

How Does Communication Structure Influence Team Performance in Complex Tasks

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커뮤니케이션 구조가 팀 성과에 미치는 영향에 관한 연구

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Abstract This is an experimental study which is designed to identify the joint relationship between communication density and centrality as independent factors to team performance, discovering how they would jointly affect work team performance. Specially different from existing studies, separating team performance into team efficiency and team effectiveness, we identified differential influences to the two independent factors. Findings suggest a competing relationship between communication density and centrality. A framework was proposed to help managers understand the joint effect of density and centrality on performance. Work team has high communication density and low centrality is “Innovating”, which is likely to have a great extent of ideas, knowledge and information sharing, and reach high effectiveness. Team with high centrality and low density is characterized as “centralized”. Such communication structure may reduce diversity of perspectives and accelerate team decision making. When both density and centrality are low, the team is “Autonomous”. To increase external validity, other factors such as leadership, organizational climate influencing on team performance should be reflected in the future research.

Key Words : effectiveness, efficiency, communication density, communication centrality, joint effect**

요약 본 연구는 커뮤니케이션 밀도와 및 커뮤니케이션 집중성이 어떻게 팀 성과에 영향을 미치는지 그 관련성을 파악하고자 진행된 실험실연구이다. 특히 기존 연구들과는 달리 팀성과를 팀효과성과 팀효율성으로 구분하여 이들 독립변수들이 어떤 차별적인 영향을 미치는지를 탐구하였다. 연구결과 커뮤니케이션 밀도가 높고, 커뮤니케이션 집중도가 낮은 팀은, 혁신적이며, 정보공유와 지식 아이디어가 많고, 업무의 효율성이 높은 것으로 나타났다. 반면 커뮤니케이션 집중성이 높고, 밀도가 낮은 팀은 신속한 의사결정을 하는 것으로 나타났다. 또한 집중성과 밀도가 동시에 낮은 팀은 보다 자율적인 팀으로 나타났다. 향후 연구에서는 실험실상황이 가져오는 외적 타당성의 문제를 해결하기 위하여 보다 현실적인 리더십, 조직풍토 등의 변수가 포함되어야 한다.

주제어 : 효율성, 효과성, 커뮤니케이션밀도, 커뮤니케이션집중성, 상호간 효과

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1. Introduction

How to improve performance has been one of the hottest issues both in academic studies and managerial practices. Recently, many scholars have turned their attention to organizing of communication inside teams. They have been discussing influences on team performance which brought by various types of characteristics of communication network (e.g. Lazer and Friedman, 2007[12]; Provan, et.al, 2007[19]. Some proposed an inverted-U shape relationship between density and performance, argued that high density and low density would both result low performance, and high performance is reached at a density level in between (e.g. Lazer and Friedman, 2007[12]; Provan, et.al, 2007)[19]. Similar arguments can be found in decision making researches as more discussion would lead to better decision quality and low speed of decision making (Hickson, et. al., 1986; Schweiger et. al., 1986; Perlow et al., 2002). Therefore, too many or too less discussion in group will deteriorate performance for causing low decision quality or low decision making speed.

This study adopted “density” and another important factor “communication centrality” –the degree of which communication centralized in one or a very few team members, intend to discover how degree of communication centralization and density would jointly affect effectiveness and efficiency, so that affect team performance. Unlike Tang conducted his research on teams with both simple and complex tasks, this study only focus on complex task teams. Since communication density is proven to have more influence on performance when team is on complex tasks than simple tasks, focusing on the joint effect of communication centralization and density is expect to yield more meaningful implications, especially when we are in an era that rapidly changing competing environment complicates many of our tasks.

2. THEORY REVIEW

2.1 Effectiveness and efficiency jointly decide performance

The separation of performance and definitions of effectiveness and efficiency show high consistence with some important classical organization study literatures. Simon (1945)[20] argued a “principle of efficiency” which is stated as “among several alternatives involving the same expenditure the one should always be selected which leads to the greatest accomplishment of administrative objectives; and among several alternatives that lead to the same accomplishment the one should be selected which involves the least expenditure.” Thompson (1967)[22] also gave a similar statement, in his book ‘Organization in Action’ he argued that efficiency is used to refer to “whether a given effect is produced with least cost or, alternatively, whether a given amount of resources is used in a way to achieve the greatest result.” Thompson also proposed two criterions for evaluation of rationality in organization: instrumental criterion and economical criterion. Instrumental criterion focuses on value acquirement on goal, concerns whether decisions made produce desired outcome. Economical criterion focuses on cost, judges whether results are obtained with the least expenditure. Both Simon and Thompson had implied the necessity of separation between concerns of value acquirement on the goal and cost expenditure in evaluating performance. In some other studies, scholars adopted similar method of separating performance and define value attainment and cost accordingly (Pérez-Nordtvedt. al. 2008; Lieder, 2014)[18].

