THESIS WRITING:
MULTILEVEL ANALYSIS ON TEAMWORK IN AVIATION TRAININGS

By

Ki Se Lee

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Thesis Committee:

Dr. Michael Hein, Thesis Director

Dr. Dana Fuller, Thesis Committee Member

Dr. Greg Schmidt, Department Chair

I dedicate this thesis to all of my family members: my wife, Jessica, and my daughter, Irene. And I also really want to thank my parents, brothers, and sisters in Korea and Seattle.

ABSTRACT

Teamwork is an elusive concept in organizations. The thesis explored the application of HLM (hierarchical linear modeling) analysis in determining the effects of communication and interdependence in the high-fidelity simulation called NASA FOCUS (flight operation center unifies simulation) on teamwork change. A total of 161 college students participated in the study. Approximately, 5 to 10 participants formed a team, and the simulations were conducted over three semesters. The teamwork data were collected with questionnaires before and after simulation. In spite of limitations of this study, it is hard to avoid the conclusion that teamwork gain scores did not vary across teams. Neither communication nor interdependence at both individual and group level influenced teamwork gains. The semester did not have an significance influence on the teamwork gain either.

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CHAPTER ONE: INTRODUCTION

A significant amount of research has been conducted for understanding the phenomena of team performance. Yet, team performance is still an elusive and complex concept in organizations. Scholars and researchers have investigated key constructs associated with teams such as teamwork, team performance, and team effectiveness. At the outset, it is necessary to explore and clarify several fundamental concepts related to teams.

Over the last several decades, economic and technological changes have increasingly demanded more diverse skills, expertise, and experience. The emergence of team-based work structures have allowed organizations to respond more flexibly and adaptively to changes than traditional bureaucratic structures did. Team can be defined as a complex social entity with more than two individuals where expertise and roles are distributed over a limited life span. These members have adaptability, shared goals, and task interdependence in hierarchical structures embedded within a larger organization or environment. The larger context tends to be influenced by ongoing team processes and performance outcomes (Salas, Stagl, Goodwin, & Burke, 2007). Kozlowski and Bell (2003) supplemented this definition by adding that teams perform organizationally relevant tasks, and members maintain and manage boundaries.

Economic, strategic, and technological advances also have contributed to a constant shift of organizations to more team-based organizational structures (Kozlowski & Bell, 2003). In this situation, researchers have started shedding light on the functioning of tightly coupled multiple teams, called multiteam systems, beyond a single team. The larger team system, called MTS, increasingly needs to be examined for deeper understanding of team performance. MTS is defined as the networks of, at least, two teams within the MTS where the component teams coordinate interdependently so that they respond to external contingencies toward the achievement of collective goals. Even though the component teams perform different operations as separate entities with different proximal goals, they share higher order MTS goals (Marks, DeChurch, Mathieu, Panzer, & Alonso, 2005). In other words, each component team is a building block of MTS, but its task completion is integrated into the achievement of higher level MTS goals. In this regard, the goal hierarchy plays a role of the linking mechanism of the multiteam system (Marks et al., 2005). Furthermore, advances in information technology and the global economy result in virtual teams or organizations whose members rarely meet face to face at their workplace.

Teamwork is another critical concept in terms of team effectiveness in organizations. Salas et al. (2007) defined teamwork as a combination of thoughts, actions, and feeling among members that promote adaptive performance as well as the achievement of shared goals. Marks, Mathieu, and Zaccaro (2001) also referred to teamwork as the concept that people work together to achieve certain goals beyond individual capabilities. Many researchers attempted to illustrate what KSAs (knowledge, skills, and attitudes) and competencies constitute teamwork. Salas et al. (2007) indentified teamwork knowledge competencies which includes cue-strategy associations, teammate characteristics, role responsibilities, shared task model, team mission/objectives/norms/resources, relation to the larger organization, task sequencing, team role-interaction patterns, procedures for task accomplishment, accurate task models, accurate problem models, boundary-spanning role, and teamwork skills. McIntyre and

Salas (1995) and Salas et al. (2007) also proposed that knowledge competencies for teamwork include mutual performance monitoring, feedback, communication, backup behavior, adaptability, shared situational awareness, leadership/team management, interpersonal relations, coordination, and decision-making. Attitude or attitudinal competencies include team orientation, collective efficacy, shared vision, team cohesion, interpersonal relations, mutual trust, collective orientation, and a belief in the importance of teamwork (Salas, Stagl, Goodwin, & Burke, 2007).

Along with the proliferation of team-focused research, numerous models and frameworks have been proposed to describe team effectiveness in organizations. One of the most influential approaches is an input-process-output (I-P-O) framework. Salas et al. (2007) incorporated 11models and frameworks into the multilevel integrative framework. In their framework, team inputs include four groups of inputs: (1) individual characteristics, (2) team characteristics, (3) task characteristics, and (4) work structure. Specifically, individual characteristics contain task KSAs, motivation, team orientation, mental models, and personality. Team characteristics contain constructs emerging over team processes (power structure and performance arrangements) as well as pre-existing constructs (team-level openness to experience and team-level team orientation). Task characteristics cover task organization, task type, and task complexity. Work structure entails not only a formal work structure but also a social structure depending on each other: it includes work assignment, team norms, and communication structure. In this framework, individual level cognition such as expectation moderates the effect of inputs on processes or throughputs (Salas et al., 2007).

Next, inputs are followed by team processes, which are the means by which team members work together to achieve their goals. Team processes are different from taskwork because team processes facilitate taskwork for greater goals. Marks et al. (2001) defined team process as interrelated actions of team members which translate inputs to proximal and distal outcomes in the process of goal-directed interdependent activities and thus coordinate taskwork to achieve higher level goals. While Marks et al. (2005) conceptualized that team processes are nested within two phases such as action and transition, Marks et al. (2001) indicated that team processes are nested within three phases by including interpersonal phase. The transition phase is referred to as a period of time when teams focus more on guiding their paths towards goal achievement. Mission analysis, goal setting, and strategy formulation typically occurs in this phase. The action phase is a time period when team members largely conduct taskwork. Consequently, team processes associated with coordination and monitoring occur during this phase. The last phase pertains to team processes promoting interpersonal relationships. Processes in the interpersonal phase primarily occur in both transition and action phases. In summary, ten team processes can be categorized into three higher phases: (1) transition phase processes are mission analysis formulation and planning, goal specification, and strategy formulation; (2) action phase processes are monitoring progress toward goals, system monitoring, team monitoring and backup behavior, and coordination; and (3) interpersonal phase processes are conflict management, motivation and confidence building, and affect management (Marks et al., 2001).

Furthermore, processes are considered mediating mechanism between inputs and outputs in the context of multiphase episodic framework of team performance even though there have been very few definitions of team process (Mark et al., 2001). In other words, the I-P-O framework is based on the idea that teams perform in sequential and simultaneous cycles of activities toward goals. These cycles are called episodes which can be defined as distinctive periods of time in which temporal intervals influence team goal-related activities. Because team performance consists of a series of closely related I-P-O epiosodes, outcomes from previous episodes serve as inputs for the next cycle. This episode-based approch to team performance implies what process a team is more actively engaged in depends on what phase a team is in. Therefore, the recurring phase model describes temporal influences on team processes.

IMOI (Input-mediator-output-input) framework has been proposed to characterize recent research and overcome limitations of the I-P-O framework (Ilgen, Hollenbeck, Johnson, & Jundt, 2005). Even though the I-P-O framework has been a dominant approach to team performance, the mediating variables of the framework failed to include emergent cognitive and affective states. Additionally, the I-P-O framework implies a single cycle from inputs to outputs by its nature in spite of the mulitilevel and dynamic nature of team performance. Moreover, the classic framework failed to identify the link between episodes which can involve nonlinear causal linkages. In contrast, the IMOI framework consists of the initial IM (input-mediator) phase (called the forming stage), the subsequent stage of the MO (mediator -output) phase (called the functioning stage), and the finishing stage of the OI (output-input) phase. What happens in the early forming stage is more affective than behavioral in the IMOI framework. Trusting in the team, planning and developing strategy, structuring norms, roles, and interaction patterns occur over this stage. Subsequently, the functioning stage is a more mature stage when team bonding, behavioral adaptation, and learning typically occur. The final finishing stage refers to disbanding of members in the life cycle of teams after achieving goals.

The purpose of this study is to examine the multilevel effects of the high fidelity simulation training on teamwork in a multi-team setting. This study is expected to explore the multilevel conceptualization of team phenomena by using multilevel techniques unlike many studies having flawed generalizations of individual level analyses to team level conclusions (Kozlowski & Bell, 2003). Traditional linear regression models do not take a nesting structure of data, or individuals within teams or semesters, into account and thus, risk overlooking the importance of group effects or contextual influences which usually exist in social science research (Bickel, 2007). Yet, the multilevel analysis, also called hierarchical linear models, mixed models, or random coefficients models in other fields, assumes that some of the coefficients in models are random. These random components represent the influence of hierarchically nested variables not included in the traditional models. Consequently, the multilevel analysis takes care of dependencies in data and also models all levels simultaneously. Therefore, the multilevel modeling provides opportunities for analyzing interplays between individuals and groups.

Additionally, the study attempts to take into consideration the effect of time on team processes. The effect of time in team research is one of the most neglected issues in team research (Kozlowski & Bell, 2003). It would be the most desirable to use growth modeling in this study. Yet, this study has to use gain scores between pre-test and post-test scores for a dependent variable because a minimum of three time points is recommended for multilevel analyses (Rosenfeld & Penrod, 2011).

The present study uses a data set with a multilevel structure which involves the relationships between individual level variables and group level variables. The use of hierarchical linear modeling (HLM) analysis in this study provides six advantages over ordinary least squares (OLS) regression: (1) better estimates of regression paths when there is between-group variance in the dependent variable, (2) the separation of the variance in the dependent variable into between-group and within-group, (3) varying slopes of individual level relationships within groups, (4) the consideration of the dependence among observations, (5) the comparison of individuals to others in the population or to people within the same groups, and (6) the cross-level relations and contextual data (Pollack, 1998; Tabachnick & Fidell, 2007; Snijders & Bosker, 2012).

The current study emerged from two basic research questions (1) does an average level of gain scores in teamwork vary across teams participating in simulations? (2) does the slope of each team vary across teams? Specifically, the aim of this paper is to explore the application of HLM (Hierarchical Linear Modeling) analysis in determining the effects of the high-fidelity simulation called the NASA FOCUS (flight operation center unifies simulation) lab on the amount of change in teamwork.

Based on the literature review above, the following two overarching hypotheses were generated in this study. Hypothesis 1 was generated for examining the relationship between communication and teamwork. Specifically, Hypothesis 1-a and 1-b were created for communication frequency and importance, respectively. Additional hypotheses ranging from hypothesis 2-a to2-e were formulated to include components of interdependence for independent variables. Additionally, under the context of the multilevel analysis, the study will examine whether, if any, the effects of independent variables vary across teams. The following hypotheses are addressed:

Hypothesis 1-a: teamwork will be predicted by expected communication frequency.

Hypothesis 1-b: teamwork will be predicted by expected communication importance.

Hypothesis 2-a: teamwork will be predicted by the expected dependence of my job on other positions

Hypothesis 2-b: teamwork will be predicted by the expected dependence of others on my job.

Hypothesis 2-c: teamwork will be predicted by the expected degree to which a respondent shares a performance goal with others.

Hypothesis 2-d: teamwork will be predicted by the expected degree to which a respondent has competing goals with others.

Hypothesis 2-e: teamwork will be predicted by the expected sense of belongingness with others.

There is no definitive sample size for HLM. Several factors such as the number of parameters estimated, the intraclass correlation, whether the data are balanced, can affect the appropriate sample size for multilevel analysis. The most common rule of thumb is at least 20 groups and 30 observations per group and even 30 groups and 30 observations per group (Bickel, 2007). The numbers of groups and observations in the present study do not meet the recommended criteria for HLM. Therefore, the estimates and standard errors of regression coefficients and variances might not be accurate. Particularly, a small sample size at level two (i.e., a sample of 50 or less) might result in biased estimates of the level two standard errors. (Maas & Hox, 2005) In this regard, it seems appropriate to limit this study of the multilevel analysis on teamwork to exploratory research.

CHAPTER TWO: METHODS

Participants

A total of 161 college students participated in the study by taking a senior level capstone course at Middle Tennessee State University in spring of 2011 and spring and fall semester of 2012. The final number of the participants was 122 in the following analyses due to missing data ($n_{fall2011}$ = 36, $n_{spring2012}$ = 43, and $n_{fall2012}$ = 43). All students were enrolled in one of aerospace disciplines such as professional pilot, flight dispatch, maintenance management, aerospace administration, and aviation technology. The participants in fall 2011, spring 2012, and fall 2012 were assigned to 5, 6, and 6 teams, respectively, and each participant completed pre-training and post-training surveys. The descriptive statistics of participants and teams / semesters are displayed in Table 1 and 2, respectively.

Procedure

In the beginning of each semester in the study, all participants enrolled in the course Aerospace 4040 submitted a consent form for the data collection. The overall process of the course is as follows: orientation, lab training, first simulation, first action review, second simulation, and second action review. The simulation part of the course was conducted from 3 pm to 6 pm on every Monday throughout the semester. In each semester, participants were organized into separate 5 – 6 teams based on each specialization. Team members represented their own specializations in the simulation. Positions in the simulation were matched with participants' specializations to the extent possible. Positions included flight dispatch coordinator, flight dispatch data, crew scheduling, weather, maintenance control, maintenance planning, ramp tower, and pilot.

Approximately, 5 – 10 participants formed each team.

There were small differences between the semesters. Simulation scheduling varied inevitably across semesters. In the fall 2012, the 30 minute-long orientation to the simulation portion of the course and performance reviews were first incorporated into simulation experience. These changes were made to provide better training experiences in the simulation. The overall process of the simulation remained the same.

