes and relations among team members (Kozlowski & Klein, 2000). From a compositional perspective, researchers found, for example, that the effectiveness of project teams is positively correlated with the functional diversity of team members (Ancona & Caldwell, 1992). From a compilational perspective, research indicates that the effectiveness of project teams is positively correlated with shared previous collaboration experience (Cummings & Kiesler, 2008; Guimera et al., 2005).

This study bridges the composition and compilation perspectives by taking a bipartite network perspective and models project teams as a collection of two types of nodes, persons and projects, and team membership as links between them. The advantages of using bipartite network models are two-fold. On the one hand, this approach preserves the interaction of personal attributes and project attributes and enables the analysis of data at various levels., We use the Multi-theoretical Multilevel (MTML) (Contractor, Wasserman, & Faust, 2006) framework to posit hypotheses about team assembly mechanisms in bipartite network models. A second advantage of using bipartite models is its ability to accommodate project teams that share members with each other. Traditional statistical models are not appropriate when teams share members due to the interdependency among the observations. The bipartite approach models this interdependency and studies the samples of project teams as a system. Statistically, we test related hypotheses using the Exponential Random Graph Models (ERGM/*p**) for bipartite networks (Robins, Pattison, Kalish, & Lusher, 2007; Wang, Sharpe, Robins, & Pattison, 2009).

Empirically testing a model to advance our understanding of team assembly requires a large sample of ad hoc project teams with changing memberships over a relatively long period of time. Getting access to these data is often challenging and laborious. Many prior empirical studies are constrained by the size of their samples (e.g. Roberts, Hann, & Slaughter, 2006; Ruef et al., 2003). Moreover, in many cases, the complexity of team projects makes it difficult to quantify project attributes, such as project difficulty, and required individual expertise.

To address these empirical challenges, this study uses virtual worlds as an exploratorium to observe and study team assembly based on rich digital traces from EverQuest II, a popular

U.S. based Massively Multiplayer Online Role-Playing Game (MMORPG). As in the offline world, project teams are widely used in this virtual world environment. In fact, scholars have argued that online games and other virtual worlds are serving as the platform for the next generation of co-workers to develop and hone their teaming and collaboration skills in complex environment (Reeves & Malone, 2007; Reeves et al., 2008). Furthermore, the movement of gamification promotes the idea of designing routine enterprise applications, such as training and recruiting, into games and suggests that the work place tomorrow might be more like what people are experiencing in games today (Reeves et al., 2008).

In these games, individuals choose characters, also called avatars, to represent themselves. They develop their own skills, such as fighting or healing. They also self-organize into teams to finish complex tasks that rely on the skills of others. Individuals are free to join or leave a team at any time. Hence, despite its fantasy settings, virtual teams in MMORPGs resemble ad hoc self-assembled project teams in the offline world. In addition, the availability of complete records on user activities in online games makes them an ideal test bed and research environment for research on self-assembled project teams. The anonymous data includes players' actions, interactions and transactions in the game as well as their demographic information, such as gender and age. In addition, because all game project and player skills are well specified by the game design, we can accurately identify project attributes, such as difficulty and duration and individual expertise such as player skill levels and roles. The project teams in the game world might be limited by the design and setting of the game, but we can still gain helpful insights from studying teams in this fantasy world since it is exceptionally difficult to collect such comprehensive dataset in offline settings.

The next section reviews prior research on project teams and team assembly, and outlines a bipartite network approach to study project team assembly. In Section 3, we introduce related social theories and propose our hypotheses. Section 4 provides details of the dataset used, measures, the analytical models and software used for this study as well as the results. In the last section, we discuss the implications and potential limitations of this study.

2 Literature Review and Theoretical Background

2.1 Project Teams

Project teams are "time-limited, draw members from different disciplines and functional units and produce one-time outputs." They have some special features that distinguish them from other types of teams in traditional organizations, such as work teams and management teams, which usually have well-defined boundaries and stable members (Cohen & Bailey, 1997; Mathieu et al., 2008; Stewart, 2006). First, project teams are usually built on the basis of common interests or activities (called *foci*) (Corman & Scott, 1994; Feld, 1981; McPhee & Corman, 1995) and often entail voluntary participation (Hahn et al., 2008). Team members do not necessarily have strong enduring bonding relationships (Cohen & Bailey, 1997; Feld, 1981). Instead, projects are both the goal of, and the reason for, the existence of project teams. Individuals gather together to work on the common projects that are otherwise too difficult for any single one to accomplish. Once the projects are accomplished, teams will disband and individuals are free to join other teams (Cohen & Bailey, 1997).

Second, project teams are usually embedded in a social context (Granovetter, 1985; Uzzi, 1997). The social relations between team members are an important factor in building project teams. Individuals build social connections during collaboration and depend on their social networks to seek future collaborators. These social relations are subject to constant change and interact with user activities. As an instance of social relations, previous collaboration is found to be one of the most important driving forces for individuals to work together repeatedly (e.g. Guimera et al., 2005; Hahn et al., 2008; Ruef et al., 2003).

2.2 Team Assembly

The mechanisms for team assembly have historically been an under-explored research topic although it is attracting more research attention in recent years. In the literature, "assembly" has been investigated either as a design process or as a self-organizing process.

The management literature has explored strategies and tools to help managers *design*, *staff* or *appoint* efficient teams. In a recent review, Zaccaro and DiRosa (2012, p. 199) note that "the purposive configuration of a team through selection strategies has received limited attention in the industrial and organizational literature, certainly in contrast to the amount of research over the last 20 years on team training." Reagan and colleagues (Reagans, Zuckerman, & McEvily, 2004) offer an example of this research when they ,discuss how managers use differences in individual demographic information and the structural features of their social networks as criteria to assign people to teams. From the perspective of knowledge management, Wi and colleagues (2009) proposed a team assembly model to help managers systematically consider team members' abilities as well as their social connections.

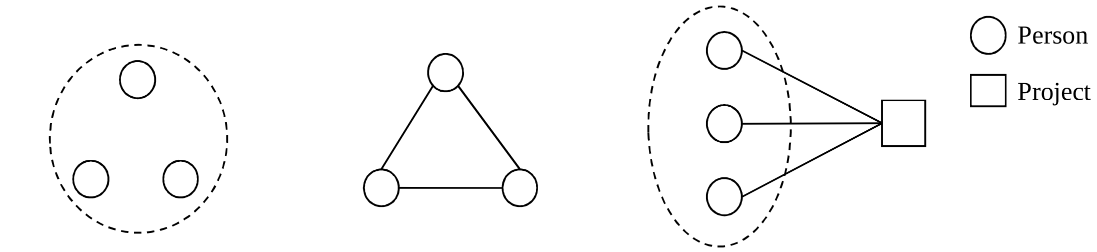
However, many teams, including most project teams, are neither pre-existing nor assigned; they are *self-organized and voluntarily created*. Several researchers (Poole, Hollingshead, McGrath, Moreland, & Rohrbaugh, 2004; Putnam, 2003; Putnam & Stohl, 1990) suggested considering these teams not as static units but as dynamic emergent entities embedded in their social contexts. A few empirical studies have been conducted to explain the motivations of assembling teams. For instance, Ruef and colleagues (2003) studied a sample of 816 organizational founding teams and showed that homophily and network constraints are important factors to predict team composition, while ecological constraints, i.e. geographical proximity, are one of the major reasons for individuals to be excluded from the teams. Using archival data and survey data from 288 contributors for projects under the control of the Apache Software Foundation (ASF), Roberts et al. (2006) identified both intrinsic motivations (e.g. fulfilling personal needs and enjoying programming experience) and extrinsic motivations (e.g. getting paid) for individuals joining ASF project teams. In the same vein, Hahn and colleagues (2008) studied 2,349 open source software (OSS) development teams on SourceForge.net. They found that developers' decisions on joining project teams are positively influenced by their collaborative ties with project initiators and the perceived status of other non-initiator members, e.g. their numbers of collaborators.

In addition to empirical studies, computer simulations are also used to study the mechanisms of team assembly. Guimera and colleagues (2005) proposed a model for the formation of academic collaboration teams based on three parameters: team size, probability of selecting incumbents (i.e. existing researchers in a field), and probability of repeated collaboration between incumbents. The results showed that the global features emerging from some simulation models are consistent with the co-authorship patterns observed in historical data. Through further simulations, they also discovered that high performance teams have higher diversity and a higher fraction of incumbents. Another simulation by Johnson et al. (2009) characterized three basic individual decision scenarios: to join a team, to leave a team and to merge teams. They proposed that the individual decisions are mainly influenced by the matching between a person's own attributes and his or her teammates' attributes with a certain tolerance level. Simulation results showed that their model captures certain features of both guilds in online games and gangs in the real world.

The primary focus of this study is to further explore the mechanisms of project team assembly as a self-organizing process. However, the findings of this will also be important to those who are interested in designing or appointing teams. Better teams may be engineered by following the natural motivations of team members to assemble discovered in this study.

2.3 Bipartite Network Approach for Project Teams

Project teams are usually interconnected and overlapping with one another since the same individuals with common foci, and being embedded in a common social context, can join multiple project teams. Consequently, a network perspective is particularly useful to study project teams in a social context. However, methodologies adopted in prior research are limited in their abilities to simultaneously incorporate individual attributes, team attributes, and the structures of membership relations.



(a) Team as aggregation of persons

(b) Team as relations among persons

(c) Team as relations between persons and projects

Fig.1. Three approaches to analyses of team assembly.

Two approaches are commonly used to study teams in the literature. The first approach considers each team as an aggregation of persons and use the composition of individual attributes and team attributes to explain individuals' motivations to join teams (e.g. Ruef et al., 2003). In this case, as illustrated in *Figure 1(a),* individual relations among team members, and between the team members and outsiders are often omitted or aggregated to the team level. The second approach considers teams as relations among persons (e.g. Guimera et al., 2005), as illustrated in *Figure 1(b)*. While capturing the patterns of intra-team and inter-team individual relations, this approach is incapable of capturing aggregate characteristics of the team or attributes of the project. Moreover, when persons belong to multiple teams over time, the existence of high order cliques blurs team boundaries and creates challenges for statistical analysis.

