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Common Intent and Information Processing Frameworks applied to Effects Based Approaches to Operations

Topics: C2 Social Domain Issues
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Abstract

Effects Based Approaches to Operations (EBAO) involve the planning, execution, and assessment of diplomatic, information, military, and economic effects towards achieving the strategic objective. At the core of the EBAO headquarters are the creation, formalization, and distribution of information. Furthermore, if the EBAO staff members are distributed then they must rely on common intent to successfully complete the mission. Thus, EBAO provides enough complexity to explore Common Intent (CI) and Team Information Processing (TIP).

Perceptual Control Theory describes an information-processing framework where perceptions are driven towards their goals as part of an internal control loop. This model is extended to describe TIP where each team member has some high-level goals in common and overlapping responsibilities. CI involves interpreting and internalizing instructions and common goals, as well as understanding each other's responsibilities. The TIP model shows that CI helps to partially de-couple and optimize team interactions.

One aim of the Multinational Experiment 4 is to find evidence of de-coupling and optimization of the team interaction during EBAO as a result of CI. The hypothesis is that if CI exists then there would be clear roles and areas of responsibilities (de-coupling), and EBAO deliverables would be produced faster and more accurately (optimization).

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Introduction

Common Intent (CI) is a relatively new concept developed by McCann and Pigeau (2000). CI is the combination of explicit and implicit intent amongst two people, a team, or an organization such as coalition operational level headquarters. This paper presents a theoretical model relating CI and team information processing and uses the resultant framework to interpret some of the results from the Multi-National Experiment 4 (MNE 4), in which Effects Based Approaches to Operations (EBAO) are under investigation.

The notion of CI is exemplified by the following sports analogy. Each player on a hockey or soccer team has specific competencies and roles. The goalie is responsible for preventing a goal. The defence player acts in concert with the goalie to thwart any offensive attack, even though the defence player has different skills and duties from the goalie. The offensive players' role is to score goals, and they too have very different duties than either the goalie or the defence. Team members who internalize the coach's explicit instructions and guidance, who understand their own as well as each other's Competencies, Authorities, and Responsibilities (CAR: Pigeau and McCann, 2000) in light of the team's objective, and whose actions are consistent with each other – that is, teams who have Common Intent – often win. Conceptually, the same would be true for an operational headquarters employing EBAO.

Pigeau and McCann took a top-down approach in developing human-centric definitions and relationships between Command, Control, Command and Control, CAR, and CI that are part of a cohesive conceptual framework. This paper takes a bottom-up approach starting with human information processing, then human-human interaction, and finally describing how team information processing is related to CI.

Information Processing Model

Consider a simple Human Information Processing (HIP) model based on Perceptual Control Theory (PCT: Powers, 1973) as shown in Figure 1. The left side shows the internal control of a single perception. The perception is compared to its goal. If perceptual error exists then a decision is made to behave (act or communicate) in an attempt to change relevant physical world states. The human interprets the sensory information and updates their perception, thus closing the internal control loop. The nature of control is to drive the perceptual error to zero by:

1) behaving in a way to influence world states that drive perception towards its goal;
2) modifying how information is interpreted and transformed into a perception; or,
3) changing the goal to match the current perception.

Not a single goal, but a hierarchy of goals may represent individual intent. The highest-level goals may be to perceive life, love, and relationship while the lowest-level (unconscious) goals might be to perceive that a neuron had fired. The specific goal – *to*

perceive that the EBAO operation is successfully completed – likely falls somewhere between these two hierarchical levels. In the sports team example, the team has a high-level, singular goal of winning (more precisely, to perceive that they have won), but that goal is decomposed into lower level goals such as preventing, thwarting, and scoring, and so on down to the neuron firing level.