Measures

The dependent variable, teamwork, is a gain score based on an average response to a 30 item questionnaire on teamwork. The questionnaire is based on the works of Mathieu and Marks who used a taxonomy of team processes by Marks, Mathieu, & Zaccaro (2001). The gain scores were obtained by subtracting pre-simulation score from post-simulation scores. The teamwork questionnaire consists of 30 items on a 1 (not at all) to 5 (to a very great extent) scale. Cronbach's alphas for the teamwork items of pre- and post-simulation were .97 and .97. The 30 items are designed to assess the three subcategories of team processes such as transition, action, and interpersonal process. The transition process is assessed by items measuring mission analysis, goal specification, and strategy and planning. The action process consists of items measuring goal monitoring, resource monitoring, team monitor and backup, and teamwork coordination. The interpersonal processes are measured by items for conflict management, motivation and confidence, and affect management.

The independent variable or covariates at the individual level are communication-related measures (i.e., anticipated communication frequency and importance among team members) and interdependence-related measures (i.e., the dependence of my job or their job on each position in the simulations, the degree to which a respondent share performance goal with each position and have competing goals with each position, and the sense of belongingness with each position). The item of the anticipated communication frequency is on a 0 (never) to 4 (more than ten times) scale. The communication frequency scale of pre- and post-simulation were found to be highly reliable (8 items; $\alpha = .76$ and.75, respectively). The item of the anticipated communication importance is also on a 0 (not at all important) to 4 (absolute essential) scale. The Cronbach alphas of the pre- and post-simulation communication importance scale were .79 and .78, respectively (8 items). The communication score is calculated as the mean of communication importance for each position rated by each individual. The interdependence questionnaire is rated on a 1 (strongly disagree) to 10 (strongly agree) Likert-type scale. In addition to the individual-level variables, team-level variables were created for the multilevel analysis by aggregating each individual level variable. Table 3 summarizes the descriptive statistics and Cronbach alphas for the dependent and independent variables.

Data Analysis

This study used IBM SPSS Version 18 for statistical analysis, formerly known as PASW (predictive analytics software) or SPSS. As mentioned above, the hierarchical linear model analysis where participants were nested within teams was conducted to test whether there are associations between communications, interdependence, and teamwork gain. The process of building a multilevel model began with the unconditional model having no predictor at both levels. This study followed the two-phase process supported by Raudenbush and Bryk (2002) and employed by the HLM program; the first is to explain within-group variability and the second is to explain between-group variability. All models in this study adopted the default covariance structure, VC (Variance Components) which provides an estimate of the intercept variance without slope variance and the estimation method of REML (residual maximum likelihood).

In the null or no predictors model, the study examined whether there exist significant variance in teamwork gain scores across teams in semesters. The null model provided an estimated mean teamwork gain score for all teams as well as a partitioning of the variance between the between-team error from the average intercept and individual-level residual. Then, within – and between – group variances were obtained and thus, the value of the ICC (intra class correlation) showed what proportion of variance accounts for by the team level. ICC shows whether HLM is an appropriate analysis method for the data set. The value of the deviance produced in this model is a measure of the degree of misfit of the model.

Next, the communication-related variables and interdependence-related variables were tested as potential covariates. As in most statistical models, this study retained, if any, statistically significant covariates or removed, if any, covariates which fail to predict significantly the teamwork gain. Particularly, grand-mean centered level 1 predictors were added to the null model. This model (Model 1) indicates whether the level 1 predictors are related to teamwork. All the corresponding variance components of the slopes were fixed at zero. The contribution of each individual predictor was assessed in this model. The improvement of the model in this step was tested by computing the difference of the deviance of Model 1 and the null model. Next, whether level 2 (team) characteristics explain the differences in the group intercept was assessed. This model is the means-as-outcomes model (Model 2). Even though the semester variable is supposed to be considered as a level 3 predictor, it was used as a level 2 predictor because it is acceptable to use a small number of categorical level 3 predictors as level 2 predictors (Tabachnick & Fidell, 2007). The level 2 slopes of level 2 predictors represent the average change in group means of the teamwork for a one point increase in level 2 predictor when controlling for, if any, other predictors in the model. Subsequently, whether any of the slopes of the predictors has a significant variance between the teams was assessed in Model 3. This model is a random coefficient regression model (Model 3).

CHAPTER THREE: RESULTS

A two-level model assessed the effects of the 7 predictors on teamwork. It was expected that these predictors would be positively related to teamwork gain scores. The level-one units were average gain scores of respondents on the 7 variables. After losses of cases due to missing data, teamwork gain scores were calculated for 122 participants comprising the level-two units or teams. The sample sizes for teams ranged from 5 to 10.

The valid sample size for the dependent variable, teamwork, was 122 out of the total 161 due to missing data. Twenty-four percent of the participants missed either before- or after-training teamwork measures. Regardless of teams, the gain score of teamwork was 0.31 on average and its standard deviation was 0.68. This indicates the aviation simulation training increased the scores of the teamwork by 0.31 over the time of training. Yet, Figure 1 shows there are three outliers, such as gain scores of -1.53, -1.73, and -2.63, at a greater distance from the median than 1.5 times the IQR (inter-quartile range). These data points represent potentially univariate outliers. The existence of outliers can have serious consequences when fitting multilevel models.

From each team perspective, teamwork gain scores vary across 17 teams. The teamwork gain score for each team is shown in Figure 2. Even though most teams showed increase in teamwork after the training, team 4, 9, and 14 showed a negative gain scores, and team 18 showed no change in teamwork. It should be noted that the standard deviations of Team 4, 7, 9, 10, 12, 14, and 17 were relatively big ranging from 0.61 to 1.42. This indicates variations within group are not small. Additionally, team 1, 11, 12, 14, and 18 had univariate outliers in teamwork gain scores.

The valid number of responses for my job’s dependence on others was 12. The gain score of my job's dependence was -0.34 on average and its standard deviation was 2.37. This indicates that participants tend to perceive that their job in the team setting is implemented in a more independent manner that expected. Yet, the perception of my job's dependence varies much across participants. Figure 3 indicates there are five univariate outliers such as the gain scores of 9.00, 7.86, 5.43, 4.57, and 4.71 at the upper end and three univariate outliers such as -5.29, -5.57, and -7.00 at the bottom end of the boxplot. It should be noted that team members of the 2012 fall semester are more likely to show extreme gain scores of the dependence of my job on other positions (two members in team 18, two in team 16, one in team 8, one in team 15, one in team 17, one in team 11).

A total of 118 responses for other's dependence on my job were used due to missing data. The gain score of others' dependence was -0.24 on average and its standard deviation was 2.41. In conjunction with my job's dependence, this shows that participants tend to perceive that their works are more likely independent than expected regardless of whose job it is. Yet, other's dependence on my job also varies across participants. Figure 4 indicates there are four univariate outliers such as the gain scores of 9.00, 7.57, 4.86, and 4.71 at the upper end and six univariate outliers such as -4.83, -4.71, two of -5.00, -6.43 and -7.14 at the bottom end of the boxplot.

Regarding sharing performance goals with others, a total of 118 responses were analyzed due to missing data. The gain score of sharing performance goals was 2.40 on average and its standard deviation was 3.22. It should be noted that the training appears to increase the perception that participants share their performance goals, and this increase occurred differentially to team members. As in Figure 5, there was no univariate outlier on the boxplot of sharing performance goals.

The valid number of responses for the sense of belongingness was 118. The gain score of the belongingness was 0.10 on average and its standard deviation was 2.43. As in my dependence, their dependence, and sharing goals, the belongingness scores increased slightly on average with different degrees. Figure 6 indicates there are six outliers such as the gain scores of 9.00, 7.57, 5.14, 4.43, 5.00 and 4.14 at the upper end and five outliers such as -4.43, -4.86, -5.57, -6.00 and -7.71 at the bottom end.

A total of 118 responses for competing goals with others were used in the study. The gain score of the competing goals decreased by -0.66 on average and its standard deviation was 3.03. Participants tend to perceive slightly less competition for goals. Yet, perceptions vary across participants. Figure 7 indicates there was two univariate outliers such as the gain scores of 8.00 and 7.43 at the upper end.

The valid communication frequency responses were 122 in total. The gain score of the communication frequency was 0.31 on average and its standard deviation was .86. Participants indicated a small increase in communication frequency and the amount of the increase is relatively similar to all participants. Figure 8 indicates there are one outlier (3.00) at the upper end and three outliers of -2.11, -2.38, and -3.43 at the bottom end.

As with other variables, the number of communication importance responses was 122. The gain score of the communication importance was 0.76 on average and its standard deviation was 0.85. Participants responded that communication is more important than expected and the increase in communication importance appears relatively similar to all participants. Figure 9 indicates there are five univariate outliers such as 2.86, 2.38, 2.14, 1.88, and 1.88 at the upper end and five outliers such as -1.63, -1.63, -

1.88, -2.25, and -2.57 at the bottom end. All the univariate outliers on the boxplots are subsequently examined again in the regression context.

There were no very highly correlated level 1 variables because all the correlations were below 0.8 (Table 4). Yet, it should be noted that there was a significant correlation between my dependence on others and others' dependence on me, $r = .76$, $p < .01$. This indicates that participants as individuals tend to perceive interdependence among them. Additionally, my dependence on others, others' dependence on me, and sharing performance with others had several significant medium correlations among the variables. Even though there were a few negative correlations, the relationships were almost all positive. Correlations between level 1 predictors are further illustrated in the following analysis.

The correlations between team characteristics showed similar patterns with varying degrees of differences and significance. The *r* coefficients ranged from -.11 to -.74. It should be noted that communication frequency had significant correlations with all other level 2 predictor variables. Similarly, communication importance, my dependence on others, and others' dependence on my job also showed significant correlations with almost all level 2 predictors. This might be associated with insignificant level 2 predictors due to collinearity. The correlation matrix among all the predictors is presented in Table 4.

Hierarchical linear modeling (HLM) was used to examine relations between teamwork gain scores and communication- and interdependence-related variables. The analyses began with a null model. The null model for individual *i* and team *j* can be represented as;

$$Y_{ij} = \beta_{0j} + \varepsilon_{ij}$$

where $\beta_{0j}$is the intercept, and ε_{ij} is the variation in individual scores within teams.

Clearly, the model is a two-level multilevel regression model which involves individual and group levels. Additionally, β_{0j} can be represented as:

$$\beta_{0j} = \gamma_{00} + \mu_{ij}$$

Where γ_{00} is the average intercept and μ_{ij} is the between-team variation in intercepts. Thus, the null model can be expressed as $Y_{ij} = \gamma_{00} + \mu_{ij} + \varepsilon_{ij}$. As in the final numeric equation, the total parameters to be estimated are three. In other words, the estimated parameters include the fixed effect value for the intercept, level 1 variance, and random level 2 variance, or the randomly varying intercept. The covariance structure of the null model is the default VC (variance components), and it is actually the same as an identity matrix because there is no random slope variance (i.e., the covariance between the intercept and slope). The details of the null model are presented in Table 5.

The overall intercept is estimated as 0.31 which is the grand mean of teamwork gain scores. The residual variance was 0.45 which is the amount of individual differences while the intercept variance, or variability within level 2 was 0.19. Thus, the overall variance of the teamwork scores is 0.46. Little variability within level 2 units indicates the nesting of individual level observations is not systematically associated with levels of outcomes. Therefore, the intercept variance indicates that there is no significant variance between the teams to be explained by level 2 predictors. The intra-class correlation is calculated as such:

$$\rho = \tau_{00}/(\tau_{00} + \sigma^2)$$

Where τ_{00} is the team level variance and σ^2 is the individual level variance.

Table 6 provides the intraclass correlation calculated from 0.19/0.46 = 0.04 or 4%. This indicates 4% of variance in teamwork lies between teams. The results of the null model suggest that multilevel analysis is not very appropriate for the data because intercepts do not vary significantly across teams (Wald Z = 0.571, p = .568/2 = .284) and only about 4% of the total variability in teamwork scores lies among teams. Variances cannot be negative but the Wald Z test is a two-tailed test. For this reason, the significance level was divided by 2 in order to represent the one-tailed test.

In summary, the null model, one-way ANOVA with random effects was not significant. The teams did not significantly differ on the teamwork gain scores. It implies that OLS (Ordinary Least Square) linear regression is more likely appropriate rather than hierarchical linear modeling. Furthermore, the reliability of the sample mean for any unit as an estimate for its population mean ranged from .17 to .30 which is low reliability. Yet, Table 6 shows there is significant variance to be explained within teams (Wald Z = 7.16, $p < .001$).

As the intraclass correlation in the null model indicated, multilevel analysis was not appropriate for the study data. Instead, a standard multiple regression analysis was performed between teamwork gain scores as the dependent variable and the grand-mean centered 7 predictor variables used in the null model. As in the null model of the multilevel analysis, all independent variables were grand-mean centered. The analysis was found to be statistically not significant, F (7, 99) = 1.62, MSE = 0.40, p = .14, R^2 = .11. None of the predictors were significant predictors even though the results of the multiple regression analysis indicate that the seven predictors explained 10.9% of the variance. Table 7 displays the regression coefficients.

The assumptions of multilevel models were evaluated. The histogram (Figure 10) and normal probability plot of residuals (Figure 11) suggested a relatively normal distributional shape of the residuals. Residual-predicted plot (Figure 12) showed homoscedasticity. The examination of casewise diagnostics suggested there were no cases having undue influence on the model because all of the cases have Cook's distances much less than the critical value of 0.37 with n = 50 and 0.19 with n = 100. Additionally, the average leverage value is calculated as .14 and then no value was twice as large as .14 or three times as large as .14. The leverage statistics also indicates no case exerts undue influence over the model. Considering that the maximum value of studentized deleted residual of 2.05 is less than 3.40 (alpha = .001) with degree of freedom of 91, there was no outlier based on residual statistics. Table 8 displays the casewise diagnostics. The partial scatterplots of the independent variables indicate that linearity is a reasonable assumption. The partial scatterplots are presented in Figure 11 to 19. Additionally, because the largest VIF was not greater than 10, multicollinearity was not an issue. The Durbin-Watson statistic (1.75) also indicates that the assumption of independent errors is tenable.

