Analyzing the Effect of Team Structure on Team Performance:
An Experimental and Computational Approach

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Abstract

This paper investigates how team structure impacts team information processing and how this affects team resilience to change. Teams in three different subgrouping structures: homogeneous, heterogeneous, or no-clustering, were instructed to make decisions in which they had to evaluate different companies and pick the best one. Each member was told to evaluate the companies in a different way, creating teams with diverse perspectives. Partway through the experiment the problem evaluation criteria changed, but teams were not informed of the change, only whether their choice was correct. Teams with homogeneous-clustering were less capable than the other two types of teams in making use of multiple preferences and in dealing with changes. A similar effect was also found in computational simulations built from a PDP model. We suggest that heterogeneous-clustering can weaken members' ownership and confirmation biases while no-clustering ensures a free flow of information, with both able to enhance team performance.

Keywords: Team Structure; Team Diversity; Decision-Making; Computational Modeling

Introduction

Tasks organizations face usually require a breadth and depth of knowledge rarely found in one single individual, and bringing different experts to work together is viewed as one way for organizations to maintain a competitive edge. Yet, team diversity studies (van Knippenberg & Schippers, 2007) revealed that cognitive heterogeneity does not always enhance team performance, depending on the quality of the team information processing. In this study, we look at how team structure affects the information processing within a diverse team, and in turn impacts performance, in particular in dynamic situations.

Teams have been characterized as information processors, and the information processing involves activities that happen within and among the minds of team members The team-level processing involves the sharing of information between members, while the individual-level processing involves individuals' evaluation and interpretation of the information shared by the others (Hinsz, Tindale, & Vollrath, 1997). Cognitive heterogeneity between members seems to affect these information processes positively and negatively. Diversity provokes social categorization that may damage team cohesion and information sharing. Individuals often place themselves and others into distinct subgroups based upon similarities between them (e.g., age, gender, educational background, and value). They tend to favor in-group members over out-group members. This intergroup bias may inhibit information sharing between dissimilar members (Cronin & Weingart, 2007). On the other hand, diversity helps reduce several information-processing biases. Individuals usually display an ownership bias, considering their own knowledge as more valid than those held by others. They tend to search and accept information supporting their preference than information opposing it. This is called confirmation bias (Nickerson, 1998). The presence of diverse preferences could make members wonder about the accuracy of their responses and lower their confidence in the task, making them more open to different perspectives. Teams having members from varied disciplines are less subject to these cognitive biases than homogeneous teams (Schulz-Hardt, Jochims, & Frey, 2002).

Team diversity research has focused on identifying under what conditions cognitive diversity is beneficial to team functioning and when it will become a disadvantage. Previously examined factors include the degree of diversity (Dahlin, Weingart, & Hinds, 2005), team size (Thornburg, 1991), and the presence of a leader (Kearney & Gebert, 2009). If team performance is a function of the range and depth of the information shared and processed within the team (Hinsz et al., 1997), then modifying the intra-team communication ties (e.g., who talks to whom, or who gives information to whom) should impact team performance. Only a few studies addressing this issue have been reported (Katz, Lazer, Arrow, & Contractor, 2004), and they mainly compared a centralized (i.e., decisions were made by a leader and information was sent upwards to the leader) and decentralized (i.e., having several individuals responsible for making decisions) structure, showing that a decentralized structure is beneficial when the tasks are novel and difficult. However, even in a decentralized team, there are still numbers of communication patterns a team could adopt, and each of them may impact the team differently. For example, creating communication ties between members from different backgrounds should promote cross-domain information sharing. Embracing the communication ties based upon homophily may result in in-group members validating each other, and making them more fixated on

their own view. In this study, we compare the effect of communication pattern (i.e., team structure) on the performance of diverse and decentralized teams.

Most past studies examined how teams behave in a static task environment, e.g., solving a hidden-profile task (Lu, Yuan, & McLeod, 2012). In a hidden-profile task, teams are asked to select one of several alternatives. Information supporting a less desirable alternative is shared by everyone, and information favoring the better alternative is known to individual team members. The optimal choice can be discovered when members share and consider all the unique information. Estimating the importance of each piece of information is not needed because they are all equally weighted. But, in reality, teams often have to face situations in which some factors are more influential than others, and also situations where their importance changes over time. For example, organizations have to anticipate and react to the constant change in consumer preferences in order to remain competitive. In this study, we examine what types of team structure can help teams excel in dynamic situations. Three structures: homogeneous-clustering, heterogeneous-clustering, and no-clustering, are compared.