To address the limitations of these two approaches and integrate both compositional and compilational perspectives (Kozlowski & Klein, 2000), this study operationalizes project teams as relations between persons and their foci, i.e. projects, as connected entities in a bipartite network (also called affiliation or 2-mode networks) (Feld, 1981; Wasserman & Faust, 1994). The two types of nodes in a bipartite network are persons and projects, as illustrated in *Figure 1(c)*, and linkages between them represent team membership. The project team assembly, i.e. the joining of a set of people to a certain project, can thus be represented by the creation of linkages between team members and their project.

This approach incorporates the features of the previous two approaches by analyzing the attributes of team members and projects and the structures of membership relations in one model. That is, by focusing on different configurations in a bipartite network, our approach enables simultaneously to incorporate personal characteristics at the individual level, project attributes at the team level, and membership relations at the dyadic level.

We conceptualize the assembly factors at various level using a Multi-theoretical Multilevel (MTML) framework as proposed by Contractor and colleagues (Contractor et al., 2006; Katz, Lazer, Arrow, & Contractor, 2004; Monge & Contractor, 2003). In this framework, individuals' decisions to create, maintain, dissolve, and reconstruct linkages to other individuals are influenced by a series of mechanisms at multiple levels. The current MTML framework focuses on link formation between individuals in a one-mode network, where only one type of nodes are present (Wasserman & Faust, 1994). This study aims to extend the MTML framework to explain the formation of *project affiliation linkages*, i.e. the connections between team members and the projects they perform. These linkages are influenced by characteristics of the individuals and the projects as well as the interactions between individuals. The next section discusses social theories in the MTML framework to explore the assembly mechanisms of project teams at multiple levels.

3 Self-assembly Mechanisms of Project Team

To characterize the assembly of self-organized project teams, this study focuses on assembly motivations at two levels: personal level motivations for joining teams and dyadic interactions between individuals in team assembly. First, individuals may join a project based on personal motivations including their own attributes and the nature of the projects. Second, individuals may join a project based on dyadic motivations which include a match between their attributes and those of other members on the project as well as previous collaboration with others. We propose seven hypotheses to explore the impacts of different mechanisms for people to assemble into project teams and organize them based on the two types of the motivations described above: personal motivations and dyadic motivations.

3.1 Personal Motivations

Self-interest. Theories of self-interest suggest that individuals make rational choices and form linkages to maximize their personal benefits (Coleman, 1986; Monge & Contractor, 2003). It is often in people's self-interest to join a project team so as to accomplish their tasks in a more efficient manner. For instance, individuals with low skills and less experience would incur a high cost (e.g. taking a long time or a high risk of failure) to complete a project by themselves. Therefore they have more utilitarian needs to team up with others and get help to accomplish these tasks. Moreover, by working in teams and observing others, low-skilled individuals may learn more from others and improve their skills. In contrast, high-skilled and experienced individuals have more knowledge and ability to work on projects efficiently and do not need to rely on teams as much. Hence we propose the following hypothesis based on the theories of self-interest:

H1. Low-skilled individuals are more likely to assemble into teams than high-skilled individuals.

Mutual interest and collective action. Unlike the theory of self-interest, the theory of mutual interest and collective action emphasizes collaboration and mutual benefits in project team assembly (Fulk, Flanagin, Kalman, Monge, & Ryan, 1996; Fulk, Heino, Flanagin, Monge, & Bar, 2004; Monge & Contractor, 2003). While individuals motivated by self-interest join a team in order to advance their personal gain, those motivated by mutual interest join a team in order to advance the collective gain for the team. When individuals have common interests or foci, they may create team linkages and work together to benefit from coordinated activities and achieve goals that are unreachable individually. In this case, the attributes of team projects, in particular project difficulty, influence the tendency of individuals participating in teams. When a project is difficult, one person may not be capable to accomplish the goal alone and it becomes necessary for individuals interested in the same project to collaborate and form a team. Hence the theory of mutual interest and collective action posits that difficult projects are more likely to motivate the participation of individuals. From the perspective of project teams, it suggests that difficult projects tend to attract more attendees compared to easier projects.

H2. Individuals are more likely to assemble into teams for more difficult projects.

Coordination cost. Even though individuals can potentially benefit from working together as a team, researchers have also found that when projects are complex the cost of coordination can be an obstacle towards successful collaboration (Becker & Murphy, 1992; Gulati & Singh, 1998; Malone & Crowston, 1994). The coordination involves substantial planning, scheduling, and division of resource and responsibility. Individuals usually have many constraints such as limited time and availability. As a result it is difficult and less likely to form a team that requires many team members to devote their efforts over a long period of time. Since rational individuals anticipate the potential costs and risk, we propose that teams that require coordination over a long period of time are less attractive for potential team members. From the perspective of project teams, it suggests that projects with a longer duration tend to attract less participants compared to ones with shorter durations.

H3. Individuals are less likely to assemble into teams on projects that require a longer duration.

3.2 Dyadic Motivations

The hypotheses proposed so far are based on individual attributes and project characteristics. However, individuals' motivations to assemble in a project team are also based on dyad-level factors among potential team members. These hypotheses are discussed next.

Exchange and Dependency Theories. According to the theory of social exchange (Blau, 1964; Homans, 1958, 1974), individuals forge links to exchange valuable resources, such as information, materials and skills, and evaluate the links based on their costs and benefits. Partly drawing on the social exchange mechanisms, resource dependency theory (Pfeffer & Salancik, 1978) also suggests the importance of forming resource exchange linkages, which is considered to be closely related to power dependencies. The theories of self-interest and mutual interest discussed above describe the compositional phenomenon of team assembly. Teams are assembled as a result of the coalescence of individual team members so that they can achieve better performance by using the sum of individual effort and skills (Kozlowski & Klein, 2000). Social exchange theory and resource dependence theory explain the pattern of resources among connected individuals (Cook, 1982) from the compilational perspective and suggest that individuals team up with those who have skills or other resources they do not have. In other words, individuals tend to create team linkages with others who have complementary resources. When assembling a project team, various expertise and associated skills and resources are usually needed. Individuals possess different expertise that they can offer to others, and at the same time they need other's expertise to accomplish a project. Thus they form team linkages to exchange their expertise and benefit from this dependency. Many empirical studies on team assembly and performance confirm expertise diversity as an important goal of the collaboration among individuals with different skills and as a predictor of high team performance (Ancona & Caldwell, 1992; Reagans et al., 2004; Reagans & Zuckerman, 2001; Schippers, Hartog, Koopman, & Wienk, 2003). Hence based on the theories of exchange and dependency, the following hypothesis is proposed:

H4. Individuals are less likely to assemble into teams with others who possess the same expertise.

Homophily and swift trust. According to the theory of homophily, individuals with similar demographic characteristics are more likely to create linkages with each other, just as "birds of a feather flock together." Researchers found that, as a source of familiarity, predictability, comfort, and validation (K. Y. Williams & O'Reilly, 1998), similarity helps to facilitate communication, increases the predictability of behavior, and fosters trust (Brass, 1995). Evidence of homophily in terms of gender, age, education, occupation, status, etc. is found in both teams and inter-personal relations (Carley, 1991; Ibarra & Andrews, 1993; McPherson & Smith-Lovin, 1987; McPherson, Smith-Lovin, & Cook, 2001). In project teams, individuals of the same gender, similar age, and same organizational affiliation are expected to collaborate in the same team because the similarity makes it easier for them to work together.

Another perspective that supports the attribute matching between team members is "swift trust" (Meyerson, Weick, & Kramer, 1996), the rapid emergence of trust in ad hoc teams. Members of ad hoc project teams usually come from different backgrounds, have diverse skills, may not have worked together previously, and may not collaborate again in the future. Unlike long term members of stable teams, who can build trust based on history and personal experience (Kramer, 1999), members of ad hoc project teams usually have limited personal information about, and experience with, other teammates. Researchers attribute the development of swift trust to judgments based on social or organizational category information (Kramer, 1999; Meyerson et al., 1996). This valuable information enables members of project teams to develop expectations of each other and foster trust building. According to swift trust theory, individuals prefer to team up with others who share similar attributes because these form the common ground for building trust. For example, candidates of a certain age will find it easier to understand the behavior of others from the same cohort. Following the theories of homophily and swift trust, we propose three hypotheses on the individual attributes of gender, age, and organizational affiliation:

H5a. Individuals are more likely to assemble into teams with others of the same gender.

H5b. Individuals are more likely to assemble into teams with others of similar age.

H5c. Individuals are more likely to assemble into teams with others who are associated with the same organizational entity.

*Interaction of homophily and social exchange***.** The individual attributes considered in Hypothesis 5 all relate to the creation of team linkages based on similar demographic attributes. We further consider the impact of functional attributes (Pelled, Eisenhardt, & Xin, 1999), such as job-related skills. Just as knowledge, skills and abilities (KSA) are important elements in an individual selecting a job, they are important factors that influence individuals' decision to join a team (Cannon-Bowers & Salas, 1997; Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995; Zaccaro & Dirosa, 2012). As discussed above the theory of homophily predicts collaboration based on common demographic attributes. It also predicts that teams may form around shared functional attributes.

Furthermore, mechanisms other than homophily can also explain the potential matching of team members according to their functional attributes. Social exchange theory (Blau, 1964; Homans, 1958, 1974) suggests that individuals create ties to exchange resources and aim to benefit from these relations. As suggested by Agneessens and Wittek (2012), when resources such as skill are unevenly distributed among individuals, high skill individuals are less likely to team up with others of low skill. On the one hand, low skill individuals cannot provide the necessary returns to entice high skill individuals to join them. On the other hand, high skill individuals would prefer to collaborate with other high skill individuals to maximize their performance.

As suggested by this interaction between homophily theory and social exchange theory, when individuals of high skill team up with each other, they feel more comfortable and can offer each other an equivalent level of resources. Consequently, individuals of low skill are left to collaborate with others of low skill. We propose the following hypothesis based on individuals' skill levels:

H6. Individuals are more likely to assemble into teams with others of similar skill levels.

