Incorporating Heterogeneity in Command Center Interactions

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Abstract

One of the many complexities of multinational coalition operations stems from differences in culture, military procedures, and command and control processes between the cooperating command centers. These differences can effect the interactions between decision makers of different command centers and can affect the outcome of the coalition operation. A model can be used to study the effect on coalition performance due to interactions between heterogeneous command centers. A coalition model, composed of individual models of the five-stage interacting decision maker model, which has been modified to include subjective parameters, was used in a virtual experiment. The subjective parameters included in the decision maker model can be any attribute that characterizes the heterogeneity of the decision makers. In this case, the parameters of power distance and uncertainty avoidance were used, two of Hofstede's [1991] cultural dimensions. Differences in these values across the cooperating command centers can cause communication and coordination difficulties. The accuracy and timeliness of the coalition's response was used to evaluate its performance as a function of heterogeneity. Including the presence of heterogeneity in the coalition model, through the use of subjective parameters, is the first step in formalizing the process for developing adaptive coalition architectures.

1.0 Introduction

The US military has seen a significant increase in the number of operations that involve coalitions of multinational military forces and civilian organizations. The interaction of the coalition command center with the individual collaborating command centers of the participating organizations becomes paramount to the success of the coalition operation. These cooperating command centers are heterogeneous, reflecting differences in their organizational structures and decision making procedures due to differences between services of the same country or differences between the same service of different countries, as well as differences between military and non-military organizations. The ability to share information between these heterogeneous command centers will be one of the factors that determine whether or not the mission will be a success or a failure.

Coalition command centers are the places where direct and intensive interactions take place. As coalition operations become increasingly common, the variety of organizations participating in the coalition will also increase. Organizations from nations that were previously considered as unacceptable are now equal partners. The cooperating command centers have different organizational architectures – each one reflecting the culture and military tradition of its country.

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While each cooperating command center has a commander, the way that decisions are made and the procedures that are used may be different. Many of these command centers have differences in methodologies and beliefs that affect the way that decision makers from these heterogeneous organizations interact together. So while corresponding decision makers may interact, each one is part of a different organization with different procedures and different sets of values.

In order to design successful coalition command centers, the effect of these interactions should be understood rather than ignored. Models of organizations can be used to study organizational behavior under different conditions in order to address questions on heterogeneous interactions. Pre-experimental modeling has been an important step in the experimental design process of subject experiments exploring adaptive homogeneous command and control organizations [Handley et al., 1997, 1998]. By constructing a software model of the experimental simulation, the behavior of the organization under design was observed before the subject experiment was conducted. Carley [1995] discusses computational and mathematical models that address organizational evolution and change. The use of simulation models to determine the effects of heterogeneous interactions is a necessary precursor to the design of coalition command centers that can function effectively in a multinational environment.

The coalition command center model is based on the five-stage interacting decision maker model [Levis, 1992]. The model has been modified to include subjective parameters in order to study heterogeneous interactions. A relatively small number of models have been developed for the systematic comparison of multinational organizations. The most useful ones are those that distinguish dimensions of culture [Mooij, 1998]. They can be used as an instrument to make comparisons between cultures and to cluster cultures according to behavioral characteristics. In the 1980's Geert Hofstede made a comprehensive attempt to capture high impact, national value differences. He selected four value dimensions to describe and classify national culture. These value dimensions were uncertainty avoidance, power distance, masculinity-femininity and individualism-collectivism. He assessed these value dimensions among thousands of IBM employees in 72 national cultures [Hofstede, 1991]. While weaknesses have been identified in Hofstede's research, this seminal study was a step forward in understanding and giving an index value to nationalistic differences. As an example of subjective parameters that can affect heterogeneous interactions, two of these parameters, power distance and uncertainty avoidance, have been chosen to be included in the coalition model.

Incorporating heterogeneity into command center interactions is the first step in designing coalition command centers that can adapt within a multinational environment. Section 2 discusses this research framework. Section 3 presents subjective parameters to be included in the model. Section 4 discusses the development of the coalition command center model that will be used in the virtual experiment, while Section 5 discusses the experimental design and results. Section 6 concludes the paper.