In a *homogeneous-clustered team*, members with similar functional background work together as a subgroup. Team members' subgroup identity should be strong because of the high similarity between subgroup members. This may inhibit cross-subgroup information sharing. Also, working with like-minded members should strengthen individuals' confidence on their own perspective and make them more reluctant to change their own views. In a *heterogeneous-clustered team*, members from different functional backgrounds form a subgroup to work together. Because of the low cognitive similarity within a subgroup, team members should have low subgroup identity. The presence of different perspectives within a subgroup should also make team members question if they have done the task correctly thus lowering their confidence. This should reduce individuals' ownership and confirmation bias. Within a *no-clustering* team, there is no subgroup. Members of this team should have the lowest subgroup identity. This should facilitate information sharing. We predict that the no-clustering and heterogeneous-clustered teams would process the information more objectively and be less fixated on their own preference, as compared with the homogeneous-clustered team. Therefore, they should be better in making decisions and adapting to the change.

To verify the proposed impact of no-clustering and heterogeneous-clustering structures on team functioning, we examine team performance in the *presence* and the *absence* of a majority preference. When there is no majority preference within the team, knowing each other's perspective is the key for making a correct decision. The absence of any subgroup in a no-clustering team should create an optimal structure for information sharing, and therefore this team should excel in this situation. When there is a majority (but incorrect) preference, a correct decision can be made only if the team members have an unbiased evaluation on each preference, independent of whether or not it is majority-preferred. Members of the heterogeneous-clustered teams should display lower ownership bias, as compared to those in the other two teams. They should be more likely to evaluate each preference objectively and thus overcome the majority.

We introduce an experiment and computational simulations to examine the impact of these team structures on team performance. The experimental study is first presented followed by the computational modeling.

Experimental Study

Method
Participants: 120 participants (F = 52, M = 68, mean age = 22.69 years, *SD* = 5.53) were recruited and randomly assigned in groups of four to take part in this study, creating 10 groups within each of the three team structures, differing in the type of subgroups: Homogeneous, Heterogeneous, or No-clustering. The mean number of females in each team was 1.73 (*SD* = 1.01), and there was no significant difference across the three team structures, *p* = .312.

Differing perspectives: Each group had to work as a team to make some investment decisions. There were twenty decision-making trials. In each trial, groups had to evaluate the profiles of three companies and pick the best one to invest in, on the basis of company performance and industry trends. Two members were assigned to evaluate the choices based on company performance, and the other two were assigned to focus on industry trends. At the beginning of the study, members were given a *unique* scoring matrix showing them what parts of the company profile they should focus on and how a company can be assessed based on the relevant information.

Members studying the same domain of information used similar scoring matrices and had similar preferences. Members in different domains evaluated the companies using different criteria and usually had diverse preferences.

Team structure: groups were randomly assigned to one of these three structures: homogeneous-clustering, heterogeneous-clustering, and no-clustering. In a *homogeneous-clustered team*, participants directed to study the same domain of information formed a subgroup. They had to first give a score, ranging from 1 (the worst) to 6 (the best), to each company, and then discuss them with the other subgroup member to learn each other's preference. The whole group would then have a discussion and pick the overall best company to invest in. The *heterogeneous-clustered teams* followed a similar decision-making procedure except that the heterogeneous subgroups were made up of one participant in each of the two domains. Members in a *no-clustering team* had to first finish the scoring alone, and then tell each other their preference followed by a team discussion.

Change of task conditions: In each trial, the correct company to invest in was the company with the highest total score, which was the weighted sum of the scores on both company performance and industry trends. For the first 10 trials, the scores on industry trends received a weight of 2 while the scores on company performance received a weight of 1. For the second 10 trials, the scores on company performance received a weight of 2 while the scores on industry trends received a weight of 1. The change between trials 10 and 11 occurred without any indication to participants, and was only learned by the participants through feedback on the accuracy of their choices over time.

