16th ICCRTS

"Collective C2 in Multinational Civil-Military Operations"

Testing Edge versus Hierarchical C2 Organizations using the ELICIT platform and Common Identification Picture tool

Topic 6 –Experimentation, Metrics and Analysis

Authors
Col. Hernan Joglar-Espinosa (PhD)
Command and Control Program
Army of Chile
Calle Zenteno # 45, Santiago, Chile
Telephone: +56-2-693 2418
hernan.joglar@ejercito.cl

Italo Seccatore-Gómez
Military Polytechnic Academy
Army of Chile
Valenzuela Llanos 623, La Reina, Santiago, Chile
Telephone: +56-2-299 4409
albergo@vtr.net

Julio Lamas-Barrientos
Military Polytechnic Academy
Army of Chile
Valenzuela Llanos 623, La Reina, Santiago, Chile
Telephone: +56-2-299 4409
jlamas@decalink.cl

Testing Edge versus Hierarchical C2 Organizations using the ELICIT platform and Common Identification Picture tool

ABSTRACT

Abundant experimentation has been conducted to compare decision-making performance of Edge versus Hierarchical organizations within the C2 research community. The most commonly utilized testing tool has been the ELICIT platform, which enables provision and sharing of data that is relevant to solve a problem. In order to enrich the interaction space provided by ELICIT, we developed a complementary tool we term CIP (Common Identification Picture), which provides a setting for problem solution sharing (attack identification). We use the combination of ELICIT and CIP to examine interactions at both the information domain (ELICIT) and the cognitive domain (ELICIT and CIP). We then make comparisons between Edge and Hierarchical organizations performance.

Our findings suggest that while Edge organizations' problem-solving abilities outperform those of Hierarchical organizations if knowledge sharing is facilitated, the overall performance of both kinds of organizations is considerably improved when the complementary tool is implemented.

One possible explanation for our results is that Edge organizations do better than Hierarchies because the enrichment of the interaction space is better exploited by the kind of organization featuring a more complete pattern of interactions and freedom to collaborate, as opposed to the more restricted one.

Regarding the use of CIP, we argue that enhanced communication channels facilitate collaboration; increase quality of interactions; enhance distribution of information and, therefore, improve awareness and understanding (Alberts and Hayes, 2006).

INTRODUCTION

The advent of new information technologies has enabled transformational changes on the way war is conducted today. In fact, US DoD's transformation is about continuous adaptation to the Information Age (Alberts and Hayes, 2003) in order to capitalize on the new resources at hand. Novel approaches point out that by leveraging the power of enhanced information availability, modern militaries are able to hasten their decision cycles to the point that it becomes extremely difficult for adversaries to react in a timely manner. In practice, however, this capability has persisted elusive as it involves a twofold challenge. On the one hand, it requires being able to deal with the coevolution of mission capability packages comprising concepts of operation, approaches to command and control, organizational forms, doctrine, corresponding C4ISR, weapons, and logistic systems (Alberts *et al*, 2001). While on the other, it demands an advanced understanding of information superiority and network centric warfare concepts, which often remain as abstract notions and are found difficult to apply to military operations and organizations.

It seems that superior unit performance is a key element to persuade leaders to become more aggressive in adopting these new Information Age military concepts. Therefore, research efforts on the usage of IT tools under different organizational configurations and their effects on team problem-solving capabilities has become a topic of high significance for the military. To deal with this need, a scientific community led by the Command and Control Research Program (CCRP) of the US DoD is exploring performance differences, within a networked environment, between a flat organizational structure where every member has the ability to access all the available information, herein termed *Edge Organization*, versus a traditional *Hierarchical* organization, where information flows are constrained by the procedural restrictions of the chain of command (Alberts and Hayes, 2003). As part of this effort, CCRP has sponsored the development of ELICIT[1], a software application designed for conducting human-in-the-loop experiments focused on information and social domain phenomena (Martin and Mc Ever, 2008).

[1] ELICIT stands for "Experimental Laboratory for Investigating Collaboration, Information-sharing and Trust".

Within this scope, this paper aims to present experimental research conducted by the Military Polytechnic Academy of the Chilean Army, which used the ELICIT platform to contrast the performance of Edge vis a vis Hierarchical organizations in both the information and the cognitive domain. For the latter, we combine ELICIT, ―whereby participants can share information about potential threats― with a complementary tool we call *Common Identification Picture* (CIP), which enables participants to share their knowledge of the situation by posting their threat identifications.

WHY EDGE VERSUS HIERARCHICAL ORGANIZATIONS?

The NATO NEC Maturity Model (NATO, 2010) has associated the ability to adopt diverse C2 approaches –conflicted, de-conflicted, coordinated, collaborative and edge– with five different levels of C2 maturity –levels 1 thru 5. Superior maturity levels correspond to the ability of an entity to adopt a broader variety of C2 approaches and to select the appropriate one depending on the ongoing situation. These approaches differ from one another in one or more of three interconnected dimensions that make up the C2 approach space, namely: allocation of decision rights; patterns of interaction; and distribution of information (Alberts and Hayes, 2006). The extremes of the C2 approach space are associated with differences in centralization of command and control practices. Thus, the most centralized mode (C2 Maturity Level 1) can only apply the Conflicted C2 approach; whereas the less centralized one (C2 Maturity Level 5) is able to apply either De-Conflicted, Coordinated, Collaborative or Edge C2 approach (NATO SAS-065, 2010). Since this model associates the highest maturity level (level 5) with Edge organizations and the lowest maturity with Hierarchies, it is expected that, within a networked environment, Edge organizations perform better than the traditional –and more centralized– Hierarchical organization in problem solving.

ELCIT: THE C2 EXPERIMENTATION ENVIRONMENT

ELICIT is an open platform designed and developed by EBR Inc. and Parity Communications Inc., sponsored by the US DoD's CCRP (Command and Control Research Program).

The version of ELICIT used for this research is the one described in Ruddy, 2007. It is a software based environment designed to experiment and research differences between Edge and Hierarchical organizational configurations within the information and social domains.

It consists of a problem-solving simulation game, where players are organized in groups of 17 individuals acting as intelligence analysts. In the game setting, players interact and collaborate, within a networked environment to accomplish the goal of identifying a potential and fictitious terrorist attack. The purpose is to complete the threat recognition by identifying *Who*, *What*, *Where* and *When* the attack will occur. During the game and across time, ELICIT provides the players with simple –and seemingly independent– pieces of information (called "factoids") that contain clues of varying value for accomplishing the identification goal. Each factoid is a logical statement that is to be complemented with other pieces of information to build up situational awareness; however no participant is given sufficient information to solve his/her problem without receiving information from others (Manso & Nunes, 2008). Besides, individuals have to perform the intelligence analysis, select the relevant factoids and share them to improve the collective awareness of the situation.

The ELICIT environment provides the option to manipulate the available communication avenues in each experiment, which enables the researcher to select the alternative organizational form. When using the Hierarchical structure, the software randomly points out a cross-team coordinator and four teams, each with an appointed team leader and three more members. Each team is tasked to answer one of the solution questions (*Who, What*, *Where* and *When*). Under this configuration, individuals are provided with factoids related to all questions. The information they obtain that is not related to their specific question can be sent to players in other team; however they can only post/pull in the website associated to their team problem. By contrast, when adopting the Edge configuration ELICIT allows all 17 individuals to share information with each other with no restriction at all. The Edge configuration has no upper/lower organizational levels or participants with special privileges (Manso & Nunes, 2008). As in the previous organization type, Edge participants receive pieces of information that are necessary to answer any of the four solution questions.