2.0 Adaptive Architectures for Heterogeneous Command Centers

The Adaptive Architectures for Command and Control (A2C2) program developed theory and tools for the analysis, design and evaluation of organizational structures at the Joint Task Force level. Different command structures were determined based on a task graph, representing the mission, and as circumstances changed, the command center could adapt by switching from one organizational form to another. Different organizational forms had different resource requirements and often resulted in different levels of performance. The results from this program represent the internal adaptation of a single cooperating command center. The Adaptive Architectures for Heterogeneous Command Centers project seeks to extend these concepts to coalition command centers at the multinational level.

Heterogeneous command centers are defined as the command centers of multinational forces at the Joint Task Force level. Given a scenario and a common mission, the cooperating command centers are directed by their respective governments to coordinate in order to accomplish the mission. As the mission evolves, the coalition command center and the cooperating command centers may need to adapt in order to achieve the prescribed mission. Each cooperating command center can adapt internally, termed intranodal adaptation, and each can also adapt externally through its interactions with the other command centers, termed internodal adaptation. This internodal adaptation represents the coalition level command center adaptation. The design of the operational architectures for the internal structure of the individual command centers, the intranode design, can be based on the work done within the A2C2 program. The model of the interconnections between these command centers, the internode design at the coalition command center level, must be created. Because the individual command centers may be adapting internally, independently of each other, it is necessary to consider the internal structure of the operational nodes representing the cooperative command centers in designing the adaptation of the internodal design at the coalition level. This current work establishes the effect of heterogeneity on the interconnectivity between nodes of different command centers, a prerequisite for implementing internodal adaptation. This research represents the first step to create coalition architectures that are created of heterogeneous command centers that can adapt at both the individual command center and the coalition level.

3.0 Subjective Parameters Effecting Heterogeneous Interactions

In order to study heterogeneous interactions, some type of subjective parameters must be included in the interacting decision maker model. These subjective parameters can be any factor that constrains the way that decision makers interact or process information. For example, the parameters can represent the differences between services of the same country, for example the differences in procedures between the US Army and the US Navy. The parameters could also represent the differences between a governmental organization and a non-governmental organization, such as the US Army and the International Committee of the Red Cross. In multinational coalitions, the parameters can represent nationalistic differences that have an affect on the performance of decision makers working together from different countries. Hofstede [1991] distinguishes dimensions of culture that can be used as an instrument to make comparisons between cultures and to cluster cultures according to behavioral characteristics. Culture is not a characteristic of individuals; it encompasses a number of people who have been conditioned by the same education and life experience. Culture, whether it is based on nationality or group membership such as the military, is what the individual members of a group have in common [Mooij, 1998].

To compare cultures, Hostede differentiated them according to four dimensions: uncertainty avoidance, power distance, masculinity-femininity and individualism-collectivism. The dimensions were measured on an index scale from 0 to 100, although some countries may have a score below 0 or above 100 because they were measured after the original scale was defined. The original data were from an extensive IBM database for which 116,000 questionnaires were used in 72 countries and in 20 languages over a six year period. Later, an additional Chinese Value Survey was conducted in 23 countries by Michael Harris Bond. The results were validated against about 40 other cross-cultural studies from a variety of disciplines including sociology, market research, and medicine [Mooij, 1998]. Two of these dimensions, power distance and uncertainty avoidance, may affect the interconnections between decision makers working together from different nationalistic organizations.

The power distance dimension can be defined as "the extent to which less powerful members of a society accept and expect that power is distributed unequally" [Hofstede, 1991]. An organization with a high power distance value will likely have many levels in its hierarchy and convey decisions from the top of the command structure to personnel lower in the command structure; centralized decision making. Organizations with low power distance values are likely to have decentralized decision making characterized by a flatter organizational structure; personnel at all levels can make decisions when unexpected events occur with no time for additional input from above. Power distance has been used in previous studies to characterize multi-cultural work environments [Helmreich et. al, 1996]. In studies of aviation and medical teams, when members differed in power distance, problems arose that affected the performance of the team. In aviation, the co-pilot must be willing to speak, interrupt, and correct the pilot and the pilot must be willing to listen, reassess, and change based on the co-pilot's input. Similar results were found in medical settings.

