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The Effects of Group Structure on Group Outcomes in an Online Game

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Abstract

Small group research has been inadequate in systematically examining the direct and indirect effect of group input on group output and statistically defining the mediating effect of group process. To address this issue, a large dataset (N = 2,465) on grouping behavior was collected from an online game. Structural equation modeling was utilized to examine how group size and group competence diversity influences the group interaction process and group performance. The results suggest that group size has both direct and indirect effects on performance outcomes. Specific path analysis also shows that group size has a positive influence on the aggregation of group expertise, which has a positive effect on group performance. Group competence diversity and group size both have a negative effect on the frequency of group IM-based chat, which is in turn negatively related to group success in the online game environment. Theoretical and methodological implications of the findings for communication and small group research are discussed.

Keywords: small groups, computer-mediated communication, virtual world, team performance

The Effects of Group Structure on Group Outcomes in an Online Game

It is commonly assumed that group input factors influence interaction processes, which in turn influence group outcomes (Hackman, 1987; McGrath, 1984). The functional perspective of small groups is particularly concerned with how practical outcomes such as performance metrics of groups can be influenced by the structural features of and interaction processes in groups (Fraidin & Hollingshead, 2005). The structural features of groups are interesting because of their straightforward association with various group outcomes (Bass, 1980, pp. 444-448). Research has documented the effects of several structure signatures of small groups. For example, group size influences the effectiveness of collective actions (Agrawal & Goyal, 2001), demographic diversity influences communication quality in groups (Krebs, Hobman, & Bordia, 2006), and aggregate expertise in groups influences their performance in tasks (Balthazard, Potter, & Warren, 2002). The wide interest in the structure of small groups has led to both theoretical inquiries of how group size and diversity influence the cognitive (Liebkind, Nystrom, Honkanummi, & Lange, 2004), sociopsychological (van Prooijen & van Knippenberg, 2000) and normative processes in groups (Kaplan & Martin, 1999), and practical studies of how to manipulate certain structural features of teams to improve effectiveness (e.g. Ren, Kraut, & Kiesler, 2007; Voelpel, Eckhoff, & Forster, 2008).

Nevertheless, multiple theoretical and empirical reviews have consistently revealed inconsistent effects of structural factors on practical outcomes in groups (e.g. Cohen & Bailey, 1997; Stewart, 2006; van Knippenberg & Schippers, 2007; K. Y. Williams & O'Reilly, 1998). According to Baron and Kenny (1986), such inconsistent relationships between the predictor variables and the dependent variables should justify a more careful examination of the intervening moderator variables. Indeed, the general conclusion from these reviews is that the

influence of structural factors on group performance varies in different contexts of team types, task characteristics and organizations. However, without a clear understanding of the internal relationships among input, process and output, it is not always easy to judge exactly what processes are moderated by these external factors. For example, it would be hard to understand how the pattern of group communication varies in different types of tasks without first knowing the direction, density and frequency of communication in groups that have different structures. Although researchers have identified the mediating effect of group communication (e.g. Stewart & Barrick, 2000), little effort has been made to structurally decompose the direct and indirect effects of structural factors and examine the statistical significance of *both* to establish the meditational paths (Holmbeck, 1997, p. 603). Instead, research tends to focus on bilateral relationships between group size and communication (e.g. Lowry, Roberts, Romano, Cheney, & Hightower, 2006), or diversity and effectiveness (e.g. Dahlin, Weingart, & Hinds, 2005). As a result, a three-way model that explicates the substantive and statistical significance of mediating variables is rarely attempted. Most research has focused on studying the effect of group structure by manipulating and investigating a single static feature such as size or diversity in laboratory settings. In contrast, teams in the real world may vary on multiple dimensions of structure, which is hard to be captured in a lab setting. For example, as a team increases in size, its members will have increasingly distinctive personal attributes. In other words, the covariance of different structural dimensions needs to be systematically incorporated in small group research.

The present study aims to tackle the relationship between structure and processes in groups that are formed by natural selection. Its objective is to study a) the structural relationships among exogenous group factors such as size and diversity, and b) the structural relationships between these exogenous variables and endogenous variables of group aggregate

expertise, group communication and performance outcomes. Each of these structural features has theoretical origins in small groups research, and their effects have been corroborated in the meta-analyses on group effectiveness by Cohen & Bailey (1997) and Stewart (2006). The selection of endogenous variables is also based on the common framework for studying internal interaction processes and effectiveness measurements for groups (Kent & McGrath, 1969; McGrath, 1984; Steiner, 1972). The context of the study is the virtual environment in a popular massively multiplayer online game (MMO), Everquest 2. In this gaming environment, thousands of individuals frequently form ad hoc groups. In these groups, players slay computer-generated monsters for certain goals such as obtaining rare virtual items and advancing the "experience" levels of animated avatar characters. Research has revealed that gaming activities in this virtual environment have both economic implications (Castronova, 2005; D. Williams, et al., 2009) and social consequences (D. Williams, 2006b). More recently, scholars have begun to pay attention to the relevance of online gaming to the issues in organizational development such as leadership building (Reeves, Malone, & O'Driscoll, 2008). Nevertheless, little research has attempted to apply small group theories in an online gaming environment in which natural groups are formed and operated frequently. The problem is how to map such groups for the classic definition of virtual teams - "teams whose members use technology to varying degrees in working across locational, temporal, and relational boundaries to accomplish an interdependent task" (Martins, Gilson, & Maynard, 2004) and also of action teams - teams with an immediate short term goal that requires action (Sundstron, DeMeuse, & Futrel, 1990). Traditionally, studies on virtual teams are based on groups working on business or educational projects. In a virtual gaming environment, players have the option to play individually or in groups, and can leave groups at will. Group membership and identity are therefore harder to establish and maintain

than in a controlled lab setting or in a formal organizational setting. However, evidence suggests that behavioral rules in the physical world do apply in such a virtual world (D. Williams, et al., 2009). Furthermore, player grouping is a popular strategy normally encouraged by game operators. Multiple features are provided in the game to facilitate communication and coordination in groups once they are formed. Players in turn are aware of the pros and cons for playing in groups of different structural features. Groups in this context are the functional unit for achieving a common task, albeit a fanciful one such as slaying a monster. They provide an interesting context for exploring the fundamental influence of group structures on social interaction and practical outcomes in small groups.

Group size

Group size is a fundamental attribute of groups that influences various group processes. Hare (1981) argues that group size is inversely related to group members' feelings of identity and commitment to group values, and positively related to the aggregation of skills and resources in groups. This effect has interesting implications for group outcomes. When group size is small, for example, groups tend to be more effective at facilitating collective action because of the visibility of other group members' actions (Olson, 1965). To explicate the advantage of a smaller group size, researchers show that small groups have more coherent perceptions of tasks and social cohesion (Carron & Spink, 1995), are more likely to share high-quality knowledge because of heightened sense of accountability among members (Voelpel, et al., 2008), and have higher cooperation rates for tasks that require simultaneous coordination (Franzen, 1995). On the other hand, group size can be positively related to the aggregation of important resources such as expertise and skills. Larger groups, for instance, tend to be better at accumulating expertise to execute tasks more effectively (Littlepage & Silbiger, 1992). The benefits of a

larger team likely depend on the objective of the team and its operational environment (Kozlowski & Klein, 2000), so for teams whose functioning relies on the possession of resources such as time, energy, money and expertise, a greater team size is more beneficial.