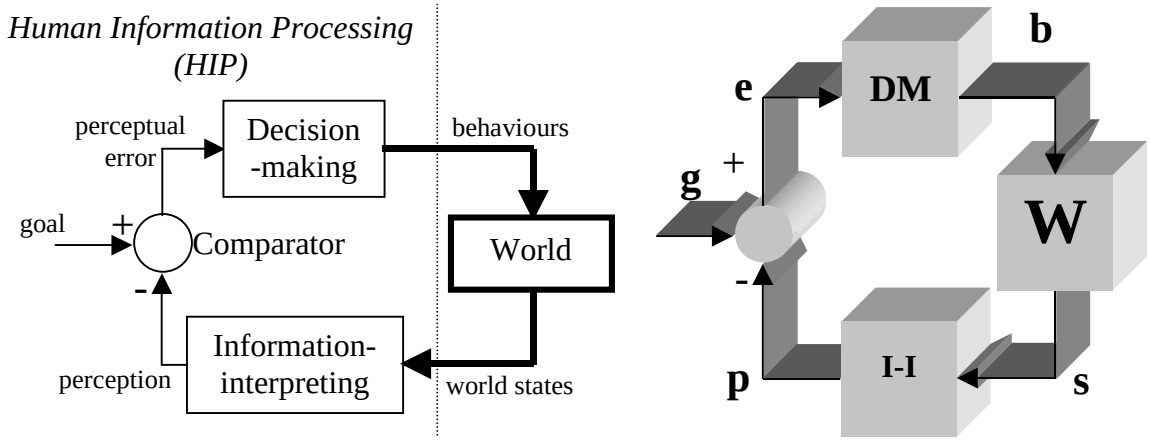

Figure 1. An information-processing model based on Perceptual Control Theory.

The goal hierarchy can be expressed as a single vector (**g**), and so the 3-D control loop on the right side of Figure 1 represents multiple and simultaneous control loops: one for each goal in the goal hierarchy. The nature of control is the same as before: to ensure that the perceptual error vector (**e**) tends towards zero. The Information-Interpreting functions (**I-I**), Comparator, Decision-Making functions (**DM**), and World dynamics (**W**) are complex nonlinear matrix transformations, and the perceptions (**p**), behaviours (**b**), and sensory information (**s**) are vectors as well. This model does not claim that the functions are determined or even determinable, yet the model can be used as a theoretical framework for describing Common Intent in the context of information processing.

A PCT Team Information Processing (TIP) model builds on the individual HIP model. Figure 2 represents human-human interaction and can be generalized to include more than two people. The interaction is coupled by means of the World function and sensory information vector. That is, the team members interact within a common environment and the same information is available for them to sense. Mathematically, the coupling introduces unstable modes (perceptions and goals diverge) as the number of team members increase. Careful design* of **DM** and **I-I** is required in order to avoid unstable modes.

For example, two people may have a common high-level goal to move a wheelbarrow from point A to point B with each person holding one of the handles. The wheelbarrow couples the interaction. They may have a common **I-I** function (the same culture, values, and expectations) and make the same decisions, but the force applied to the handles (their

* "Design" in the sense of changing cognitive structures by training, education, experience, culture, and other psychological (and physiological) aspects.

behaviours) must be perfectly balanced or else they might produce an unstable situation, veer off course, and not achieve their common goal.