In the multiple regression analyses, the average gain score of the teamwork was 0.33 which is similar to the null model. As in the multicollinearity assumption above, there was no substantial correlation among the grand-mean centered predictors. Yet, it should be noted that the communication frequency had a large positive correlation with the communication importance ($r = .49$, $p < .001$). Additionally, there were significant correlations between variables: the dependence on others' job and the sense of belongingness with the dependence of my job ($r = .76$, $p < .001$ and $r = .49$, $p < .001$, respectively), the dependence on my job with sharing goals ($r = .37$, $p < .001$), and the competing goals with sharing goals ($r = .49$, $p < .001$). Because the communication frequency correlates best with the dependent variable ($r = .76$, $p < .001$), it is likely that communication frequency will best predict the teamwork. While the seven predictors accounted for 10.9% of the variation in teamwork gain, the adjusted r^2 (.04) indicates that the cross-validity of the model is not bad because it is approximately 6% less variance than the r^2 in the dependent variable. Yet, the value itself was very small (4.2%). The Durbin-Watson statistic (1.75) shows that the assumption of independent errors has been likely met because it is very close to 2. The results of ANOVA indicate that the model is not a significant fit of the data overall ($F = 1.62$, p =14). In terms of model parameters, unstandardized coefficients indicated that many variables have positive relationships with teamwork: the communication frequency ($b = 0.17$), communication importance ($b = 0.05$), sharing goals with others ($b = 0.02$), and the sense of belongingness ($b = 0.06$). Specifically, as the best possible predictor, communication frequency, increases by one unit, teamwork increases by 0.17 when effects of other predictors are controlled. From the standardized coefficients (β) perspective, as the sense of belongingness increased by one standard deviation, the teamwork increases by 0.22 standard deviations. However, as in the null model indicated, no predictor made a significant contribution to the multiple regression model. As in following multilevel analyses, all independent variables were grand-mean centered because it enables researchers to have the multiplicative interaction term approximately orthogonal to the main effect independent variables which likely leads to less inflated standard errors and more precise coefficient estimate (Bickel, 2007). Table 7 displays the results of the multiple regression analysis.

Subsequently, Model 1 with grand-mean centered level 1 predictors was run and then SPSS generated a warning message “The final Hessian matrix is not positive definite although all convergence criteria are satisfied. The MIXED procedure continued despite this warning. Validity of subsequent results cannot be ascertained”. In case that the Hessian is not positive definite, it indicates that some effects might be perfectly or highly correlated and provide redundant information about the dependent variable. As discussed in the correlation matrix, there were no very highly correlated variables because all the correlations were below .8. Yet, many level 1 predictors show medium correlations with other predictors. Specifically, the sense of belongingness with others is significantly correlated with three predictors: the dependence of my job on other positions, $r = .49$, the dependency of others on my job, $r = .58$, sharing performance goals with others, $r = .26$ (all ps < .01). The dependence of my job on other positions is also significantly correlated with other three variables at the .01 level: the dependence of their job on my job ($r = .76$), sharing performance goals with others ($r = .37$), and the sense of belongingness ($r = .49$).

Table 9 and 10 show there was no serious problems with multicollinearity. All VIF values were smaller than 10, and all condition indexes were not greater than 15. Even though there are not clear multicollinearity problems, two variables such as communication frequency, and my job with relatively high correlations were excluded from Model 1 to avoid not positive definite Hessian matrix and then, the revised model

(Model 1-1) was run again. Yet, all level 1 grand-mean centered predictors still were not significant even though the model did not produce the Hessian matrix issue in this revised Model 1. Table 5 displays fixed effects and variance component of Model 1-1.

In Model 2, a total of ten parameters (7 level 2 predictors, intercept, residual, and level 2 random effect) are described in Table 5. The team level variables are generated by aggregating individual scores within each team. The seven aggregated level 1 variables, or level 2 predictors represent the team context variables. As in the level 1 of Model 1, Model 2 can be represented as:

$$Y_{ij} = \beta_{0j} + \varepsilon_{ij}$$

Where τ_{00} is the team level variance and σ^2 is the individual level variance.

The level 2 model can be represented as:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}W_{1j} + \gamma_{02}W_{2j} + \gamma_{03}W_{3j} + \gamma_{04}W_{4j} + \gamma_{05}W_{5j} + \gamma_{06}W_{6j} + \gamma_{07}W_{7j} + u_{0j}.$$

Where β_{0j} is the intercept of the average teamwork gain score in the j^{th} team, γ_{00} is the grand mean teamwork gain score for all teams, γ_{00} through γ_{07} are the increment to the average teamwork gain for W_{1j} through W_{7j}, W_{1j} through W_{7j} is team means of seven level 2 predictor, and u_{0j} is the residual errors for team j.

The regression coefficients in the level 2 model above represents the average change in the team means of the teamwork gain scores for a 1 unit increase in the team-level predictor when controlling for other level 2 predictors in the model. Regarding the level 2 predictors, it should be noted that all the aggregated team-level predictors are not significant predictors for teamwork gain scores: the aggregated dependency of my job on others (γ_{01} = 0.13, *t* = 1.11, *p* = .31), the aggregated dependency of their job on my job (γ_{02} = -0.12, *t* = -0.79, *p* = .45), the aggregated degree to which a respondent shares performance goals with others (γ_{03} = -0.04, *t* = -0.51, *p* = .62), the aggregated sense of belongingness with others (γ_{04} = -0.41, *t* = -0.39, *p* = .71), the aggregated degree to which a respondent has competing goals with others (γ_{05} = 0.01, *t* = 0.07, *p* = .95), the aggregated communication frequency (γ_{06} = 0.82, *t* = 2.24, *p* = .05), and the aggregated communication importance (γ_{07} = -0.48, *t* = -0.48, *p* = .15). It should be noted that the *p*-value of the aggregated communication frequency is .052, which is very close to the alpha level. The addition of the team-level aggregated variables changes the intercept from 0.31 in the null model to 0.44.

The estimates of fixed effect in Model 2 are shown in Table 5. The estimates of the variance components suggests that the level 2 predictors barely reduce the level 2 variance from 0.02 to 0.01 and the level 1 variance from 0.45 to 0.44. Specifically, the variance reduction at level 1 is .54% (= (0.45-0.44) / 0.45). The reduction in variance between teams is 31% (= (0.019-0.013) / 0.019). The ICC of the model 1 are barely reduced from 0.19/0.46 = 0.04 or 4% to .13/.46 = .03 or 3%. Table 4 shows there is still significant variability to be explained within teams (Wald Z = 7.21, $p < .001$) but not between teams (Wald Z = .33, *p* = .74).

Additionally, Model 3 with a semester variable examined whether semester contexts affect teamwork gain. The 2012 fall training had a highest teamwork gain score (0.35) among three semesters. Based on this result, a dummy variable for semester was created (2012 fall = 1 and the other semesters = 0). A total of 4 parameters were estimated in Model 3. The addition of the semester variable shows a small change in intercept from 0.31 in the null model to 0.35 in Model 3. This indicates that the 2012 fall training or the latest training increased 0.35 point of the teamwork score on average. The non-2012 fall trainings increased 0.30 point of the teamwork on average.

The estimates of the variance components of Model 3 suggest that the semester variable did not change the variance in the individual and team level. Table 5 shows there is still significant variability to be explained within teams (Wald Z = 7.17, $p < .001$) but not between teams (Wald Z = 0.67, $p = .50$).

Since no predictor was significantly related to teamwork gain scores, there was no need to see if the slope varies across teams and thus, other possible multilevel Models were not further assessed. Table 5 shows the results of two-level multilevel models to predict the teamwork gain scores.

CHAPTER FOUR: DISCUSSION

This study attempted largely to illustrate what variables affect teamwork gain scores by constructing a two-level model. HLM or Multilevel modeling was used to measure the dependent variable within and between teams in three semesters. Regarding the research question about a randomly varying intercept, it was hard to avoid the conclusion that teamwork gain scores did not vary across teams. Additionally, individual-level communication frequency and importance did not influence individual teamwork gain scores. Neither did the components of the interdependence such as the dependence of my job on others, the dependence of their job on my job, sharing performance goals with others, having competing goals with others, and the sense of belongingness with others. Additionally, the aggregated characteristics of individual-level predictors as team contexts did not have a significant influence on the level of teamwork gain either. The semester as a level three variable was not a factor for the teamwork gain scores. In summary, nothing was a significant predictor on teamwork gain scores.

In spite of these findings, there remain limitations inherent in this study. Clearly, there are a range of problems to be explained and more research is needed to illuminate the relationship between the dependent and independent variables in this research. First, there might be new predictors or a better combination of predictors because correlated predictors might be problematic in multilevel linear modeling. Tabachnick and Fidell (2007) recommend to select a small number of uncorrelated predictors if possible. Otherwise, it is more likely that none of regression coefficients are statistically significant. Initially, this study started with a pre-determined range of variables to predict teamwork and thus, other predictors were not allowed to avoid correlated predictors in the study. Variables with lower correlations among predictors would improve the results of this study.

Moreover, some relationships among variables can be interpreted in different ways. For example, this study assumed that the higher communication frequency, the more teamwork gain scores. Yet, because members in the simulations might have to adapt to a new team environment or a contingency situation by reducing communication as interactions, this assumption might not be always appropriate in interpreting the relationship between them. Competing goals also might have a different relationship than expected because facing steep competition among members either contributes to more teamwork or less teamwork. Also this might depend partially on individual characteristics.

Another problem remains to be explained. The fact that team members have different roles in the simulation might affect the perceptions on how to improve teamwork. The inclusion of position variables might provide better chances to explain how differently each member perceived the teamwork and then, responded to the simulation situations because the extent to which members increase communication or interdependence may depend largely on roles and responsibilities rather than what team they belong to in the simulations. For example, there might be higher communication gain scores, interdependence gain scores, and teamwork gain scores between pilots and air traffic controllers in ramp tower than between crew scheduling and weather forecasters. Additionally, possible task sequences in aviation simulations might have a differential impact on teamwork gain scores across team members. For example, simple communication, such as delivering simple weather information to ramp tower or flight dispatcher, might not contribute to teamwork gain as much as do communications for flight route changes between air traffic controller in ramp tower and pilot under severe weather conditions or aircraft maintenance problems. In this regard, taking into consideration gain scores from the inter-positional perspective would be another step toward richer and more inclusive understanding of teamwork.

Furthermore, This study initially limited predictors only to communication- and interdependence- related measures. Because teamwork is an elusive concept involving possibly a range of confounding variables, the predictors chosen in this study might not fully explain what factors have an influence on teamwork or predictors in the simulation setting. The fact that the maximum correlation between teamwork and the predictors was 0.21 indicates the possibilities that the measures of teamwork might be conceptually flawed or irrelevant to teamwork. In this regard, there may be more appropriate predictors or essential covariates to interpret teamwork gain scores. In order to capture teamwork gain as a result of ongoing team processes, the future study may need to include meansures for individual characteristics such as motivation, team orientation, or functional skill levels. These individual knowledge, skills, and attitude (KSA) can play a critical role for explaining communication, interdependence, and teamwork on the individual level. Additionally, from the perspective of the IMOI framework, if any, temporary construct resulting from previous I-P-O episodes could be considered as a predictor or covariate in the future analysis. In this way, the study will be able to control more team process variables and then, explain more on what mediating and moderating variables possibly play an important roles between communication / interdependence and teamwork.

More importantly, this study might lack the adequacy of the sample size for multilevel analysis. Large and complex models such as multilevel modeling require a substantial sample size at each level even though only a few predictors are entered (Tabachnick & Fidell, 2007). According to Eliason (1993), at least, a sample size of 60 is required even if fewer than 5 parameters are estimated. Additionally, according to the power analysis software called Optimal Design (Spybrook, 2011), the settings used in this study requires about 151 groups of teams with power of .80, 10 sample size within team (the default value is 20), the effect size of .25, and the intraclass correlation of .10. Furthermore, Kreft and DeLeeuw (1998) indicated that statistical power grows with the intracorrelation (ICC) and emphasized this for the tests for the level 2 effects and cross-level interactions. The lack of the cluster-level covariate was not helpful either. For all reasons and explanations given previously, additional research needs to be done in the future in order to reach a fuller understanding of the relationship among the variables.

REFERENCES

Bickel, R. (2007). *Multilevel analysis for applied research: it's just regression!* New York, NY: US: Guilford Press.

Ilgen, D. R., Hollenbeck, J. R., Johnson, M., & Jundt, D. (2005). Teams in organizations: From input-process-output to IMOI models. *Annual Review of Psychology, 56*, 517-543.

Kozlowski, S., & Bell, B. (2003). Work groups and teams in organizations. In W. C. Borman, D. R. Ilgen, & R. J. Klimoski, *Handbook of Psychology, Vol. 12* (pp. 333-375). New York: Wiley: Industrial and Organizational Psychology.

Maas, C. J., & Hox, J. J. (2005). Sufficient Sample Sizes for Multilevel Modeling. *Methodology: European Journal of Research Methods for the Behavioral and Social Sciences 1 (3)*, 86-92.

Marks, M. A., DeChurch, L. A., Mathieu, J. E., Panzer, F. J., & Alonso, A. (2005). Teamwork in multiteam systems. *Journal of Applied Psychology, 90*, 964-971.