Regardless of groups' objective and external environment, these studies generally imply that group size has an indirect effect on group outcomes as it influences group processes in different ways. In one of the more widely accepted models, Steiner proposes that group size influences both resource gains and process losses for groups (1972). Simply put, as groups become larger, they tend to gain more resources, but it may be more difficult or costly for them to motivate members and coordinate group actions, hence the "loss" of time or human resources (Markham, Dansereau, & Alutto, 1982; Mullen, Symons, Hu, & Salas, 1989). This inherent disadvantage of larger groups is particularly obvious in tasks that require complex coordination. However, it has been increasingly recognized that coordination leads to necessary communication that is important for team building (McGrath, 1991). The effective exchange of both social and task information through frequent communication not only enables group members to develop a shared mental model about the distribution of expertise (Brandon & Hollingshead, 2004), but also helps them cultivate a social environment of openness and trust (Nahapiet & Ghoshal, 1998). Therefore, the precise effect of group size can be considered as the interplay of concurrent changes in interaction patterns and collective resources in groups.

There is reason to think that smaller group size will promote effective group communication. Research has shown that smaller groups are more committed to internal information exchange (Cruz, Boster, & Rodriguez, 1997), and tend to have more and better communication than larger groups especially when face-to-face interaction is unavailable (Lowry, et al., 2006). This is because of the relative easiness in setting team agenda and

arranging communication flows with fewer people involved. In larger groups, in contrast, the difficulty in coordinating and motivating members for a collective goal can make the groups a poor environment for communication and interaction. Members of larger groups tend to have less motivation and make less effort to coordinate and communicate with one another about the tasks (e.g. Cruz, et al., 1997). Even with the assistance of advanced communication technologies, production blocking and social loafing are more likely to occur because of weaker attention to the needs of others and lowered cost for free-riding (Voelpel, et al., 2008). It is thus hypothesized that group size has a negative effect on the frequency of group communication.

Hypothesis 1: Group size is negatively related to the frequency of group communication.

In-group communication can positively influence the socialization process in groups. The acts of communication, sharing and cooperation contribute to an open and bonding social environment (Nahapiet & Ghoshal, 1998). This social bondage has several benefits for groups. For example, it helps groups build social identities that foster in-group cohesion and stimulate competition in inter-group comparisons (Hogg & Reid, 2006; Levine & Moreland, 1994). Furthermore, it also facilitates the construction of shared cognition and knowledge of situations and tasks that groups encounter (Cramton, 2001; Waller, Gupta, & Giambatista, 2004). These social benefits of in-group communication are directly related to certain practical outcomes such as improvement in productivity and effectiveness. When task-related information is frequently communicated, group members can develop a more cohesive perception of the challenges and opportunities in the tasks and coordinate efforts to adjust their solutions. For example, groups tend to perform better and have higher productivity when they communicate more often about both shared and unshared task information and knowledge (Stasser & Titus, 1985; Wittenbaum, 1998). It has been noted that frequent communication actually indicates that groups are having

problems in performing tasks. This is especially true when groups lack pre-existing relationships in unfamiliar tasks. However, the negative association of communication frequency with group performance does not hold, if groups actively communicate and develop interpersonal familiarity to compensate for lack of task familiarity (Espinosa, Slaughter, Kraut, & Herbsleb, 2007). We argue that over time, frequent communication of task and social information helps group members develop a more comprehensive understanding of the requirement and distribution of efforts and competence for the tasks (Brandon & Hollingshead, 2004). Overall, it is hypothesized that the frequency of in-group communication is positively related to group performance in the long term.

Hypothesis 2: The frequency of in-group communication has a positive effect on group performance.

On the other hand, group size can influence group outcomes in positive ways because it correlates with the collective resources that individuals bring into the groups. That is, group size can be a simple metric of aggregate resources that are necessary for groups to function. Research has shown that for tasks that require little coordination, productivity grows linearly as group size increases (Littlepage, 1991). This is simply because groups with more members have more resources to generate more products. The linear aggregation of desirable competences and abilities of individuals such as talent and knowledge provides a group-level advantage in most production tasks (Stewart, 2003). Even for tasks that do require delicate coordination, larger groups can effectively gather more "raw" resources such as energy, money and expertise (Kozlowski & Klein, 2000). Expertise refers to specialized knowledge and skills that enable stable and outstanding performance in domain-specific tasks (Faraj & Sproull, 2000; Sonnentag, 1998). Individuals with domain expertise have the related experience and competencies in group

tasks. A larger group simply holds an aggregate advantage in their intellectual resources than a smaller group. Therefore, it is hypothesized that group size is positively related to the aggregation of one important group resource – level of expertise.

Hypothesis 3: Group size has a positive effect on the aggregate expertise resources in groups.

Research has generally supported a positive link between aggregate resources and group performance (Hill, 1982). These resources are expected to be particularly beneficial for completing tasks in complex and uncertain environments. As a whole, team performance is improved when more members have the desired personality traits and relevant expertise (Stewart, 2006). A positive association between aggregate expertise resources and group performance is therefore proposed.

Hypothesis 4: Aggregate expertise resource has a positive effect on group performance.

Diversity

Structural diversity is another important attribute of groups. It is defined as "a characteristic of social grouping that reflects the degree to which objective or subjective differences exist between group members" (van Knippenberg & Schippers, 2007). The differences among group members can be measured on demographical lines, psychosocial traits and background characteristics (Stewart, 2006). Such differences can influence groups' social interactions and task performance in contrasting ways, which can be explained in two different perspectives. Based on the social identity theory (Brewer, 1979; Tajfel & Turner, 1986), the social categorization perspective suggests that diversity disrupts group activities by weakening the group social identity and creating communication barriers (Earley & Mosakowski, 2000; Rendel, 2002). On the contrary, the information-processing perspective holds that diversity

enables groups to process and integrate a wider range of information and perspectives (e.g. Hinsz, Tindale, & Vollrath, 1997; van Knippenberg, De Dreu, & Homan, 2004). These two perspectives often lead to drastically different interpretations of the mixed performance outcomes of groups with certain degrees of diversity. For example, while some research shows a negative link between heterogeneity and performance (e.g. Murninghan & Conlon, 1991), other studies support a positive relationship between diversity and innovative output (e.g. Bantel & Jackson, 1989). The inconsistent effect of diversity on group performance is more perplexing when multiple dimensions of diversity exist in groups. For example, although functional diversity–defined as different functional affiliations in organizations–has a positive effect on performance, tenure diversity–in the forms of history, status and experience–correlates with lower performance (Ancona & Caldwell, 1992).