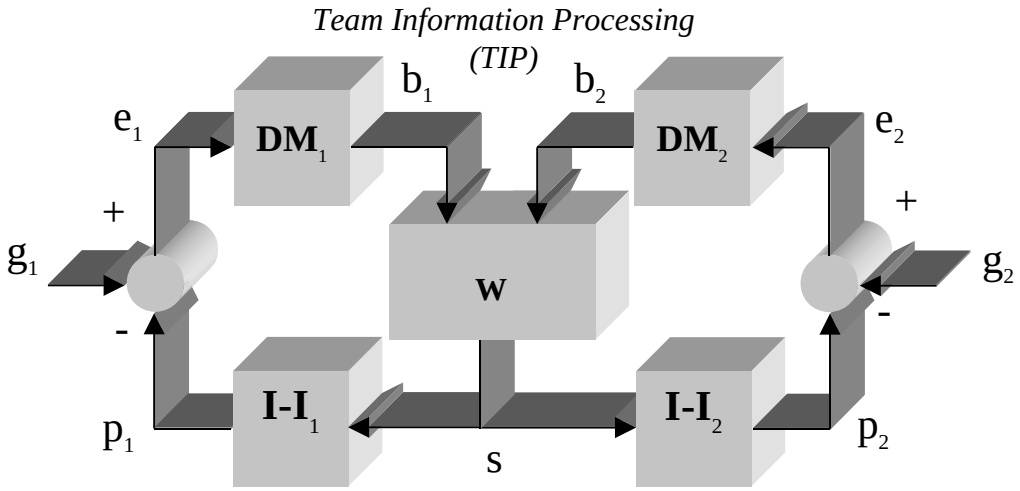

Figure 2. Two-person depiction of a multiple-human interaction model

Common Intent and the TIP model

Common Intent is more than just having a common high-level goal as in the wheelbarrow or sports team examples. McCann, Pigeau, and English (2003) decompose Common (or shared) Intent into two parts:

1. Explicit Intent
   "*intent that is made publicly available through orders, briefings, questions and discussions*"; and,
2. Implicit Intent
   "*the interpretation of explicit intent … derive[d] from personal expectations, military training, tradition and ethos and from deep cultural values*".

Explicit Intent is a restatement of the highest-level single goal: expressed as the Commander's intent or guidance for an operational level headquarters. Team members will need to perceive, internalize, and then understand their own competencies, authorities, and responsibilities (CAR) with respect to the "big picture". This is a first step towards de-coupling the system.

Explicit Intent also involves providing guidance for the lower-level shared goals. A Commander may give his or her staff specific areas of responsibility within which certain goals must be achieved. This parsing of goals and responsibilities is akin to having separate feedback control loops. When a person's CAR matches their assigned goals then there would be a high probability that the separate feedback control loop will be stable, and conversely when CAR does not match then the control loop would likely become unstable.

Pigeau, McCann, and English introduced the notion of a Balanced Command Envelope where there exists a balance of CAR within the organization. The equivalent notion in the TIP model is that each control loop (representing a team member) has the appropriate

information interpreting (competency), behaviour (competency), and decision-making (authority) structures for the assigned set of goals (responsibility) within a specific portion of the world (area of responsibility) – and so the entire system of control loops are de-coupled as depicted in Figure 3, and stability depends primarily on the individuals' cognitive and behavioural capabilities.

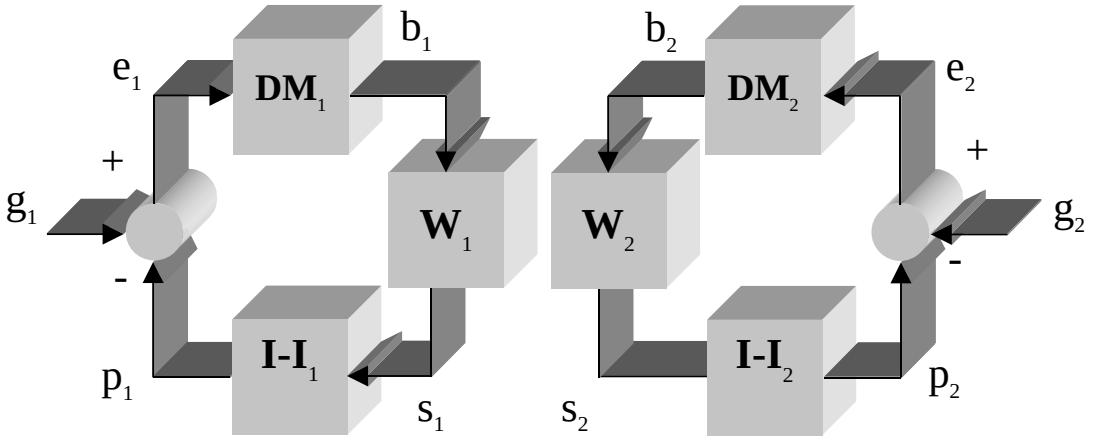

Figure 3: De-coupled interaction. Overall stability depends on each person's capabilities.