2.2 Influences brought by more frequent communication

As everyone is so limited by his or her personal experiences, knowledge, and acquired information, he or she can only generate a solitary point of view of a

matter and is unlikely to cover most related important aspects. More frequent communication indicates more sharing of knowledge, information, and perspectives between team members, so the team as a whole would be able to generate more novel ideas, better understand the matter to solve, and finally generate better solutions (Larson, et.al., 1998; Hedlund, 1998; Cross and Cummings, 2004; Balkundi and Harrison, 2006; Lechner, et.al., 2010)[11]. Furthermore, more communication is argued to indicate greater mutual interdependence between members, which in turn fosters cooperation so that enhance performance (Sparrowe, et. al., 2001)[21].

On the other hand, more frequent communication will deteriorate efficiency. One receives advice or information from others at work, and absorbs such information, understands the advice, transforms and relates it to his/her own knowledge, then reacts which usually consumes considerable energy, effort, and time of the person (Provan et. al, 2007[19]; Tang, 2014; ChangHyeon, al, 2014[2]). Hirokawa and Johnston (1989)[8] argued the encoding and decoding involved in information processing, and the cognitive process need to go through for achieving a cognitive schema in one's mind would be energy and time consuming. Hence, more frequent communication will negatively influence task team efficiency, especially when the team is performing on complex tasks as more complex task often requires more knowledge and information.

As a conclusion, more frequent communication between members is expected to have positive influence on task team's effectiveness and have negative influence on its efficiency.

2.3 Influences brought by more centralized communication structure

Communication centrality in this study describes how much a team's communication centralized in one or only a few members. One example of highly centralized communication system is the vertical and hierarchical structured organization. The formal

reporting system is designed in a way that information flow from lower to higher level of hierarchy, and leave the important decision making to the one at the top of organization pyramid. Such system is said to be efficiency since least communication is incurred, and all necessary information delivered to the one that is believed to possess necessary knowledge and ability to make the correct decision (Simon, 1945)[20]. In a team with very centralized communication structure, the one in the center of team communication would have more power and advantages since he is mostly likely in the broker position and benefit from structure hole. As most information go through the person, he performs a major amount of encoding and decoding of various information and knowledge, and his *cognitive schema would most greatly affect group decision(Han-Jin, al, 2015[6]). Consequently, he can reduce diversity of perspectives and accelerate speed of decision making, that is, increase efficiency.

H1: highly centralized communication would have positive impact on team efficiency.

On the other hand, highly centralized communication will have a negative influence on task team's effectiveness. As argued earlier in this paper, an individual is always limited and can only generate a solitary point of view on a matter. Such limitations become more obvious when he need to make a decision in complex situations. Organization structured vertically with many levels of hierarchy has been argued least flexible to environment change. Centralized communication network reduces diversity of perspectives and impede sharing activities of ideas, knowledge, and information.

* Cognitive schema represents that basic set of cognitive "resources" employed by the individual in dealing with the decision task. It consists of the perception, evaluations, comprehensions, attitudes, values, beliefs, assumptions, presuppositions, and heuristics that the individual takes into account, and ultimately relies on, in attempting to complete the decision tasks (Hirokawa & Johnston, 1989).

H2: highly centralized communication would have negative impact on team effectiveness.

The joint effect of centralization and density of communication

Since higher density and lower centralized communication will give positive influence on effectiveness and negative influence on efficiency. It perceives the team with the most adhocracy and innovating capacity should have high communication density and low centralized communication structure. Active knowledge, information, idea sharing allow to reach high effectiveness on the cost of efficiency

H3: Density and centrality will show differential interaction effects to performance in a way of improving effectiveness while costing of efficiency.

Highly centralized communication structure with low communication density will benefit efficiency but deteriorate effectiveness of task teams. Those teams want to reach both high in communication density and centrality will most likely experience failure due to the incompatibility between high density and centrality. Teams with moderate communication density could have different level of centralized communication. Well managing the balance and reach a proper combination of density and centralization of communication is a key issue for team leaders.