Coevolution. Ongoing interpersonal and team linkages can also develop from prior collaborations (Guimera et al., 2005; Gulati, 1995), and the previous experience of working together can improve individual or team performance (Cummings & Kiesler, 2008; Guimera et al., 2005; Hahn et al., 2008; Ruef et al., 2003). According to theories of coevolution (McKelvey, 1997), individuals seek out prior collaborators in order to harness these performance gains from repeated interaction. Previous collaboration experience can also help individuals easily assess each other's intentions and develop "history-based" trust (Kramer, 1999). In the assembly of project teams, individuals who previously collaborated in the same team have shared history, and thus a better mutual understanding, which may improve team performance (Costa, Roe, &

Taillieu, 2001). This potential benefit makes it more likely for individuals to work with their previous partners again. Hence, the theories of coevolution suggest the following hypothesis:

H7. Individuals are more likely to assemble into teams with those with whom they previously collaborated on a project.

Figure 2 summarizes the seven hypotheses proposed in this study with graphical illustrations. In the figure, circles represent individuals and squares represent projects. Nodes with certain attributes are indicated by gray shading. The plus or minus signs indicate positive or negative impacts of a hypothesized factor on the likelihood of team linkages. For instance, the gray circle in Figure 2a represents a person with a certain skill and the graph shows that the individual skill level has a negative impact on the likelihood of joining a team as described in Hypothesis 1. Similarly Figure 2d shows that two people with expertise in the same area are less likely to join a team (Hypothesis 4). Likewise, Figure 2g illustrates the scenario where two or more individuals who collaborated on one team are more likely to work together again on another team (Hypothesis 7).

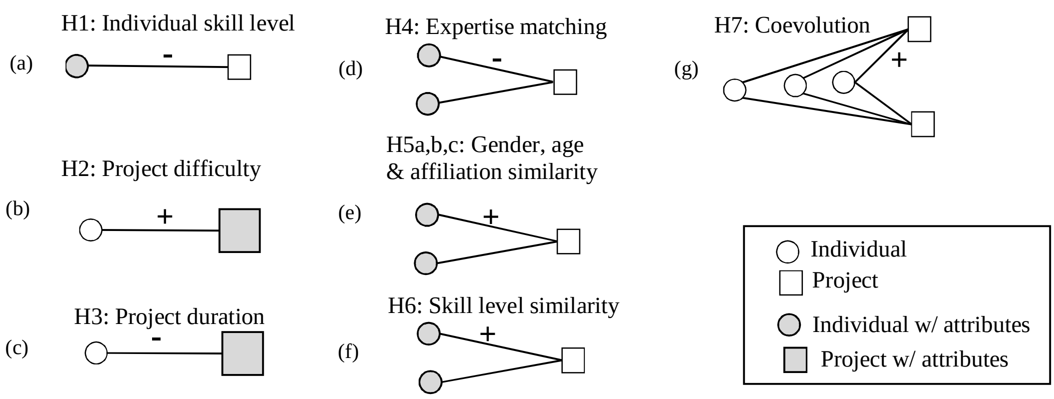


Fig. 2. Summary of hypotheses

4 Data and Method

We tested the hypotheses of project team assembly in the context of a large virtual world – EverQuest II, one of the largest fantasy based massively multiplayer online role-playing games (MMORPG). In EverQuest II, each player creates game characters, completes a set of combat activities, develops skills, and advances their levels in the game. The core of the game requires combat activities against monsters, which are non-player characters (NPCs) that can be attacked and can attack back. Other game activities include supporting actions such as preparing equipment and gathering plunder following a combat. In order to advance faster, player characters can form teams and collaborate with others to fight monsters and complete game activities in the virtual world.

Although players collaborate on game activities and interact virtually, the combat teams in EverQuest II share many common features with distributed project teams in more (non-game) organizational contexts. First, like organizational project teams, combat teams in EverQuest II are assembled around common interests or shared activities such as killing certain monsters. Sometimes, when facing extremely strong monsters, players need to form teams, discuss strategies, and coordinate their offensive and defensive activities. As in organizational project teams, members of the combat teams in EverQuest II do not necessarily have strong enduring relationships with one another. Teams disband after achieving a set of finite common goals and members may or may not collaborate again in the future. In addition, even though the specific benefits of winning and the cost of failure in EverQuest II are different from situations encountered by organizational project teams, members share similar experience to those in organizational contexts. When projects are successful, individuals benefit by gaining new skills and items; when projects are not successful, they experience delay in personal development, punishment, and a feeling of frustration.

Second, combat teams are embedded in an organizational and social context that exists in and extends beyond the virtual world. For example, 82% of players are affiliated with guilds, a type of virtual organization for game players. Members in a guild meet in its guild hall, a special in-game meeting place, and communicate through dedicated web forums to socialize or organize combat activities. Furthermore, guild members contribute to and increase the status of their guilds by completing certain projects in the game. In addition to providing meeting places and dedicate communication channels, a well-functioning guild provides its members other benefits, such as bonus items and extra equipment. In these ways, the function of a guild resembles that of a professional association in organizing and supporting collaborations among its members. Moreover, players bring their offline social relations into the virtual world. An independent survey conducted on EverQuest II players showed that around 70% of respondents played with friends or relatives whom they already knew offline (Dmitri Williams, Yee, & Caplan, 2008). These results suggest that game players' real and virtual lives are not totally separate like some in the media have conjectured. Players are individuals teaming up with other individuals, most probably someone they have known in the offline world.

4.1 Data Samples and Identifying Teams

The data samples are constructed from the server logs of the server “Guk”, one of the U.S. based EverQuest II game servers. Player information comes from a snapshot collected on September 4th 2006. We measured players' age and character skill levels at this time point. Based on the availability of data and the capacity of current statistical analysis tools, we took the following week as the sampling time period. Hence the team assembly data includes all combat activities conducted by the players between September 5th and September 11th, 2006.

Consistent with the definition of project teams, a combat team in EverQuest II is defined as a group of players who jointly accomplish a project in a finite amount of time. The project includes the combat activities of killing one or more monsters. EverQuest II has a built-in system to support the assembly of combat teams. Any individual can initiate a team and provide information on projects (or “quests”) to be finished and expected skills from teammates. This information is then made publicly available in the game. Others can search for potential teams and join the teams in which they are interested. One player can only join one team at a time. Hence the team assembly is an ad hoc self-organizing process. Although the information on the assembly teams is not explicitly available in the server log files, we were able to recover the combat teams by analyzing the records of combat activities in the server log files. To best recover the existing combat teams, we used the following three rules as guidelines. First, if a group of players gathered together at the same locations and fought monsters collaboratively, they belonged to the same combat team. In the log files, these records usually have consecutive sequential ids. Second, if the membership of a team changed, such as a member joining or leaving an existing team, we assumed that the new group of players formed a different team. This is reflected by the change of team size in the log records. Team size change happens when one or more team members *actively* join or leave the team. A temporary disconnection from the system due to network problems usually does not influence the team membership nor team size. Third, the disbanding of a team is signaled by the ceasing of activities. If an existing team does not have any activity for over 30 minutes, this indicates that the team had completed its project and disbanded. If the same set of players collaborates again in the future, they are considered as forming a new team working on another project. The 30 minute cut-off was chosen based on standards used in session detection in most web applications (Catledge & Pitkow, 1995; Cooley, Mobasher, & Srivastava, 1999). Further tests on our dataset shows that this cut-off gives stable results: using 1 hour or 2 hours as cut-off values, the number of teams identified did not significantly decrease. Based on the three rules above, we recovered 4,537 project teams assembled by 2,426 unique player characters in the one-week activity logs. We then generated the bipartite team network by connecting players with project teams they joined. This provided an exceptionally rich source of data on team assembly not easily obtained from offline sources. But this rich source of data also created a network that was computationally challenging to analyze.

We addressed this challenge by investigating networks within zones. The game world of EverQuest II is very large and is organized into relatively separate geographical regions called zones. Each zone is either a continent or a collection of connected islands, and there are few connection points between zones through travel services such as boats, griffons, and flying carpets. The zones are designed for players at different game stages with activity of different types and difficulty levels. Because of the separation and different design of the zones, we divided the team network into 12 subsets based on the zones where team projects occurred. Dividing the network into these separate zones had the added advantage of reducing one large network into 12 relatively distinct smaller networks which in turn made the analyses to test the hypotheses much more computationally feasible. Table 1 summarizes the descriptive statistics of the 12 zone-based subsets. As an example, Figure 3 shows a visualization of the team network in the zone Antonica, in which white circles indicate players and black squares indicate project teams. The visualization indicates that most players join only a handful of teams. The largest component indicates that a large proportion of the players are indirectly connected to many other players by virtue of joining common teams. But there are several isolated components of players who did not team up with many others. These represent collections of individuals who confine their choices of teammates to a small selection of other players. Networks from other zones are quite similar to Antonica.

Table 1. Descriptive statistics of 12 zone-based samples

Zone name	# players	# Teams	Avg Team Size
Antonica	333	426	3.01
Commonlands	239	318	3.04
Desert of Flames	473	687	3.47
Enchanted	514	653	3.73
Everfrost	192	189	3.66
Feerrott	216	220	3.90
Kingdom of Sky	451	648	3.20
Lavastorm	168	159	3.80
Nektulos	223	244	3.05
Qeynos	80	67	2.39
Thundering Steppes	612	757	3.24
Zek	168	169	2.85

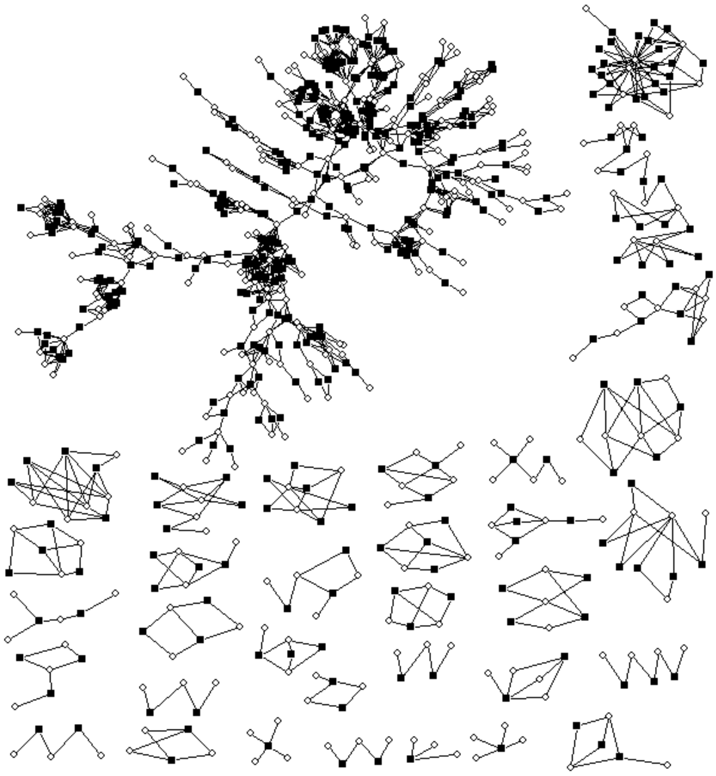


Fig. 3. Team network in Zone Antonica.