Scholars have proposed several mediation mechanisms that integrate the conflicting perspectives (e.g. van Knippenberg & Schippers, 2007). For example, the salience of common social identities may increase individual's motivation and willingness to share information in diverse groups (van Knippenberg, et al., 2004). Group norms of interdependence and cooperation may alleviate the detrimental effect of demographic dissimilarity on group performance (Chatman & Spataro, 2005). And time may also attenuate the effect of diversity as group members interact more and become more familiar with one another (Harrison, Price, Gavin, & Florey, 2002). A common factor behind these mechanisms is internal group communication, because communication is the essential practice for groups to willingly share information, develop norms and solve relational conflict over time. The communication pattern is central to both social categorization and information exchange processes, which serves as a mediating factor for the inconsistent effect of diversity on group performance. Evidence

suggests that when internal communication is successful, diversity in experience and tenure leads to better performance (Reagans & Zuckerman, 1999). And when demographic and tenure diversity prohibits effective communication, it hurts group performance (Ancona & Caldwell, 1992).

To understand the effect of diversity on group performance, therefore, it is necessary to examine how it influences primary means of in-group communication. Research shows that heterogeneity in gender, age, status and nationality constrains communication in groups (e.g. Lind, 1999; Maznevski & Chudoba, 2000; Owens, Neale, & Sutton, 2000). People simply cannot or will not talk because of these inherent differences. The negative effect of heterogeneity is somewhat mitigated by the use of new communication technologies, because inequalities or differences in status, gender and personality are less salient in the computer-mediated communication (CMC) condition (Nowak, 2003; Sproull & Kiesler, 1986). As a result, the negative influence of demographic dissimilarity on trust formation in virtual teams is reduced (Krebs, et al., 2006). In contrast, unless formal or normative intervention is executed in teams to motivate communication, diversity in task-related competency or expertise normally discourages group communication. For example, status difference can negatively influence group interactions even with the assistance of computer medium (Hollingshead, 1996). This is aligned with the status expectations theory, which states that the difference in status based on competence and expertise in groups leads to certain behavioral expectations (Ridgeway & Diekema, 1992). Members with a lower level of competence might have less confident self-perception and inferior status beliefs, thus feeling less inclined to talk. Members with a higher level of competence in contrary might perceive little benefit in communicating across the status barriers. This mechanism is one of the ways that diversity in task experience and competencies

can be negatively associated with the frequency of communication in groups. It is therefore hypothesized that:

Hypothesis 5: Diversity of competencies in groups has a negative effect on the frequency of in-group communication.

As diversity in competence distribution can have serious implications for in-group social interaction, it also influences the process of how groups accumulate resources. A fundamental argument from the information processing perspective on diversity is that groups can benefit from a higher degree of diversity in task-related information. This is because groups of high diversity bring into work a broader range of perspectives (Dahlin, et al., 2005), explore and coordinate group learning behavior among members with different backgrounds (Gibson & Vermeulen, 2003), and overcome obstacles with more innovative solutions that span across barriers of experience and competence (Dunbar, 1997). The benefit of diversity for aggregate resources in groups is also documented in the social capital literature. Early research shows that heterogeneity in socioeconomic status makes it possible for groups to interact with a diverse set of relationally weak ties and expand their reach for a wider range of information (Granovetter, 1973). Recent studies affirm that teams formed with higher functional diversity have higher bridging social capital, because such teams span the structural barriers within organizations and obtain early and quick access to diverse information (Burt, 2000). For tasks that require the creative aggregation of multiple domains of skills and competence, this is particularly important. It is hence proposed that diversity in task-related competence is positively related to aggregated resources of expertise.

Hypothesis 6: Diversity of competence is positively related to aggregate expertise in groups.

Figure 1 presents a schematic representation of the structural equation model that contains the hypothesized paths. The structural equation model has two exogenous variables (group size and group competence diversity), and three endogenous variables (aggregate group expertise, the frequency of group communication, and group performance). The two exogenous variables are assumed to be correlated, because groups can have different distribution of competence when they grow bigger o smaller. The measurement errors of the endogenous variables, however, are assumed to be uncorrelated because they are measured and calculated in separate ways in this study. The model is over-identified with three degrees of freedom, allowing for both the global test of the structural equation model and the local test of the fit of each path.

{Figure 1 here}

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Method

Context of research

This study investigates grouping behavior and outcomes for players in Everquest II, a popular massive multiplayer online game (MMO). In this game, players create avatar characters to explore a computer-simulated virtual environment and complete various tasks in order to earn virtual items such as money and equipment. In addition, social interaction with characters controlled by other human players is also a main component of the game experience (Taylor, 2003; D. Williams, Caplan, & Xiong, 2007). This virtual environment is relevant to small groups research because of this social experience. In this game, players' performance is mostly determined by how well they tackle various quests in the game – tasks that are assigned by virtual in-game agents to complete a specific storyline. Rewards for completing such quests

include equipment, armor, money and experience points. These quests are divided into three difficulty levels that are explicitly associated with grouping activities. Specifically, a solo quest is relatively simple and can be completed by one player. Heroic quests are more difficult, and require group efforts. The most difficult tasks are epic quests, which often require several groups to work together. Such quests, or the so-called raids, can be undertaken by up to 4 groups with 6 members in each. The aggregate value of group size thus influences players' long-term performance in a systematic and coherent way.

For example, when a group is formed, players automatically join an ad hoc chat channel to communicate with their group mates. The chat channel is usually a text-based instant messaging system. The content of communication can be mainly focused on the tasks in hand, but casual exchanges of personal and social information can also happen (D. Williams, 2006a). As groups grow larger, it becomes more difficult to manage task-related communication and coordinate effective actions. Hence the effect of group size on performance can be mediated by the precise pattern of communication in groups. Furthermore, groups are often formed among player characters with different competences and skills, which can be indicated by their "experience level". The experience level is an important indicator of players' skills and competence, as players have accrued enough experience points in order to progress over time up to level 70. Diversity of experience levels in a group simply suggests that member have various degrees of knowledge and experience with the game, which is equivalent to tenure diversity in teams (Valenti & Rockett, 2008). Finally, when players at different experience levels form a group, their average will be calculated as the actual experience level of the group. This actual level is used as a simple metric of the group's aggregate expertise, which in turn determines the appropriate challenge of tasks and rewards for completing these tasks.

Subjects

Everquest II consists of identical game environments that are hosted on data servers all over the world. Slightly different behavior rules are implemented on 4 types of servers: Player vs. Environment (PVE), Player vs. Player (PVP), Role Playing (RP), and Exchange (EXG). PVE is the default server for players to focus on exploring the virtual landscape, producing virtual goods and fighting monsters without having to fighting other human players. This study investigates the unique groups that actively played on a PVE server located in North America during the first week of September in 2006.