The collaboration modes allowed by ELICIT are "Share", "Post" and "Pull". The Share feature works like an email that allows direct communication among players. On the other hand, Post and Pull features operate through websites that enable information loading and downloading. There is one website associated to each question: *Who*, *What*, *Where* and *When*. The particular functionalities of these features and its behavior under both of the organizational forms are described in Table N° 1.

Collaboration Mode	Description	Edge	Hierarchical
Share	Individuals can send a factoid to a specific player.	All players can share factoids with each other.	Players can deliver factoids to team mates. Team leaders can also share factoids with the cross-team coordinator.
Post	Individuals can publish factoids in a website visible to other members of their entity.	All players can post factoids to every website.	Players can only post factoids in the website associated to his/her team.
Pull	Individuals can download factoids from a website accessible to other members of the entity.	Every player can download the posted factoids.	Team members can only access factoids posted in the website associated to their particular team.

Source: adapted from Manso & Nunes, 2008.

Table N° 1. Description of ELICIT collaboration features.

BRINGING EXPERIMENTATION CLOSER TO NCW PRACTICES

As indicated before, the NCW research community needs to persuade military leaders about the contribution of less structured organizational practices for leveraging C2 technologies. Accordingly, the main purpose of experimenting on Edge organizations is to develop empirical evidence about the value of this organizational configuration compared to the traditional –and currently more utilized– hierarchy.

Within this context, our analysis of ELICIT functionalities indicated that this tool exhibits a limitation with respect to knowledge sharing, since it only allows sharing pieces of information (i.e. factoids); but not already analyzed and contextualized notions, which is an

essential part of knowledge conceptualization (see for instance Leonard & Sensiper, 1998; Liebowitz, 1999; Alavi & Leidner, 2001) .

We believe that, in order to complete the experimentation environment, it is necessary at least to include direct communication channels (discussion) and to emulate the availability of intelligence reports from other entities (elaborated judgment). Both are usual practices in real-world C2 environment. Combining ELICIT with direct communication has already been explored in earlier research (see for instance Leweling & Nissen, 2007 and Chong *et al*, 2008), therefore our efforts have been oriented to include a complementary feature that allows each participant to share the outcome of his/her evaluation of the circumstances, after sharing information with his/her peers and thoroughly analyzing the situation.

For selecting this feature, we have considered the dimensions through which C2 maturity level is measured, so that our suggested improvements facilitate the identification of potential differences between organizational configurations. We believe that by implementing this new functionality we are providing improvements associated with two out of the three dimensions of the C2 Approach Space (NATO SAS-065, 2010). The option of sharing "threat identifications" (IDs) and knowing what is the solution selected by other peer analysts at any moment, offers an opportunity to develop richer *Patters of Interaction* within the experimentation environment. Besides, providing access to already worked out intelligence benefits *Distribution of Information*, since it enhances the extent to which the information needed to accomplish required tasks is available.

CIP: COMMON IDENTIFICATION PICTURE TOOL

The Common Identification Picture Tool (CIP) is a software tool built to complement ELICIT functionalities. It aims to include in the experimentation setting the real-world practice of issuing intelligence reports and making them available to other units. It provides a knowledge sharing avenue to enhance the information sharing features already implemented in ELICIT.

CIP consists of an application that allows visualization of the threat perception of each participant that during the game considers has gathered sufficient information to make a

judgment on the situation. It supports sharing of complete or partial attack identifications (IDs), posted by ELICIT players during the execution of experiments. Thus, it enables participants to post their answers to each of the *W*s (*Who*, *What*, *Where* and *When*). The tool shows six (6) bar charts that consolidate the information regarding each of the four *W*s. It deploys three bar charts for *When* as it divides this identification into *Month*, *Day* and *Time*.

CIP supports both organizational forms included in ELICIT –Hierarchical and Edge– providing similar information access schemas. For the Hierarchical organization depicted in Figure N° 1, CIP provides the following information:

E5 : May access the information on all four (4) variables (six charts activated).
A1…A4 : May access the information on variable "*Who*" (one chart activated).
B1…B4 : May access the information on variable "*What*" (one chart activated).
C1…C4: : May access the information on variable "*Where*" (one chart activated).
D1…D4 : May access the information on variable "*When*", which is composed of three charts *Month*, *Day* and *Time AM/PM* (three charts activated).

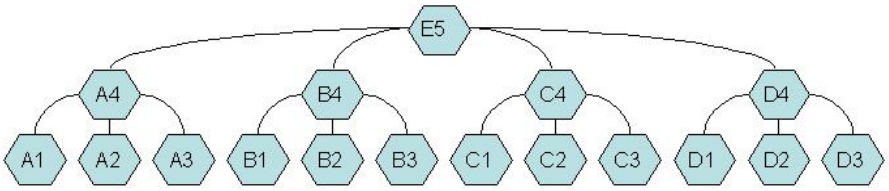

Figure N°1. Hierarchical organization configuration.

For the Edge organization depicted in Figure N° 2, CIP provides access to the information on all four (4) variables (six charts activated).

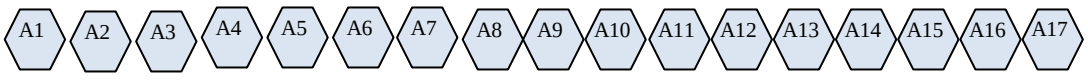

Figure N° 2. Edge organization configuration.

To determine the information access rights of each player, CIP requires participants to identify themselves through a username when they load the application at the beginning of the game. This required username matches the pseudonym assigned by ELICIT, which enables the CIP tool to identify each player's role in the game.

The general configuration of the user interface of CIP is the one shown in Figure N° 3. It is divided into three sections: Chart, Identification and History Section.

The "Chart Section" includes one chart for each identification to be made as explained above. Depending on the role of the user the charts may be activated (one grey bar) or deactivated (one red bar). The gray bar in activated charts indicates the accumulated number of pending IDs. Thus, the size of this bar diminishes as IDs are made.

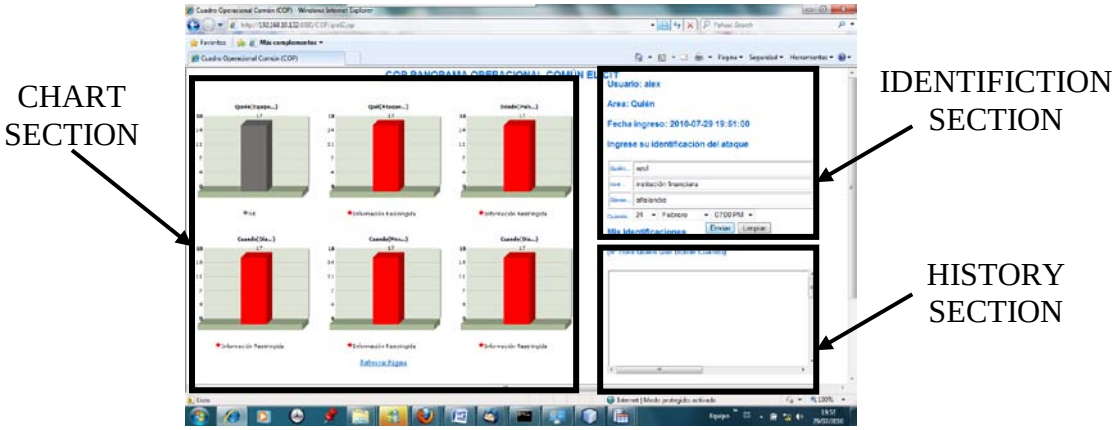

Figure N° 3. CIP initial screen with one chart activated.