Marks, M. A., Mathieu, J. E., & Zaccaro, S. J. (2001). A temporally based framework and taxonomy of team processes. *Academy of Management Review, 26*, 356-376.

Pollack, B. N. (1998, 2(4)). Hierarchical linear modeling and the unit of analysis problem: a solution for analyzing responses of intact group members. *Group Dynamics: theory, research, and practice*, 299-312.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: applications and data analysis methods, 2nd edition.* Thousand Oaks, CA: Sage.

Rosenfeld, B., & Penrod, S. D. (2011). *Research methods in forensic psychology.* Wiley.

Salas, E., Stagl, K. C., Goodwin, G. F., & Burke, C. S. (2007). Fostering team effectiveness in organizations: Toward an integrative theoretical framework.

Snijders, T., & Bosker, R. (2012). *Multilevel analysis, 2nd edition.* Thousand Oaks, CA: Sage Publications.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics, 5th edition.* Boston: Pearson Education.

APPENDICES

APPENDIX A: Tables

Table 1

Participant Characteristics (N = 161)*

Position	Frequency	Percent	Valid Percent
First simulation			
Flight Dispatch Coordinator	18	11.18%	12.32%
Flight Dispatach Data	27	16.77%	18.49%
Crew Scheduling	16	9.94%	10.95%
Weather	14	8.70%	9.58%
Maintenance Control	18	11.18%	12.32%
Ramp Tower	16	9.94%	10.95%
Pilot	37	22.98%	25.34%
Total	146	90.68%	100.00%
Missing	15	9.31%	
Grand Total	161	100.00%	
Second simulation			
Flight Dispatch Coordinator	17	10.55%	12.97%
Flight Dispatch Data	29	18.01%	22.13%
Crew Scheduling	15	9.32%	11.45%
Weather	14	8.70%	10.68%
Maintenance Control	15	9.32%	11.45%
Ramp Tower	11	6.83%	8.39%
Pilot	30	18.63%	22.90%
Total	131	81.36%	100.00%
Missing	30	18.63%	
Grand Total	161	100.00%	
Specialization			
Administration	39	24.22%	26.17%
Flight Dispatch	22	13.66%	14.76%
Maintenance Management	20	12.42%	13.42%
Professional Pilot	62	38.50%	41.61%
Technology	6	3.72%	4.02%
Total	149	92.54%	100.00%
Missing	12	7.45%	
Grand Total	161	100.00%	

Note. *. The valid number of the participants was 122 due to missing data.

Table 2

Descriptive Statistics for Teams (N = 17) and Semesters (N = 3)

Team	*n* (Participants)	Description
Semester 1		
Team 1	9	Team 1 in 2011 fall
Team 2	9	Team 2 in 2011 fall
Team 3	5	Team 3 in 2011 fall
Team 4	7	Team 4 in 2011 fall
Team 5	6	Team 5 in 2011 fall
Valid N (listwise)	36	
Semester 2		
Team 7	9	Team 1 in 2012 spring
Team 8	6	Team 2 in 2012 spring
Team 9	6	Team 3 in 2012 spring
Team 10	7	Team 4 in 2012 spring
Team 11	5	Team 5 in 2012 spring
Team 12	10	Team 6 in 2012 spring
Valid N (listwise)	43	
Semester 3		
Team 13	8	Team 1 in 2012 fall
Team 14	5	Team 2 in 2012 fall
Team 15	7	Team 3 in 2012 fall
Team 16	8	Team 4 in 2012 fall
Team 17	7	Team 5 in 2012 fall
Team 18	8	Team 6 in 2012 fall
Valid N (listwise)	43	
Total	122	

Table 3

Descriptive Statistics for Individual, Team, and Semester Level Data

Variable	*N*	*Mean*	*SD*	Min	Max	Reliability	
						pre-test	post-test
Individual-level							
Teamwork gain scores (dependent variable)	122	0.31	0.68	-2.63	1.73	0.97	0.97
Gain score of the dependence of my job on others	118	-0.34	2.37	-7.00	9.00	0.91	0.89
Gain score of the dependence of others on my job	118	-0.24	2.41	-7.14	9.00	0.87	0.85
Gain score of sharing performance with others	118	2.40	3.22	-6.00	9.00	0.91	0.90
Gain score of the sense of belongingness	118	0.10	2.43	-7.71	9.00	0.92	0.91
Gain score of the competing goals with others	118	-0.66	3.03	-7.86	8.00	0.93	0.96
Gain score of the communication frequency	122	0.03	0.86	-3.43	3.00	0.77	0.75
Gain score of the communication importance	122	0.08	0.85	-2.57	2.86	0.80	0.80
Team-level							
Gain score of the dependence of my job on others	161	-0.36	0.79	-2.52	1.57		
Gain score of the dependence of others on my job	161	-0.25	0.94	-2.37	1.82		
Gain score of sharing performance with others	161	2.35	1.39	0.28	5.48		
Gain score of the sense of belongingness	161	0.08	1.04	-2.07	1.69		
Gain score of the competing goals with others	161	-0.68	1.13	-2.47	1.05		
Gain score of the communication frequency	161	0.02	0.39	-0.70	0.67		
Gain score of the communication importance	161	0.06	0.41	-0.61	0.90		
Semester-level (dummy variable)							
Semester	161	0.30	0.21	0.00	1.00		
2011 fall semester and 2012 spring semester = 0	113						
2012 fall semester = 1	48						

Table 4

Pearson Correlations Among Variables (*N* = 122)

	1	2	3	4	5	6	7	8
Individual level								
Teamwork gain scores (dependent variable)	1							
Gain score of the communication frequency	.21*	1						
Gain score of the communication importance	.20*	.49**	1					
Gain score of the dependence of my job on others	.01	-.01	.17	1				
Gain score of the dependence of others on my job	.03	.04	.21*	.76**	1			
Gain score of sharing performance with others	.08	.09	.18	.37**	.33**	1		
Gain score of the competing goals with others	-.07	.13	.12	.17	.19*	.49**	1	
Gain score of the sense of belongingness	.15	-.03	.13	.49**	.58**	.26**	.08	1
Team level								
Teamwork gain scores (dependent variable)	1							
Gain score of the communication frequency	.10	1						
Gain score of the communication importance	.05	.67**	1					
Gain score of the dependence of my job on others	-.04	.27**	.30**	1				
Gain score of the dependence of others on my job	.05	.50**	.71**	.18*	1			
Gain score of sharing performance with others	-.11	.26**	.35**	.74**	.23**	1		
Gain score of the competing goals with others	.20*	.44**	.45**	.13	.55**	-.06	1	
Gain score of the sense of belongingness	.05	.27**	.09	.12	.33**	.09	.71**	1

Note. **. Correlation is significant at the .01 level (2-tailed). *. Correlation is significant at the .05 level (2-tailed).

Table 5

Fixed effects for OLS Regression and HLM Models

Variables	Null Model				OLS Regression				Model 1				Model 1-1				Model 2				Model 3			
	Est	*SE*	*t*	*Sig*	*B*	*SE*	*t*	*Sig*	*Est*	*SE*	*t*	*Sig*	*Est*	*SE*	*t*	*Sig*	*Est*	*SE*	*t*	*Sig*	*Est*	*SE*	*t*	*Sig*
Intercept	0.31	0.07	4.54	0.00	0.33	0.06	5.14	0.00	0.33	0.06	5.14	0.00	0.32	0.06	4.95	0.00	0.44	0.25	1.75	0.12	0.35	0.12	2.89	0.01
Individual-level																								
Communication frequency					0.17	0.10	1.75	0.08	0.17	0.10	1.75	0.08												
Communication importance					0.05	0.10	0.50	0.62	0.05	0.09	0.50	0.62	0.15	0.08	1.91	0.06								
Dependence of my job on others					-0.02	0.04	-0.34	0.73	-0.02	0.04	-0.34	0.73												
Dependence of others on my job					-0.03	0.05	-0.53	0.60	-0.03	0.05	-0.53	0.60	-0.04	0.04	-1.02	0.31								
Sharing performance with others					0.02	0.03	0.87	0.39	0.02	0.02	0.87	0.39	0.02	0.02	0.73	0.46								
Competing goals with others					-0.03	0.03	-1.25	0.21	-0.03	0.03	-1.25	0.21	-0.03	0.03	-1.06	0.29								
Sense of belongingness					0.06	0.03	1.66	0.10	0.06	0.03	1.66	0.10	0.05	0.03	1.51	0.13								
Team-level																								
Communication frequency																	0.82	0.36	2.24	0.05				
Communication importance																	-0.48	0.30	-1.58	0.15				
Dependence of my job on others																	0.13	0.11	1.11	0.31				
Dependence of others on my job																	-0.12	0.15	-0.79	0.45				
Sharing performance with others																	-0.04	0.08	-0.51	0.62				
Competing goals with others																	0.01	0.10	0.07	0.95				
Sense of belongingness																	-0.04	0.10	-0.39	0.71				
Semester-level (dummy variable) Semester																								
[Semester_new = 0]																					-0.05	0.15	-0.34	0.74
[Semester_new = 1]																					-	-		
-2 Restricted Log likelihood	254.61								220.89				216.98				263.51				256.48			

Table 6

Variance components for HLM Models

	Null Model				Model 1				Model 1-1				Model 2				Model 3			
Variables	*Est.*	*SE*	*Wald Z*	*Sig.*	*Est.*	*SE*	*Wald Z*	*Sig.*	*Est.*	*SE*	*Wald Z*	*Sig.*	*Est.*	*SE*	*Wald Z*	*Sig.*	*Est.*	*SE*	*Wald Z*	*Sig.*
Residual	0.45	0.06	7.16	0.00	0.40	0.06	6.78	0.00	0.41	0.06	6.28	0.00	0.44	0.06	7.20	0.00	0.45	0.06	7.17	0.00
Intercept [subject = Team]	0.02	0.03	0.57	0.57	.00[a]	0.00			0.00	0.03	0.04	0.97	0.01	0.04	0.33	0.74	0.02	0.04	0.67	0.50
ICC	0.04				-				0.00				0.03				0.05			

a. This covariance parameter is redundant. The test statistic and confidence interval cannot be computed.

Table 7

Summary of Multiple Linear Regression Analysis

Variable (gain scores)	*B*	*SE (B)*	*Beta*	*t*	*Sig.*	95% CI Lower Bound	95% CI Upper Bound	Collinearity Statistics *VIF*
(Constant)	0.33	0.06		5.14	.01	0.20	0.46	
Communication frequency	0.17	0.10	0.22	1.75	.08	-0.02	0.37	1.59
Communication importance	0.05	0.09	0.06	0.50	.62	-0.14	0.24	1.65
Dependence of my job on others	-0.02	0.04	-0.05	-0.34	.73	-0.10	0.07	2.53
Dependence of others on my job	-0.03	0.05	-0.09	-0.53	.60	-0.12	0.07	3.06
Sharing performance with others	0.02	0.02	0.10	0.87	.39	-0.03	0.07	1.49
Competing goals with others	-0.03	0.03	-0.14	-1.25	.21	-0.08	0.02	1.36
Sense of belongingness	0.06	0.03	0.22	1.66	.10	-0.01	0.12	1.78

Note. *B* = unstandardized regression coefficients; *Beta* = standardizded regression coefficients

Table 8

Casewise Diagnostics

No.	Case Number	Cook's Distance	Mahalanobis Distance	Centered Leverage Value
1	1	0.01	4.48	0.05
2	2	0.00	11.63	0.12
3	3	0.00	6.51	0.07
4	4	0.00	1.59	0.02
5	5	0.00	2.88	0.03
6	6	0.00	4.00	0.04
7	7	0.00	5.03	0.05
8	8	0.00	2.28	0.02
9	10	0.01	2.93	0.03
10	12	0.01	7.78	0.08
11	13	0.01	3.91	0.04
12	16	0.01	2.26	0.02
13	17	0.00	11.12	0.11
14	18	0.00	3.71	0.04
15	19	0.01	25.93	0.26
16	20	0.01	3.16	0.03
17	22	0.00	4.36	0.04
18	23	0.00	9.65	0.10
19	25	0.02	6.18	0.06
20	26	0.00	2.32	0.02
21	32	0.01	4.16	0.04
22	33	0.00	2.57	0.03

Table 8, Continued
Casewise Diagnostics

No.	Case Number	Cook's Distance	Mahalanobis Distance	Centered Leverage Value
23	34	0.00	6.42	0.06
24	35	0.02	6.25	0.06
25	36	0.00	7.05	0.07
26	37	0.02	7.01	0.07
27	38	0.01	5.94	0.06
28	40	0.01	7.65	0.08
29	41	0.01	4.78	0.05
30	42	0.00	2.48	0.03
31	46	0.00	5.41	0.05
32	49	0.01	5.28	0.05
33	50	0.01	6.30	0.06
34	53	0.00	2.13	0.02
35	54	0.00	2.62	0.03
36	55	0.00	2.92	0.03
37	56	0.02	6.39	0.06
38	57	0.01	2.03	0.02
39	62	0.01	5.63	0.06
40	64	0.00	1.85	0.02
41	66	0.00	3.23	0.03
42	70	0.04	8.57	0.09
43	71	0.00	1.28	0.01

Table 8, Continued
Casewise Diagnostics

No.	Case Number	Cook's Distance	Mahalanobis Distance	Centered Leverage Value
44	72	0.01	6.82	0.07
45	76	0.14	9.49	0.10
46	77	0.01	0.89	0.01
47	80	0.01	21.99	0.22
48	82	0.03	6.16	0.06
49	86	0.03	16.63	0.17
50	87	0.00	11.16	0.11
51	90	0.01	2.43	0.02
52	92	0.00	6.69	0.07
53	93	0.00	18.75	0.19
54	96	0.00	6.08	0.06
55	97	0.00	6.26	0.06
56	99	0.01	4.42	0.04
Total N		56	56	56

a. Limited to first 100 cases.