Uncertainty avoidance can be defined as "the extent to which people feel threatened by uncertainty and ambiguity and try to avoid these situations" [Hofstede, 1991]. An organization which scores high on uncertainty avoidance will have standardized and formal procedures; clearly defined rules are preferred to unstructured situations. In organizations with low scores on uncertainty avoidance, procedures will be less formal and plans will be continually reassessed for needed modifications. Klein et al. [2000] hypothesized that during complex operations, it may not be possible to specify all possible contingencies in advance and to take into account all complicating factors. "Operators must continually reassess ongoing plans for needed modifications of action. Information may be incomplete and inaccurate but may be the best information available at the time. If the decision is postponed, more information may become available, allowing a better decision, but time and opportunity will be lost" [Klein et al., 2000]. The trade off between time and accuracy can be used to study the affect of both power distance and uncertainty avoidance in the model.

Messages exchanged between decision makers can be classified according to three different message types [Zaidi, 1991; Zaidi and Levis, 1995]. Information messages contain inputs, outputs, and data; control messages are the enabling signal for the initiation of a subtask; and command messages indicate that another response is dependent on this message. The messages exchanged between decision makers can be classified according to these different message types and each message type can be associated with a subjective parameter. For example, uncertainty avoidance can be associated with control signals. Control signals are used to initiate subtasks according to a standard operating procedure. A decision maker with high uncertainty avoidance is likely to follow the procedure regardless of circumstances, while a decision maker with low uncertainty avoidance may be more innovative. Power distance can be associated with command signals. A command center with a high power distance value will respond promptly to a command signal, while in a command center with a low power distance value this signal may not always be present. When a message is received by a decision maker, first the message type is checked. Based on the message type, the subjective values of both the sender and the receiver decision maker are compared. Differences in these values across command centers can cause communication and coordination difficulties.

4.0 Coalition Command Center Model

The task of modeling a coalition command center starts with constructing a rather abstract and generic command center model and then instantiating the generic model with a specific scenario and coalition design. Since coalitions are created only when needed for a specific situation and have only a finite lifetime, the model must be flexible. The use of the five-stage interacting decision maker model for the individual decision makers within the command center is appropriate as it is conceptually the most generic class of a decision maker; all roles in a heterogeneous command center can be instantiated from the model.

4.1 The Five-Stage Interacting Decision Maker Model

Levis (1992) described a five-stage decision maker model that was the culmination of years of research and evolution. It began with the investigation of tactical decision making in a distributed environment with efforts to understand cognitive workload, task allocation, and decision making. The five-stage model allows the algorithm in each stage to be defined and makes explicit the input and output places of the decision maker, and has a well defined algorithm for defining workload. This has become a consistent model for fixed and variable structure organizations. Perdu and Levis [1998] described an adaptive decision maker model that used an object class to represent the ability of decision makers to dynamically adapt with local adaptation. Handley et al. [1998] explored pre experimental modeling for subject experiments as part of the A2C2 program. This model allowed decision makers to complete coordinated tasks. Finally Handley [1999] returned to the five-stage paradigm to create an adaptive five-stage decision maker model that combined local and global adaptation within the five-stage approach.

The five-stage decision maker model of Levis [1992] is shown in Figure 1. The decision maker receives a signal, x, from the external environment or from another decision maker. The Situation Assessment stage (SA) represents the processing of the incoming signal to obtain the assessed situation, z, which may be shared with other decision makers. The decision maker can also receive situation assessment signals z’ from other decision makers within the organization; z’ and z are then fused together in the Information Fusion (IF) stage to produce z’’. The fused information is then processed at the Task Processing (TP) stage to produce v, a signal that contains the task information necessary to select a response. Command information from other decision makers is received as v’. The Command Interpretation (CI) stage then combines v and v’ to produce the variable w, which is input to the Response Selection (RS) stage. The RS stage then produces the output y to the environment, or the output y’ to other decision makers.