As shown in Figure N° 4, once the experiment begins and IDs are registered, new bars appear in the activated charts; as many as different identifications are made. These additional bars represent the accumulated number of identical IDs already made. In this figure there is only one chart activated, meaning that this is the screen corresponding to the member of one of the four teams of a Hierarchical organization. On top of each of the bars that represent a different ID appears the number of participants that have coincided in the same identification. Similarly, on top of the gray bar appears the number of identifications pending. When charts are blocked, the number on top of the red bar is always 17.

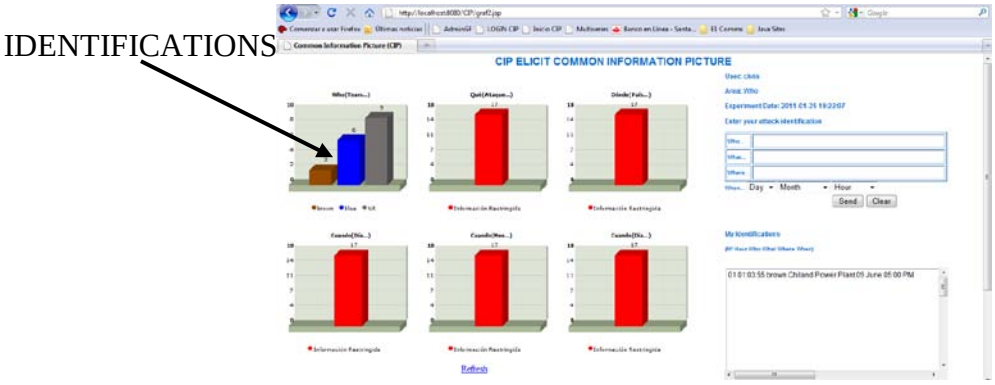

Figure N° 4. CIP initial screen with one chart activated.

Figure N° 5 represents a situation similar to that depicted in Figure N° 4; but the screen in this case corresponds to an Edge player or to the cross-team coordinator of a Hierarchical organization.

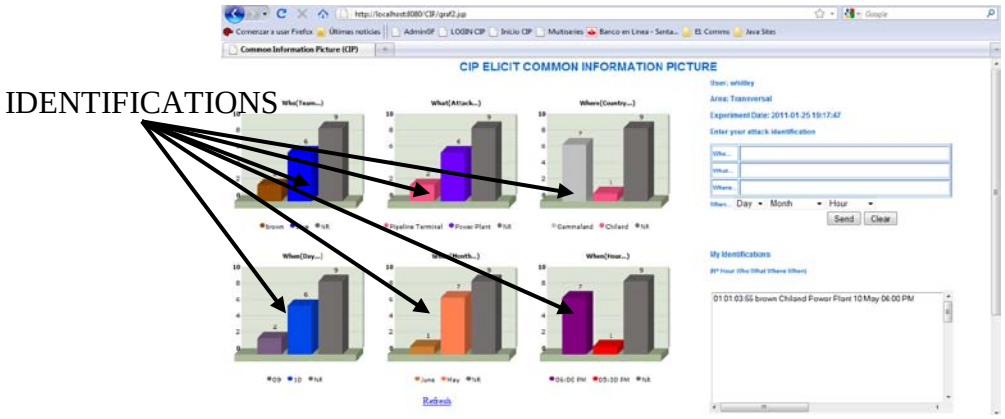

Figure N° 5. CIP initial screen with all six charts activated.

The identification section provides fields for typing in the IDs corresponding to *Who*, *What* and *Where* and drop down menus for *Month*, *Day* and *Time* to register *When* IDs. It also includes a "send" and a "clear" button. Here, participants may post complete or partial identifications, that is, it is not necessary to provide answers for all of the questions.

Since participants can change their identifications whenever they want, the history section keeps those identifications that have been once registered, but the author changed his/her evaluation afterwards. This record is cleared when a new experiment is started.

Each time an identification is registered, the charts are updated to reflect the new entry.

HYPOTHESIS

Since the CIP tool enhances the functionalities associated to the execution of advanced *Patterns of Interaction* and improved *Distribution of Information* among entities (NATO SAS-065, 2010), we believe that our experiment results will evidence better unit problem-solving performance for entities utilizing this tool, while the organizational configuration is kept constant. We also expect that Edge organizations outperform Hierarchical ones both using and without using the CIP tool since, as indicated in the associated theory (Alberts & Hayes, 2003; 2006), this outcome is a generally expected consequence of working in a networked environment such as the one provided by ELICIT. Further, by combining these two conceptions, we also conjecture that the difference in the problem-solving performance of a Hierarchical organization using CIP and an Edge organization without using such instrument will be rather meager.

Given the arguments above, we set the following hypotheses:

Hypothesis A: The problem-solving performance of the *Edge organization using CIP* will be superior to that of the *Edge organization without using CIP*.

Hypothesis B: The problem-solving performance of the *Hierarchical organization using CIP* will be superior to that of the *Hierarchical organization without using CIP*.

Hypothesis C: The problem-solving performance of the *Edge organization without using CIP* will be superior to that of the *Hierarchical organization without using CIP*.

Hypothesis D: The problem-solving performance of the *Edge organization using CIP* will be superior to that of the *Hierarchical organization using CIP*.

Hypothesis E: The problem-solving performance of the *Edge organization without using CIP* will be similar to that of the *Hierarchical organization using CIP*.

Even though we will call our propositions "hypothesis", we warn the reader that our experiments and their results will not be sufficient to validate or reject strict hypothesis, given the reduced sample size (17 participants in each of 4 groups), which is insufficient for proper and complete statistical analysis.

EXPERIMENTATION METHODOLOGY

Experiment Design

Our set of experiments comprised four ELICIT runs, each with a different group of participants.

Every group used the ELICIT platform, two of them adopted an Edge configuration and the other two a Hierarchical structure. Besides, one of the Edge and one of the Hierarchical groups used the CIP (Common Identification Picture) tool to complement the ELICIT platform. Therefore the groups participating in each of the experiments were the following (see Figure N°6):

- Group N°1: Edge NO CIP
- Group N°2: Edge USING CIP
- Group N°3: Hierarchical NO CIP
- Group N°4: Hierarchical USING CIP

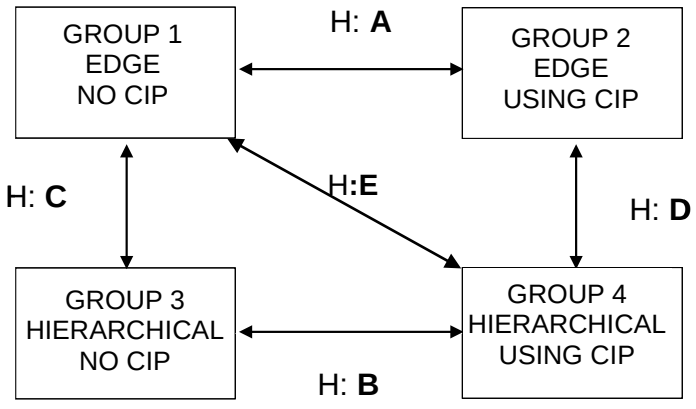

Figure N°6. Groups and hypotheses.