Measurement

Sony Online Entertainment (SOE)–the company that operates Everquest II–provided the data for this study. Whenever a player conducts an activity that is associated with getting experience points, a line of record is created in a server database. This record contains a time stamp, character information, group size, several group level measurements and the amount of experience points (see Table 1 for an example of the server log). With millions of lines of in-game behavior records, such data provides an unobtrusive record of basic group activities in the game.

{Table 1 here}

We identify groups as sets of players who received experience points from an activity at the same time and in the same place. The time refers to the real time periods as recorded in the timestamps in the logs, and the place includes all possible areas and zones on the same game server. Among the variables of interest, group size is the group size value from the server logs. Group competence diversity is computed as the normalized standard deviation of the character levels of all the members of a group. Group aggregate expertise is calculated as the sum of the

actual group levels in the group (the level indicates how far the member has advanced in the game and is one way of assessing expertise), normalized by the number of members in the group. Group communication frequency is calculated as the aggregate frequency of text chat messages within the groups in the sample, normalized by the number of group events associated with activities on getting experience points. Performance is calculated as the average number of experience points that the group members gained in each experience point group event.

Analysis

The data was collected by executing SQL scripts on a remote data server in a large midwestern campus computing facility. The scripts contained functions that determined groups and calculated the average and dispersion statistics for each of the variables of interest for each group. A raw table was retrieved converted into a data format compatible with SPSS 16. The data table was then entered in LISREL 8.7, a structural equation modeling software. Based on modifications indices provided by LISREL, the original model was revised until satisfactory results were obtained. The results reported in this article are from the revised model that generated the best global and local goodness-of-fit metrics.

Results

Descriptive Statistics

Grouping data were collected for the unique player characters on the Guk (PVE) game server during the first week of September 2006. After filtering out groups that have missing values on any of the variables, 2465 unique groups were used for data analysis. For these groups, the average group size is 5.58 (*sd = 2.33*), the average group competence level diversity is 1.50 (*sd* = 0.57*),* the average group level is 50.86 (*sd* = 14.46), the average chat frequency for these groups is 67.89 (text chat messages in each experience-point event) (*sd* = 177.78), and the

average gain of experience points per experience-point event is 399.70 (*sd* = 294.24).

Test of the Model

Results from the first run of the structural equation model showed that the model had a poor fit (χ^2 =32.78 , *df* = 3, *p* = 0.00; RMSEA = 0.06, RMR=185.54, Model AIC=66.68). The modification of the model was conducted in several steps and stages. First, the modification indices from the LISREL outputs recommended that direct paths from group size and group competence diversity to the endogenous variable of performance be added. Second, additional feedback paths among all the endogenous variables were also recommended. Previous analytic models generally supported a direct effect of group structure on group performance (cf Bass, 1980; Cohen & Bailey, 1997; Hare, 1981), because change in group size or competence diversity can generally influence the collective perception of the task and the strategies for completing the task. For example, the addition of group members simply helps the group to improve productivity, all else held constant (Steiner, 1972). However, there is no theoretical justification for any feedback loops from the performance measure to aggregate group expertise and communication frequency. Because these measures were calculated as composite aggregates over a relatively long time period in the game, it makes little sense to assume that these performance metrics will have a causal influence on group communication and aggregate expertise. Therefore, only the direct paths from the endogenous variables to the dependent variable of group performance were added.

The revised model showed a slight improvement in the goodness-of-fit statistics (χ^2 = 23.94, *df* = 1, *p* = 0.00, RMSEA = 0.096, RMR=197.83, Model AIC=61.83), but the model still failed to satisfactorily represent the observed data. Model modification again involved two steps. First, the direct path from group competence diversity to performance was not significant

and was dropped (Gamma = 11.73, t = 1.13). Second, the modification indices continued to recommend that feedback loops among the endogenous variables be added in the model. Although there is no theoretical reason for adding a path from the performance variable to group process variables such as aggregate expertise and communication, there is logical reason to assume that group aggregate expertise can directly influence communication among its members. A high-level group will normally consume game content that is more challenging than a low-level group. To facilitate play, more communication is necessary for such groups. However, the reversed path cannot be assumed because the aggregate behavior of communication cannot directly influence the aggregate group expertise which is relatively fixed once a group is formed. Therefore, an additional path from group aggregate expertise to communication frequency was added.

The final model showed a significantly large improvement in the goodness-of-fit statistics (χ^2 = 1.28, df = 1, p = 0.26, RMSEA = 0.011, RMR = 0.94, Model AIC = 39.28). The improvement in the chi-square statistic over the original model was substantial and significant ($\Delta\chi^2$ = -31.5, $\Delta\, df$ = 2, $p < 0.001$). There were no non-significant paths and there were no more modification indices. The path diagram for the final model is presented in Figure 2.

{{ Figure 2 about here }}

Additional model estimation was performed with using AMOS 16 (Arbuckle, 2007). To improve the reliability of the test, the estimation was conducted with another method, General Linear Squares (whereas the LISREL estimation was based on the Maximum Likelihood method). Similarly satisfactory goodness-of-fit statistics were obtained (RMSEA = 0.011, RMR = 22.17, NCP = 0.278, Model AIC = 29.28).

The revised structural equation model provides partial support for the hypotheses. The

hypothesis that group size negatively influences group communication (H1) is not supported. Rather, the influence of group size on communication is positive. As hypothesized, group size has a positive effect on aggregated group expertise (H3). Group competence diversity has a negative effect on the frequency of group chat (H5). But contrary to what was hypothesized (H6), group competence diversity has a negative effect on aggregated group expertise. Also as hypothesized (H4), aggregated group expertise has a positive effect on the performance of individual group members. But contrary to the hypothesis (H2), communication frequency is negatively related to group performance.

Furthermore, the results suggest that the direct effect of group size on group performance exists and interacts with its indirect effect in interesting ways. For example, group size has a positive direct effect on individual performance (Standardized Gamma = 0.07), which accounts for 39% of the total effect (Standardized Gamma = -0.03). The indirect effect of group size on group performance is not only large, but in the reversed direction (Standardized Gamma = -0.11). This suggests a significant mediating effect of process variables. Table 2 provides a detailed summary of how the results support each hypothesis and generate new paths.

Discussion

Overview

The results provide partial support for the hypothesized theoretical model. The grouping process and outcomes in a persistent virtual environment are theorized in a model that delineates the direct and indirect effect of group size and group competence diversity on group performance. The results suggest that correlation between group structural features should be systematically considered for their separate effects on outcome variables in the model. The results also systematically reveal the concurrent mediating effects of group communication and

group aggregate expertise on performance measures.