Implicit Intent is intangible and yet it seems to turn 'good' teams into 'excellent' teams. Ideally, if a team member can interpret and anticipate other members' goals and behaviours, respectively, in the context of their own goals and behaviours, then they could make adjustments to their decision-making so that goal achievement is optimized (faster with a smaller perceptual error). The interpretation and anticipation, however, involves the team member's own personal expectations that are shaped by training, tradition, and culture. The more that training, tradition, and culture are common amongst team members, the more likely that the interpretation and anticipation will yield an optimal interaction. Something as basic as team members speaking the same language will improve Implicit Intent.

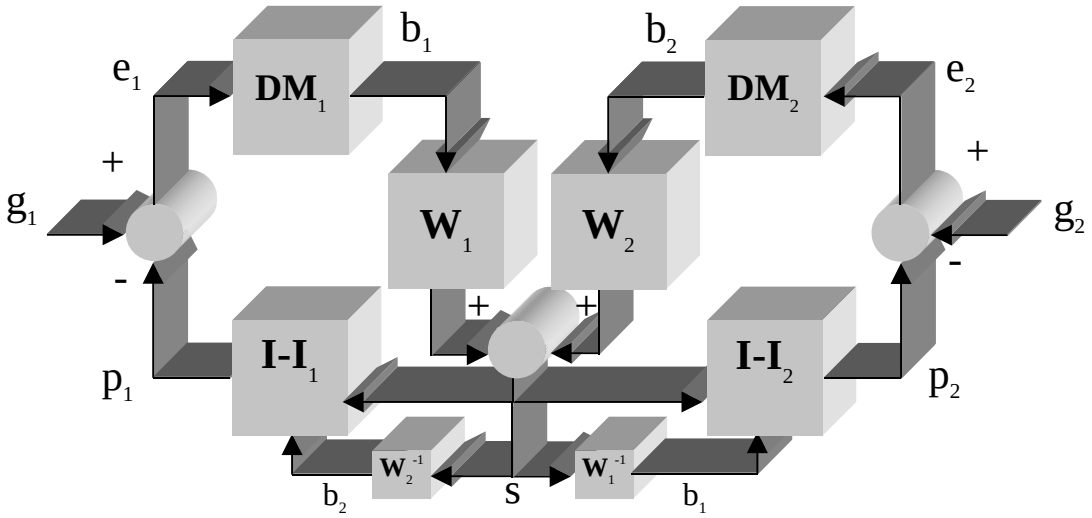

Figure 4: Partially coupled interaction where partners can see all world states and each other's behaviours.

One possible model for Implicit Intent is that each partner sees each other's behaviours as well as the world states, although they have separate areas of responsibility as shown in Figure 4. They would sense not only the world states but also their partners' behaviours and may use this information to anticipate their partners' next action and make decisions on their own next action.

Recall the wheelbarrow example. If each person could see how well the wheelbarrow were on course as well as sense of how much force and torque their partner was applying to the handle, they would have the opportunity to anticipate their partner's actions and would compensate by making the appropriate force adjustments to maintain stability. Ultimately the behaviours may be decoupled where one person might apply the moving force, while the other would primarily steer the vehicle. Their actions would be consistent with each other but not necessarily the same. This example illustrates the assertion that Implicit Intent can be observed as team members' actions that are consistent with each other.

According to the TIP model, Explicit Intent would tend to de-couple the system by having separate areas of responsibility while Implicit Intent would tend to optimize the system by having common expectations that lead to action consistency. Thus, CI would contribute to the de-coupling and optimization of human-human interaction.