The combination and comparison of data between these groups gave rise to our experiments and their associated hypotheses:

- Experiment A: Comparison between two Edge groups, one of them used CIP tool.
- Experiment B: Comparison between two Hierarchical groups, one of them used CIP tool.
- Experiment C: Comparison between two groups, Edge and Hierarchical respectively. None of them used CIP tool.
- Experiment D: Comparison between two groups, Edge and Hierarchical respectively. Both of them used CIP tool.
- Experiment E: Comparison between two groups, one Hierarchical using CIP tool and one Edge without using such instrument.

Participants

The experiments involved 68 Army officers from the Military Polytechnic Academy of the Chilean Army. They were mostly Lieutenants and Captains with an average of 8 years of professional experience. To run the experiments, they were organized into the four groups identified above. Each group was internally as homogeneous as possible and externally equivalent to the other groups in the averaging background knowledge and experience of the assigned participants as well as in gender, age and military ranks.

Prior to the experiment every group attended a standardized instructional session where they watched the ELICIT video (translated to Spanish) and were given a presentation on the experiment purpose, ELICIT software features and, when necessary, CIP functionalities and operation. After the theoretical preparation, all groups went through a practical training run. The information used for training purposes was different from that used in the actual experiments.

Controls

In order to ensure that each run was played with totally unknown information, four new factoid sets were prepared and used in our experimental sessions. All factoid changes were not structural but only superficial (e.g. *Alphaland* became *Thetaland*). Besides, to keep steady conditions either instructions and training or software configurations; as well as

physical laboratory environments remained unchanged across experiment runs. Further, participants were instructed not to communicate with each other except via the ELICIT or CIP applications.

Variables

The independent variable was either "Organizational Configuration" (Edge or Hierarchy) or "Usage of CIP Tool". The former follows the original ELICIT experimentation design, whereas the latter is conceptualized as an enhancement of the experimentation environment with a knowledge sharing channel that facilitate improving both the patterns of interactions and the distribution of information among entities. Since both of the independent variables are binary, a total of four groups –as described above– covered the desired experimental conditions.

In every case the dependent variable was "Performance" (P), which should be understood as the ability of an organization of making decisions based on correct shared awareness of a circumstantial situation gained in a minimum time.

Specifically, the variable P was defined as being directly proportional to "Accuracy" (A), and inversely proportional to Time (T). In other words, P increases as A increases and decreases as T increases.

$$P = K^* (A/T)$$

Where K = 100,000, a constant included just for convenience in calculations and readability of figures.

The Performance (P) of each group was obtained by calculating the average of the performance of all the members of the group.

The variable "Accuracy" (A) measured the ability of organizations to gain correct shared awareness of the situation under analysis. To obtain the value of this variable, a particular score was assigned to each correct answer of every team member. Correct answers to questions *Who*, *What* and *Where* were assigned 0.25 points each, whereas question *When* was divided into three portions: month, day and time, weighing 0.083 each. No score (or

zero) was assigned to wrong or missing answers. The result for each participant was computed as the addition of his/her scores. Therefore, the highest individual score was 1.0 if all answers were right. Finally, the Accuracy of a group was calculated as the average of the sores of all its members.

The variable "Time" (T) measured the total time taken by participants to submit a threat identification through the ELICIT platform. Accordingly, the figures used in our calculations were obtained from the log files of the ELICIT software.

Data Analysis

Data analyses were performed using the statistical package SPSS 13.0 (www.spss.com). A detailed description of the computations and its results are included in Appendix 1.

Once the figures were extracted from the log files, the individual Performance (P) was computed. For each hypothesis we followed two steps:

First, we obtained a comparative boxplot in order to examine and contrast the main parameters of the data distributions.

Second, we run an ANOVA hypothesis test using 95% of confidence ($\alpha = 0.05$). For this purpose, we first checked for compliance of the conditions that validate the appropriateness of applying an ANOVA test (Petrie & Watson, 2006):

- We checked for normality through the Kolmogorov-Smirnov and the Shapiro-Wilk tests.
- We also verified homogeneity of variances through the Levene test.

After compliance was confirmed, we performed a mean comparison through ANOVA and –whenever possible– rejected the corresponding null hypothesis within a confidence interval of 95%.

If the results of the tests mentioned above were not satisfactory, and therefore ANOVA was not applicable, we applied the non parametric Kruskal-Wallis Test for mean comparison, as recommended in Camacho, 2006.

These procedures gave us sufficient information to compare the "Performance" of the groups involved in every hypothesis, which enabled us to validate or reject such propositions.

In order to check if complementary information could be captured from the communication behavior among entities during the experiments, we also examined and practiced ANOVA tests using the figures of "Share", "Post" and "Pull" variables provided by the ELICIT log files.

RESULTS

As described in Appendix 1, our normality checks for the dependent variable "Performance", executed prior to all hypotheses testing, yielded satisfactory results. Similar outcomes were obtained for homogeneity of variances check in every Levene test we practiced. Normal distribution of and similarity of variances between the dependent variables support the suitability of applying ANOVA to determine if the manipulations of the independent variables resulted in statistically significant differences among the sample populations. The only exception to this assertion was found in the testing of Hypothesis E, where ANOVA was not suitable and therefore a Kruskal-Wallis Test was applied.

CIP usage

When manipulating CIP usage combined with Edge organizational form, we obtained figures indicating that the CIP usage have a significant positive effect (p = 0.044; see Appendix 1). To explain this result, we observe that the differences between the means of Performance component factors varied considerably. While the means of Time were not very different (1323 for EDGE NO CIP and 1622 for EDGE USING CIP), the means of Accuracy were notably dissimilar (47% for EDGE NO CIP and 86% for EDGE USING CIP), which finally accounts for a superior mean of Performance variable of the group using CIP (38.42 for EDGE NO CIP versus 54.69 for EDGE USING CIP). Therefore we attribute the improved performance observed when using CIP mainly to a better shared situational awareness. This result validates our Hypothesis A, therefore **"The problem-**

solving performance of the *Edge organization using CIP* was superior to that of the *Edge organization without using CIP"*.

Similarly, when varying CIP usage while keeping Hierarchical configuration unchanged, we also found a significant positive effect of CIP usage ($p = 0.003$; see Appendix 1). Here, again, the means of the Time variable were rather alike (1734 for HIERARCHY NO CIP and 1950 for HIERARCHY USING CIP); yet the means of Accuracy were quite different (38.73% for HIERARCHY NO CIP and 75.49% for HIERARCHY USING CIP). Therefore, Accuracy is the factor that explains the higher Performance mean obtained by the organization using CIP (22.35 for HIERARCHY NO CIP versus 39.55 for HIERARCHY USING CIP). Accordingly, in this additional case we once more attribute this enhanced performance mainly to a better shared situational awareness achieved through CIP usage. This result validates our Hypothesis B, therefore **"The problem-solving performance of the *Hierarchical organization using CIP* was superior to that of the *Hierarchical organization without using CIP"***.

It is important to note that in both cases analyzed above the mean of the Time variable in the groups that did not use CIP was a little lower than the mean of the group using CIP, in other words, CIP usage slightly slows down the decision making process, however it still yields a positive net effect in Performance because of the much better Accuracy it brings about.