3. LABORATORY STUDY DESIGN

We employed a laboratory study to test proposed hypotheses. The laboratory study is designed to create a situation that a group performs on a task, which is to answer a set of questions. Since density changes in a different rate according to group size, we employed a four member group setting since it gives more complexity than a three member group and less likely to separate into subgroups than a group with five or

even more members. Hedlund (1998)[5] also adopted four members group in discussion of group communication.

Participants were randomly grouped into small groups. Each group unit was asked to answer a same set of questions. Different groups are expected to adopt more or less different communication styles density in answering questions. After finishing answering questions, members of each group were asked to complete a questionnaire independently to evaluate how frequent they interact with other members in the group. Accordingly, communication density and centrality of each group was calculated.

A regression analyses were performed to examine the influence of communication density and centrality on effectiveness and efficiency. An extra moderated regression analysis was conducted to examine the interactive effect between communication density and centrality. Regression analyses were conducted by using SPSS 18.0.

At the end, we grouped all teams into four categories according to variables of communication density and centrality. By discussing and comparing characteristics of each category, we were looking forward to acquire more fruitful results.

3.1 Measurements of Variables

Effectiveness and Efficiency as dependent variables

When measuring effectiveness and efficiency, it is difficult to obtain variance at both ends. In order to acquire variance on both effectiveness and efficiency, the laboratory study adopted a time pressing situation. Groups are given more questions than they can possibly finish within given time, and are asked to answer as many questions as possible, and as correct as possible. Each group can decide themselves whether to answer more questions or to acquire higher score on a single question. Since each team answers a different number of questions, more questions answered leads to higher value of efficiency. Effectiveness measures the degree of how accurate questions were answered.

Since each team answers a different number of questions, total score divided by number of questions represent effectiveness average score. Performance is represented by the total score acquired by each team, which equals to the value of effectiveness multiply efficiency. Notably, time pressing situation forces participants to best utilize their effort, energy, and time, helps groups to coordinate more effectively (Gersick, 1989; Isenberg, 1981)[4] and improves individual information processing (Edland, 1994; Kerstholt, 1994)[3].

Equation 1. $Eff_{group(i)} = \sum_j S_{ji} / n_i$

Equation 2. $Eff_{group(i)} = T_i / n_i$

Equation 1 shows how to calculate group effectiveness (Effe), for group 'i', 'j' refers to the number of answered questions, S_{ji} is the score of the answered question 'j' by group 'i', 'n_i' represents the number of answered questions in general by group 'i'. Effectiveness of group 'i' in the experiment was decided by the sum of score of all answered questions divided by number of answered questions. In Equation2, the amount of time used by group 'i', which was 'T_i', divided by number of questions answered by group 'i' decided the group's efficiency(Effi) in experiment.

Communication Density

As mentioned early, the strength of tie is vital information to this study. The questionnaire was derived from early study by Parise (2007)[17], in which participants were asked how frequently they interacted give/take information or advice with others, and we adopted a 7-point likert-scale which '1' refers to rarely and '7' represents very frequently.

We asked how frequently A communicates with B. Density of communication was calculated according to Equation 5. 'i' is the number of group, 'a' and 'b' refer to any two members in a group and 'a≠b,' and 'Str(a->b)' is the total score of all strength between any two members in the group. 'm' represents the

number of experiment. Value '84' indicates the possible maximum communication in a group which is calculated by possible ties in a group $4 * (4-1)$ multiplying the possible highest value of tie strength '7' in our study. Density of communication is decided by total strength divided by possible maximum communication in the group

Equation 5. $Density_{QualityComm(i)} = \sum_{a \neq b} Str(a \rightarrow b) / group(i) * 84$

Communication Centrality

Communication centrality is adopted to assess degree of centralized communication in teams. We ask two questions 'how often did you give information from X when doing test,' 'how often did you offer advice from X.' If A→B and B→A both confirmed then a connection is built between them.

Accordingly, we can count the number of ties of each node (team member), and calculate the variance of communication ties of a team. Value of variance is considered as communication centrality of the team. Higher value indicates more centralized communication structure.

4. RESULTS

4.1 Factor Analysis

If considering any two members as A and B, communication A→B was measured by asking A 'how often does he/she(A) give information/advice from B,' and asking B 'how often does he/she(B) get information/advice from A' (see <Table 1>). The questions are items for variable of communication intensity (A→B). Results of factor analysis are shown in <Table 1>, loadings of each item all exceed .800 and value of Chronbach's Alpha is .886. It suggests high reliability of acquired value on communication intensity tie strength. The four items combined account for 74.560% of the variance.