4.2 Measures

We computed six individual attributes, three project attributes, and one structural measure of player-project networks to test the seven hypotheses of project team assembly. The individuals in this study are players of EverQuest II and the projects accomplished by these project teams involve combat with monsters.

4.2.1 Gender and age

Player gender and age are obtained from the players' self-reported demographic information during registration. Although there are a few outliers, the statistics of the sample population are consistent with the results of an independent survey conducted in this game

(Dmitri Williams et al., 2008). Gender and age variables are used to control for differences in tendency to join project teams across different demographic groups. Gender matching and age differences are used to test Hypotheses 5a and 5b, which posit that players of the same gender or a similar age are more likely to join the same team.

4.2.2 Skill level

Player character level was used to measure a player's skill level in game activities. Starting at Level 1, players collect experience points from fighting monsters and advance up to Level 70. In general, the longer characters have played, the higher their level. This measure is used to test Hypothesis 1 which posits that players with higher levels are less likely to join combat teams. In addition, we use the level difference between players to test whether individuals will choose to team up with others of similar level (Hypothesis 6).

4.2.3 Expertise

In EverQuest II, players fall into four major classes, *fighter*, *priest*, *mage*, and *scout*, and develop expertise commensurate with their different roles in a team. For example, the major expertise of a fighter is to be the "tank" in a team and defend teammates by diverting the attention of monsters with which the team is fighting. The primary expertise of a priest is to protect teammates by "healing" them with magical powers. Mage and scout players provide the main offensive force of the team. The need for different expertise and skills in EverQuest II combat teams is similar to project teams in the real world. For example, in software development teams, members with different areas of expertise, such as designing, implementing, and coordinating, need to work together to improve efficiency and performance. Similarly, in a combat team, players want to join individuals with different areas of expertise in order to exchange resources and skills. We use this measure to test whether individuals are less likely to form teams with others having the same expertise (Hypothesis 4). In addition, we used three dummy variables (for the mage, priest and scout classes, with fighters as the base class) to control for the differential tendency of individuals with different areas of expertise to join teams.

4.2.4 Affiliation with an organizational entity

Affiliation with an organizational entity is measured in EverQuest II as membership in guilds. As in-game organizations, guilds organize team activities and facilitate team assembly through various channels. Guilds share a lot of similarities with organizations in the offline world. For example, EverQuest II offers members of guilds the possibility to gain access to a specific meeting place (called a guild hall) and special text-based in-game chat channels. Individuals can contribute to guilds by attending guild events and earn status points for the organization. In EverQuest II, each player can only join one guild at any time. 85.3% of the 2,426 unique players in the dataset were affiliated with one of 315 total guilds. We used matching of guild membership to test Hypothesis 5c, which posits that individuals are more likely to form teams with others who belong to the same organization (guild).

4.2.5 Project difficulty

Some projects are difficult and players need to work in a team in order to defeat monsters that are stronger than any single player. Although teams may fail several times or even give up before successfully killing the most difficult monsters, the highest levels of monsters they killed provide a good estimate of the overall difficulty of the project. Hence project difficulty is measured by the highest level of the monsters killed by a team. We used this measure to test Hypothesis 2, which posits that individuals are more likely to form a team to accomplish difficult projects.

4.2.6 Project duration

Project duration is measured by the number of minutes a team played together. Since individuals have their own time constraints, maintaining a team and finishing a big project needs more coordination. We used this measure to test Hypothesis 3, which posits that individuals are less likely to form larger teams to accomplish complex projects with a longer duration.

4.2.7 Re-teaming

In addition to player and project attributes, *re-teaming* measures the extent to which individuals who played together in one team also joined together in another team. We expect this structure to be frequently observed among individuals joining project teams (H7).

4.2.8 Control variables

In addition, we included control variables that may potentially impact the team assembly processes but are not the focus of this study. There are some extremely difficult monsters, called heroic and epic monsters in the game. It is impossible for any individual to defeat them and the system requires a team (rather than an individual) to fight such monsters. We used a dummy variable, *Teaming required*, to control for this system requirement.

Prior teaming measures the number of teams a player joined teams during the previous month, i.e. August 2006. This measure controls for a players' general tendency to join teams. Some players are simply more likely to join teams than others.

Three network statistics are used to control for basic network structures: the density of the network; the distribution of players' teaming propensity, e.g., whether there is a tendency for a few promiscuous players to join many teams are more likely to be observed; and the distribution of team sizes, i.e. whether big teams are more likely to be observed.

Table 2 reports the descriptive statistics of continuous and binary variables for the 2,426 players and 4,537 completed team projects. Appendix A provides these statistics by zone.

Table 2. Descriptive statistics of variables

Player Attributes	Mean	S.D.	Min	Median	Max
Female	0.34		0		1
Fighter expertise class	0.32		0		1
Priest expertise class	0.25		0		1
Mage expertise class	0.25		0		1
Scout expertise class	0.18		0		1
Age	33.86	9.85	14	33	76
Skill level	40.90	16.41	2	41	70
Prior teaming	6.42	9.80	0	3	88
Team Project Attributes	Mean	S.D.	Min	Median	Max
Teaming required	0.62		0		1
Project difficulty	39.03	14.81	8	38	72
Project duration	31.17	40.41	0	16	432

4.3 Statistical Analysis Method – ERGM/*p**

The network data used in this study poses significant analytical challenges. Traditional statistical techniques assume that observations are independent. However, the membership relations between a player and a team project are inter-dependent and form specific network structures. For example, one player may join multiple teams, which makes the observations on teams no longer independent from each other. As another example, two individuals who played on one team may be more likely to join another team together. In order to control for these endogenous effects, we used the bipartite version of the Exponential Random Graph Model or *p** model (ERGM/*p**) (Frank & Strauss, 1986; Robins & Pattison, 2005; Wang, Pattison, & Robins, in press; Wasserman & Pattison, 1996) to test the hypotheses.

ERGM/*p** was first developed to analyze one-mode networks and estimates the degree to which certain network configurations are likely to occur in observed networks while considering different levels of dependencies among node attributes and link structures (for a review, see

Robins et al., 2007). Starting with an initial effort by Skvoretz and Faust (1999), several researchers extended and applied the basic ERGM/*p** to affiliation networks (Agneessens & Roose, 2008; Agneessens, Roose, & Waege, 2004; Faust, Willert, Rowlee, & Skvoretz, 2002; Wang, Sharpe, et al., 2009). ERGM/*p** for bipartite networks offers an opportunity to examine networks based on multiple levels of analysis ranging from the nodal, dyadic, and triadic, to the group level. This makes ERGM/*p** particularly appropriate for examining the network structures in team assembly at the personal, dyadic, and team levels in this study. Specifically, we used the program BPNet (Wang, Sharpe, et al., 2009) to test the hypotheses. As with logistic regressions, positive and significant coefficients in bipartite ERGM/*p** models indicate that the corresponding structures are more likely to occur than random chances.

5 Results

The hypotheses were tested for the relatively distinct networks in each of the twelve zones: three hypotheses that describe the impact of individual attributes and project attributes on team assembly and four hypotheses that posit dyadic level effects on team assembly. Each model also includes the 10 control variables described above. Table 3 reports the detailed results, again using the Antonica zone as an example. The absolute values of the convergence statistics of all the effects in the model are below an acceptable 0.1. Technical details on BPNet terms included in the model are listed in Appendix B and the goodness of fit of the model for zone Antonica is available in Appendix C as an example. More technical details are available on request.

Table 3. ERGM/*p** model results for one zone (Antonica)

Effect	Hypothesis	Estimate (S.E.)
Density (edge)	Control	-0.78 (.62)
Player's teaming propensity (player alt. k-stars)	Control	0.23* (.10)
Big teams (team alt. k-stars)	Control	-2.81* (.41)
Female	Control	0.05 (.10)
Age	Control	0.01* (.003)
Priest expertise class	Control	-0.17 (.09)
Mage expertise class	Control	-0.32* (.09)
Scout expertise class	Control	-0.51* (.10)
Prior teaming	Control	0.01* (.003)
Team required	Control	1.05* (.17)
Skill level	H1	-0.007 (.004)
Project difficulty	H2	0.03* (.007)
Project duration	H3	-0.008* (<.001)
Expertise matching	H4	-0.57* (.08)
Gender matching	H5a	-0.007 (.06)
Age difference	H5b	-0.01* (.002)
Guild matching	H5c	1.32* (.03)
Skill level difference	H6	-0.03* (.004)
Re-teaming (alt. k-2-paths linked by players)	H7	0.02* (.009)

* indicates p<0.05

Results show that the main effect of player skill level is not significant. There is no evidence to support the argument that players who have low skills (lower levels) are more likely to join combat teams than those who have higher skills. Hence Hypothesis 1 is not supported. As predicted by Hypotheses 2 and 3, project difficulty has a significant positive impact and project duration has a significant negative impact on project team assembly; that is, players are more likely to join team projects to fight more difficult monsters but are less likely to join team projects that take a longer duration. The coefficient of expertise matching is negative and significant. That is, individuals are less likely to join project teams with members who possess the same class of expertise (e.g., scouts not teaming with other scouts and fighters not teaming with other fighters).This shows a strong effect of complementarity in project teams in that players are less likely to play with others in the same expertise class. As proposed in Hypothesis 4, players are more likely to join a project team with players of different expertise. Gender, age, and guild affiliation homophily (Hypotheses 5a, 5b and 5c) are partly supported. The coefficient for age difference is negative and significant. This shows that, as predicted by Hypothesis 5b, players are less likely to team up with those of a different age. A positive and significant coefficient for guild matching indicates that, as posited by Hypothesis 5c, being in the same guild greatly increases the chance for two players to join the same project team. The effect of gender matching, however, is not significant and individuals are not more likely to join teams with others of the same gender. The gender homophily hypothesis (H5a) is therefore not supported. The negative and significant coefficient of player level difference indicates that players are less likely to join teams with others whose levels are very different from their own, supporting Hypothesis 6. Finally, the re-teaming (alternating k-2-paths linked by players) has a positive impact as predicted in Hypothesis 7. As suggested in previous literature (Agneessens & Roose, 2008; Wang, Sharpe, et al., 2009), this term can be interpreted as the tendency to observe two teams sharing multiple members. A positive and significant coefficient indicates that more cases of two teams sharing many common members are observed in the teaming network than expected by random chance. Therefore, as posted by Hypothesis 7, individuals who collaborated on one team project are more likely to collaborate together on another team project. From the perspective of an individual, if this focal individual has been on one team with other individuals and these other individuals join another team at a later time, it is more likely for the focal individual to also join this new team than any other team with strangers.