To perform well, groups had to first learn that they should rely more heavily on industry trends in making the decisions. After the change, teams had to be able to notice that industry trends were no longer driving the correct decision, and company performance was now important.

Majority condition: The 20 decision-making trials could be divided into two types: Absence (12 trials) and presence (8 trials) of a majority preference.

Absence of a majority preference: In these trials, among the three companies presented, one had relatively good performance, one was in a relatively good industry, and one was average in both domains. Participants directed towards company performance would give high score to the first company, and those directed toward industry trends would give a high score to the second one. This generated two initial preferences, each favored by two participants, creating a 2 vs. 2 situation (2-2 trial).

The evaluations on the two domains were not equally weighted, and the outstanding company in the heavily weighted domain usually had the highest overall score except in one case: When participants in the more important domain did not have a strong preference (i.e., all companies got average/low scores) and the alternative company was highly preferred (getting a score of 5 or 6) by participants in the less important domain, the alternative company would then have the highest overall score. To make a correct choice, teams had to figure out which domain was more important, and consider the preference of all members.

Presence of a majority preference: In these trials, the company profiles were scripted in a way that there was no single clear choice for members studying the same domain of information and they would give a high score to different companies. This resulted in them preferring different companies. There were only three companies to choose, thus one member studying company performance and one member studying industry trends would prefer the same company, creating a 2 vs. 1 vs. 1 situation (2-1-1 trial). We had scripted the company profiles in a way that the overall score of the majority-preferred company was only the second best, and the best company was the one preferred by the other member in the more important domain. A correct decision can be made only if the teams do not conform to the majority and can consider the evaluation provided by each member objectively.

Although members in the same domain preferred different companies initially, we had scripted the company profiles to ensure similar scoring between members in the same domain, and a bigger disparity between the evaluations based on different domains of information.

Procedures: Prior to the main study, participants were given five minutes to study the folder containing the evaluation guidelines. After that, they were told that some of them would evaluate the companies on the basis of company performance, and some would evaluate the companies on the basis of industry trends. They were also told that the evaluations on company performance and industry trends were not equally important, and it was up to them to figure out which domain deserved the most weight when trying to arrive at the correct decision.

Participants would then have to complete three practice trials. The company profiles in the practice trials were scripted so that all participants would pick the same company as the best one, and that company was also the correct choice. This insured that participants could not create immediate perception of one participant or factor being more important than the others.

In each trial, participants were given a maximum of three minutes to finish the scoring and make the individual or subgroup decision. Then, they had another three minutes to converse with the others and make a final decision. Feedback was provided after each trial, indicating whether they picked the best, second best, or the worst company.

Groups were randomly assigned to solve the 20 trials in one of the two presentation orders. In each order, the 2-2 and 2-1-1 trials were intermixed randomly.

Results

Two teams were excluded from the analysis because of low scoring accuracy (one team member had less than 60%). The mean accuracy on scoring was 93.71% (SD = 8.32). Only trials on which all four members had made the correct initial decision were included in the analysis. This eliminated 19.66% of the data, which were evenly distributed across the three conditions, before and after change, p = .98. Performance in each trial was assessed in a 3-point scale (0: pick the worst company, 1: pick the second best company, 2: pick the best company).

Team performance: The 20 decision-making trials were divided into 4 equal blocks, representing the early and late trials, presented before and after the change. An ANOVA on team performance with Block (1st, 2nd, 3rd, or 4th Block) as a within-subject factor and Team (homogeneous-clustering, heterogeneous-clustering, or no-clustering) as a between-subjects factor was conducted. No main effect for Team was found, $F(2, 24)$ = 2.31, p = .12. A significant quadratic effect for the interaction between Block and Team was reported, $F(2, 24)$ = 4.35, p = .02, implying that the Team effect was more significant in some blocks than the others.