〈Table 1〉 Factor Analysis

Item	Loading
A reports: how often A get information from B when doing test?	.863
A reports: how often A get advices from B when doing test?	.856
B reports: how often B give information to A when doing test?	.867
B reports: how often B give advices to A when doing test?	.868
Cronbach's Alpha	.886
% of Variance Explained	74.560

In addition, the answers to complex questions were evaluated independently by two different researchers, the correlation between the two set of evaluated scores was 0.781 with a significance level $p < .001$. Results of the evaluation by the two researchers were highly correlated. We take the average as the score for each group.

4.2 Correlation Analysis

〈Table 2〉 shows correlations between variables. Density is positively correlated to effectiveness and negatively correlated to efficiency. Communication centrality does not have any significant correlation with neither effectiveness nor efficiency. Correlation between centrality and density is not significant. Effectiveness and efficiency are highly negatively correlated, which implies a competing relationship between them.

4.3 Regression Analysis

〈Table 3〉 shows the major results of this study.

Communication centrality presents significant negative influences on effectiveness in model 1 to 3, which support hypothesis 2. Significant positive relationship is found between communication density and effectiveness. Major has negative influence on effectiveness in model 1 to 3 suggests that a very much diversified major composition is better to be

avoided in constructing a team. Positive influence given by ConMean suggests more related knowledge and information in team members would benefit team effectiveness. By entering density as independent variable, the R square of model 2 increased by 0.113 compared to model 1. No significant interactive relationship is found between density and centrality, the increment of R square is very limited in Model 3. Regarding efficiency, communication density shows to have significant negative impact on efficiency in model 5. No significant relationship is found between communication centrality and efficiency, that is, hypothesis 1 is rejected. Diversified major composition positively affects efficiency.

4.4 Additional Analysis

In order to better understand the connection between communication structure and performance, we conducted an additional study, adopted K-mean method and categorized all groups into four categories according to variables of density and centrality. In category 1, very high density with very low centrality allowed highest effectiveness and lowest efficiency among all four categories. Groups in this category are

〈Table 2〉 Correlations

	Centrality	Density	Effi	Effe	Major	Gender	AgeMean	AgeVar	ConMean
Density	-0.122								
Effi	0.103	-.487**							
Effe	-0.224	.466**	-.684**						
Major	-0.233	-0.047	.343*	-.267*					
Gender	0.154	-0.143	0.067	0.108	-0.040				
AgeMean	-0.212	-0.084	0.095	0.059	.541**	-0.003			
AgeVar	-0.007	0.075	-0.096	0.023	0.216	0.074	0.097		
ConMean	-0.092	.335*	-.302*	.495**	-0.046	-0.189	-0.075	-0.021	
ConVar	0.180	-0.135	0.036	0.016	-0.075	0.061	-0.045	.324*	0.047

***Significance level $p < .0001$, ** Significance level $p < .01$, *Significance level $p < .05$

<Table 3> Regression Analysis

IV	DV=Effectiveness			DV=Efficiency		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Centrality	-1.751*	-1.542*	-1.591+	.012	0.009	0.011
Density		6.067***	5.798*		-0.089**	-0.076
DenCen			-0.562			0.028
Major	-4.693**	-4.562**	-4.544**	.066*	0.064**	0.063*
Gender	2.998+	3.125*	3.164*	-.004	-0.006	-0.008
AgeMean	.940	0.793	0.807	-.014	-0.012	-0.013
AgeVar	.235	0.274	0.265	-.002	-0.003	-0.002
ConMean	4.941***	3.546**	3.547**	-.047*	-0.027	-0.027
ConVar	-.125	0.458	0.496	.010	0.001	-0.001
R2	0.484	0.597	0.598	0.301	0.421	0.422
ΔR2		0.113	0.001		0.120	0.001
F test	4.482***	6.233***	5.535***	2.062*	3.049**	2.726**

***Significance level $p < 0.001$, ** Significance level $p < 0.01$, *Significance level $p < 0.05$, + Significance level $p < 0.10$, DenCen=Density*Centrality, ConMean=average value of concern of questions, ConVar=variance of concern of questions

innovating teams referred earlier in this study, such finding supports hypothesis 3. Groups in category 3 show very high level of centrality and relatively low level of density. Such communication structure results high efficiency and lowest effectiveness among all four categories. Category 3 can be seen as the opposite to category 1 (Hyun-Jeong, al, 2015).