Organizational configuration

When we contrasted the Performance of Edge versus Hierarchical organizational form using just the ELICIT platform, our results indicated that there is no significant difference in the performance of both kinds of organization ($p = 0.051$, see Appendix 1). In order to explain this result we examined the means of the factors of Performance variable. Within this context, it becomes evident that the Edge outperforms the Hierarchical organization; however, the differences are reduced. While the Time means indicate that the Edge organization was in average 23.7% faster than the Hierarchy (1323 for EDGE NO CIP and 1734 for HIERARCHY NO CIP), the Accuracy means render a much tighter difference of 11.73% in favor of the Edge configuration (47% for EDGE NO CIP and 38.73% for

HIERARCHY NO CIP). Thus, our results provide some hints that allow us to conjecture about a superior performance of the Edge organization; however our outcomes are not conclusive. These arguments induce us to reject our Hypothesis C; therefore **"The problem-solving performance of the *Edge organization without using CIP* was not superior to that of the *Hierarchical organization without using CIP"***.

By contrast, when evaluating the Performance of both kinds of organizational configurations while consistently using the CIP tool, the results clearly indicated that the Edge organization performs better than the Hierarchy (p = 0.006; see Appendix 1). These results are confirmed by the analysis of the means of Performance factors. The comparison of the Time means indicates that the Edge organization is 16.8 % faster than the Hierarchy (1622 for EDGE USING CIP versus 1950 for HIERARCHY USING CIP), whereas the means of Accuracy indicate that the –correct– perception of the situation in the Edge organization is also higher than in the Hierarchy (86% for EDGE USING CIP and 75.49% for HIERARCHY USING CIP). It is relevant to notice that in this case the results of both factors are better for the Edge organization. In other words, the Edge organization is both faster and more accurate than the Hierarchy. Thus, the superior results for Performance variable exhibited by the Edge organization is a consequence of the results of both of its factors. These results validate our Hypothesis D; therefore, **"The problem-solving performance of the *Edge organization using CIP* was superior to that of the *Hierarchical organization using CIP"***.

CIP usage and organizational configuration

We further evaluated our data to compare Performance if both CIP usage and organizational configuration were varied. In this context, when comparing the figures of the Edge organization without using CIP with the Hierarchical organization using the tool, we found similar performance. In fact, our statistical comparison between the performance of these two groups yielded no statistically significant difference (p = 0.513, see Appendix 1). We attribute this similarity to the fact that one of the factors of the variable Performance favors the results of the first group, while the other favors the outcomes of the second one. Specifically, Time means indicate that the Edge organization was in average 32% faster than the Hierarchy (1323 for EDGE NO CIP and 1950 for HIERARCHY USING CIP). By

contrast, the Accuracy means indicate that the Hierarchy is 28.49% more accurate than the Edge organization (47% for EDGE NO CIP and 75.49% for HIERARCHY USING CIP). These opposite results make the Performance means of both groups look very alike, even though the populations are completely different. From these result observations we can validate our Hypothesis E; therefore we state that **"The problem-solving performance of the *Edge organization without using CIP* was similar to that of the *Hierarchical organization using CIP".***

Finally, our analyses of the data provided by the ELICIT log files regarding Share, Post and Pull variables did not evidence statistically significant differences between the communication behaviors of any of the groups tested in these experiments.

RESULT DISCUSION

As expected, the results of our experiments clearly indicate that the introduction of the CIP tool, to complement the functionalities provided by ELICIT, improved the performance of all types of organizations operating in a networked environment. This outcome is explained by the fact that the CIP tool provided an inexistent avenue that allowed sharing already analyzed and contextualized knowledge. This functionality accompanied by the previously available information sharing channels provides a more complete –and also realistic– setting for decision-making ability testing. This conjoint set of tools resembles the interaction channels accessible for tactical command posts, where messaging and sensors provide intelligence clues and also some official reports from higher command and from parallel and lower level units.

Besides, from a theoretical standpoint, we contend that the CIP tool helps organizations to enhance their abilities in two of the dimensions in which C2 maturity level is weighed (NATO SAS-065, 2010), namely *Patterns of Interactions* and *Distribution of Information*. By sharing decisions already worked out, organizations interact at the cognitive level –as opposed to the less elaborated and more constrained information level– which yields opportunities for rising interactions to a more refined and less intellectually restricted level that, in turn, allows for more unconstrained interaction patterns. We believe these arguments neatly reflect the spirit of the definition provided in NATO for the former

dimension: *"Patterns of interaction among participant entities are a function of their respective abilities and willingness to interact as well as the opportunities they have as a result of the actual occurrence of interactions and collaboration"* (NATO SAS-065, 2010 p. 48).

Additionally, when the distributed product is both information and knowledge derived from that information, the receiver obtains an extra value-added set of notions that implies access to a broader and more integrated body of ideas that facilitate decision making. Here, again, we argue that this explanation captures the essence of the definition provided by NATO for the latter dimension: *"Distribution of information across participating entities refers to the extent to which the information needed to accomplish required tasks is available to each participant"* (NATO SAS-065, 2010 p. 49).

Expected as well was the fact that, regardless of the organizational configuration, it took a little more time to make decisions when using the CIP tool. This result is a consequence of having a more complete set of interaction channels. Yet, it was less expected that this slower decision process would considerably increment the accuracy of such judgments. We had anticipated a better accuracy; however the magnitude of the improvement was rather unforeseen. We attribute this significant improvement to the fact that providing information apprises the receiver, who still needs to perform analysis to understand the context and if time is constrained, decisions turn out less precise. Sharing knowledge, on the other hand, offers access to notions that already have the potential to influence action (Alavi & Leidner, 2001), therefore the receiver efforts can concentrate on detailed analysis that add precision to his/her decisions.

More surprising was the result indicating that when comparing the performance of both organizational forms, there was scarce discrepancy when CIP was not used; but considerable difference when this tool was utilized. We attribute the difference in the "Time" variable to the fact that the Edge organization enable concurrent and dynamic information processing whereas Hierarchies follow sequential processing through the chain of command, which slows down decision-making (Alberts and Hayes, 2003). From a more general perspective, we contend that this outcome indicates that incremented interaction channels as well as increased cognitive level teamwork, benefits the less constrained

organization in a higher degree. Specifically, we argue that the enrichment of the interaction space was better exploited by the kind of organization featuring a more complete pattern of interactions and freedom to collaborate as opposed to the more restricted one. Put in other words, we contend that the organization type that is better able to exploit the new functionality reaped more benefits out of the improvements provided by the CIP tool.

As a final point, we contend that as a consequence of improving the interaction channels and raising the cognitive level of collaboration efforts, the hierarchical organization can mitigate its structural communicational limitations, making its problem solving performance equivalent to that of an Edge organization in which such improvements have not been made.

CONCLUSIONS

In this paper we have proposed a complementary tool that enriches the experimentation environment provided by the ELICIT platform, which we term Common Identification Picture (CIP) tool. After presenting this application, we explained the theoretical foundations backing its development and the way it complements the ELICIT platform. Subsequently, we formulated five hypotheses aimed at verifying the effects and usefulness of the CIP tool. We then tested our theorized suggestions through a set of five carefully designed experiments that were implemented at the Polytechnic Academy of the Chilean Army.

The CIP tool allows the players to share their understanding of the situation after analyzing the pieces of information provided by ELICIT. It resembles the widespread practice of writing and sharing intelligence reports among units in the field, which enable the recipients to assemble their own situational picture. In summary, this application facilitates knowledge sharing among operational entities.

Our results indicate that, when units make efforts to communicate their understanding of the situation to their peers, it becomes easier for the collective to form “correct” shared awareness. Such practice might take a little longer than a process in which sharing

knowledge is excluded; nevertheless the added accuracy considerably pays off the additional time consumed. These outcomes suggest that, in order to leverage the new functionalities provided by a networked setting, the practice of performing information analysis, and diffusing/sharing intelligence at all levels should be stressed and deeply embedded in doctrinal practices.