Table 9
Collinearity Diagnostics

			Variance Proportions							
Dimension	Eigenvalue	Condition Index	Constant	Communication Frequency	Communication Importance	My job's dependence	Others' dependence	Sharing performance goals	Competing goals	Sense of belongingness
1	2.74	1.00	0.00	0.00	0.01	0.04	0.03	0.03	0.02	0.04
2	1.57	1.32	0.01	0.19	0.13	0.01	0.01	0.00	0.01	0.02
3	1.13	1.56	0.02	0.02	0.05	0.00	0.02	0.16	0.29	0.04
4	0.99	1.66	0.91	0.00	0.01	0.00	0.00	0.03	0.00	0.00
5	0.52	2.28	0.04	0.02	0.03	0.02	0.05	0.59	0.41	0.08
6	0.48	2.40	0.00	0.02	0.02	0.26	0.01	0.04	0.14	0.62
7	0.37	2.71	0.00	0.74	0.76	0.01	0.00	0.06	0.08	0.00
8	0.20	3.67	0.00	0.01	0.00	0.65	0.89	0.09	0.04	0.20

APPENDIX B: Figures

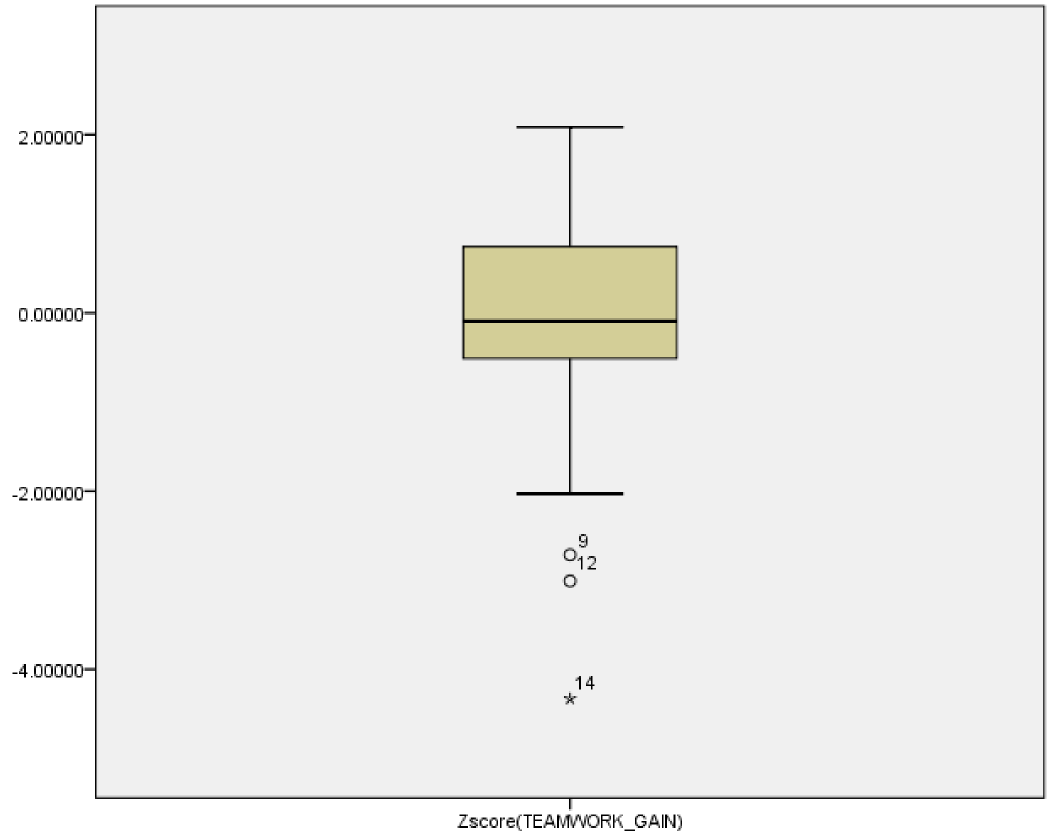

Figure 1. Boxplot of teamwork gain scores.

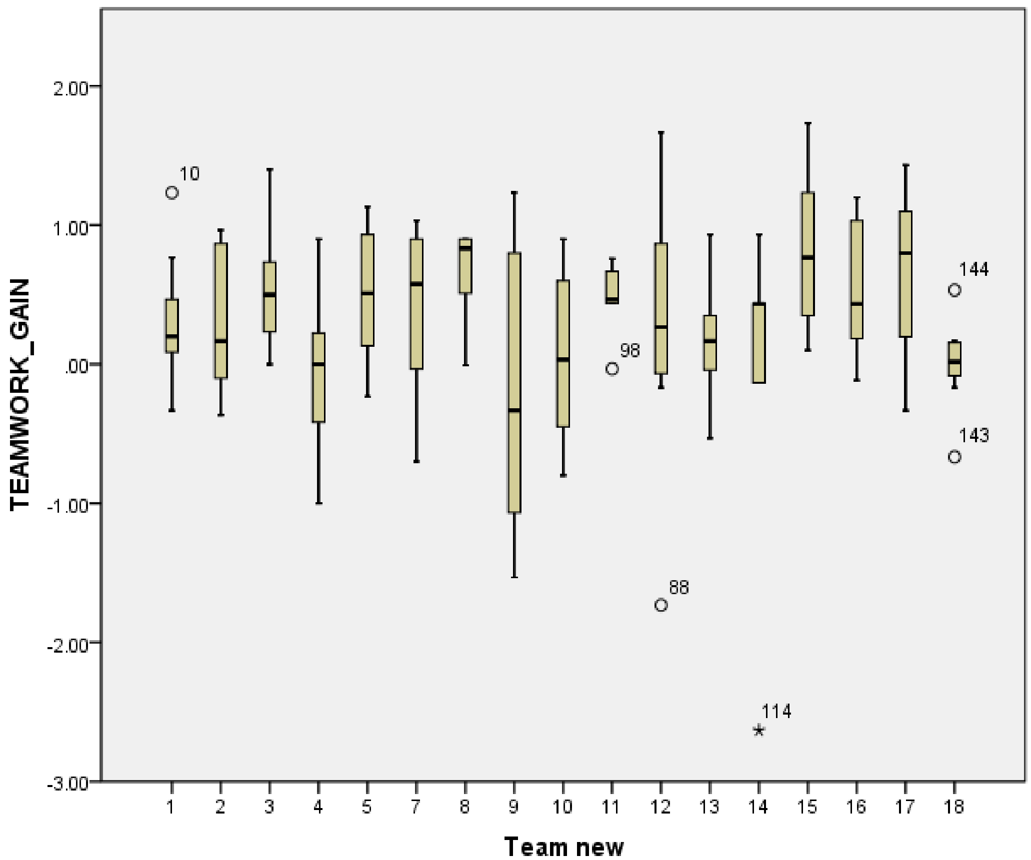

Figure 2. Boxplots of teamwork gain scores per team.

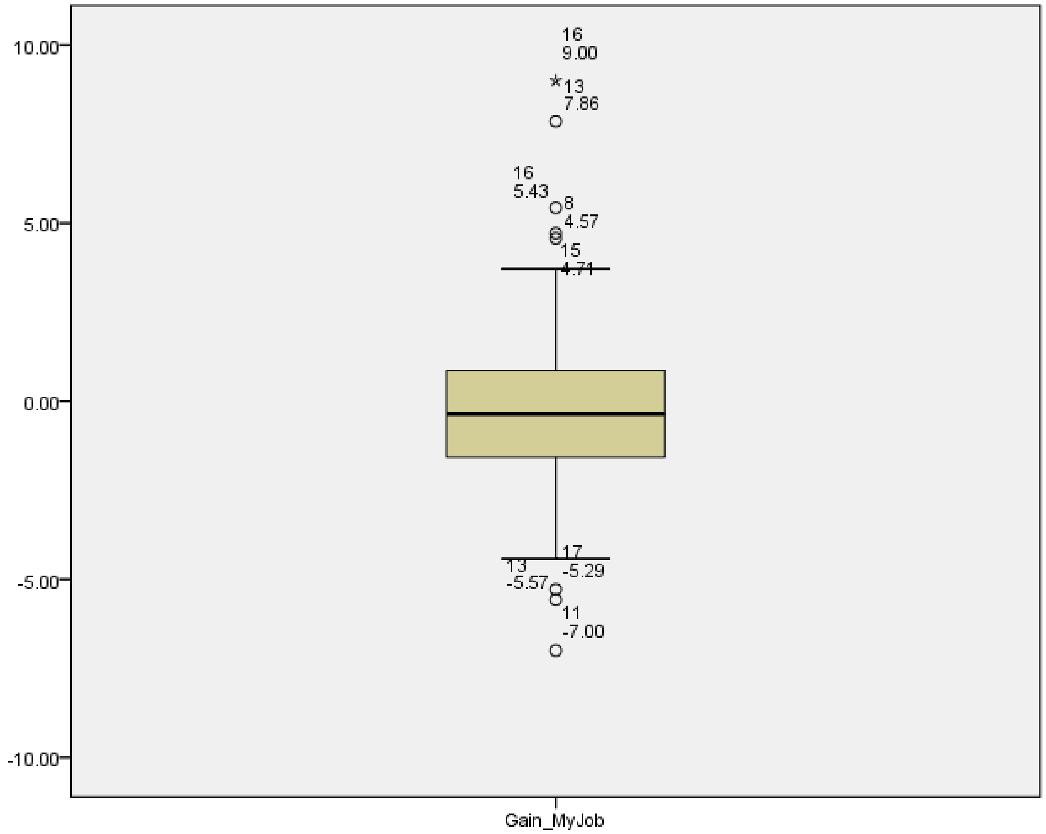

Figure 3. Boxplot of my job's dependence on others.

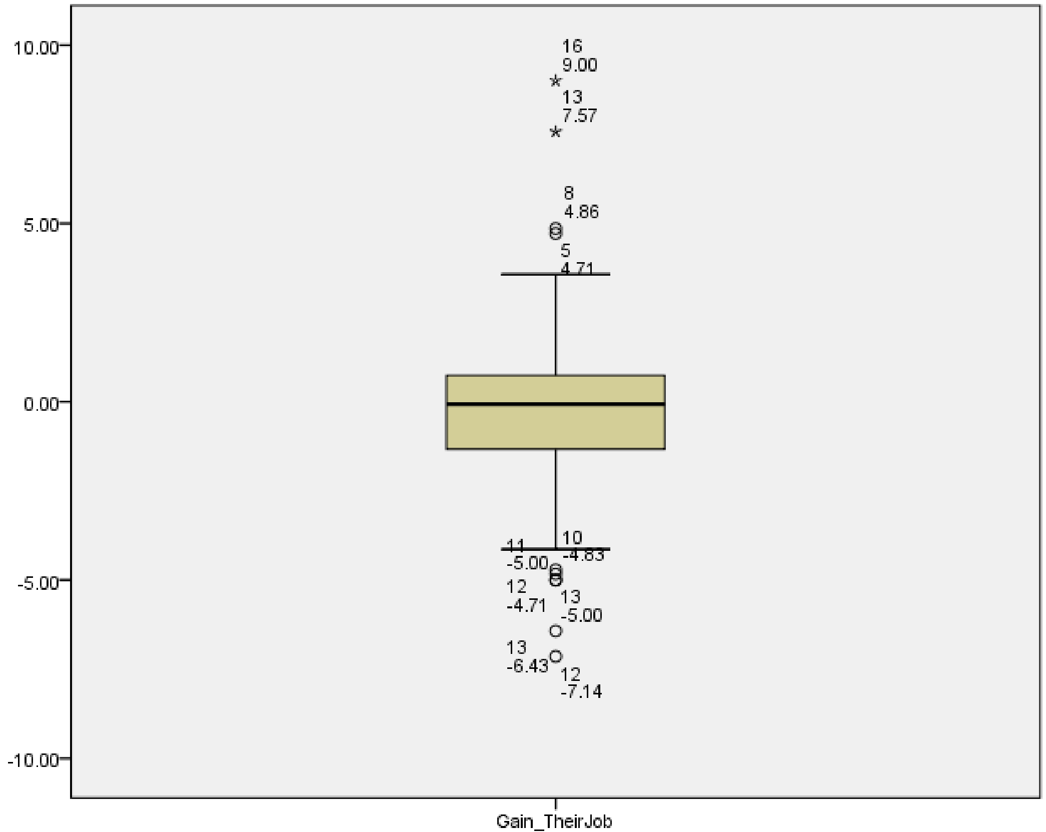

Figure 4. Boxplot of others' dependence on my job.