One-way ANOVAs were conducted as the following-up analyses to compare the performance among the three teams

in each block. A significant Team effect was found in the 1st block, $F_{(2, 24)} = 5.53$, $p = .01$, and the 4th block, $F_{(2, 25)} = 3.98$, $p = .03$. In both blocks, the no-clustering and heterogeneous-clustered teams performed better than the homogeneous-clustered team, all $p < .05$. No difference was found between the no-clustering and heterogeneous-clustered teams, $p > .80$. The performance differences in the 1st block suggest that the homogeneous-clustered teams were slower than the other teams in figuring out the way in combining different perspectives. All teams were impaired by the change to the same degree, as indicated by the non-significant Team effect in the 3rd block. The significant Team effect in the 4th block supports that the heterogeneous-clustered and no-clustering teams were more capable in adapting to the change. There was a significant Block effect, $F_{(1, 24)} = 9.35$, $p = .01$, revealing that the performance on the last block was better than on all the previous blocks, all $p < .05$. This can be attributed to the learning effect and the successful recovering from change in the heterogeneous-clustered and no-clustering teams (see Figure 1).
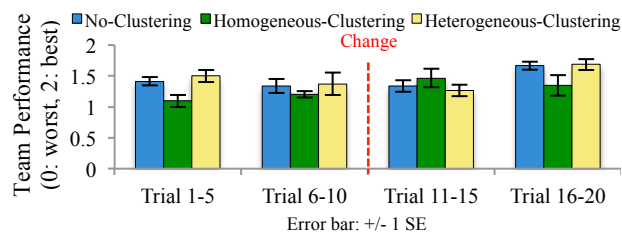

Figure 1. Team performance by block and team structure.

Majority condition: To test if there is a differential effect of team structure on 2-2 and 2-1-1 trials, a 2 (Trial: 2-2 or 2-1-1) x 3 (Team: homogeneous-clustering, heterogeneous-clustering, or no-clustering) ANOVA on team performance was conducted. There was a significant Trial effect, $F_{(2, 25)} = 25.89$, $p < .001$, that the 2-1-1 trials were more difficult than the 2-2 trials. A main effect for Team was found, $F_{(2, 25)} = 3.46$, $p = .05$, showing that the no-clustering and heterogeneous-clustered teams performed better than the homogeneous-clustered teams. There was an interaction between Team and Trial, $F_{(2, 25)} = 3.65$, $p = .04$. For 2-2 trials, the no-clustering teams performed significantly better than the homogeneous-clustered teams, $p = .02$. A performance drop for 2-1-1 trials was found in the homogeneous-clustered, $p = .02$, and no-clustering teams, $p = .001$. The heterogeneous-clustered teams maintained robust performance and outperformed the other two teams, all $p < 0.05$, in the 2-1-1 trials (see Figure 2).
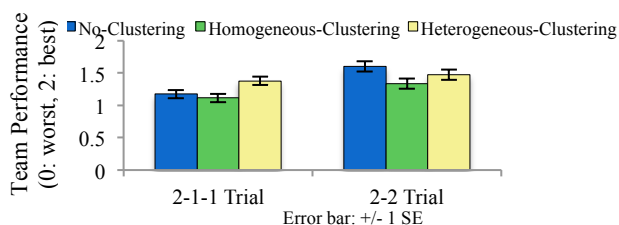

Figure 2. Team performance by trial type and team structure.

Discussion

We examine the effect of team structure on team decision-making in a dynamic environment. The no-clustering and heterogeneous-clustered teams made better decisions and were more adaptive to the change, as compared with the homogeneous-clustered teams. The interaction between team structure and trial type implies that the heterogeneous-clustering and no-clustering structures are suited for different decision-making situations.

Because of the functional similarity between participants in the homogeneous subgroup, they should confirm and validate each other's perspective. Thus, they may overrate and fixate on their own preference, making them less able to adjust their decision-making strategy and adapt to the change. As expected, the homogeneous-clustered teams were not as effective as the no-clustering and heterogeneous-clustered teams in learning how to make the optimal decision and in adapting to the change. The heterogeneous-clustered and no-clustering teams displayed similar overall performance.

The differing performance of the no-clustering and heterogeneous-clustered teams for the 2-2 and 2-1-1 trials suggests that these two structures may facilitate different types of information processing. Solving a 2-2 trial relies on knowing and combining all the evaluation with the correct weight. The no-clustering structure allowing a free flow of information may account for the outperformance of the no-clustering team in solving these trials, as compared with the homogeneous-clustered teams. A heterogeneous-clustering structure allowing dissimilar members to share ideas should prevent members overrating their own view. Members should therefore be able to evaluate each perspective objectively. Thus, these teams performed better than the others in solving the 2-1-1 trials.