In category four, groups present moderate density and moderate centrality. Group in this category tend to search a balance between density and centrality. However, results also shows they have the poorest performance among all four categories. The improper balance between density and centrality cost them both in effectiveness and efficiency.

Groups in category 2 are different in a particular way. They show lowest density and lowest centrality among all four categories. That is, groups here gave great autonomy to each team member, and each member was responsible for part of the question, least communication was incurred. Results suggest such groups yield very high efficiency and relatively low effectiveness. However, by looking into their answers by detail, their performance is not consistent due to lack of communication.

In categories 1, 3, and 4 (exclude category 2 for rare communication had happened), effectiveness drops as centrality rises, which provides support for their negative relationship.

5. DISCUSSION

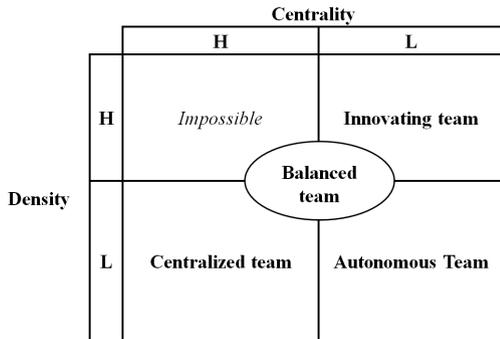
This study adopted Tang’s (2014) perspective of dividing performance into effectiveness and efficiency, and discussed the influence centralized communication network on task team performance. Results suggest that communication centrality has positive influence on team effectiveness <Table 3>, <Table 4> and negative influence on team efficiency <Table 4>.

<Table 4> Communication Structure Typology

Category	1	2	3	4	AN-OVA
No.	19	11	6	19	
Effectiveness	14.605	9.059	8.867	10.086	0.006
Efficiency	0.176	0.261	0.253	0.201	0.004
Performance	2.252	2.307	2.170	1.854	N/A
Density	0.928	0.128	0.498	0.571	0.000
Centrality	0.194	0.159	2.250	1.079	0.000

Furthermore, this study also discussed how communication density and centrality would jointly affect team performance. By adopting K-mean grouping and ANOVA analysis, all groups participated experiment were categorized into four categories. According to their characteristics, teams in the four categories were named as innovating team, centralized team, autonomous team, and balanced team. Because of the competing relationship between density and

centrality, it is impossible for a team to reach high both in communication density and centrality. Detailed descriptions of each category are as following. [Fig. 1] concludes the communication structure typology.



[Fig. 1] Communication Structure Typology

Innovating team: more communicating and low centrality allows a great extent of idea, knowledge, information sharing, and members are more likely to engage learning activities. Such kind of team is likely to generate more useful solutions and yield high effectiveness.

Centralized team: the member in the center of communication network would have major advantage in influencing other members and final solution. He could also use the power given by his position to reduce diversity of perspectives and accelerate team decision making.

Autonomous team: because of lacking communication, members do not need to engage encoding and decoding of information and knowledge, which in turn promises high efficiency. On the other hand, members have to use their own knowledge and information to work on the task, so performance is greatly depend on individual member's competencies. Differences of competency are expected to cause gaps between personal performances, which will greatly deteriorate team performance when members' work closely interact with each other.

Balanced team: according to situation, it may shift

toward innovating team, centralized team, or autonomous team. However, team leaders need to understand the competing relationship between communication density and centrality, be cautious of falling into a position that chasing high density and centrality simultaneously.

5.1 Implications

Findings of this study have generated some important implications for both managerial practice and academic study. First of all, the results of communication centrality having positive influence on team efficiency and negative influence on team effectiveness provide important principles for team leaders in organizing and coordinating communication between team members(Man-Ki K, 2008[16]. It also suggests managers need to search for a centrality that allows optimum combination of effectiveness and efficiency. Secondly, by discussing the joint effect of communication density and centrality, this study proposed four types of teams—innovating, centralized, autonomous, and balanced. It argued that managers or team leaders need to balance communication density and centrality according to given situation (e.g. task complexity, team resources, team members' competencies). The balanced team may shift to directions of either innovating, centralized, or autonomous team. However, it should avoid to fall in the position of pursuing high density and centrality at the same time.

5.2 Limitations and future research direction

This study is basically conducted in experimental design regardless of realistic situations including other factors such as leadership, organizational climate influencing on team performance. Those limitations decreased external validity of this study. Future research should be done reflecting these elements.

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