Common Intent Experimental Design

MNE 4 provides an excellent opportunity to test the de-coupling and optimization aspects of CI. US Joint Forces Command (JFCOM) J9 (experimentation) has been exploring EBAO since 2001 with partner nations, including Canada's Canadian Forces Experimentation Centre (CFEC). The EBAO Concept of Operations (JFCOM, 2005) describes four major phases: Knowledge Base Development (KBD), Effects Based Planning (EBP), Effects Based Execution (EBE), and Effects Based Assessment (EBA). Each phase has multiple activities. Each activity has multiple steps. Each step lists the required procedures to perform the step. In essence, the Concept of Operations (CONOPS) describes a hierarchy of desired tasks that can be converted readily into a goal hierarchy (Kobierski, Coates, and Torenvliet, 2005).

The EBAO organization (the team) is subdivided into seven staffs (sub-teams). The Command Group (CG) provides the strategic level instructions and guidance for the staff members who produce the EBAO products. The Knowledge Base Development (KBD) staff develops and maintains the Knowledge Base (KB: a database that captures the political, military, economic, social, information, and infrastructure states of the area of operations as well as the EBAO documents and products), while the Knowledge Management (KM) staff governs and facilitates the knowledge activities throughout the headquarters. The EBP, EBE, and EBA staffs perform their respective EBAO activities, steps, and procedures. The Multinational Interagency and Coalition Agency Groups (MNIG/CAG) advise the CG and the other staffs on diplomatic and development issues.

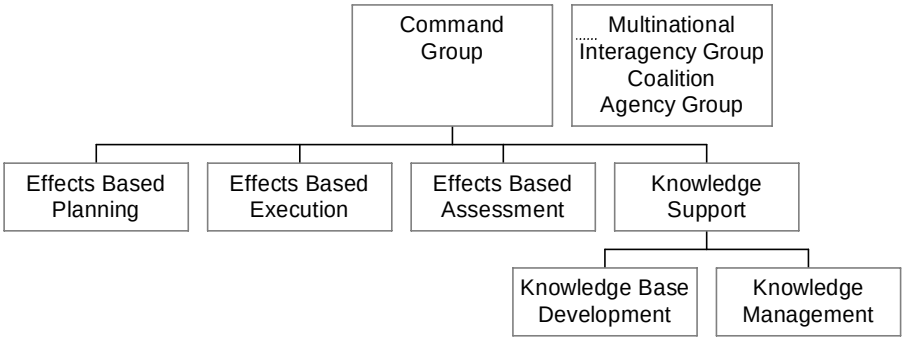

Figure 5: EBAO Organization Chart for MNE 4

The EBAO technologies include software tools for distributed collaboration, situation awareness, planning, modelling and simulation. Distributed team collaboration is likely to be the way militaries will do business in the future. In this experiment, MNE 4, staff members are distributed across North America and Europe in seven facilities. Their primary means of communication is text and audio chat over a secure network. The team shares documents and software tools, and access the KB via a portal.

The EBAO process, organization, and technology must work synchronously with each other in order to assure successful mission completion. CI can be thought of as the "lubricant" that keeps EBAO running smoothly.

Common Intent was previously measured within a similar complex situation: MNE 3 (Farrell et al., 2005). Those measurements indicated CI between medium and low (Farrell, 2005b). Farrell (2005b) assumed that 100% action consistency is the highest level of CI, 0 to 50% action consistency would be considered low, and medium would be around 70% (fuzzy and nonlinear scale). Two questions immediately arose: 1) what does "high", "medium" or "low" CI mean in terms of team performance, and 2) what caused CI to fall between medium and low? Farrell (2005b) attributed the CI result to low performance in the process steps and an ineffective organization, while the technology was deemed moderately useful.