One may argue that the task-specific team effect could be explained without proposing any information processing difference between the three teams. In a 2-2 trial, the initial choice of two members was also the correct answer of the trial. In a 2-1-1 trial, only one member's initial choice was the correct answer. From a probabilistic perspective, the chance of choosing the correct answer from the initial choices was 50% for a 2-2 trial and 25% for a 2-1-1 trial, and thus there was a performance drop for the 2-1-1 trials. However, this explanation fails to account for the interaction effect between team structure and trial type.

In sum, our findings suggest that team structure could affect the flow of information within a team, and this would impact team decision-making. In this study, the team structure only affected the flow of information at the initial decision-making stage. Team members could learn each other's preference during the team discussion. But, this still cannot attenuate the effect of team structure, suggesting that information received during individuals' preference formation could strongly impact team decision-making. To further validate this claim, we implement three neural networks (Rumelhart & McClelland, 1986) to model the effect of team structure on team decision-making.

Computational Modeling

Method

Three multi-layer neural network models with supervised learning were constructed. Each model consisted of 4 nodes in the input layer, 4 nodes in the hidden layer, and 1 node in the output layer.

Differing perspectives: In the behavioral study, teams were composed of four members. Each member had a unique evaluation on the three alternatives (i.e., company A, B, C). To represent this, each node in the input layer, I_i, receives the evaluation scores based on the scoring matrix used by Member i, $i = 1, 2, 3, 4$, as the input. There are three units in each node, each storing the score of one company.

Team structure: There are feedforward connections between adjacent layers and lateral connections within the hidden layer in each model. The three models differ in the interconnectivity between the input and hidden layers, representing the homogeneous-clustering, heterogeneous-clustering, and no-clustering structures (see Figure 3).

Figure 3. The architecture of the models.
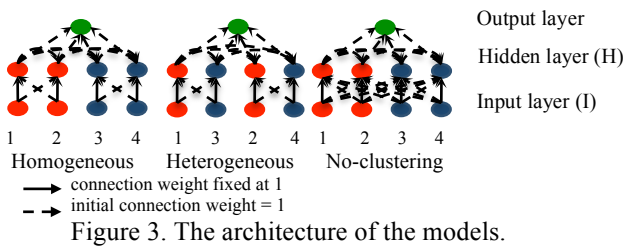
In all three models, each input node, I_i, has a corresponding node, H_i, $i = 1, 2, 3, 4$, in the hidden layer, and activation is sent from the input node to that hidden node with connection weight fixed at 1. The positive weight reflects individuals' ownership bias towards their own perspective. In the homogeneous-clustered model, in addition to receiving activation from its corresponding input node, each hidden node also receives activation from another input node that carries the evaluation from another member studying the same domain of information. This represents the homogeneous-clustering structure that members studying the same domain of information formed a subgroup and exchange perspectives. The initial connection weight between them is 0 to reflect individuals' neutral preference to others' evaluation at the beginning. To represent teams with heterogeneous-clustering, each hidden node in the heterogeneous-clustered model receives activation from its corresponding node (weighted fixed at 1) and another input node that carries the evaluation from a member studying another domain of information (initial weight = 0). In the no-clustering model, each hidden node receives activation from its corresponding input node (weight fixed at 1) and all other input nodes (initial weight = 0). This captures the no-clustering structure in that each member learned the preference of other members after finishing the scoring.

Group discussion: To simulate the team discussion that members can talk to and influence each other, nodes in the hidden layer are fully-connected with each other allowing them to inhibit or excite each other. The lateral connection weights defining the influence of one node on another are all set at 0 initially, reflecting individuals' neutral preference to each other at the beginning.

Changing task conditions: Two sets of training trials (10 pre-change trials and 10 post-change trials) were prepared. Multiple cycles of training were usually needed for a PDP model to learn the task. In this study, each model was first trained using the pre-trial training set for 200 cycles. Then, the models were trained on the post-change trials for another 200 cycles. The change of the training set represents the change in the task environment. The scores of the companies in each trial and the method for choosing the overall best one were same as those in the behavioral study.