As for the control variables, the positive coefficient of players' propensity to join teams (i.e. player alternating k-stars) can be interpreted in the following way: Some players joined more teams than expected in a random network while other players joined fewer teams (Wang, Sharpe, et al., 2009). In other words, there is a high variance in the number of teams that players joined and there are a significant number of very promiscuous team players. Similarly, the negative coefficient of team alternating k-stars (our control for big teams) suggests that teams tend to have relatively similar sizes. Taken together, the above two effects indicate that teams in EverQuest II have similar sizes, even though players vary substantially in the number of teams they joined.

The non-significant coefficient for female gender indicates that there is no evidence to suggest that females have a different tendency to join teams than males. The positive and significant coefficient of age suggests that older players are more likely to join teams than are younger players. The coefficients for the binary indicator variables for priest, mage, and scout expertise class indicate the relative tendency for players of these three expertise classes to join teams, as compared to the fighter class. For instance, a negative coefficient for the mage expertise class suggests that players in the mage expertise class are less likely to join teams compared to those in the fighter expertise class. A positive and significant coefficient for prior teaming indicates that individuals who joined a lot of teams previously are likely to continue that trend, and this variable helps to control for this general effect. The team level variable *Teaming required* captures the impact of game design in the cases where joining teams to accomplish are mandatory.

Estimation results are mostly consistent across the twelve zones. To show the overall impacts, we use the meta-analysis approach proposed by Snijders and Baerveldt (2003) to summarize all results and report the results in the same format (See Table 4).

Table 4. Results of meta-analyses for all twelve zones

Effect	Hypothesis	N	T^2	$\hat{\mu}_\theta^{WLS}$	(s.e.)	$\hat{\sigma}_\theta$	Q	(p)
Density (edge)	Control	12	536	-0.85	(2.40)	8.22	263.26	(<0.001)
Player's teaming propensity (player alt. k-stars)	Control	12	94	-0.006	(0.128)	0.41	88.49	(<0.001)
Big teams (team alt. k-stars)	Control	12	213	-2.57*	(1.29)	4.41	175.02	(<0.001)
Female	Control	12	131	-0.25	(0.14)	0.45	99.47	(<0.001)
Age	Control	12	96	0.01*	(0.002)	0.00	65.63	(<0.001)
Priest expertise class	Control	12	54	-0.16*	(0.06)	0.16	23.10	(0.017)
Mage expertise class	Control	12	512	-0.14*	(0.06)	0.15	39.81	(<0.001)
Scout expertise class	Control	12	115	-0.33*	(0.06)	0.17	20.42	(0.040)
Prior teaming	Control	12	778	0.02*	(0.002)	0.00	85.46	(<0.001)
Teaming required	Control	12	241	0.51*	(0.09)	0.25	55.73	(<0.001)
Skill level	H1	12	167	-0.004	(0.006)	0.00	142.33	(<0.001)
Project difficulty	H2	12	258	0.06*	(0.01)	0.03	52.78	(<0.001)
Project duration	H3	12	156	-0.01*	(<0.001)	0.00	20.10	(0.044)
Expertise matching	H4	12	1253	-0.84*	(0.08)	0.24	98.58	(<0.001)
Gender matching	H5a	12	201	-0.15	(0.10)	0.35	155.24	(<0.001)
Age difference	H5b	12	378	-0.01*	(0.003)	0.00	159.68	(<0.001)
Guild matching	H5c	12	20671	1.44*	(0.12)	0.43	722.21	(<0.001)
Skill level difference	H6	12	2358	-0.06*	(0.008)	0.03	462.98	(<0.001)
Re-teaming (alt. k-2-paths linked by players)	H7	12	1367	-0.03	(0.03)	0.11	165.25	(<0.001)

* p<0.05

In Table 4, *N* indicates that the meta-analyses for each measure are based on all 12 zones. The effect strength is captured and reported as T^2, which was used in the meta-analysis model to test whether or not the total effect is nil (Snijders & Baerveldt, 2003). A larger T^2 indicates a stronger effect in the corresponding hypothesis. For instance, the strongest effect is guild matching with $T^2 = 20671$, which indicates that guild matching is a very important factor that influences team assembly. The estimated average effect size $\hat{\mu}_\theta^{WLS}$ reported in Table 4 shows that in the meta-analyses, all measures we tested are consistent with the results from Antonica (reported in Table 3) except for re-teaming (H7). This further suggests that Antonica is not unusual among the samples. The last three columns report the estimated between-zone standard deviation of the effect size, the statistic for testing that true effect variance is zero, and the *p*-value of the test (Snijders & Baerveldt, 2003). For all effects included in our model, the true parameter variances are significant with $p<.05$. That is to say that the true parameter variances are significantly different from zero even though some of the standard deviations are quite small, and the true effect sizes might be different across different zones. This explains the non-significant effect of re-teaming measured by the alternating k-2-path (linked by players) statistics. In fact, this effect is significant in eight of twelve zones: five positive and three negative. This indicates players are more likely to team up with their previous teammates in five zones, but less likely in three zones. This might be related to the differences in the nature of the zones. For instance, the three zones with negative re-teaming tendencies are all less accessible, which lowers the chances of the same set of players to meet each other in these zones in the first place. The five zones with positive re-teaming tendencies, in comparison, are relatively easy to reach in the game.

Overall, together with small p-values, the results show that, with the exception of re-teaming, players have similar team assembly behaviors across all zones.

6 Discussion and conclusion

This study explored the self-assembly mechanisms of project teams using multiple social theories at various levels utilizing the data on teams in EverQuest II. Theories of self-interest (H1), mutual interest and collective action (H2), and coordination (H3) reveal the personal motivations behind team formation. They rely on characteristics of individuals such as their skill level and features of projects such as task difficulty and duration. Theories of exchange and dependency, homophily, and of coevolution (H7) explain the dyadic motivations for team assembly. Specifically they focus on matching up attributes of potential team members, such as complementary expertise (H4), homophily on demographic attributes (H5a, H5b, and H5c), matching of individual skill levels (H6), and re-teaming (H7).

Although Hypothesis 1 suggests that individual skill levels would have a negative impact on the likelihood of joining teams, i.e. game players at low levels are more likely to join teams, we found no significant effect of skill level. However, at the team project level, project difficulty had a positive impact on team formation, while project duration had a negative impact – players are more likely to team up for difficult projects (H2) and less likely to team up for projects with long durations (H3). Controlling for the fact that some projects require teams and the fact that some individuals tend to work in teams, the results show that players team up to reduce the gap between project difficulty and their abilities and achieve better performance. However, if projects are too complex and require an extended period of collaboration, potential coordination costs offset the potential performance gains of teaming up and individuals are less likely to engage in the collaboration. For example, software developers would not team up because of a lack of skills, but because of project characteristics. Even a highly skilled programmer may not be capable of finishing a difficult project alone. The self-assembling mechanisms discussed here many not be applicable for long-term, complex development, which usually requires persistent coordination and management.

Besides the main effects of individual and project attributes on team assembly, individuals tend to choose their teammates based on the expertise needed and other matching criteria. In EverQuest II, class matching has a significant negative impact – if two players have the same expertise class their odds of being on the same team are only 43% (i.e. $e^{-0.84}$) of those with different classes (H4). With four player expertise classes in the game, teams implement certain group strategies to exploit the complementarity of diverse expertise. Even though a team does not necessarily include all four classes, having players with different expertise, such as attacking, defending, and supporting makes a team more efficient and more attractive to other players. This is analogous to assembling members with different roles, such as project sponsors, facilitators, and subject matter experts, for a successful organizational project.

Other than player expertise, homophily effects are observed for team assembly based on player age (H5b) and organizational affiliation (H5c). Results show that teams tend to be formed by players of similar age: older players join older players and younger players join younger players, after controlling for older players' tendency to join more teams. At the same time, guild affiliation facilitates team formation. If two players are in the same guild, their odds of being on the same team are 4.22 times (i.e. $e^{1.44}$) higher than for those in different guilds. These findings suggest that players rely on social and organizational relations to build swift trust and form teams. Gender homophily, however, is not supported by the results (H5a). Additional analysis suggests that male players tend to play with males, but females also tend to play with males. One potential explanation provided in Williams, et al., (2009) is that 32% of people play EverQuest II with a romantic partner. Actually, the lack of offline records makes it hard to rule out the impact of pre-existing offline relations. A substantial number of women played EverQuest II in order to gain the attention of their male significant others who were consumed with the game and were likely to neglect their partners offline. This insight can also explain the findings of Hypotheses 5a, 5b, and 5c since the partners usually have similar ages and different genders and join the same guild.

Skill level differentials are another important factor for assembling into teams. Our results support Hypothesis 6 in which players with a large difference in skill levels are less likely to play together in a team. This suggests that matching of skill levels is one of the foundations of team assembly. To entice others to collaborate, individuals must be able to offer different resources but at the same level as their teammates.