For MNE 4, the hypothesis is that if staff members have clear roles and responsibilities then Explicit Intent would be high. The analyses that provided data on roles and responsibilities could be correlated with the Explicit Intent results, and this correlation would provide indirect evidence that the team interactions were de-coupled to some extent. The Explicit Intent question is as follows:

To what extent do you (an observer) believe that the sub-team understood the Commander's orders and guidance? (Not at all) 1 2 3 4 5 6 7 (Completely)

This question was included in the MNE 4 survey on Common Intent and it was given to observers/data collectors who are embedded in all areas of the organization. A simple scale from 1 to 7 captures their opinion. The question was asked seven times, once for each sub-team. This set of questions was presented to the observers six times over a

three-week period given that Explicit Intent was likely to change over the course of the event. The survey was given to both the Coalition Task Force (CTFHQ: CG, EBP, EBE, EBA, KS, and MNIG staffs that were distributed in six locations around the world) as well as the NATO Response Force headquarters (NRF: CG, EBP, EBE, EBA, KS, and CAG staffs that were collocated in one building), which also conducted EBAO concurrently. This provided an opportunity to compare Explicit Intent between a distributed organization and a collocated organization.

The hypothesis for Implicit Intent is that if there were high action consistency (an indicator of II) then EBAO process would be optimized, and this would be evident by improvements in products and decision-making. The plan was to repeat the EBAO process three times, and so one might be able to track quality of the products and decision-making. However, the purpose of the experiment was to test the robustness (vice effectiveness) of the EBAO process. Thus, the product quality was not measured and only questions related to decision-making were given. The Implicit Intent questionnaire questions are as follows:

To what extent do you (on staff A) believe staff B's actions are consistent with the Commander's intent? (Not at all) 1 2 3 4 5 6 7 (Completely)

To what extent do you believe the staff A's actions are consistent with staff B's actions?

This survey was given to the experiment players within the EBAO organization. A simple scale from 1 to 7 captures their opinion. The two questions were asked seven times, once for each sub-team. This set of questions was presented to the experimental audience six times over a three-week period given that Implicit Intent was likely to change over the course of the event. The questionnaire was given to both the CTFHQ as well as the NRF. The first question provided a type of baseline for Implicit Intent. That is, there may be action consistency amongst the staff, but their actions might be contrary to the Commander's Intent.

Results and Discussion

The Explicit and Implicit Intent results are presented and discussed in this section, and the results are compared to the roles and responsibilities and decision-making results. Before the results are presented it is important to introduce a vector method alternative for data reduction.

The vector method treats each response as an element in a vector and then compares the resultant measured vector to a reference vector (Farrell, 2005a). Consider the two dimensional example in Figure 4. Each subject selects a response for Question A along his or her orthogonal dimension. The responses are added using vector algebra to produce a vector that has a magnitude and a direction with respect to a reference vector. In this case, the reference vector is chosen to represent the highest value that all subjects could give for the question.

A Euclidean product (or the projection of the measured vector onto the reference vector) is one way of representing the degree of similarity between two vectors. The percentage values given in this paper are Euclidean product calculations that represent the degree of similarity between measured and reference vectors. This two-dimensional example is extended to multiple subjects as well as multiple questions. The key advantage for this method is that a single vector may represent data from multiple players answering multiple questions since each answer is treated as its own dimension. For more details on the method see Farrell (2005a).

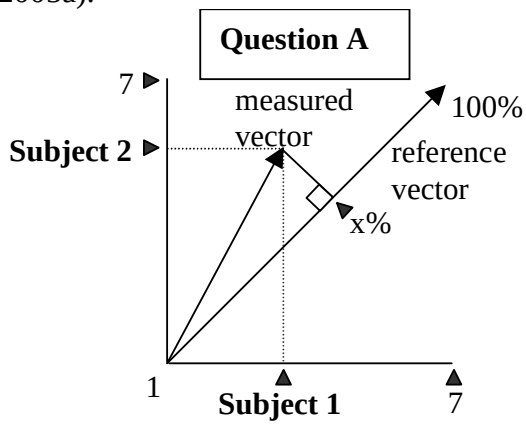

Figure 6. Each subject's response is an element in the measured vector.

The measured vector for Explicit Intent was formed from the CTF observers' answers to all the questions on a particular day, and then another measured vector for the NRF observers' answers. These two measured EI vectors were compared to the reference vector (where, ideally, all observers would mark a "7" for all the questions, indicating 100% Explicit Intent). Table 1 provides the EI results with respect to complete understanding of the Commander's guidance and orders.