Our comparison of different organizational structures reveals that the less structured entities (i.e. Edge) are better able to take advantage of knowledge sharing functionalities than the more restricted ones (i.e. Hierarchies), since the former enjoys more complete pattern of interactions and enhanced freedom to collaborate. Interestingly, the noticeable difference among both kinds of organizations emerges only when knowledge sharing is implemented. These results led us to make two conclusions.

First, our empirical work supports the theoretical work regarding NNC2MM (NATO SAS-065, 2010) and "*Power to the Edge*" (Alberts & Hayes, 2003), since it provides evidence indicating that in a NCW environment the Edge organization can exhibit superior performance than Hierarchies. Therefore, it is correct to recommend Edge configuration usage whenever the situation permits lowering the level of decision right allocation. And second, in order to materialize Edge superior performance, all the potential of NCW environment must be implemented and exploited. This includes, but is not restricted to, rich communication channels; information diffusion and, indeed, knowledge sharing.

Since sometimes it is not possible to adopt an Edge configuration, it is relevant to note that the architectural communication restrictions of Hierarchies can be reduced by providing technology and implementing procedures that enable and encourage intelligence sharing. Such enhanced interaction capability may allow Hierarchies to improve their ability to achieve shared awareness and to perform at levels very similar to those of Edge organizations that only share information.

Based on our findings, we recommend enhancing the functionalities of the ELICIT platform so that it facilitates more complete interactions and fosters knowledge sharing among entities. Such enhancements should enable measurements of variables associated to "*Agility*" attributes (Alberts & Hayes, 2003, p. 128), which are not collected by the current version.

Although our results clearly back our conclusions above, we would like to warn the reader that these outcomes are far from being conclusive, as the reliability and validity of the outcomes can not be accredited through the reduced number of observations that we were able to capture. However, these results combined with those of a number of earlier experiments carried out within the ELICIT scientific community may validate part of our findings, namely those that surface the differences between Edge and Hierarchical organizations.

Future work should be oriented to verify the robustness of these results by implementing similar experiments that complete the sample size. For this purpose, the Military Polytechnic Academy of the Chilean Army is open to share the CIP tool with members of the ELICIT community.

REFERENCES

1. Alberts, D.S. & Hayes, R.E. (2003). *Power to the Edge*. Washington, D.C.: DoD, CCRP Publication Series.
2. Alberts, D.S.; Garstka, J.J.; Hayes, R.E. and Signori, D.A. (2001). *Understanding Information Age Warfare*. Washington, D.C.: DoD, CCRP Publication Series.
3. Alberts, D.S. & Hayes, R.E. (2006). *Understanding Command and Control*. Washington, D.C.: CCRP Publication Series.
4. Alavi, M & Leidner, D. (2001). "Knowledge management and knowledge management systems: conceptual foundations and research issues". *MIS Quarterly*, Vol. 25, N° 1, pp. 107-136.
5. Camacho, J (2005). *Estadística con SPSS*. Madrid, Spain: Alfaomega Ra-Ma.
6. Chong, N.E.; Thunholm, P.; Cheah, M.; Yong, T.K.; Chau, N. & Lian, C.C. (2008). "Exploring alternative edge versus hierarchy C2 organizations using the ELICIT platform with configurable chat system". *Proceedings of the 13th International Command and Control Research and Technology Symposium*. Bellevue, WA.
7. Leonard D. & Sensiper S. (1998). "The role of tacit knowledge in group innovation". *California Management Review*. Vol. 40, N°3, pp. 112-132.
8. Leweling, T.A. and Nissen M. E. (2007). "Hypothesis testing of edge organizations: Laboratory Experimentation using the ELICIT multiplayer intelligence game". In *Proceedings of the 12th International Command and Control Research and Technology Symposium*. Newport, R.I.
9. Liebowitz, J. (1999). *Knowledge Management Handbook*. Boca Raton, FLA: CRC.
10. Manso, M. & Nunes, P (2008). "ELICIT and the future C2: Theoretical foundations for the analysis of ELICIT experiments". In *Proceedings of the 13th International Command and Control Research and Technology Symposium*. Newport, R.I.
11. Martin, D.M & McEver III, J.C (2008). Metrics, analysis and methods for the exploitation of ELICIT experimental data topic: Network centric experimentation and analysis. *Proceedings of the 13th International Command and Control Research and Technology Symposium*. Bellevue, WA.
12. NATO SAS-065 (2010). NATO NEC C2 Maturity Model. Washington, D.C.: DoD, CCRP Publication Series.
13. Petrie, A & Watson, P.F. (2006). *Statistics for Veterinary and Animal Science*. Hoboken, NJ: Blackwell Publishing.
14. Ruddy, M. (2007). "ELICIT – The Experimental laboratory of investigating collaboration, information-sharing and trust". In *Proceedings of the 12th International Command and Control Research and Technology Symposium*. Newport, R.I.

APPENDIX 1

EXPERIMENT RESULTS

A. TESTING OF HYPOTHESIS "A" (H-A)

1. COMPARING: EDGE NO CIP – EDGE USING CIP

Dependent Variable : P = Group Performance
Independent Variable: CIP tool usage (Common Identification Picture tool usage)
Organization Type: EDGE
Group 1: EDGE NO CIP
Group 2: EDGE USING CIP

a. Performance variable distribution.

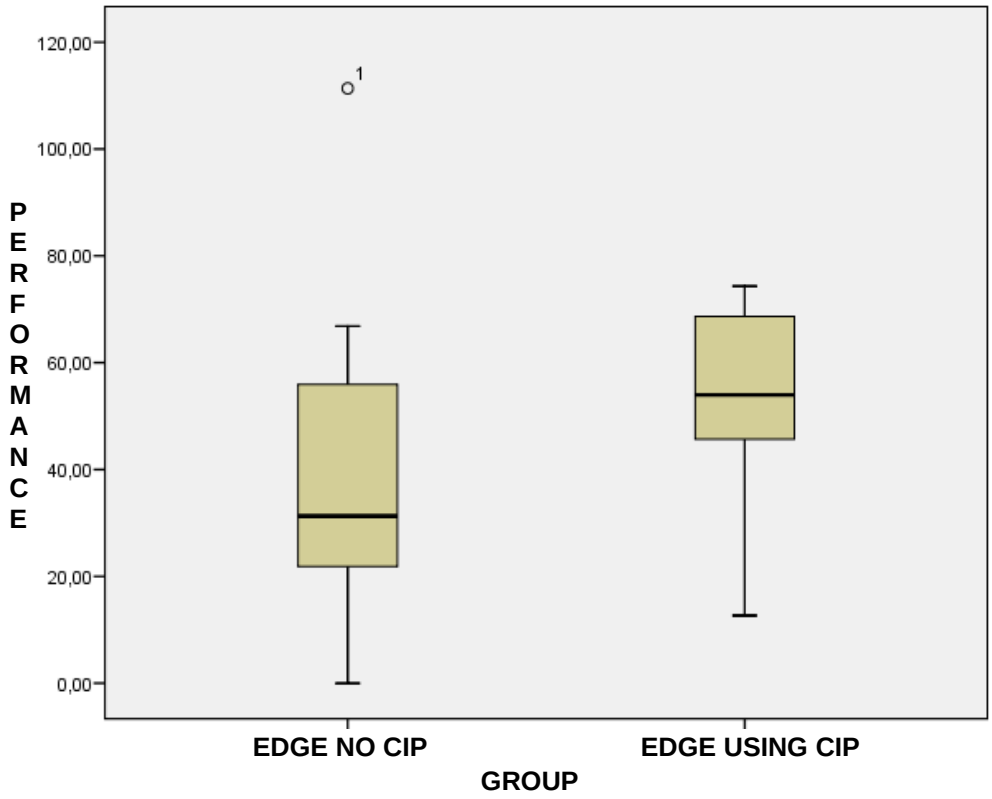

Figure N° 7. Boxplot of Performance variable, H-A.