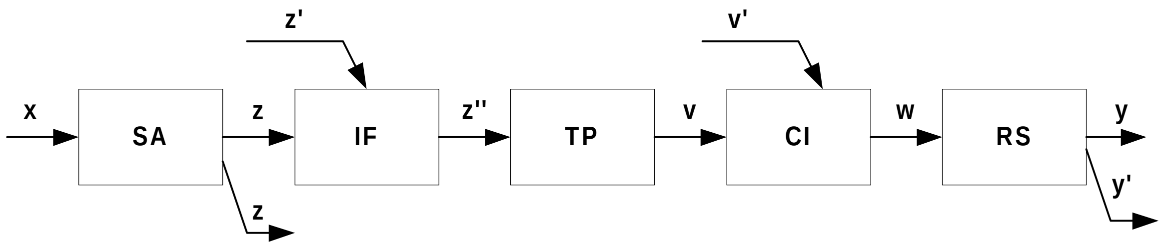


Figure 1: Five Stage Interacting Decision Maker [Levis, 1992]

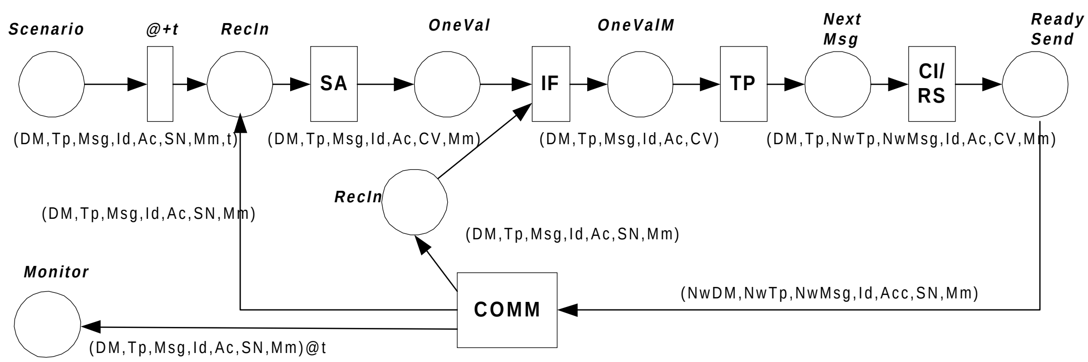
The model depicts the stages at which a decision maker can interact with other decision makers or the environment. A decision maker can receive inputs from the external environment only at the SA stage. However, this input x can also be from another decision maker’s y’. A decision maker can share his assessed input through the z output at this stage. The z’ input to the IF stage is used when the decision maker is receiving a second input. This input must be generated from another decision maker and can be the output of the SA or RS stage. The fused information from the IF stage, z’, is the input to the TP stage. The decision maker’s processing is performed at this stage and results in the output v. In the CI stage, the decision maker can receive command information as the input v’. This is also internally generated and must originate from another decision maker’s RS stage. In the RS stage, an output is produced; y is the output to the environment and y’ is the output to another decision maker. Thus the interactions between two decision makers are limited by the constraints enumerated above: the output from the SA stage, z, can only be an input to another decision maker’s IF stage as z’, and an internal output from the RS stage, y’, can only be input to another decision maker’s SA stage as x, IF stage as z’, or CI stage as v’.

Previously, the algorithms used with this model were based on operational data and procedures; they did not contain any subjective parameters. Subjective parameters can be included in the model by rule sets associated with each cooperating command center. These rules sets can affect the behavior of the decision maker model in specific situations, such as when messages are being exchanged with decision makers from a different command center. These parameters can force the decision makers response to a different state in specific circumstances. In order to evaluate the effect of these subjective parameters on the output of the decision maker and on the coalition performance, an executable model must be created. Colored Petri nets are used to create the executable model.