Table 1. EI results (% of complete understanding)

Date	**28 Feb**	**2 Mar**	**7 Mar**	**9 Mar**	**14 Mar**	**16 Mar**
NRF	62	68	67	70	74	74
CTF	53	54	59	59	61	62

Note that the NRF results are higher than CTF. The NRF staff was collocated even though they were using distributed collaboration tools. Also, the NRF staff had worked together as a staff just before the MNE 4 event, while the CTF was pulled together just for the event. Thus, the NRF would likely know each other's competencies, authorities, and responsibilities while the CTF might not.

EI results steadily increase over time, for the most part. It will take time for an organization to reach and maintain high levels of EI. Interestingly, on 9 March there were new orders given to the staffs, however, EI seemed to steadily increase. This increase might be because the Commander's new guidance was not much different than his previous orders, or that EI is more sensitive to understanding CAR in relation to the orders than the orders themselves. If the previous sentence is true, then the result shows a steady increase in understanding each other's CAR.

EI results extend from 53% to 74%, but it is not clear what would be considered low, medium, or high EI. There are preliminary indications that an EI value of around 70% would be sufficient to conduct EBAO. However, resolving this issue would require a calibration of the survey instrument.

Recall that the EI hypothesis suggests that high EI means that there are clear roles and responsibilities. Unfortunately, a specific roles and responsibilities (R&R) question was not developed to evaluate this hypothesis, however, there were other R&R results that can be used to shed light on this hypothesis. Two R&R questions were:

R&R1 – rate the extent to which "my team was effective in assigning specific responsibilities to members (every person knew what to do)"

R&R2 – rate the extent to which "The CONOPS in combination with the job descriptions appropriately describes how to conduct the tasks for which I am responsible (KBD staff only)"

Using the vector technique, their percentages of the reference vector are given in Table 2.

Table 2. Comparing EI and Roles and Responsibilities Results

Date	**13 Mar**	**14 Mar**	**15 Mar**	**16 Mar**
Question	R&R1	EI	R&R2	EI
NRF	75	74	50	74
CTF	68	61	38	62

Just like the EI results, the NRF R&R results are higher than the CTF. However, the R&R survey was not given over a series of days so there was no time evolution available. Nevertheless, this limited result indicates that the NRF had somewhat clearer roles and responsibilities than the CTF staff and seems to be correlated with the EI results.

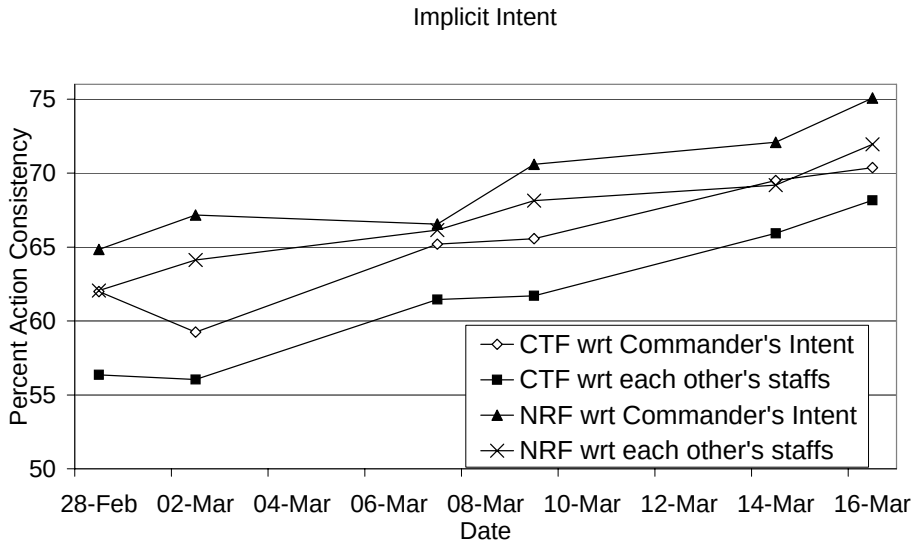

Figure 7. Action consistency results plotted over time.