Specifically, the results show that although the structural features of groups are weakly correlated with each other, they might have differing effects on group processes. Group size has a significantly positive effect on the aggregate expertise in groups, so that a larger group can effectively increase the total expertise level to be more productive and successful. At the same time, a greater level of dispersion of competence can negatively influence the frequency of communication in groups. As a result, group members with different levels of competence actually chat less more during tasks because unequal access to skills and other resources in the game undermines the collective communication based on a shared frame of reference. These results are aligned with previous group research which identifies similar phenomena in groups in the physical world (e.g. Ancona & Caldwell, 1992; Kozlowski & Bell, 2003).

More importantly, the results provide systematic support for the meditational process in groups. Group size can have significant direct and indirect effects on group outcomes. This provides empirical evidence for the analytic model proposed by Cohen and Bailey (1997) which emphasizes the interplay of direct and indirect effect of group composition features. The proportion of the direct effect in the total effect of group size is moderate (39%), but its indirect effect is significant, complex and in a reversed direction. On the contrary, there is no direct effect of group competence diversity on group performance at all. These phenomena suggest that aggregate group expertise and group communication mediate the influence of group structural features in different ways. Specifically, the effects of group process variables on group performance seem to suggest that the influence of group size and group competence diversity is attenuated in a virtual environment. It is not simply the structure of a group that determines its success, but rather how it coordinates communication and aggregate useful resources that does.

However, the results also reveal interesting discrepancies. Contrary to the prediction, group size is positively related to group communication frequency, so that a larger group actually engages in more textual chat in the game. Group competence diversity does not lead to higher aggregate expertise in the groups, but rather has a negative effect. In turn, the process variable of group communication frequency is negatively rather than positively related to group performance. These discrepancies have both practical explanations and theoretical implications.

The unique virtual game environment conditions the ways groups behave. In the game, various high-end content such as challenging monsters in difficult dungeons often requires committed and dedicated coordination of large groups. Changes in group size are often not purely quantitative, but rather qualitative in that group members need to communicate, collaborate and compete with one another in entirely different ways than they need for regular requests. For example, it is almost customary for large groups to use both voice and text chat systems to coordinate a difficult raid (D. Williams, et al., 2006). This explains why our results show a positive link from group size to group communication frequency. Further, precisely because larger groups need to rely on external voice chat systems to work together, the in-game text chat system – the communication channel we measured – becomes a relatively supplemental channel. It is probable that the success of such groups is more attributed to voice communication, a more effective channel than text (D. Williams, et al., 2007). Therefore text chat frequency is actually negatively related to group success, because successful groups simply use less text chat. An alternative interpretation can be generated from the studies on the role of communication in action teams. The teams in EQ2 resemble action teams such as military units or EMTs, that is, teams with clear goals that can be achieved relatively quickly and that have clear role differentiation. Research on action teams suggests that effective teams practice

extensively and know how to react to situations that confront them. Only when things "break down" is communication necessary in such teams (Bowers, Braun, & Morgan, 1997). So it may well be the case that communication is a signal that the team is not performing well, hence leading to a negative relationship. In sum, this discrepancy in the effect of group communication reveals that task contingencies as well as the communication affordances have important moderating effect on communication processes in groups.

The results also suggest that group competence diversity is negatively related to group aggregate expertise. Like other MMOGs, Everquest II has specific rules about forming groups with members of different level. The game is so designed that grouping with players at similar levels is encouraged and grouping players in a wider gap is penalized[1]. This makes experience gap a less desirable group attribute for high-level players who are focused on high-end content in large-scale raids. Therefore lower group competence diversity will actually be observed more in high-level groups, whereas higher diversity is still regular among low-level groups whose game activities are less focused on high-end challenging tasks. This phenomenon reveals that the effect of competence diversity in groups is actually moderated by external factors that determine the pattern of expertise aggregation and internal communication.

These unique phenomena in the virtual game environment suggest virtual groups can behave in entirely different ways than conventional groups, depending on the behavioral rules and requirements of the task contexts. Theoretical explanations should be advanced to explicate this difference. The discrepancies in the effects of group size and group competence diversity on group processes suggest that task contingencies need to be considered. Task features such as difficulty and interdependence moderate the effect of group size on group communication, so

[1] There is no hard evidence on this design strategy. Various online game forums have discussed this point. See e.g. http://www.cesspit.net/drupal/node/533, http://www.eq2center.com/db/article.asp?id=1375.

that a larger group needs more communication efforts for a highly interdependent task than an easy, routine one. A group comprised of members with diverse competence will not be a group that has sufficient aggregate expertise and effective communication to handle difficult tasks. While we did not set out to study the moderating effect of task types on group processes, our results provide strong evidence that task contingencies –task difficulty and interdependence, to be specific – can moderate the relationship between group structural features and group processes. Our revelation of the discrepant effects of group structural features in a virtual environment facilitates the exploration of exactly how contextual contingencies moderate group processes (Kenny, Mannetti, Pierro, Livi, & Kashy, 2002).

Implications

This study has interesting implications for the research of groups in a virtual world. First, it shows that composite measures of structure and process on the group level can influence the outcomes of grouping behavior. In a virtual environment like Everquest II, group structural features such as size and competence diversity are directly visible to actors. Their influence on individual outcomes therefore corroborates the general theories from traditional groups research. Even though group processes such as communication and resource aggregation can be operationalized differently in a virtual environment, structural features still play a fundamental role in shaping how these processes influence group outcomes. The direct and indirect effects of structure persist in virtual groups whose goals and practices might significantly differ from those in formal organizations. Second, the study reveals the need and feasibility for systematically explicating the complex meditational process in groups by decomposing direct and indirect effect of group input separately. The decomposition of the total effect of group composition features not only facilitates the statistical test of the mediating effect of group interaction processes. It

also provides the foundation for theoretically re-conceptualizing the influence of group structure on different aspects of group process, and facilitates the examination of the specific direction and pattern of the external intervention of moderating factors such as task features and organizational environment.

Limitations

The study has important limitations in internal and external validity. First, serious interdependence exists in the observations. Groups can play in the same area at the same time with other groups that are included as unique observations. Multiple characters can also be owned and played by the same real human player. Although the aggregation approach has reduced the possible bias of interdependence on parameter effect estimates, the same interdependence may have distorted the errors and variances of variables that are highly intercorrleated. Second, several of the variables are measured and calculated in ways that may not accurately operationalize the theoretical construct. For example, we only measure and test group competence diversity based on play levels, whereas by theory and in practice competence diversity can also be related to various dimensions of task contexts (Reagans & Zuckerman, 1999). Furthermore, the unreliable measures of group communication based on the aggregation of individual counts of chat may have also made the variable a weak predictor. Third, the study is based on the data from only one online game, Everquest II, therefore it is unclear whether the pattern of influence from group structure and meditational effects of group process can be applied to other online gaming environment, and more generally the overall virtual environment. However, despite these obvious limitations, we are confident that our approach has sufficient theoretical rigor and methodological innovation for a preliminary case on how to extend the classical group theories in an exciting new platform for observing group behaviors and

outcomes.