4.2 The Colored Petri Net Model

Petri nets provide a graphical modeling language with which to represent a system and an underlying mathematical theory for rigorous analysis [Murata, 1989]. They can represent the external interactions of the decision makers as well as any internal algorithms the decision maker must perform, such as the inclusion of the subjective parameters. Ordinary Petri nets are bipartitie directed graphs [Peterson, 1981]. There are two sets of nodes: places denoted by a circle node and transitions modeled by a bar node. The arcs or connectors that connect these nodes are directed and fixed. They can only connect a place to a transition or a transition to a place. A Petri net also contains tokens. Tokens are depicted graphically by indistinguishable dots and reside in places. A marking of a Petri Net is a mapping that assigns a non-negative integer, representing the number of tokens, to each place. A transition is enabled by a marking, if and only if all of its input places contain at least one token. An enabled transition can fire. When the firing takes place, a new marking is obtained by removing a token from each input place and adding a token to each output place. The dynamical behavior of the system is embedded in the changing of the markings.

Colored Petri nets are an extension of Petri nets [Jensen, 1990]. Instead of indistinguishable tokens, tokens now carry attributes or colors. Tokens of a specific color can only reside in places that have the same color set associated with them. The requirements to fire a transition are now specified through arc inscriptions; each input arc inscription specifies the number and type of tokens that need to be in the place for the transition to be enabled. Likewise, output arc inscriptions indicate what tokens will be generated in an output place when the transition fires. A global declaration node of the Colored Petri net contains definitions of all variables, color sets, and domains for the model. Figure 2 shows the top level of the hierarchical, executable model.




```
color Ident = string;
var DM,Id,NwDM : Ident;
color Cont = string timed;
var Msg,NwMsg : Cont;
color Penal = int;
var Ac : Penal ;
color Val = with H|L|U;
var CV: Val;
color Org = with USA|AUS|ROK;
var SN : Org;
color Type = with CTR|CMD;
var Tp,NwTp : Type;
color Mult = with DIN|SCIN|DOUT|NULL;
var Mm : Mult;
color FctTime = int timed;
var t : FctTime;
color RecIn = product Ident*Type*Cont*Ident*Penal*Org*Mult;
color OneVal =product Ident*Type*Cont*Ident*Penal*Val*Mult;
color OneValM =product Ident*Type*Cont*Ident*Penal*Val;
color NextMsg = product Ident*Type*Type*Cont*Ident*Penal*Val*Mult;
color ReadySend = product Ident*Type*Cont*Ident*Penal*Org*Mult;
```

Figure 2: Top Level Net of Executable Model

The transitions that represent the individual stages of the five-stage model are compound transitions; each represents a separate page of the model that contains the functionality of that stage. The first stage, Situation Assessment, compares the basis for the subjective parameters for the sending and receiving decision maker. The model can be configured to use any basis for comparison and to include the corresponding subjective parameters. In this case, the nationality of the two decision makers is compared, and the power distance and uncertainty avoidance parameters for each are obtained. To simplify this initial model, only one set of subjective parameters is retained, based on the incoming message type. If the message type is 'command', then the power distance parameters are retained, if the message type is 'control', then the uncertainty avoidance parameters are retained.

In order to compare the subjective parameters, a breakpoint must be determined based on the scenario to distinguish low versus high values. In this case a value of 50 was used; 50 is the median value of the Hofstede index. Values below this are considered low (L) and values above this are considered high (H). If both parameters are high, or if both are low, the model's internal parameter is set to high or low, respectively, indicating compatibility between the two decision makers. However, if there is a disagreement in the values, i.e., one value is high and the other is low, the internal parameter is set to undetermined (U), indicating there may be incompatibility on this parameter.

The second stage, the Information Fusion stage, is used when a decision maker is a fusion node. This occurs when a control signal is required in order to continue processing the task. If the internal parameter for uncertainty avoidance is high, then the decision maker will wait for the control signal before continuing his processing. If however, the internal parameter for uncertainty avoidance is low, the decision maker will proceed without waiting for the control signal. If this occurs, the accuracy value for this task is decreased by one. If the uncertainty avoidance parameter is undetermined, a toggle is used to decide if the decision maker waits for the control signal before proceeding.