The boxplot above shows a graphical representation of the distribution data. It is evident that the "Edge Using CIP" group (Group 2) clearly outperformed the "Edge No CIP" group (Group 1).

From the boxplot, it can also be observed that the overall data distribution of Group 2 spans through higher values than the distribution data of Group 1.

The most relevant parameters of the distribution data are the following:

Performance

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Edge NO CIP	17	38,4188	27,28475	6,61752	24,3903	52,4473	,00	111,36
Edge USING CIP	17	54,6935	16,66355	4,04150	46,1259	63,2611	12,68	74,35
Total	34	46,5562	23,74452	4,07215	38,2713	54,8410	,00	111,36

Table N° 2. Relevant parameters of Performance distribution, H-A

b. Compliance of conditions for ANOVA hypothesis test, Performance variable, H-A.

We practiced the Kolmogorov-Smirnov and the Shapiro-Wilk tests for normality check. We also verified homogeneity of variances through the Levene test. For all tests we used 95% of confidence ($\alpha = 0.05$). Our results turned out satisfactory as indicated in the following tables.

Tests of Normality

GROUP	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Perf. N° 1	,132	17	,200*	,927	17	,191
N° 2	,131	17	,200*	,919	17	,141

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table N° 3. Test of normality results, H-A.

Since for both groups Sig. (Significance or *P* value) is greater than $\alpha = 0.05$ in both tests, then the normality of the distribution is confirmed.

Test of Homogeneity of Variances

PERF

Levene Statistic	df1	df2	Sig.
3,084	1	32	,089

Table N° 4. Test of homogeneity of variance results, H-A

The value of the parameter Sig = 0.089 is greater than $\alpha = 0.05$. This verifies the homogeneity of variance of the distribution.

c. ANOVA results for mean comparison of Performance variable, H-A.

In this section we check whether the mean values of Performance variable of both groups differ significantly as a consequence of using the CIP tool.

Null Hypothesis "Ho": The means of the distribution of Performance variable in both groups are equal (similar).

ANOVA results:

ANOVA

PERF

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2251,361	1	2251,361	4,405	,044
Within Groups	16354,106	32	511,066		
Total	18605,467	33			

Table N° 5. ANOVA results for Performance variable, H-A

Since Sig = 0.044 is lower than $\alpha = 0.05$, the Null Hypothesis "Ho" must be rejected, which means that there exists a difference between the means of both distributions at this significance level.

We state that the performance of Group 2 EDGE USING CIP is significantly superior to the performance of Group 1 EDGE NO CIP, within a confidence interval of 95%, which is legitimately attributable to the use of CIP.

The following is a result summary for Performance variable:

PERFORMANCE	EDGE NO CIP	EDGE USING CIP	Hypothesis Test	Confidence Interval
Mean	38.42	54.69	There exists significant difference	95%
Standard Deviation	27.28	16.66		
Comparison variable: CIP Usage				

Table N° 6. Results summary for Performance variable, H-A.

d. ANOVA results for mean comparison Share, Post and Pull variables, H-A.

We practiced an ANOVA procedure to compare the means of the variables Share, Post and Pull of Groups 1 and 2; however no significant differences were detected.

B. TESTING OF HYPOTHESIS "B" (H-B)

1. HIERARCHY NO CIP – HIERARCHY USING CIP

Dependent Variable : P = Group Performance
Independent Variable: CIP tool usage (Common Identification Picture tool usage)
Organization Type: HIERARCHY
Group 3: HIERARCHY NO CIP
Group 4: HIERARCHY USING CIP

a. Performance variable distribution.

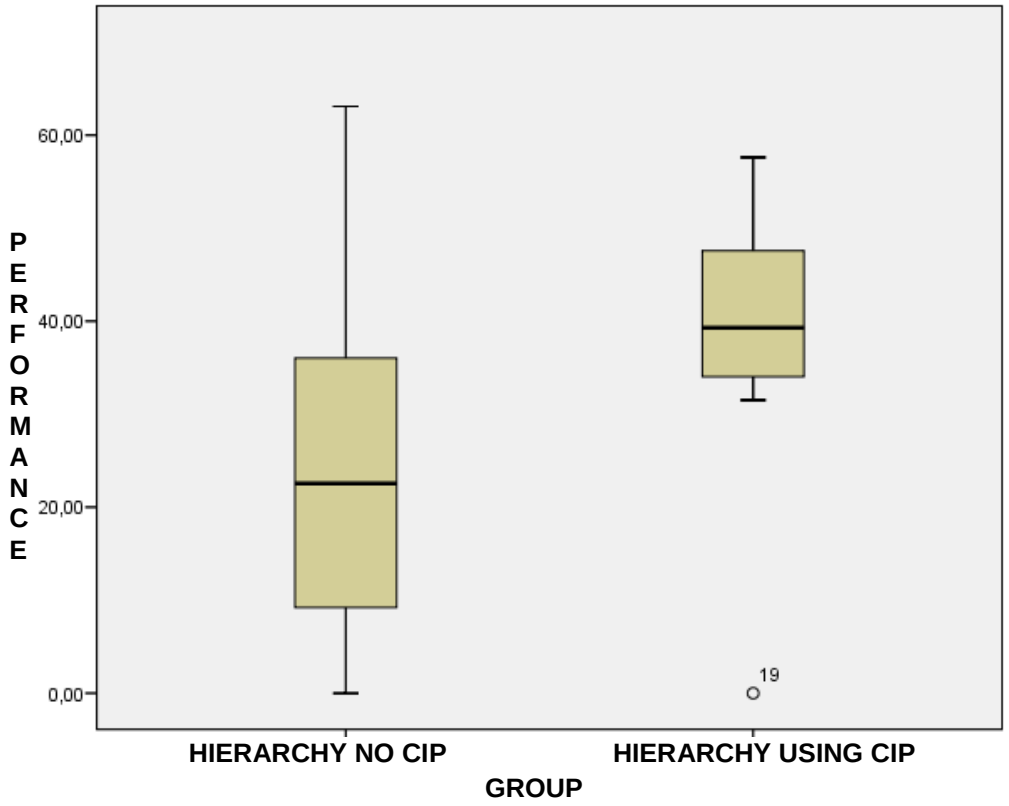

Figure N° 8. Boxplot of Performance variable Hypothesis B (H-B).

The boxplot above shows a graphical representation of the distribution data of both groups. It is evident that the "Hierarchy Using CIP" group (Group 4) clearly outperformed the "Hierarchy No CIP" group (Group 3).

From the boxplot, it can also be observed that the overall data distribution of Group 4 spans through higher values than the distribution data of Group 3.

The most relevant parameters of the distribution data are the following:

Performance

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Hierarchy NO CIP	17	22,3524	17,98712	4,36252	13,1042	31,6005	,00	63,09
Hierarchy USING CIP	17	39,5500	12,96281	3,14394	32,8851	46,2149	,00	57,60
Total	34	30,9512	17,73465	3,04147	24,7633	37,1391	,00	63,09

Table N° 7. Relevant parameters of Performance distribution, H-B

b. Compliance of conditions for ANOVA hypothesis test, Performance variable, H-B.