Future research

Future research should focus on two directions. First, the role of communication in group process needs to be more carefully examined. As shown in the study, while group size has a positive effect on the frequency of group text chat, group diversity negatively influence group communication consistently. The communication frequency based text chat, in turn, has a negative influence on group performance. This may suggest that communication in groups like these suggests that they are having problems with performance.. Further research on the different influence mechanisms of group process as it related to task progress seems warranted.

Second, the role of time needs more careful investigation in the research on virtual groups. Previous framework on the influence of group interaction on performance emphasizes time as an important factor for groups to internalize procedures and group norms (McGrath, 1991). In a virtual environment, the evolution of groups over time may play an important role in the group process that is accompanied by the socialization among players in different social settings. The aggregate measurement technique in the present study provides useful information on the interrelationship between group structure and process, but it also fails to capture the information on the time that an individual spends in each group. It would be interesting to explore how the influence of some group structure features persists at different times for players with different use patterns over time, and how the influence of other group structure features is changed when groups co-evolve in the larger community of players. A longitudinal study can be combined with the current study based on aggregated variables over time, and greatly enrich the meanings of the present findings.

References

Agrawal, A., & Goyal, S. (2001). Group Size and Collective Action: Third-party Monitoring in Common-pool Resources. *Comparative Political Studies, 34*(1), 63-93.

Ancona, D. G., & Caldwell, D. F. (1992). Demography and design: predictors of new product team performance. *Organization Science, 3*, 321-341.

Arbuckle, J. (2007). AMOS (Version 16.0.1): Amos Development Corporation.

Balthazard, P. A., Potter, R. E., & Warren, J. (2002). *The Effects of Extraversion and Expertise on Virtual Team Interaction and Performance.* Paper presented at the 35th Annual Hawaii International Conference on System Sciences (HICSS'02), Hawaii, USA.

Bantel, K., & Jackson, S. (1989). Top management and innovations in banking: Does the composition of the team make a difference? *Strategic Management Journal, 10*, 107-124.

Baron, R. M., & Kenny, D. A. (1986). The Moderator-Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. *Journal of Personality and Social Psychology, 51*(6), 1173-1182.

Bass, B. M. (1980). Team Productivity and Individual Member Competence. *Small Group Research, 11*(4), 431-504.

Brandon, D. P., & Hollingshead, A. B. (2004). Transactive memory systems in organizations: Matching tasks, expertise and people. *Organization Science, 15*, 633-644.

Brandon, D. P., & Hollingshead, A. B. (2006). Characterizing online groups. In A. Joinson, K. Y. A. McKenna, T. Postmes & U. Reips (Eds.), *Oxford Handbook of Internet Psychology* (pp. 105-119). Oxford, UK: Oxford University Press.

Brewer, M. B. (1979). In-group bias in the minimal intergroup situation: a cognitive-motivational analysis. *Psychological Bulletin, 86*, 307-324.

Burt, R. S. (2000). The Network Structure of Social Capital. In B. M. Staw & R. I. Sutton (Eds.), *Research in Organizational Behavior* (pp. 345-423). New York, NY, USA: Elsevier Science JAI.

Carron, A. V., & Spink, K. S. (1995). The Group Size-Cohesion Relationship in Minimal Groups. *Small Group Research, 26*(1), 86-105.

Castronova, E. (2005). *Synthetic Worlds: The Business and Culture of Online Games*. Chicago, IL: University of Chicago Press.

Chatman, J. A., & Spataro, S. E. (2005). Using self-categorization theory to understand relational demography-based variations in people's responsiveness to organizational culture. *Academy of Management Journal, 48*, 321-331.

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.

Cramton, C. D. (2001). The mutual knowledge problem and its consequences for dispersed collaboration. *Organization Science, 12*(3), 346-371.

Cruz, M. G., Boster, F. J., & Rodriguez, J. I. (1997). The Impact of Group Size and Proportion of Shared Information on the Exchange and Integration of Information in Groups. *Communication Research, 24*(3), 291-313.

Dahlin, K. B., Weingart, L. R., & Hinds, P. J. (2005). Team diversity and information use. *Academy of Management Journal, 48*(6), 1107-1128.

Dunbar, K. (1997). How scientists think: Online creativity and conceptual change in science. In T. B. Ward, S. M. Smith & J. Vaid (Eds.), *Creative thought: An investigation of*

conceptual structures and processes (pp. 461-493). Washington, DC: American Psychological Association.

Earley, P. C., & Mosakowski, E. (2000). Creating hybrid team cultures: an empirical test of transnational team functioning. *Academy of Management Journal, 43*, 26-49.

Espinosa, J. A., Slaughter, S. A., Kraut, R. E., & Herbsleb, J. D. (2007). Familiarity, Complexity, and Team Performance in Geographically Distributed Software Development *Organization Science, 18*(4), 613-630.

Faraj, S., & Sproull, L. (2000). Coordinating Expertise in Software Development Teams. *Management Science, 46*(12), 1554-1568.

Fraidin, S. N., & Hollingshead, A. B. (2005). “I know what I'm doing": The impact of gender stereotypes about expertise on task assignments in groups. In M. A. Neale, E. Mannix & M. C. Thomas-Hunt (Eds.), *Managing groups and teams* (Vol. 7, pp. 121-141). Greenwich, CT: JAI Press.

Franzen, A. (1995). Group Size and One-Shot Collective Action. *Rationality and Society, 7*(2), 183-200.

Gibson, C., & Vermeulen, F. (2003). A healthy divide: subgroups as a stimulus for team learning behavior. *Administrative Science Quarterly, 48*, 202-239.

Granovetter, M. (1973). The strength of weak ties. *American Journal of Sociology, 78*, 1360-1380.

Griffiths, M., Davies, M. N., & Chappell, D. (2003). Breaking the stereotype: The case of online gaming. *CyberPsychology & Behavior, 6*(1), 81-91.

Hackman, J. R. (1987). The design of work teams. In J. W. Lorsch (Ed.), *Handbook of organizational behavior* (pp. 315-342). Englewood Cliffs, NJ: Prentice Hall.

Hare, A. P. (1981). Group size. *American Behavioral Scientist, 24*(5), 695-708.

Harrison, D. A., Price, K. H., Gavin, J. H., & Florey, A. T. (2002). Time, teams, and task performance: changing effects of surface- and deep-level diversity on group functioning. *Academy of Management Journal, 45*, 1029-1045.

Hill, G. W. (1982). Group versus individual performance: Are N+1 heads better than one? *Psychological Bulletin, 91*, 517-539.

Hinsz, V. B., Tindale, R. S., & Vollrath, D. A. (1997). The emerging conceptualization of groups as information processes. *Psychological Bulletin, 121*(1), 43-64.