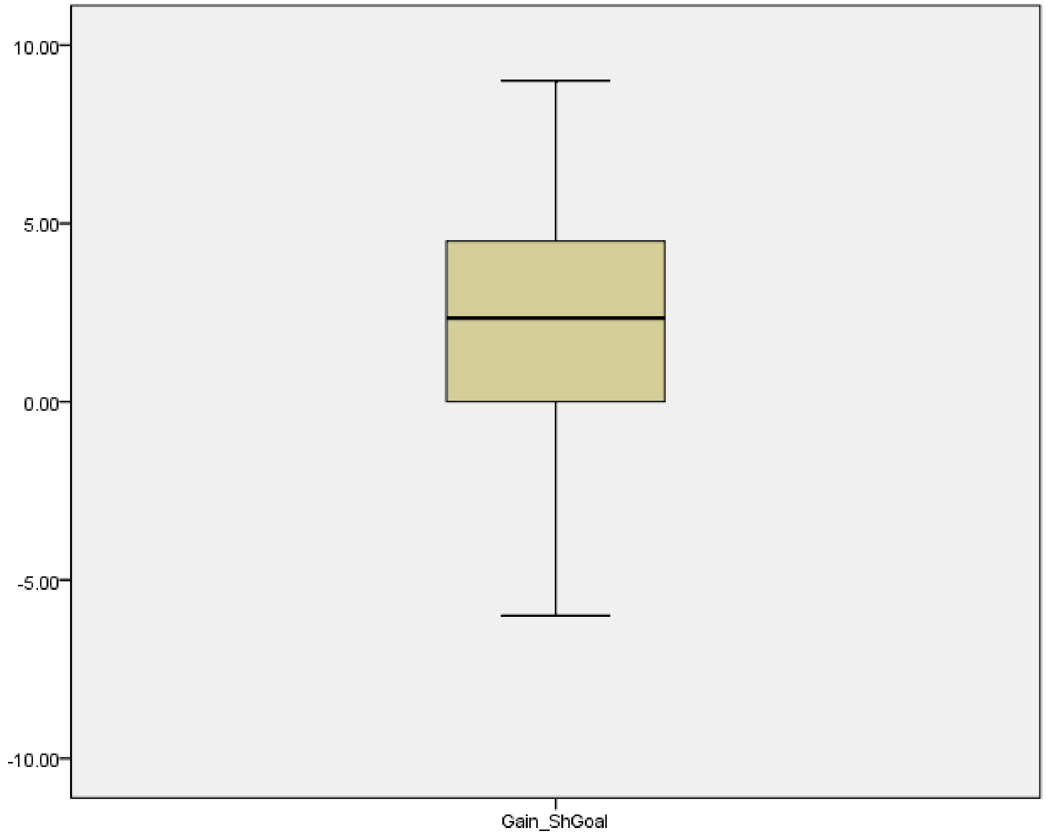

Figure 5. Boxplot of sharing performance goals.

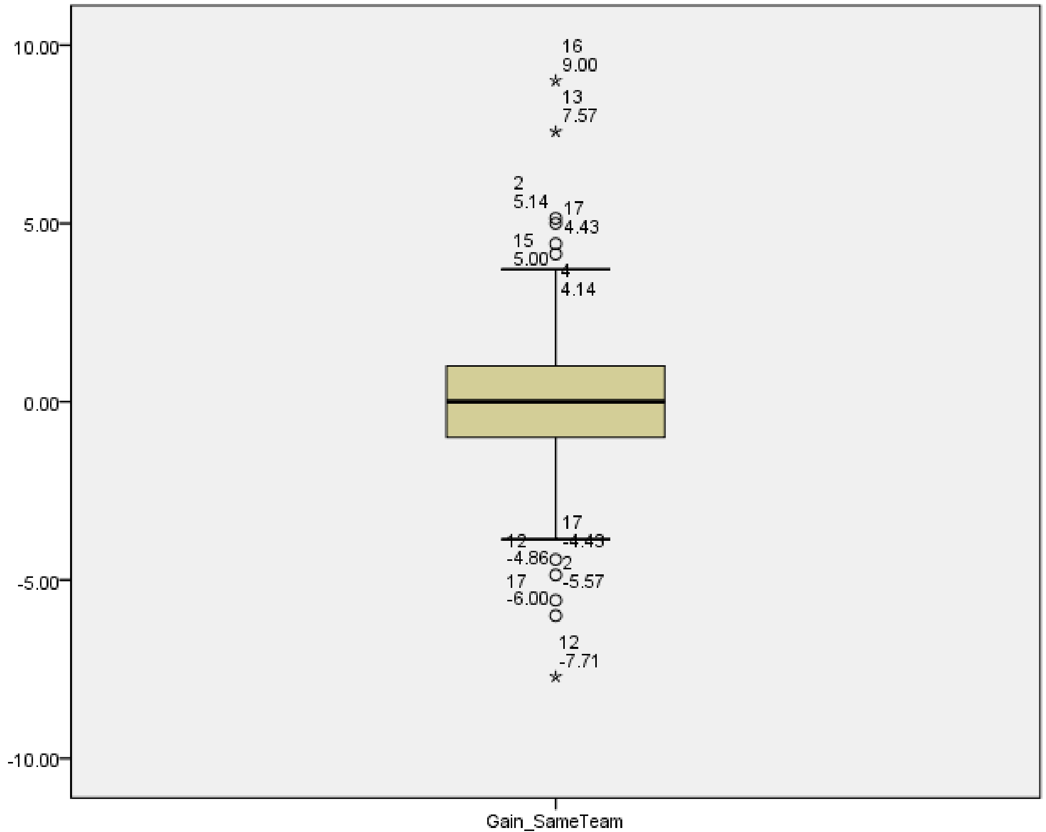

Figure 6. Boxplot of the sense of belongingness.

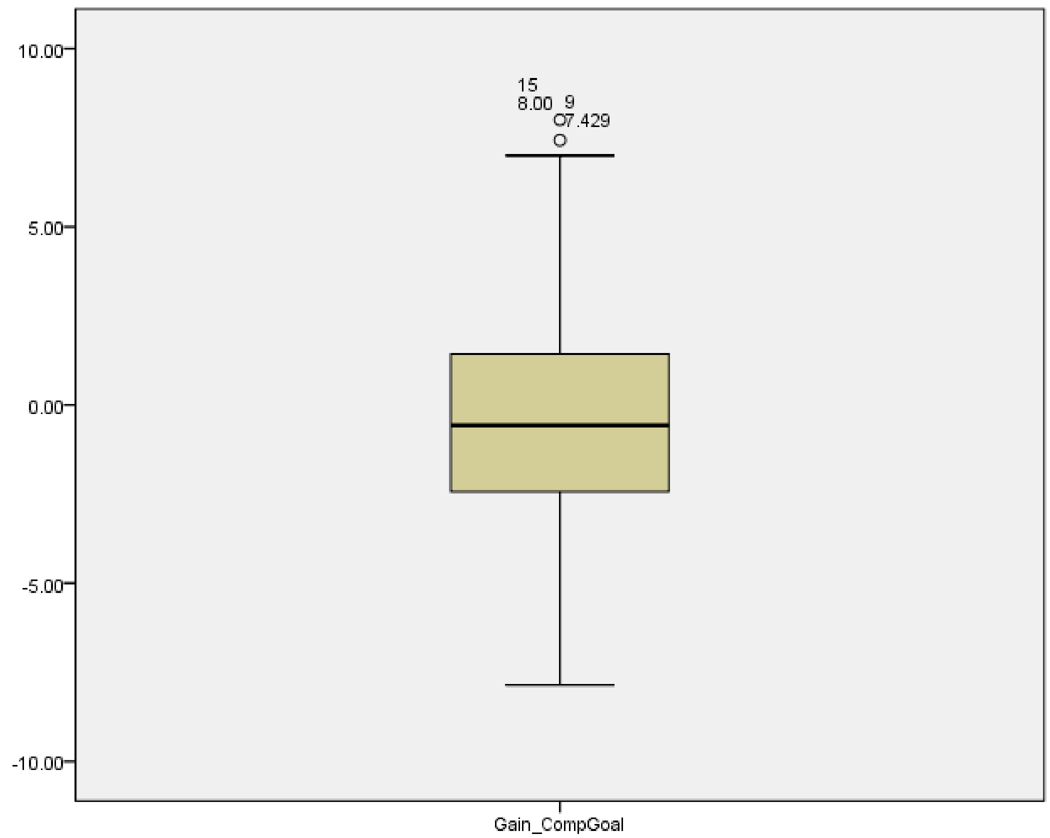

Figure 7. Boxplot of competing goals.

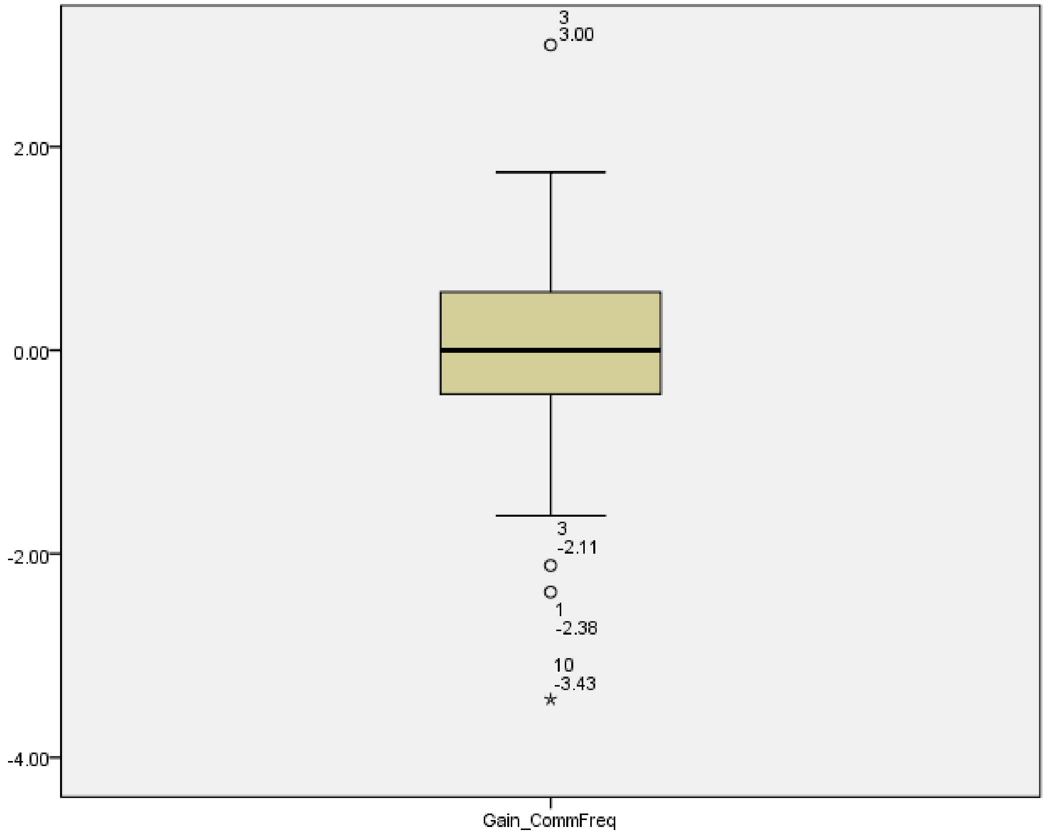

Figure 8. Boxplot of communication frequency.

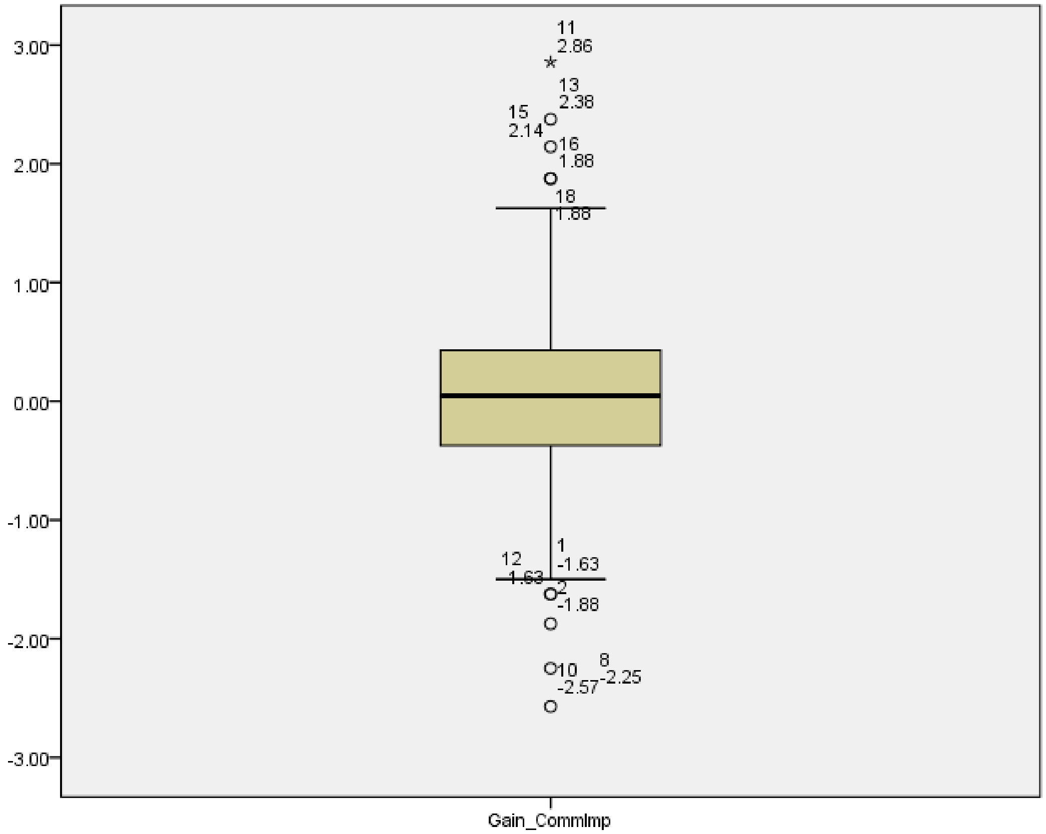

Figure 9. Boxplot of communication importance.