Finally, our results show no consistent effect for re-teaming (H7): individuals re-team with their previous teammates only in some zones. In the literature on teams, previous collaboration history is an important factor to nurture further collaboration (Hahn et al., 2008), and repeated collaborations form the basis of successful collaboration (Cummings & Kiesler, 2008; Guimera et al., 2005; Ruef et al., 2003). However, one can also speculate that collaborations among repeated incumbents preclude the introduction of new ideas and innovation (Lazer et al., 2009). The mixed findings here might be due to the different restrictions across the game zones and these results call for future comparative studies.

This study contributes to the literature of team studies and social network analysis in two ways. First, we adopt a bipartite perspective of project teams and study team linkages as relations between individuals and their projects. As discussed above, this method enables us to simultaneously study individual level attributes, team project level attributes, and team relations in one model. Second, we address the difficulties of data collection and processing in large-scale team studies by utilizing digital traces of team assembly behavior in online contexts. This illustrates the recent interests in advancing computational social science (Contractor, 2013; Ducheneaut, Yee, Nickell, & Moore, 2006; Lazer et al., 2009). EverQuest II provides a socially oriented game environment and encourages players to work collectively on in-game projects. The content and difficulty levels of in-game projects as well as players' related skills and experience are well defined and quantitatively measurable. Hence the game world provides an ideal test bed to examine the impact of individual and project attributes as well as of individual interactions on the process of self-assembling project teams with considerable generalizability to organizational contexts. Indeed the insights from team assembly in virtual worlds are increasingly generalizable since the millennial generation constituting the emerging workforce has been weaned on virtual worlds and online games.

There are also limitations of using data in virtual worlds. A primary concern is whether online teams behave like teams traditional organizational contexts. People in virtual worlds interact online, perform activities through avatars, and try to accomplish fantasy tasks. Although this study reveals that people have collaboration behavior consistent with various social theories, there is clearly room for more research to identify boundary conditions for the applicability of these findings to offline settings. The second limitation of this research is related to the game context. As commercial entertainment products, online games implement certain mechanisms and constraints. EverQuest II has multiple game zones with different activity settings: some have easy tasks for beginners and facilitate social interactions, while some are dedicated to a few difficult tasks. This heterogeneous design may induce different behavior across the zones. In addition, unlike World of Warcraft in which players can finish tasks and advance levels by themselves (D. Williams, 2010), EverQuest II encourages group activities and collaboration in teams through certain level restrictions. It is very difficult for one player to defeat a monster in EverQuest II if the monster is of a higher level than the player, and some monsters require team participation regardless of player levels. Although we applied various control variables to reduce the impact of the game design, some external effects may remain. A third limitation relevant to our study in particular is that we only investigated teams with specific well-defined activities. If teams did not leave any combat logs, their formation process was not captured. As we mentioned at the start of this study, the findings we report must only be considered as relevant to project teams that conduct well-defined activities over a fine short period of time.

Despite these limitations, our results suggest that project characteristics and team member matching are two important factors for the process of self-assembling in project teams. Even though in-game projects usually involve defeating monsters instead of designing software or developing a sales plan, the underlying principles of teaming to solve a task at hand are consistent. The mapping principle outlines a systematic approach to investigate conditions under which mechanisms identified in online environments are also generalizable in the offline contexts. Moreover, because of the growth of virtualization and gamification (Reeves & Malone, 2007; Reeves, et al., 2008), more companies conduct their projects in a distributed digital environment and recast routine tasks into games. As such, the mechanisms of virtual team formation are critical to understanding this new type of collaboration.

The virtual teams we studied have four essential features: they are temporary and self-organized, their projects are well-defined, and they bring together diverse expertise. Everyone has transparent information about both projects and potential team members, and everyone tries to improve their personal efficiency by utilizing others' expertise over the course of the project. As such, the findings apply only to similar temporary teams in the real world, such as scientific collaboration teams, open source software development teams, and training teams. Teams with different objectives, such as product innovation and social interaction, may have different formation mechanisms.

Finally, in this study, we used individual and project attributes to study the self-assembly of project teams and we modeled the relations between individuals indirectly through the matching of their attributes. Due to the limitations of the data and the constraints of current techniques to analyze bipartite networks, individual social relations such as friendship were not incorporated in the models directly. Future research conceptualizing teams as hypergraphs (Taramasco, Cointet, & Roth, 2010) offers a promising avenue to address this limitation. We also did not consider the temporal effect of team assembly. Exploring the impact of pre-existing relations on the dynamic process of team assembly and the evolution of team assembly represents important areas for future research, especially with the availability of recently developed models for such analysis (Koskinen & Edling, 2012; Snijders, Lomi, & Torló, in press).

Acknowledgement

This study was supported by the National Natural Science Foundation (Grant No. BCS-0940851, OCI-1244747, & IIS-1249137). We also would like to thank the guest editors and the anonymous reviewers for their constructive suggestions and comments.

References

Acedo, F. J., Barroso, C., Casanueva, C., & Galán, J. L. (2006). Co-Authorship in Management and Organizational Studies: An Empirical and Network Analysis. *Journal of Management Studies, 43*(5), 957-983.

Agneessens, F., & Roose, H. (2008). Local structural patterns and attribute characteristics in 2-mode networks: p* models to map choices of theater events. *Journal of Mathematical Sociology, 32*, 204-237.

Agneessens, F., Roose, H., & Waege, H. (2004). Choices of theatre events: p* models for affiliation networks with attributes. *Developments in Social Network Analysis, Metodoloski Zvezki, 1*, 419-439.

Agneessens, F., & Wittek, R. (2012). Where do intra-organizational advice relations come from? The role of informal status and social capital in social exchange. *Social Networks, 34*(3), 333-345.

Ancona, D. G., & Caldwell, D. F. (1992). Demography and Design: Predictors of New Product Team Performance. *ORGANIZATION SCIENCE, 3*(3), 321-341. doi: 10.1287/orsc.3.3.321

Becker, G. S., & Murphy, K. M. (1992). The Division of Labor, Coordination Costs, and Knowledge. *The Quarterly Journal of Economics, 107*(4), 1137-1160

Beyene, T., Hinds, P. J., & Cramton, C. (2009). Walking through jelly: Language proficiency, Emotions, and disrupted collaboration in global work. Working paper: Harvard Business School.

Blau, P. (1964). *Exchange and Power in Social Life*. New York: Wiley.

Brass, D. J. (1995). A social network perspective on human resources management. *Research in Personnel and Human Resources Management, 13*, 39-79.

Cannon-Bowers, J. A., & Salas, E. (1997). Teamwork competencies: The intersection of team member knowledge, skills, and attitudes. In H. F. O'Neil (Ed.), *Workforce readiness: Competencies and assessment* (pp. 151-174). Hillsdale, NJ: LEA.

Cannon-Bowers, J. A., Tannenbaum, S. I., Salas, E., & Volpe, C. E. (1995). Defining competencies and establishing team training requirements. In R. A. G. E. Salas (Ed.), *Team effectiveness and decision making in organizations* (pp. 333-380). San Francisco, CA: Jossey-Bass.

Carley, K. (1991). A theory of group stability. *American Sociological Review, 56*(June), 331-354.

Catledge, L., & Pitkow, J. (1995). Characterizing browsing behaviors on the World Wide Web. *Computer Networks and ISDN Systems, 27*(6), 1065-1073.

Cohen, S. G., & Bailey, D. E. (1997). What Makes Teams Work: Group Effectiveness Research from the Shop Floor to the Executive Suite. *Journal of Management, 23*(3), 239-290. doi: 10.1177/014920639702300303

Coleman, J. S. (1986). *Individual interests and collective action: Selected essays*. New York: Cambridge University Press.

Contractor, N. (2013). Some assembly required: leveraging Web science to understand and enable team assembly. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 371*(1987). doi: 10.1098/rsta.2012.0385

Contractor, N., Wasserman, S., & Faust, K. (2006). Testing multi-theoretical multilevel hypotheses about organizational networks: An analytic framework and empirical example. *Academy of Management Review, 31*, 681-703.

Cook, K. S. (1982). Network structures from an exchange perspective. In P. V. Marsden & N. Lin (Eds.), *Social structure and network analysis* (pp. 177-218). Beverly Hills, CA: Sage.

Cooley, R., Mobasher, B., & Srivastava, J. (1999). Data preparation for mining world wide web browsing patterns. *Knowledge and Information Systems, 1*(1), 5-32.

Corman, S. R., & Scott, C. R. (1994). Perceived Networks, Activity Foci, and Observable Communication in Social Collectives. *Communication Theory, 4*(3), 171-190.

Costa, A. C., Roe, R. A., & Taillieu, T. (2001). Trust within teams: The relation with performance effectiveness. *European Journal of Work and Organizational Psychology, 10*(3), 225-244. doi: 10.1080/13594320143000654

Cummings, J. N., & Kiesler, S. (2008). *Who Collaborates Successfully? Prior Experience Reduces Collaboration Barriers in Distributed Interdisciplinary Research.* Paper presented at the Cscw: 2008 Acm Conference on Computer Supported Cooperative Work, Conference Proceedings, New York.

Dabbish, L., Stuart, C., Tsay, J., & Herbsleb, J. (2012). *Social coding in GitHub: Transparency and collaboration in an open software repository.* Paper presented at the the 2012 ACM Conference on Computer Supported Cooperative Work, Seattle, Washington.

Ducheneaut, N., Yee, N., Nickell, E., & Moore, R. J. (2006). *"Alone together?": exploring the social dynamics of massively multiplayer online games.* Paper presented at the the SIGCHI conference on Human Factors in computing systems, ACM, Montréal, Québec, Canada.

Faust, K., Willert, K. E., Rowlee, D. D., & Skvoretz, J. (2002). Scaling and statistical models for affiliation networks: Patterns of participation among Soviet politicians during the Brezhnev era. *Social Networks, 24*, 231-259.

Feld, S. L. (1981). The Focused Organization of Social Ties. *The American Journal of Sociology, 86*(5), 1015-1035.

Fong Boh, W., Slaughter, S. A., & Espinosa, J. A. (2007). Learning from Experience in Software Development: A Multilevel Analysis. *Management Science, 53*(8), 1315-1331. doi: 10.1287/mnsc.1060.0687

Frank, O., & Strauss, D. (1986). Markov Graphs. *Journal of the American Statistical Association, 81*(395), 832-842.