Hogg, M. A., & Reid, S. A. (2006). Social identity, self-categorization, and the communication of group norms. *Communication Theory, 16*(1), 7-30.

Hollingshead, A. B. (1996). Information suppression and status persistence in group decision making: The effects of communication. *Human Communication Research, 23*(2), 193-219.

Holmbeck, G. N. (1997). Toward terminological, conceptual, and statistical clarify in the study of mediators and moderators: Examples from the child-clinical and pediatric psychology literatures. *Journal of Consulting and Clinical Psychology, 65*(4), 599-610.

Kaplan, M. F., & Martin, A. M. (1999). Effects of Differential Status of Group Members on Process and Outcome of Deliberation. *Group Processes Intergroup Relations, 2*(4), 347-364.

Kenny, D. A., Mannetti, L., Pierro, A., Livi, S., & Kashy, D. A. (2002). The statistical analysis of data from small groups. *Journal of Personality and Social Psychology, 83*(1), 126-137.

Kent, R. N., & McGrath, J. E. (1969). Task and group characteristics as factors influencing group performance. *Journal of Experimental Social Psychology, 5*, 429-440.

Kozlowski, S. W. J., & Bell, B. S. (2003). Work groups and teams in organizations. In W. C. Borman, D. R. Ilgen & R. J. Klimoski (Eds.), *Comprehensive handbook of psychology: Industrial and organizational psychology* (Vol. 12, pp. 333-375). New York, NY: John Wiley.

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, resesrch, and methods in organizations: Foundations, extensions, and new directions* (pp. 3-90). San Francisco: Jossey-Bass.

Krebs, S. A., Hobman, E. V., & Bordia, P. (2006). Virtual Teams and Group Member Dissimilarity: Consequences for the Development of Trust. *Small Group Research, 37*(6), 721-741.

Levine, J. M., & Moreland, R. (1994). Group socialization: Theory and research. *European Review of Social Psychology, 5*, 305-336.

Liebkind, K., Nystrom, S., Honkanummi, E., & Lange, A. (2004). Group Size, Group Status and Dimensions of Contact as Predictors of Intergroup Attitudes. *Group Processes & Intergroup Relations, 7*(2), 145-159.

Lind, M. R. (1999). The gender impact of temporary virtual work groups. *IEEE Transactions on Professional Communication, 42*, 276-285.

Littlepage, G. E. (1991). Effects of Group Size and Task Characteristics on Group Performance: A Test of Steiner's Model. *Personal Social Psychology Bulletin, 17*(4), 449-456.

Littlepage, G. E., & Silbiger, H. (1992). Recognition of Expertise in Decision-Making Groups: Effects of Group Size and Participation Patterns. *Small Group Research, 23*(3), 344-355.

Lowry, P. B., Roberts, T. L., Romano, N. C., Jr., Cheney, P. D., & Hightower, R. T. (2006). The Impact of Group Size and Social Presence on Small-Group Communication: Does Computer-Mediated Communication Make a Difference? *Small Group Research, 37*(6), 631-661.

Markham, S. E., Dansereau, F., & Alutto, J. A. (1982). Group size and absenteeism rates: A longitudinal analysis. *Academy of Management Journal, 25*, 921-927.

Martins, L. L., Gilson, L. L., & Maynard, M. T. (2004). Virtual Teams: What Do We Know and Where Do We Go From Here? *Journal of Management, 30*(6), 805-835.

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

McGrath, J. E. (1984). *Groups: Performance and interaction*. Engelwood Cliffs, NJ: Prentice Hall.

McGrath, J. E. (1991). Time, Interaction, and Performance (TIP): A Theory of Groups. *Small Group Research, 22*(2), 147-174.

Mullen, B., Symons, C., Hu, L.-T., & Salas, E. (1989). Group size, leadership behavior, and subordinate satisfaction. *The Journal of General Psychology, 116*(2), 155-169.

Murninghan, J. K., & Conlon, D. E. (1991). The dynamics of intense work groups: a study of British string quartets. *Administrative Science Quarterly, 36*, 165-186.

Nahapiet, J., & Ghoshal, S. (1998). Social capital, intellectual capital and the organizational advantage. *Academy of Management Review, 23*(2), 242-266.

Nowak, K. L. (2003). Sex categorization in computer mediated communication (CMC): Exploring the utopian promise. *Media Psychology, 5*, 83-103.

Olson, M. (1965). *The Logic of Collective Action: Public Goods and the Theory of Groups*. Boston, MA: Harvard University Press.

Owens, D. A., Neale, M. A., & Sutton, R. I. (2000). Technologies of status management: Status dynamics in e-mail communications *Research on managing groups and teams* (Vol. 3, pp. 205-230). Greenwich, CT: JAI Press.

Reagans, R., & Zuckerman, E. W. (1999). *Networks, diversity, and performance: the social capital of corporate R&D units*: Graduate School of Industrial Administration, Carnegie Mellon University.

Reeves, B., Malone, T. W., & O'Driscoll, T. (2008). Leadership's Online Labs. *Harvard Business Review*(May 2008).

Ren, Y., Kraut, R., & Kiesler, S. (2007). Applying Common Identity and Bond Theory to Design of Online Communities. *Organization Studies, 28*(3), 377-408.

Rendel, A. E. (2002). Identity salience: a moderator of the relationship between group gender composition and work group conflict. *Journal of Organizational Behavior, 23*, 749-766.

Ridgeway, C. L., & Diekema, D. (1992). Are gender differences status differences? . In C. L. Ridgeway (Ed.), *Gender, interaction, and inequality*. New York, NY: Springer-Verlag.

Sonnentag, S. (1998). Expertise at Work: Research Perspectives and Practical Interventions for Ensuring Excellent Performance at the Workplace *European Journal of Work and Organizational Psychology, 7*(4), 449-454.

Sproull, L., & Kiesler, S. (1986). Reducing social context cues: Electronic mail in organizational communication. *Management Science, 32*, 1492-1512.

Stasser, G., & Titus, W. (1985). Pooling of unshared information in group decision making: Biased information sampling during discussion. *Journal of Personality and Social Psychology, 48*(1467-1478).

Steiner, I. D. (1972). *Group process and productivity*. New York, NY: Academic Press.

Stewart, G. L. (2003). Toward an understanding of the multilevel role of personality in teams. In M. R. Barrick & A. M. Ryan (Eds.), *Personality and work: Reconsidering the role of personality in organizations* (pp. 183-204). San Francisco: Jossey-Bass.

Stewart, G. L. (2006). A Meta-Analytic Review of Relationships Between Team Design Features and Team Performance. *Journal of Management, 32*(1), 29-55.

Stewart, G. L., & Barrick, M. R. (2000). Team structure and performance: Assessing the mediating role of intrateam process and the moderating role of task type. *Academy of Management Journal, 43*, 135-148.

Sundstron, E., DeMeuse, K. P., & Futrel, D. (1990). Work teams: Applications and effectiveness. *American Psychologist, 45*(1), 120-133.