In the Task Processing stage the input message is processed and the response message is generated. If the message requires a degree of redundancy, then more than one response message may be generated. A delay of one time unit is incurred to process this stage of the task and the accuracy value is increased by one to indicate that this step is complete. The following stage, Command Interpretation, is active when the message type is command and the internal parameter, representing power distance, is high. In this case the model incurs a delay of one time unit, representing command confirmation. In the other cases, if the internal parameter is low or the message type is not command, then this stage is a pass through and no delay is incurred. If the internal parameter setting is undetermined, then a toggle is used to determine if a delay is incurred.

The final stage is the Response Selection stage, which prepares the response message to be sent. First the next decision maker is chosen to send the response message to. This is done by checking the next billet required in the task processing. Then the nationality of the sending decision maker is appended to the message; this will be used by the receiving decision maker in his situation assessment stage. The message is now ready to be sent.

The communications page simply provides the logic to route messages between decision makers until a task is complete. The input to the communication page is the output of the decision maker's Response Selection stage. The message is routed to the next decision maker's Situation Assessment stage. When a task is finished, an output is made to the Message Monitor place where the task id, the task accuracy, and the task processing time will be used to score the performance of the coalition in completing the task.

5.0 The Experimental Design and Results

The consequences of heterogeneity in command center interactions can be illustrated by conducting a virtual experiment. An experimental design was created which simulates the coalition model under different levels of heterogeneity. The organizational design used to populate the coalition model and the task graphs used to create the input scenario were extrapolated from a scenario currently being used for coalition research.

The Decision Support Systems for Coalition Operations (DSSCO) project is developing tools that US military planners can use to improve the effectiveness of multinational coalition operations involving diverse military and civilian organizations. A prototype is being developed by SPAWAR Systems Center - San Diego to support the Operations Planning Team (OPT) of the Commander in Chief, United States Pacific Command. The goal of DSCCO is to apply and integrate organizational design concepts and decision support technologies in planning and executing multinational coalition operations. As part of this development, an operational scenario, an Indonesian "Rebel Territory" scenario, has been developed to provide a context for development and demonstration of DSSCO tools and products [Heacox, 1999]. This scenario was used as the basis of the experimental design.

The scenario depicts a situation where growing tensions among multiple ethnic groups has lead to armed conflict between a rebel militia group and the host country's military. The rebel group has fled to an enclave of land on the eastern portion of the island nation and has detained a large number of citizens within the rebel-secured territory. Many of these citizens are unsympathetic to the rebels and are considered to be at risk. The host government recognizes that they are unable to maintain peace and that the tide of world opinion has turned against them; the government then asks the US to lead the anticipated coalition operation in an effort ensure aid is delivered to the rebel-secured territory where the food and water supply and sanitation facilities are limited.

When a coalition is composed of one lead country with the majority of the forces, the coalition is not very heterogeneous and its command center is not very integrated. On the other hand, when the coalition is composed of many, equally represented organizations, the coalition is very heterogeneous and also very integrated. In order to represent varying degrees of heterogeneity, three participating command centers were chosen based on the coalition scenario: the United States (USA), Australia (AUS) and the Republic of Korea (ROK). The command centers were assigned to billets as indicated in Table 1. The scenario is first completed by homogeneous command and control centers where there should be no effect of heterogeneous interactions. Then, the coalition command center is equally integrated by assigning billets alternately from two countries. Finally the command center is integrated equally among the three countries present in the scenario. Note that permutations of the order of the mappings did not produce significant differences in performance due to the high interaction of all billets.