Fulk, J., Flanagin, A. J., Kalman, M. E., Monge, P. R., & Ryan, T. (1996). Connective and communal public goods in interactive communication systems. *Communication Theory, 6*(1), 60-87.

Fulk, J., Heino, R., Flanagin, A. J., Monge, P. R., & Bar, F. (2004). A Test of the Individual Action Model for Organizational Information Commons *Organization Science, 15*, 569-585.

Granovetter, M. (1985). Economic Action and Social Structure: The Problem of Embeddedness. *The American Journal of Sociology, 91*(3), 481-510.

Guimera, R., Uzzi, B., Spiro, J., & Amaral, L. A. N. (2005). Team Assembly Mechanisms Determine Collaboration Network Structure and Team Performance. *Science, 308*, 697-702.

Gulati, R. (1995). Social Structure and Alliance Formation Patterns: A Longitudinal Analysis. *Administrative Science Quarterly, 40*(4), 619-652.

Gulati, R., & Singh, H. (1998). The Architecture of Cooperation: Managing Coordination Costs and Appropriation Concerns in Strategic Alliances. *Administrative Science Quarterly, 43*(4), 781-814

Hackman, J. R., & Katz, N. (2010). Group behavior and performance. In S. T. Fiske, D. T. Gilbert & G. Lindzey (Eds.), *Handbook of social psychology* (5th ed., pp. 1208-1251). New York: Wiley.

Hahn, J., Moon, J. Y., & Zhang, C. (2008). Emergence of New Project Teams from Open Source Software Developer Networks: Impact of Prior Collaboration Ties. *Information Systems Research, 19*(3), 369-391. doi: 10.1287/isre.1080.0192

Hinds, P., Liu, L., & Lyon, J. (2011). Putting the Global in Global Work: An Intercultural Lens on the Practice of Cross-National Collaboration. *The Academy of Management Annals, 5*, 135-188.

Homans, G. C. (1958). Social behavior as exchange. *Journal of American Sociology, 62*, 597-606.

Homans, G. C. (1974). *Social Behavior: Its elementary forms*. New York: Harcourt Brace Jovanovich.

Huckman, R. S., Staats, B. R., & Upton, D. M. (2009). Team Familiarity, Role Experience, and Performance: Evidence from Indian Software Services. *Management Science, 55*(1), 85-100. doi: 10.1287/mnsc.1080.0921

Ibarra, H., & Andrews, S. B. (1993). Power, social influence, and sense-making: Effects of network centrality and proximity on employee perceptions. *Administrative Science Quarterly, 38*, 277-303.

Johnson, N., Xu, C., Zhao, Z., Ducheneaut, N., Yee, N., Tita, G., & Hui, P. M. (2009). Human group formation in online guilds and offline gangs driven by a common team dynamic. *Physical Review E, 79*(6), 066117.

Jones, B. F., Wuchty, S., & Uzzi, B. (2008). Multi-University Research Teams: Shifting Impact, Geography, and Stratification in Science. *Science, 322*, 1259-1262.

Katz, N., Lazer, D., Arrow, H., & Contractor, N. (2004). Network Theory and Small Groups. *Small Group Research, 35*(3), 307-332. doi: 10.1177/1046496404264941

Keegan, B., Gergle, D., & Contractor, N. (2013). Hot Off the Wiki: Structures and Dynamics of Wikipedia's Coverage of Breaking News Events. *American Behavioral Scientist*. doi: 10.1177/0002764212469367

Koskinen, J., & Edling, C. (2012). Modelling the evolution of a bipartite network—Peer referral in interlocking directorates. *Social Networks, 34*(3), 309-322. doi: 10.1016/j.socnet.2010.03.001

Kozlowski, S. W. J., & Klein, K. J. (2000). A multilevel approach to theory and research in organizations: Contextual, temporal, and emergent processes. In K. J. Klein & S. W. J. Kozlowski (Eds.), *Multilevel theory, research and methods in organizations: Foundations, extensions, and new directions* (pp. 3-90). San Francisco, CA: Jossey-Bass.

Kramer, R. M. (1999). Trust and distrust in organizations. *Annual Review of Psychology, 50*, 569-598.

Lazer, D., Pentland, A., Adamic, L., Aral, S., Barabasi, A.-L., Brewer, D., . . . Van Alstyne, M. (2009). Computational Social Science. *Science, 323*(5915), 721-723. doi: 10.1126/science.1167742

Malone, T. W., & Crowston, K. (1994). The interdisciplinary study of coordination. *Computing Surveys, 26*(1), 87-119.

Margolin, D., Ognyanova, K., Huang, M., Huang, Y., & Contractor, N. (2012). Team Formation and Performance on Nanohub: A Network Selection Challenge in Scientific Communities. In a. M. S. Balázs Vedres (Ed.), *Networks in Social Policy Problems* (pp. 80-100). Cambridge UK: Cambridge University Press.

Mathieu, J., Maynard, M. T., Rapp, T., & Gilson, L. (2008). Team Effectiveness 1997-2007: A Review of Recent Advancements and a Glimpse Into the Future *Journal of Management, 34*, 410-476.

Maznevski, M. L., & Chudoba, K. M. (2000). Bridging space over time: Global virtual team dynamics and effectiveness. *Organization Science, 11*, 473-492.

McKelvey, B. (1997). Quasi-natural organization science. *Organization Science, 8*(4), 352-380.

McPhee, R. D., & Corman, S. R. (1995). An activity-based theory of communication networks in organizations. *Communication Monographs, 62*(2), 132-151.

McPherson, M., & Smith-Lovin, L. (1987). Homophily in voluntary organizations: Status distance and the composition of face to face groups. *American Sociological Review, 52*.

McPherson, M., Smith-Lovin, L., & Cook, J. M. (2001). Birds of a feather: Homophily in social networks. *Annual Review of Sociology, 27*, 415-444.

Meyerson, D., Weick, K., & Kramer, R. (1996). Swift trust and temporary groups. In R. T. Kramer, T. (Ed.), *Trust in Organizations: Frontiers of Theory and Research* (pp. 166-195). Thousand Oaks, CA, US: Sage Publications, Inc.

Mintzberg, H. (1980). Structure in 5's: A Synthesis of the Research on Organization Design. *Management Science, 26*(3), 322-341. doi: 10.1287/mnsc.26.3.322

Monge, P., & Contractor, N. (2003). *Theories of Communication Networks*. Oxford, UK: Oxford University Press.

Pelled, L. H., Eisenhardt, K. M., & Xin, K. R. (1999). Exploring the Black Box: An Analysis of Work Group Diversity, Conflict, and Performance. *Administrative Science Quarterly, 44*(1), 1-28.

Pfeffer, J., & Salancik, G. R. (1978). *The External Control of Organizations: A Resource Dependence Perspective*. New York, NY: Harper and Row.

Poole, M. S., Hollingshead, A. B., McGrath, J. E., Moreland, R. L., & Rohrbaugh, J. (2004). Interdisciplinary Perspectives on Small Groups. *Small Group Research, 35*(1), 3-16. doi: 10.1177/1046496403259753

Putnam, L. L. (2003). Rethinking the nature of groups: A bona fide group perspective. In R. Y. Hirokawa, Cathcart, R.S., Samovar, L.A. and Henman, L.D. (Ed.), *Small group communication theory and practice: An anthology* (pp. 8-16). Roxbury, Los Angeles.

Putnam, L. L., & Stohl, C. (1990). Bona fide groups: a reconceptualization of groups in context. *Communication Studies, 41*(3), 248-265.

Reagans, R., Zuckerman, E., & McEvily, B. (2004). How to Make the Team: Social Networks vs. Demography as Criteria for Designing Effective Teams. *Administrative Science Quarterly, 49*(1), 101-133.

Reagans, R., & Zuckerman, E. W. (2001). Networks, Diversity, and Productivity: The Social Capital of Corporate R&D Teams. *Organizational Science, 12*(4), 502-517. doi: 10.1287/orsc.12.4.502.10637

Reeves, B., & Malone, T. (2007). Leadership in Games and at Work: Implications for the Enterprise of Massively Multiplayer Online Role-playing Games. Retrieved from http://www.seriosity.com/downloads/Leadership_In_Games_Seriosity_and_IBM.pdf

Reeves, B., Malone, T. W., & O'Driscoll, T. (2008). Leadership's Online Labs. *Harvard Business Review, 86*(5), 58-67.

Roberts, J. A., Hann, I.-H., & Slaughter, S. A. (2006). Understanding the Motivations, Participation, and Performance of Open Source Software Developers: A Longitudinal Study of the Apache Projects. *Management Science, 52*(7), 984-999. doi: 10.1287/mnsc.1060.0554

Robins, G., & Pattison, P. (2005). Interdependencies and social processes: Dependence graphs and generalized dependence structures. In P. J. Carrington, J. Scott & S. Wasserman (Eds.), *Models and Methods in Social Network Analysis*. New York: Cambridge University Press.

Robins, G., Pattison, P., Kalish, Y., & Lusher, D. (2007). An introduction to exponential random graph (p*) models for social networks. *Social Networks, 29*(2), 173-191.