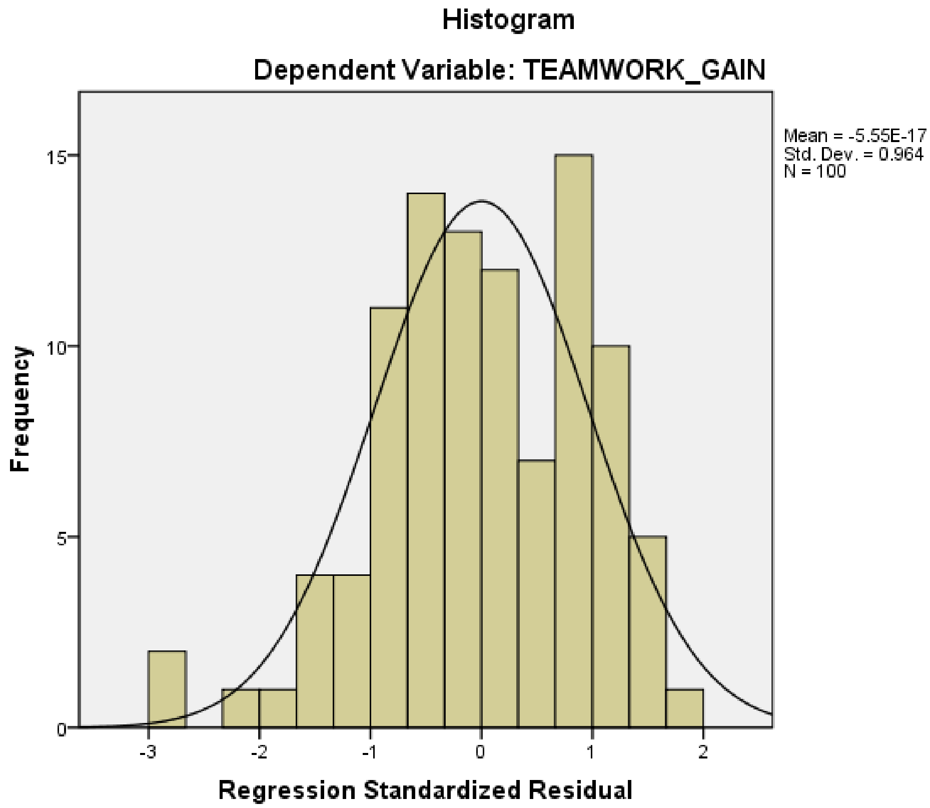

Figure 10. Histogram of standardized residuals.

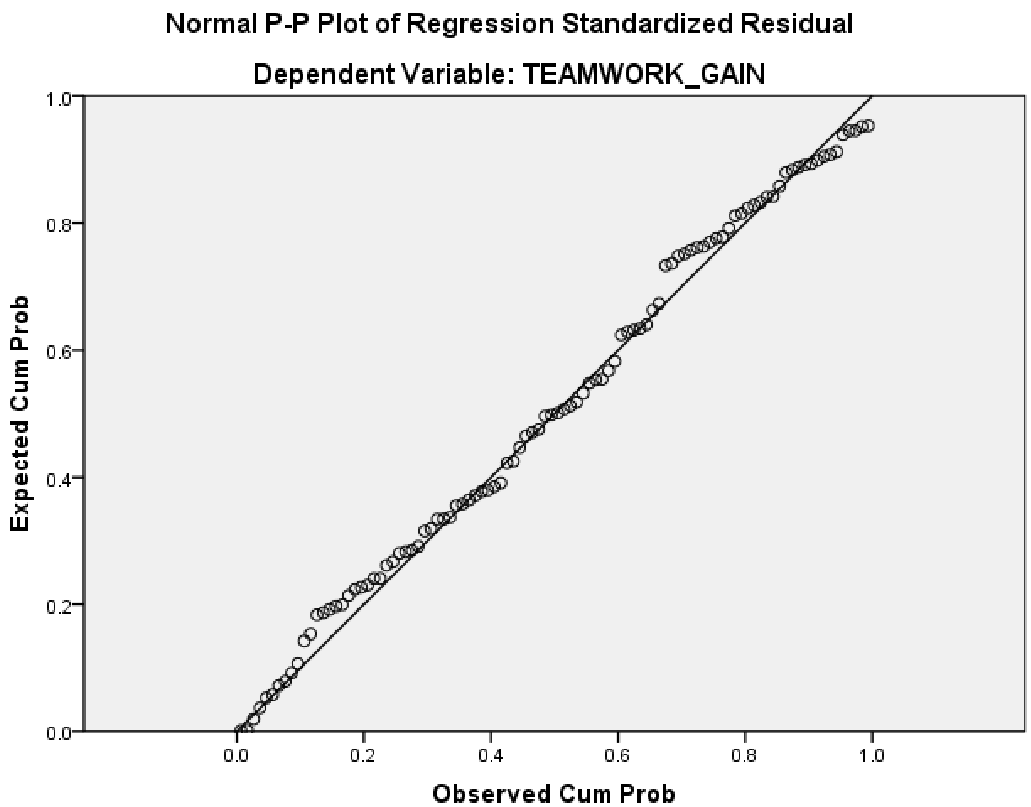

Figure 11. Normal probability plot of residuals.

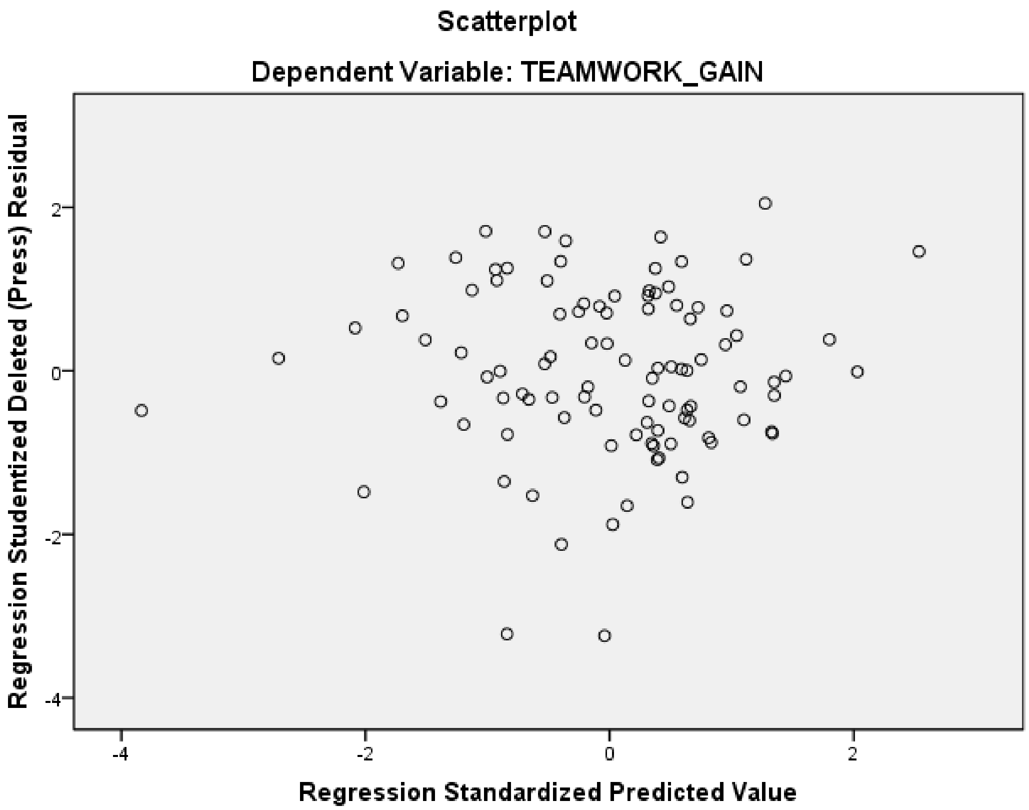

Figure 12. Residual-Predicted plot.

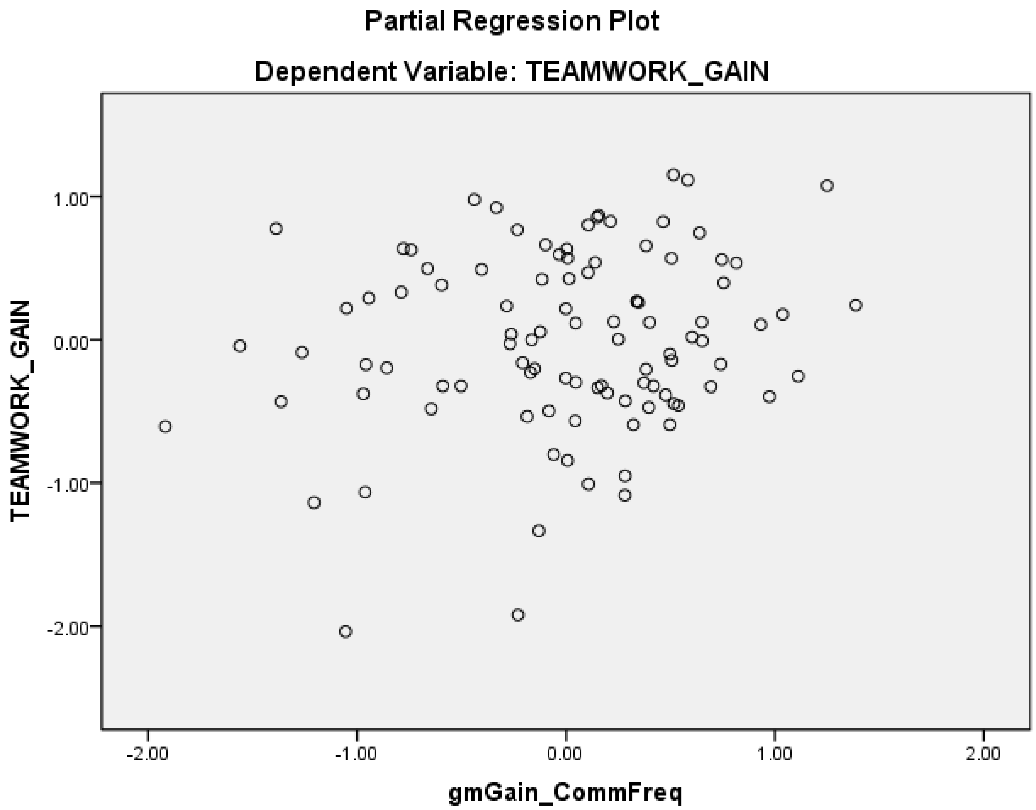

Figure 13. Partial scatter plot of communication frequency.

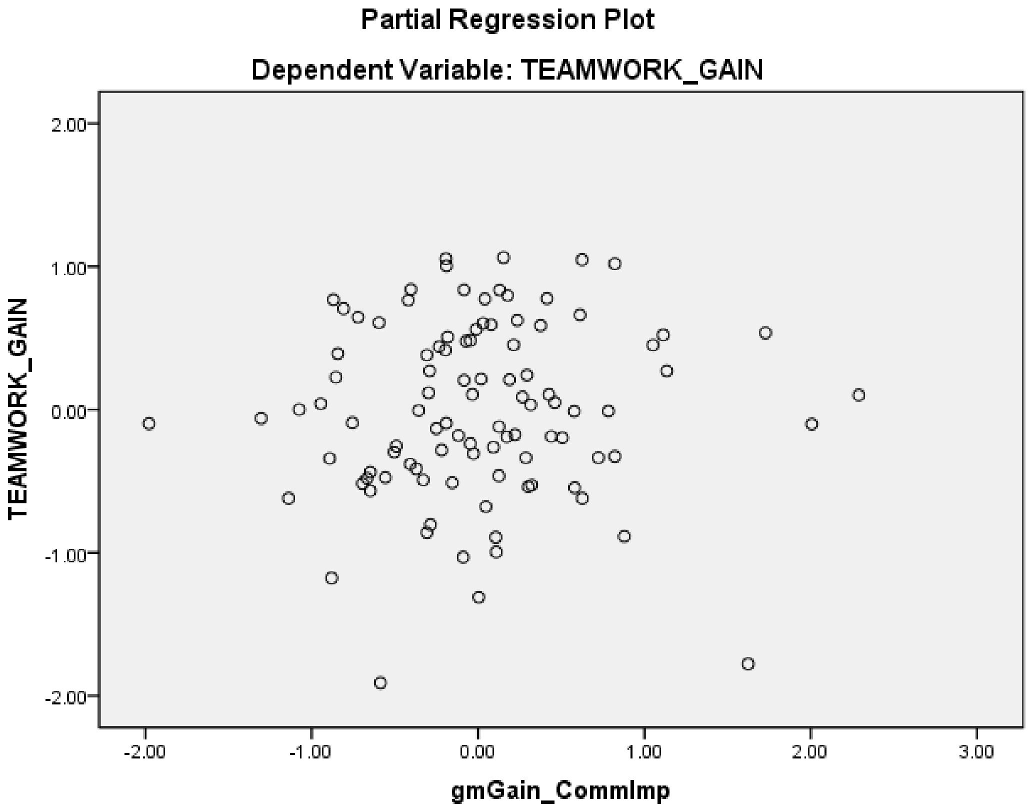

Figure 14. Partial scatter plot of communication importance.