Table 1: Billet Assignments

COUNTRY **BILLET**	**USA**	**AUS**	**ROK**	**USA-AUS**	**USA-ROK**	**AUS-ROK**	**USA-AUS-ROK**
CINC	USA	AUS	ROK	USA	USA	AUS	USA
CCTF	USA	AUS	ROK	AUS	ROK	ROK	AUS
PSAT	USA	AUS	ROK	USA	USA	AUS	ROK
SJA	USA	AUS	ROK	AUS	ROK	ROK	USA
PAO	USA	AUS	ROK	USA	USA	AUS	AUS
J1	USA	AUS	ROK	AUS	ROK	ROK	ROK
J3	USA	AUS	ROK	USA	USA	AUS	USA
J4	USA	AUS	ROK	AUS	ROK	ROK	AUS
J6	USA	AUS	ROK	USA	USA	AUS	ROK
CMOC	USA	AUS	ROK	AUS	ROK	ROK	USA
NAVFOR	USA	AUS	ROK	USA	USA	AUS	AUS
TRNBN	USA	AUS	ROK	AUS	ROK	ROK	ROK
DJTFAC	USA	AUS	ROK	USA	USA	AUS	USA
AMC	USA	AUS	ROK	AUS	ROK	ROK	AUS
CAO	USA	AUS	ROK	USA	USA	AUS	ROK

The input scenario used to simulate the model was taken from DSSCO task blocks sections A ("Situation Assessment and Preparation") and B ("Coordinate Operations Across Sectors"). Sixteen tasks were identified that require a series of messages among the command center decision makers until an output is generated back to the operation lead. They are composed of command (orders) and control (initiate) messages. A sample, message id "idb6" which concerns "Conduct Civil Military Operations" is shown in Table 2 and graphically in Figure 3.

Table 2: Task "idb6" Message Sequence

From	**To**	**Type**	**Msg**
CCTF	J4	CMD	B6
J4	CAO	CMD	B6
CAO	CMOC	CMD	B6b
CAO	J3	CNR	B6c
J3	SJA	CNR	B6c1
J3	PAO	CNR	B6c2
SJA	J3	CNR	B6c1R
PAO	J3	CNR	B6c2R
J3	CAO	CNR	B6cR
CMOC	CAO	CMD	B6R
CAO	J4	CMD	B6R
J4	CCTF	CMD	B6R

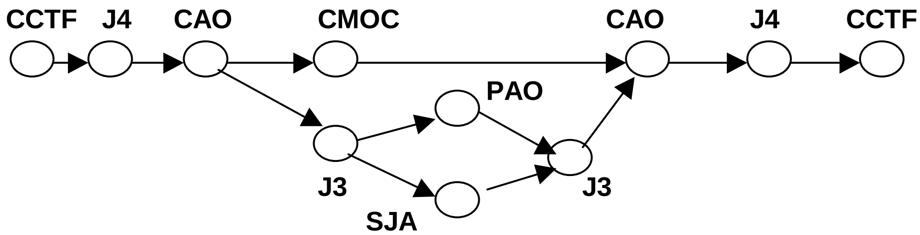


Figure 3: Task “idb6” Message Graph

For this experimental design, the independent variables are the organizational configuration, the mapping of command center entities to billets, and the scenario used to stimulate the model, the series of tasks to be performed. The dependent variable, the variable to be observed and measured, is the performance of the coalition completing the tasks. Monitoring the performance of the coalition provides the ability to compare or judge the different levels of heterogeneity. Table 3 indicates the Hofstede values for the scenario countries that were included as subjective parameters. Two measures, timeliness and accuracy, were used to evaluate the coalition output.

Table 3: Hofstede Values

	Power Distance	Uncertainty Avoidance
United States	40	46
Australia	36	51
Republic of Korea	60	85

Timeliness expresses an organization’s ability to respond to an incoming task within an allotted time. The allotted time is the time interval over which the output produced by the organization is effective in its environment. This allotted time can be described as a window of opportunity whose parameters are determined a priori by the requirements of the task. Different task types may have different windows of opportunity. Two quantities are needed to specify the window of opportunity: the lower and the upper bounds of the time interval, t_s and t_f, respectively, or one of the bounds and the length of the interval, e.g. t_s and Δt [Cothier and Levis, 1986]. The timeliness of each coalition output was scored based on the task’s window of opportunity; if the response was within the window, it was given a score of two, if it was on the boundary it was given a score of one, otherwise it received a score of zero.

Similarly, accuracy expresses an organization’s ability to make a correct response to an incoming task. The accuracy for each task can be described as an interval that contains the correct response plus or minus a margin of error within which the response is still acceptable. The accuracy value of each coalition output was scored based on the accuracy interval determined a priori for each task. If the value was within the range it was given a score of two, if it was on the limits of the range, it was given a score of one, otherwise it received a score of zero.