Model performance: The output produced by the network was compared with the target output. The target output is (1, 0, 0) if company A is the best, (0, 1, 0) if company B is the best, or (0, 0, 1) if company C is the best. The error generated, i.e., the difference between the output and the target, is propagated backwards through the network for adjustments of the present weights in a direction to minimize the error. This is similar to the role of feedback in the behavioral study. Models were trained using Doug's Momentum with learning rate = .05 and momentum = 0.1.

Results

Examining the level of error and its rate of decline over time indicates how well a model does in learning the task. Figure 4 presents the error of the three models when learning the pre- and post-change trials. The heterogeneous-clustered and no-clustering models demonstrated a steeper decline in error initially, as compared with the homogeneous-clustered model. Yet, such differences become less significant over time. All models were impaired by the change of the training set, indicated by the significant increase in error immediately after the change. All models demonstrated a decrease in error after the first few cycles of training. But the homogeneous-clustered model showed no further improvement after that. Only the heterogeneous-clustered and no-clustering models continued to improve, showing a rapid and effective response to the changed conditions.
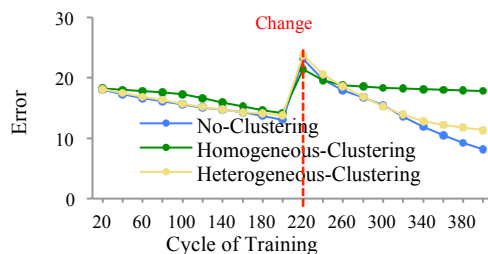

Figure 4. Computational model performance.

Discussion

The computational simulations mirror the experimental findings that the heterogeneous-clustered and no-clustering teams performed better than the homogeneous-clustered teams in decision-making and adapting to the change, and that they perform at about the same level as each other.

The memory capacity of a model is proportional to the number of connections (Rumelhart & McClelland, 1986). The no-clustering model has more interlayer connections, as compared with the two models, and this may explain the good performance of the no-clustering model. It is important to note that the heterogeneous-clustered model having fewer interlayer connections performed as well as the no-clustering model. It had lower error than the homogeneous-clustered model, even though they have the same number of connections. Having connections that allow nodes to receive information about different perspectives seems to be the key factor in enhancing the model performance in this study.

General Discussion

The behavioral and computational results converge to support that arranging teams into different structures, which embrace different intra-group communication ties, impacts team decision-making. The heterogeneous-clustered and no-clustering teams were more capable that the homogeneous-clustered teams in making use of multiple perspectives and in adapting to changes. The differing performance of the three teams for the 2-2 and 2-1-1 trials suggest that the heterogeneous-clustering and no-clustering structures have different positive impact on team information processing.

We suggest that heterogeneous-clustering would reduce individuals' ownership bias, allowing for a more objective evaluation on the information they received. The no-clustering structure would facilitate information sharing by inhibiting social categorization. Homogeneous-clustering would increase members' subgroup identity and confidence to their own preferences, making them less open to alternative perspectives and less flexible in dealing with change. In line with this, Minson & Mueller (2012) revealed that individuals who made decisions collaboratively were more confident in their decisions than were those who made decisions alone. The greater confidence level may make individuals more reluctant to revise their initial decisions. Our findings suggest that assigning members who disagree with each other to work together during the formation of their initial preference can avoid over-confidence.

Our studies focus on decision-making in small teams. When team size increases, it is time consuming to ensure that members have learned each other's perspective. It is also cognitively demanding for members to digest all the perspectives. Although clustering a team could limit the flow of information, it could prevent overtaxing individuals' cognitive capacity. Differences between no-clustering and heterogeneous-clustering, which are beyond those found in the present study, may emerge in larger teams.

In sum, our studies revealed that, for teams with different perspectives, heterogeneous-clustering and no-clustering could facilitate the use of multiple perspectives to make decisions and to deal with changes. Our findings have significant implications theoretically and practically. On a practical level, organizations often bring experts from different areas to work on a specific project. Identifying factors that most effectively leverage diversity is essential for enhancing the performance of work teams. On a theoretical level, past studies were often limited to examining teams with minimal structure performing tasks in static task environments. We extend the current body of research by exploring the link between team structure, team diversity, and decision-making in changing environments.

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