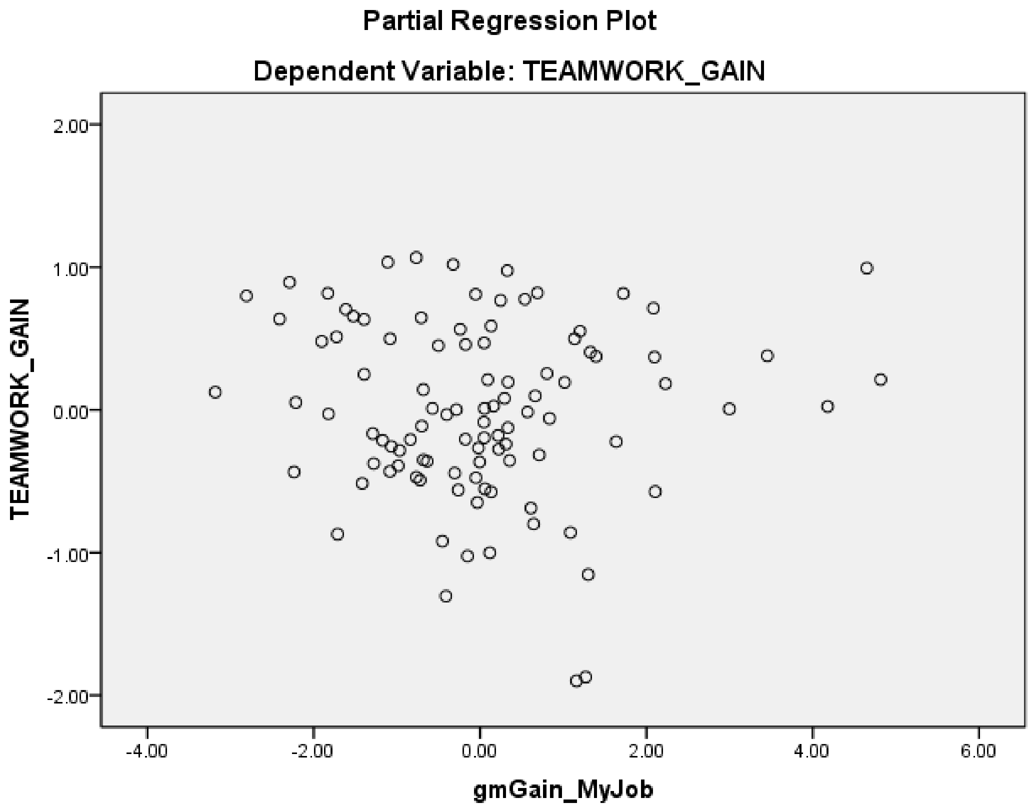

Figure 15. Partial scatter plot of my job’s dependence on others.

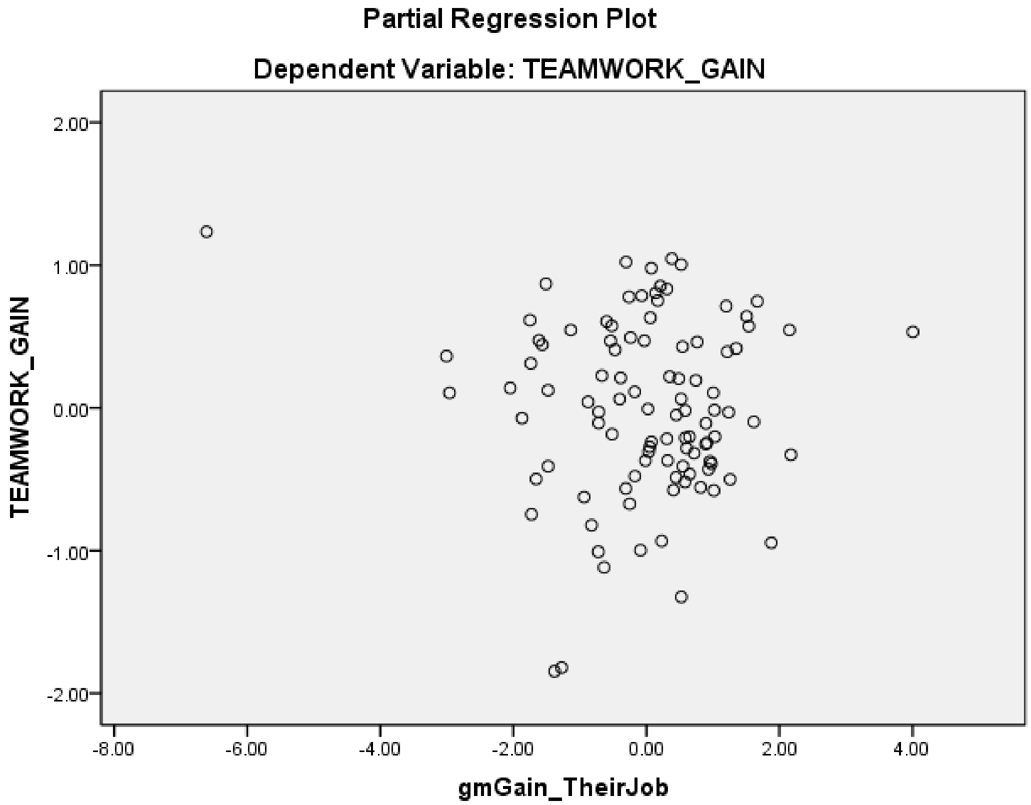

Figure 16. Partial scatter plot of others' dependence on my job.

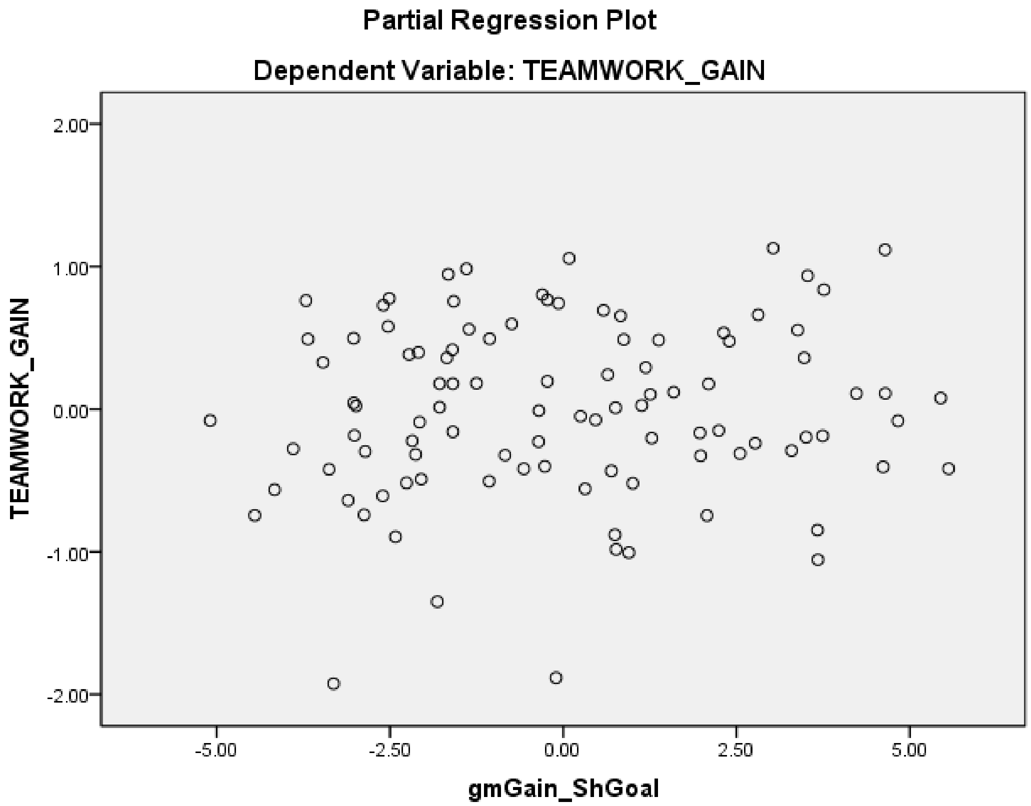

Figure 17. Partial scatter plot of sharing performance goals.

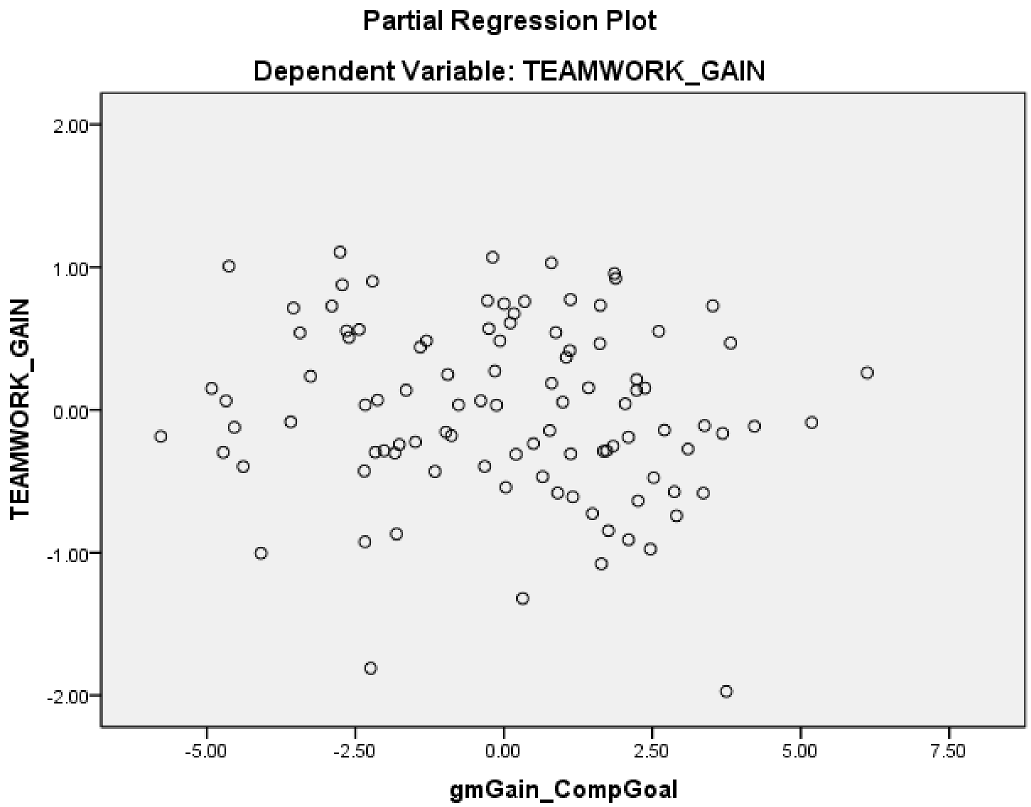

Figure 18. Partial scatter plot of competing goals.

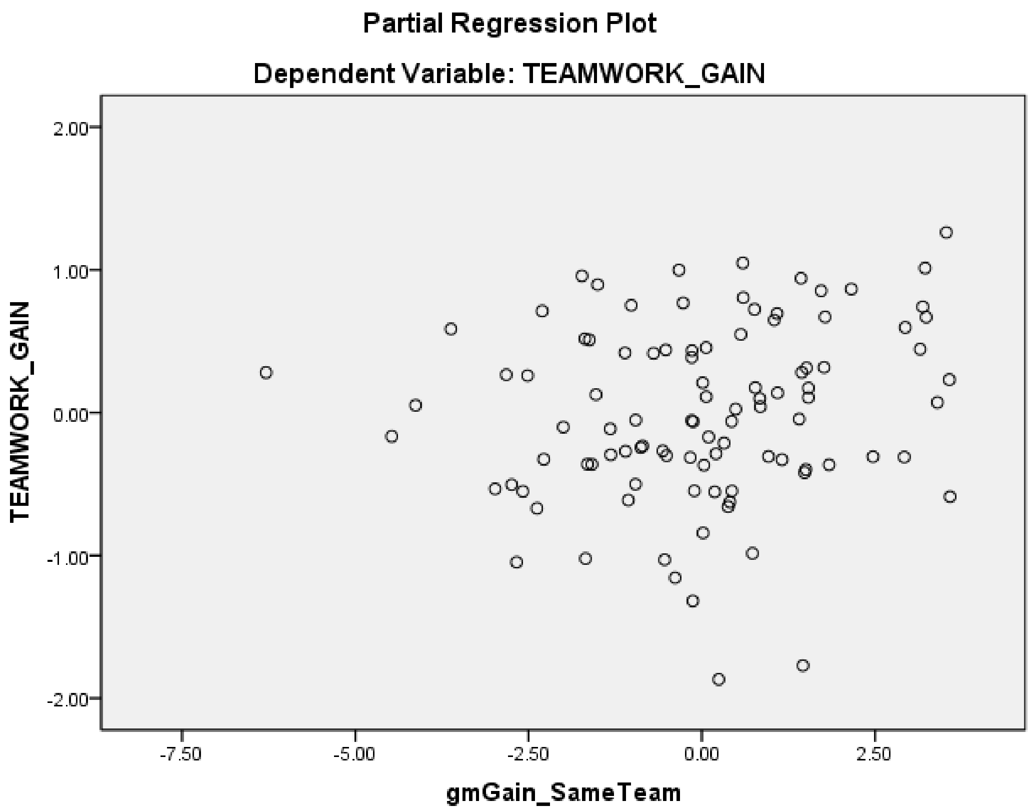

Figure 19. Partial scatter plot of the sense of belongingness.

APPENDIX C: IRB Approval Letter

April 21, 2010

Jennifer Henslee, Paul Craig, Glenn Littlepage
Department of Psychology and Aerospace
jennihenslee@gmail.com, pcraig@mtsu.edu, glittlepage@mtsu.edu

Re: Protocol Title: "The relationship between shared mental models and effective crew performance in MTSU aerospace students"
Protocol Number: 10-313

Dear Investigator(s),

I found your study to be exempt from Institutional Review Board (IRB) continued review. The exemption is pursuant to 45 CFR 46.101(b) (2). This is because your study involves the use of survey procedures. Additionally, the data obtained will be recorded in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects and any disclosure of the subjects' responses outside the research could not reasonably place the them at risk of criminal or civil liability or be damaging to their financial standing, employability, or reputation.

You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. Complete research means that you have finished collecting data and you are ready to submit your thesis and/or publish your findings. Should you not finish your research within the three (3) year period, you must submit a Progress Report and request a continuation prior to the expiration date. Please allow time for review and requested revisions. Your study expires on **April 21, 2013.**

Any change to the protocol must be submitted to the IRB before implementing this change. According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. **If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance before they begin to work on the project.** Once your research is completed, please send us a copy of your final report to the Office of Compliance.

Also, all research materials must be retained by the PI or **faculty advisor (if the PI is a student)** for at least three (3) years after study completion. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

Ashley Grooms
Graduate Assistant to- Leigh Gostowski, Compliance Officer