Tajfel, H., & Turner, J. C. (1986). The social identity theory of intergroup behavior. In S. Worchel & W. Austin (Eds.), *Psychology of Intergroup Relations* (pp. 7-24). Chicago, IL: Nelson-Hall.

Taylor, T. L. (2003). *The Sopranos meets Everquest: Socialization processes in massively multi-user games*. Paper presented at the Digital Arts and Culture (DAC) Streaming Wor(l)ds Conference.

Taylor, T. L. (2006). *Play between worlds: Exploring online game culture*. Cambridge, MA: MIT Press.

Valenti, M. A., & Rockett, T. (2008). The Effects of Demographic Differences on Forming Intragroup Relationships. *Small Group Research, 39*(2), 179-202.

van Knippenberg, D., De Dreu, C. K. W., & Homan, A. C. (2004). Work group diversity and group performance: an integrative model and research agenda. *Journal of Applied Psychology, 89*, 1008-1022.

van Knippenberg, D., & Schippers, M. C. (2007). Work Group Diversity. *Annual Review of Psychology, 58*, 515-541.

van Prooijen, J. W., & van Knippenberg, D. (2000). Individuation or Depersonalization: The Influence of Personal Status Position. *Group Processes Intergroup Relations, 3*(1), 63-77.

Voelpel, S. C., Eckhoff, R. A., & Forster, J. (2008). David against Goliath? Group size and bystander effects in virtual knowledge sharing. *Human Relations, 61*(2), 271-295.

Waller, M., Gupta, N., & Giambatista, R. C. (2004). Effects of Adaptive Behaviors and Shared Mental Models on Control Crew Performance *Management Science, 50*(11), 1534-1544.

Williams, D. (2006a). Groups and Goblins: The Social and Civic Impact of Online Gaming. *Journal of Broadcasting and Electronic Media, 50*(4), 651-670.

Williams, D. (2006b). On and off the 'net: Scales for social capital in an online era. *Journal of Computer-Mediated Communication, 11*(2), article 11.

Williams, D., Caplan, S., & Xiong, L. (2007). Can You Hear Me Now? The Impact of Voice in Online Communities. *Human Communication Research, 33*(4), 427-449.

Williams, D., Castronova, E., Huang, Y., Shen, C., Keegan, B., Ratan, R., et al. (2009). As real as real? Macroeconomic behavior in a large-scale virtual world. *New Media & Society, 11*(5), 685-707.

Williams, D., Ducheneaut, N., Xiong, L., Zhang, Y., Yee, N., & Nickell, E. (2006). From tree house to barracks: The social life of guilds in World of Warcraft. *Games & Culture, 1*(4), 338-361.

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* (pp. 77-140). Greenwich, CT: JAI Press.

Wittenbaum, G. M. (1998). Information Sampling in Decision-Making Groups: The Impact of Members' Task-Relevant Status. *Small Group Research, 29*(1), 57-84.

Yee, N. (2007). Motivations of play in online games. *CyberPsychology & Behavior, 9*, 772-775.

Appendix 1: Tables

Table 1 Example Row of the Everquest II Server Log

Log date	2006-04-04 00:54:58
Zone	(Anonymized)
Sequence ID	1143818449
Account ID	(Anonymized)
Character ID	(Anonymized)
Character Name	(Anonymized)
Player Character Class	Warlock
Player Effective Level	46
Player Group Level	47
Player Group Size	5
Player Level	46
Amount of Experience Points	35
Reason (for gaining experience points)	Combat defeated bonus

Table 2 Test results for hypotheses and revised paths

Hypotheses/Paths	Support	Coefficient	Standardized Coefficient	T-value	P-value
H1: Group size is negatively related to the frequency of group communication.	No (Opposite Direction)	49.33	0.65	42.03	0.000
H2: The frequency of group communication has a positive effect on group performance.	No (Opposite Direction)	-0.34	-0.21	-7.82	0.000
H3: Group size has a positive effect on the aggregate expertise resources in groups	Yes	1.19	0.19	9.85	0.000
H4: Aggregate expertise resource has a positive effect on group performance.	Yes	3.93	3.26	7.95	0.000
H5: Diversity of competence in groups has a negative effect on the frequency of group communication.	Yes	-12.28	-0.04	-2.56	0.005
H6: Diversity of competence in groups has a positive effect on the aggregation of group resources such as expertise.	No (Opposite Direction)	-4.51	-0,18	-9.09	0.000
Added path from group size	New	9.10	0.07	2.75	0.003

to performance					
Added path from group aggregate expertise to group communication frequency	New	0.94	0.08	4.90	0.000

Appendix 2: Figures

Figure 1 Theoretical Model

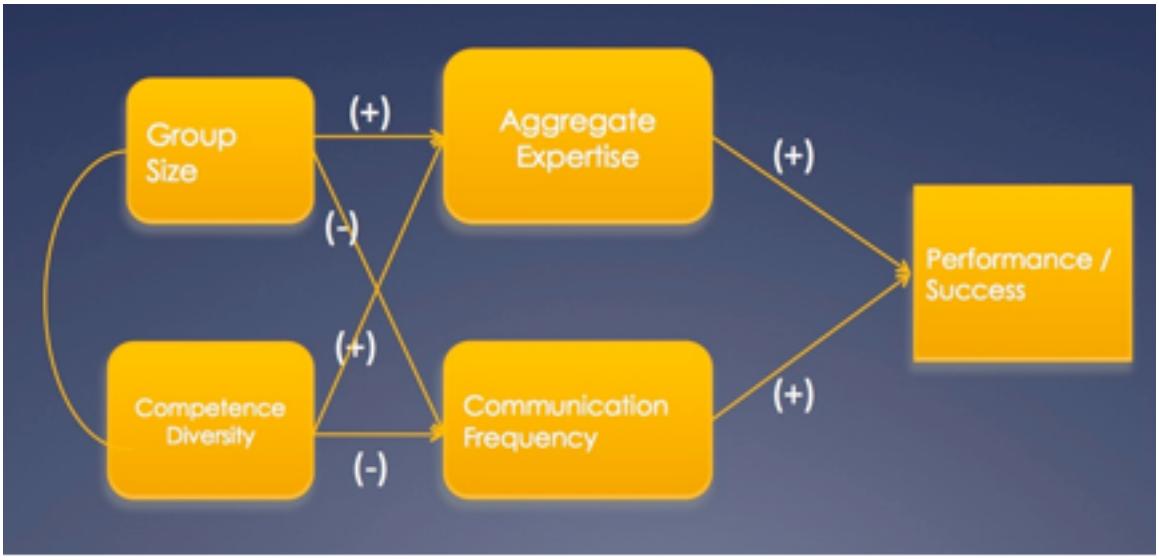

Figure 2 Revised Theoretical Model for the Server of Guk (Player Vs Environment) with Standardized Path Coefficients