The measured vector for Implicit Intent (II) was formed from both NRF and CTF players' answers to the II question with respect to Commander's Intent and II with respect to each other's staffs. These two questions were asked every Tuesday and Thursday over the three weeks of the experiment play. The four vectors per day provided an overall

measure of II, and it was compared to the reference vector (where, ideally, all players would mark a "7" for all the questions, indicating 100% action consistency). Figure 7 provides the II results.

The II results show that NRF is always higher than CTF, likely for the same reasons as stated above. In fact, EI and II results are highly correlated ($r > 0.90$). The II results with respect to Commander's Intent are higher than the II results with respect to each other's staffs since the Commander's Intent is publicly disseminated while the intentions of each of the staffs must be inferred. As before, the question about "how much II is enough II?" is still open to debate and requires a study to calibrate the survey results.

The II hypothesis indicates an improvement in outcomes and decisions. However, for MNE 4, the actual plan, execution of the plan, or the assessment of the plan was not the focus, but rather whether the process, organization, and technologies were robust enough to support EBAO. Thus, no specific questions were designed to assess EBAO outcomes, but some questions were asked to assess decision-making such as:

Q1. In general, how would you rate the quality of decision making by your team?
Q2. In general, in terms of outcome, how successful were the decisions made by your team?
Q3. Rate your mental demand (includes thinking, remembering, searching, deciding)?

One would expect that II would be directly related to the first two questions, and inversely related with the third question if II aids in optimizing decision-making.

Questions 1 and 2 were only given once. Nevertheless, the NRF answers are consistently higher than the CTF for both II and decision-making (although the decision-making differences are in the order of 1%). Decision-making quality seems to be invariant across NRF and CTF. However, Question 3 (about decision-making intensity) was administered daily, and so a correlation value could be calculated between II and mental demand. The correlation is in the direction as predicted by the model: that is, as II goes up, mental demand would go down (or decision-making became easier).

Table 2. Comparing II and Decision-making Q1 and Q2 Results

Date	**13 Mar**	**14 Mar**	**14 Mar**	**16 Mar**	**16 Mar**	**16 Mar**
	Q1	II wrt Cmd Intent	II wrt Each other	Q2	II wrt Cmd Intent	II wrt Each other
NRF	67	72	69	72	75	72
CTF	66	75	64	71	71	68

Table 3. Comparing II and Decision-making Q3 Results

Correlation between	II wrt Cmd Intent and Q3	II wrt each other and Q3
NRF (four data points)	-0.92	-0.97
CTF (six data points)	-0.42	-0.51

Conclusions

Using Perceptual Control Theory, a Team Information Processing model was developed, and a relationship between TIP and Common Intent was postulated. The model

suggested that Explicit Intent would stabilize team interaction by having clear roles and responsibilities, while Implicit Intent would optimize team interaction and this would be evident in the improvement of products and decisions.

The MNE 4 experimental results indicated that both EI and II increased over the 3-week exercise and that NRF CI was consistently higher than CTF. There is still the need to calibrate this CI survey. Also, there were indications that EI and Roles and Responsibilities were directly related to each other. Similarly, II and decision-making seem to be related as predicted by the model.

MNE 4 provided an excellent opportunity to measure CI in a complex environment, however to truly evaluate the proposed model, it is recommended that a limited objective experiment be designed that would a) calibrate the CI measurement, and b) determine the relationship (if any) between CI, roles and responsibilities, and outcomes. It is also recommended to use the CI instrument as frequently as possible in military exercises and large-scale experiments. Because of its simplicity, it is easy to administer and takes in the order of 15 seconds to complete. But as data are gathered on this measurement, the confidence in its ability to accurately monitor the organization's "health" increases.

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