Ruef, M., Aldrich, H. E., & Carter, N. M. (2003). The Structure of Founding Teams: Homophily, Strong Ties, and Isolation among U.S. Entrepreneurs. *American Sociological Review, 68*(2), 195-222.
Schiller, S. Z., & Mandviwalla, M. (2007). Virtual Team Research: An Analysis of Theory Use and a Framework for Theory Appropriation. *Small Group Research, 38*(1), 12-59.
Schippers, M. C., Hartog, D. N. D., Koopman, P. L., & Wienk, J. A. (2003). Diversity and Team Outcomes: The Moderating Effects of Outcome Interdependence and Group Longevity and the Mediating Effect of Reflexivity. *Journal of Organizational Behavior, 24*(6), 779-802.
Skvoretz, J., & Faust, K. (1999). Logit models for affiliation networks. In M. E. Sobel & M. P. Becker (Eds.), *Sociological Methodology 1999* (Vol. 29, pp. 253-280). Cambridge, MA: Basil Blackwell.
Snijders, T. A. B., & Baerveldt, C. (2003). A Multilevel Network Study of the Effects of Delinquent Behavior on Friendship Evolution. *The Journal of Mathematical Sociology, 27*(2), 123 - 151.
Snijders, T. A. B., Lomi, A., & Torló, V. J. (in press). A model for the multiplex dynamics of two-mode and one-mode networks, with an application to employment preference, friendship, and advice. *Social Networks*. doi: 10.1016/j.socnet.2012.05.005
Stewart, G. (2006). A Meta-Analytic Review of Relationships Between Team Design Features and Team Performance. *Journal of Management, 32*(1), 29-55.
Sundstrom, E., McIntyre, M., Halfhill, T., & Richards, H. (2000). Work groups: From the Hawthorne studies to work teams of the 1990s and beyond. *Group Dynamics: Theory, Research, and Practice, 4*(1), 44-67. doi: 10.1037/1089-2699.4.1.44
Taramasco, C., Cointet, J.-P., & Roth, C. (2010). Academic team formation as evolving hypergraphs. *Scientometrics, 85*(3), 721-740.
Uzzi, B. (1997). Social structure and competition in interfirm networks: The paradox of embeddedness. *Administrative Science Quarterly, 42*, 35-67.
Wang, P., Pattison, P., & Robins, G. (in press). Exponential random graph model specifications for bipartite networks—A dependence hierarchy. *Social Networks*. doi: 10.1016/j.socnet.2011.12.004
Wang, P., Robins, G., & Pattison, P. (2009). PNet User Manual. Retrieved from http://www.sna.unimelb.edu.au/pnet/download/PNet/PNetManual.pdf
Wang, P., Sharpe, K., Robins, G. L., & Pattison, P. E. (2009). Exponential random graph (p*) models for affiliation networks. *Social Networks, 31*(1), 12-25.
Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*: Cambridge University Press, Cambridge.
Wasserman, S., & Pattison, P. (1996). Logit models and logistic regressions for social networks: I. An introduction to Markov graphs and p*. *Psychometrika, 61*(3), 401-425.
Wi, H., Oh, S., Mun, J., & Jung, M. (2009). A team formation model based on knowledge and collaboration. *Expert Systems with Applications, 36*(5), 9121-9134.
Williams, D. (2010). The mapping principle, and a research framework for virtual worlds. *Communication Theory, 20*(4), 451–470.
Williams, D., Consalvo, M., Caplan, S., & Yee, N. (2009). Looking for Gender (LFG): Gender Roles and Behaviors Among Online Gamers. *Journal of Communication, 59*, 700-725.

Williams, D., Contractor, N., Poole, M. S., Srivastava, J., & Cai, D. (2011). The Virtual Worlds Exploratorium: Using Large-Scale Data and Computational Techniques for Communication Research. *Communication Methods and Measures, 5*(2), 163-180.

Williams, D., Yee, N., & Caplan, S. E. (2008). Who plays, how much, and why? Debunking the stereotypical gamer profile. *Journal of Computer-Mediated Communication, 13*(4), 993-1018.

Williams, K. Y., & O'Reilly, C. A. (1998). Demography and diversity in organizations: a review of 40 years of research. In B. M. Staw & L. L. Cummings (Eds.), *Research in Organizational Behavior* (Vol. 21, pp. 77-140). Greenwich, CT: JAI Press.

Zaccaro, S. J., & Dirosa, G. A. (2012). The Processes of Team Staffing: A Review of Relevant Studies *International Review of Industrial and Organizational Psychology 2012* (pp. 197-229): John Wiley & Sons, Ltd.

Appendix A:

Mean and standard deviation of variables by zone

Zone name	Players in the zone				Project in the zone		
	Female	Age	Skill level	Prior teaming	Teaming required	Project difficulty	Project duration
Antonica	0.20	33.39(10.68)	23.07(10.10)	4.82(7.81)	0.73	19.31(4.52)	29.77(38.91)
Commonlands	0.18	32.28(9.28)	25.77(13.67)	4.48(7.78)	0.54	19.40(4.09)	35.24(46.64)
Desert of Flames	0.17	33.84(9.68)	53.26(6.66)	8.14(10.90)	0.46	52.60(3.96)	33.37(44.15)
Enchanted	0.18	33.04(9.38)	39.55(9.17)	8.96(12.38)	0.70	37.92(3.50)	24.35(32.75)
Everfrost	0.14	32.11(8.96)	46.65(6.54)	10.24(12.65)	0.81	47.05(2.26)	34.92(47.11)
Feerrott	0.22	33.56(9.02)	45.03(7.87)	11.70(13.75)	0.82	43.39(3.86)	30.61(44.02)
Kingdom of Sky	0.16	35.13(10.06)	61.82(5.29)	8.00(11.67)	0.58	61.98(3.76)	32.53(42.77)
Lavastorm	0.18	34.13(9.18)	48.55(7.86)	9.12(12.08)	0.64	46.09(3.23)	27.42(34.67)
Nektulos	0.22	33.72(9.74)	35.24(10.79)	9.70(11.77)	0.51	29.48(4.61)	39.19(42.83)
Qeynos	0.18	35.04(11.91)	20.76(13.65)	2.91(6.84)	0.49	16.10(7.69)	24.90(28.83)
Thundering Steppes	0.18	33.76(10.59)	31.91(10.91)	7.29(11.09)	0.70	28.40(3.78)	31.35(37.78)
Zek	0.19	33.98(9.10)	39.52(9.93)	11.11(14.98)	0.35	36.02(3.32)	29.43(32.48)

Appendix B.

Here we describe the structural effects used in our models with corresponding BPNet terminology (See Wang, Robins, & Pattison, 2009 for a detailed manual). We used three network structures, *edges (L in BPNet)*, *player alternating k-stars (K-Sp,λ=2)*, and *team alternating k-stars (K-Sa,λ=2)* to control for the endogenous impacts in the affiliation network: The number of edges controls for the *density* of the affiliation network, the player alternating k-star statistic controls for distribution of *players' propensity to join many teams*, and the project alternating k-star statistic controls for the distribution of the number of members in each team, i.e. *team size*. The main effects of categorical control variables, including gender and expertise, were tested using recoded binary variables for each category and included in BPNet using *[attr]_RP* terms. These parameters assessed the extent to which gender and expertise influenced individual's preferences to join teams. The main effects of continuous control variables, including age and prior teaming, as well as one hypothesized variable, skill level, were tested using *[attr]_PRC* terms. These parameters assessed the extent to which age, prior teaming, and skill level influenced an individual's preferences to join teams. Similarly, the main effects of team-level variables, including teaming required, project duration, and project difficulty, were tested using *[attr]_RA* and *[attr]_RAC*. These parameters assessed the extent to which project characteristics such as teaming required, duration and difficulty of projects influence an individual's preferences to join teams. The homophily effects were tested as follows: Categorical individual attributes, i.e. gender, class, and guild matching were tested using *[attr]_2path_match_P*. The effects of differences of players' ages and skill levels were tested using *[attr]_TSOPCD*. Finally, the effect of re-teaming was tested using the *alternating k-2-paths linked by players (K-Cp,λ=2)*. We tested another slightly different structure *K-Ca*, *alternating k-2-paths linked by teams*, which captures the effect of two individuals collaborating in multiple teams. Since the models with both *K-Cp* and *K-Ca* did not converge, only *K-Cp* terms are used to measure the re-teaming effect.

Appendix C.

The goodness-of-fit results of the model in Table 3 (for Zone Antonica)

Effects	Observed	Mean	Std	t-ratio
L	1283	1283.795	32.301	-0.025
Sa2-stars	1575	1618.503	152.588	-0.285
Sp2-stars	4385	3573.882	801.860	1.012
Sa3-stars	1113	1394.978	367.999	-0.766
Sp3-stars	16868	10824.052	8918.481	0.678
L3	24484	23127.227	10583.146	0.128
C4	2957	1547.941	1678.976	0.839
Ksa (2.0)	1131.875	1133.586	58.702	-0.029
Ksp (2.0)	1532.479	1535.907	69.421	-0.049
Kca (2.0)	853.067	1365.935	47.491	-10.799
Kcp (2.0)	3201.969	3212.069	439.931	-0.023
Teaming_required_rA	1004	1004.912	30.950	-0.029
difficulty_rAc	25075.000	25142.749	682.331	-0.099
duration_rAc	35286.000	35263.084	890.914	0.026
female_rP	282	281.084	17.775	0.052
prist_ expertise_rP	329	328.887	15.980	0.007
mage_ expertise_rP	270	270.609	14.660	-0.042
scout_ expertise_rP	241	241.070	21.452	-0.003
level_rPc	26483.000	26489.241	524.277	-0.012

age_rPc	43370.000	43391.978	1202.504	-0.018
prior_teaming_ rPc	6927.000	6937.847	355.892	-0.030
level_tsoPcd	8711.000	8735.499	622.320	-0.039
age_tsoPcd	16209.000	16262.295	1970.695	-0.027
expertise_match_2pP	311	311.810	36.722	-0.022
guild_match_2pP	336	342.625	156.522	-0.042
gender_match_2pP	1048	1051.891	94.969	-0.041
Std_Dev_degree_dist_A	1.156	1.227	0.142	-0.498
Skew_degree_dist_A	0.963	2.109	0.323	-3.544
Std_Dev_degree_dist_P	3.917	3.181	0.574	1.283
Skew_degree_dist_P	2.533	1.805	0.894	0.815
Global_Clustering	0.483	0.217	0.124	2.150

ACCEPTANCE RATE: 0.017

Mahalanobis distance =116.182 (13498.293)

In general the model is a good fit: the t-ratios of structures included in the model are smaller than 0.1 and the t-ratios of structures not included are around 2.0, except the alternating k-2-path linked by teams (Kca). It seems that Ksa and Ksp did a pretty good job to control the degree distributions: Sa2-stars, Sp2-stars, Sa3-stars, and Sp3-stars have a relatively good fit (mostly smaller than 1.0). The t-ratios of Std_Dev_degree_dist and Skew_degree_dist for players and teams are also reasonable. These statistics suggest that the degree distribution of the simulated networks is not very different from the observed network. Furthermore, statistics of simulated networks generated during the goodness of fit processes show that the probability of observing a team with more than 6 members is very rare. For instance, in zone Antonica, there are on average 0.24 out of 426 teams in the simulated networks that have more than 6 members.