Timeliness identifies weaknesses caused by delayed information; organizations that have high uncertainty avoidance and high power distance are hypothesized to score lower on timeliness.

Accuracy identifies weaknesses caused by incomplete information; organizations that have low uncertainty avoidance and low power distance are hypothesized to score lower on accuracy.

Figure 4 shows the results of the virtual experiment. The results illustrate the trade off between timeliness and accuracy for the different combinations of nationalities. USA and AUS are similar on power distance but differ in uncertainty avoidance. This shows a similar timeliness score, but a difference in the accuracy. AUS and ROK are different on power distance but the same on uncertainty avoidance, thus the accuracy is similar but the timeliness is different. USA and ROK are different on both parameters and this is reflected in their scores. Perhaps the most interesting is the triple combination (UAK), where neither score is maximized, however neither is a minimum either.

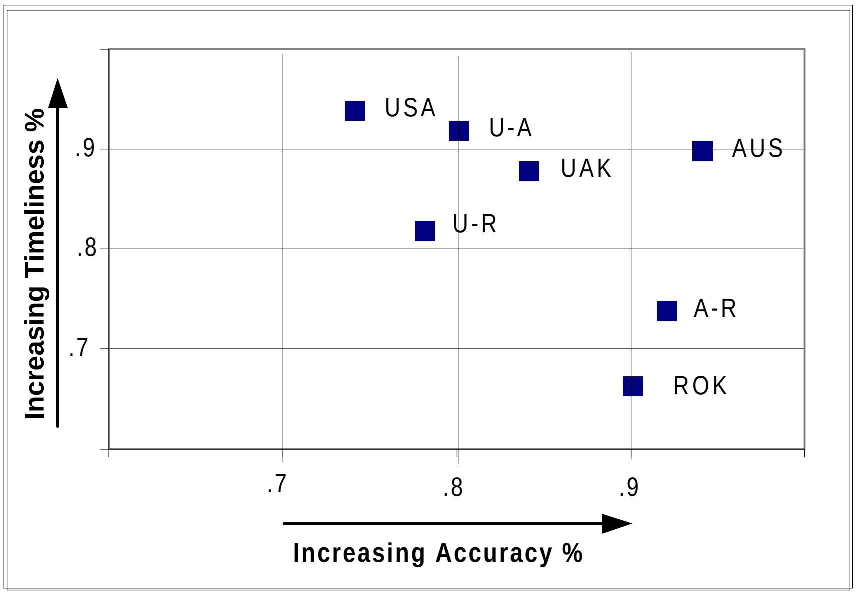


Figure 4: Experimental Results

6.0 Conclusions

This research looked at the impact of heterogeneous factors on decision maker interactions by adding the ability to include subjective parameters into the five-stage model of the interacting decision maker. By running a virtual experiment using the DSSCO coalition scenario, the effect of heterogeneity within a coalition command center could be explored. On the basis of national differences, the effect of two parameters, power distance and uncertainty avoidance, were observed on the coalition command center output. Two measures were used to evaluate the coalition's performance, timeliness and accuracy. While homogeneous command centers obtained the maximal score on one parameter, the other score was less acceptable. The heterogeneous command centers received less extreme scores on both measures, indicating that heterogeneity may serve to moderate performance. The coalition command center composed of all three participating nations received both timeliness and accuracy scores in the 85^{th} percentile.

The model used in this virtual experiment is a generic model which can be populated with data to reflect any type of military or non-military command center, and include any subjective parameters that can be assessed on the different entities in order to explore other effects of heterogeneity. Other performance measures can also be used that examine other aspects of coalition performance. The effect of interactions between decision makers of different command centers within a coalition is the first step in designing adaptive, coalition command centers. The next step is to create a dynamic coalition model that allows the different cooperating command centers to join and leave the coalition. This dynamic coalition model will need to adjust its interactions, the internodal design, as the composition of the cooperating command centers change over time and to recognize changes within the individual command centers, the intranodal design.

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