We practiced the Kolmogorov-Smirnov and the Shapiro-Wilk tests for normality check. We also verified homogeneity of variances through the Levene test. For all tests we used 95% of confidence ($\alpha = 0.05$). Our results turned out satisfactory as indicated in the following tables.

Tests of Normality

GROUP	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Perf. N° 3	,165	17	,200*	,935	17	,261
N° 4	,209	17	,047	,851	17	,011

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table N° 8. Test of normality results, H-B.

Since for both groups Sig. (Significance or *P* value) is greater than $\alpha = 0.05$ in both tests, then the normality of the distribution is confirmed.

Test of Homogeneity of Variances

PERF

Levene Statistic	df1	df2	Sig.
3,041	1	32	,091

Table N° 9. Test of homogeneity of variance results, H-B

The value of the parameter Sig = 0.091 is greater than $\alpha = 0.05$. This verifies the homogeneity of variance of the distribution.

c. ANOVA results for mean comparison of Performance variable, H-B.

In this section we check whether the mean values of Performance variable of both groups differ significantly as a consequence of using the CIP tool.

Null Hypothesis "Ho": The means of the distribution of Performance variable in both groups are equal (similar).

ANOVA results:

ANOVA

PERF

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2513,952	1	2513,952	10,228	,003
Within Groups	7865,133	32	245,785		
Total	10379,085	33			

Table N° 10. ANOVA results for Performance variable, H-B

Since Sig = 0.003 is much lower than $\alpha = 0.05$, the Null Hypothesis "Ho" must be rejected, which means that there exists a difference between the means of both distributions at this significance level.

We state that the performance of Group 4 HIERARCHY USING CIP is significantly superior to the performance of Group 3 HIERARCHY NO CIP, within a confidence interval of 95%, which is legitimately attributable to the use of CIP.

The following is a result summary for Performance variable:

PERFORMANCE	HIERARCHY NO CIP	HIERARCHY USING CIP	Hypothesis Test	Confidence Interval
Mean	22.35	39.55	There exists significant difference	95%
Standard Deviation	17.98	12.96		
Comparison variable: CIP Usage				

Table N° 11. Results summary for Performance variable, H-B.

e. ANOVA results for mean comparison Share, Post and Pull variables, H-B.

We practiced an ANOVA procedure to compare the means of the variables Share, Post and Pull of Groups 3 and 4; however no significant differences were detected.

C. TESTING OF HYPOTHESIS "C" (H-C)

1. EDGE NO CIP – HIERARCHY NO CIP

Dependent Variable : P = Group Performance
Independent Variable: Organizational configuration (Edge v/s Hierarchy)
Group 1: EDGE NO CIP
Group 3: HIERARCHY NO CIP

a. Performance variable distribution.

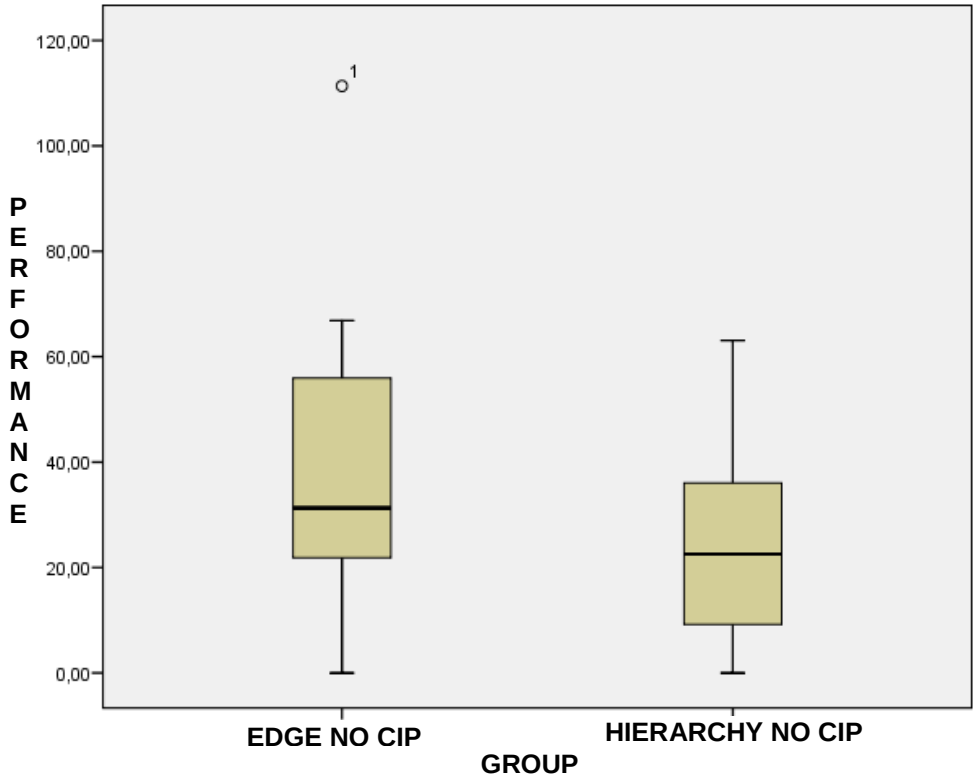

Figure N° 9. Boxplot of Performance variable Hypothesis C.

The boxplot above shows a graphical representation of the distribution data of both groups. It is evident that the "Edge NO CIP" group (Group 1) outperformed the "Hierarchy No CIP" group (Group 3).

From the boxplot, it can also be observed that the overall data distribution of Group 1 in general spans through higher values than the distribution data of Group 3.

The most relevant parameters of the distribution data are the following:

Performance

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Edge NO CIP	17	38,4188	27,28475	6,61752	24,3903	52,4473	,00	111,36
Hierarchy NO CIP	17	22,3524	17,98712	4,36252	13,1042	31,6005	,00	63,09
Total	34	30,3856	24,17238	4,14553	21,9514	38,8197	,00	111,36

Table N° 12. Relevant parameters of Performance distribution, H-C

b. Compliance of conditions for ANOVA hypothesis test, Performance variable, H-C.

We practiced the Kolmogorov-Smirnov and the Shapiro-Wilk tests for normality check. We also verified homogeneity of variances through the Levene test. For all tests we used 95% of confidence ($\alpha = 0.05$). Our results turned out satisfactory as indicated in the following tables.

Tests of Normality

GROUP	Kolmogorov-Smirnov [a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Perf. N° 1	,132	17	,200*	,927	17	,191
N° 3	,165	17	,200*	,935	17	,261

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table N° 13. Test of normality results, H-C.

Test of Homogeneity of Variances

PERF

Levene Statistic	df1	df2	Sig.
1,949	1	32	,172

Table N° 14. Test of homogeneity of variance results, H-C

The value of the parameter Sig = 0.172 is greater than $\alpha = 0.05$. This verifies the homogeneity of variance of the distribution.

.

c. ANOVA results for mean comparison of Performance variable, H-C.

In this section we check whether the mean values of Performance variable of both groups differ significantly as a consequence of having different organizational structures.

Null Hypothesis "Ho": The means of the distribution of Performance variable in both groups are equal (similar).

ANOVA results:

ANOVA

PERF

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2194,118	1	2194,118	4,109	,051
Within Groups	17087,907	32	533,997		
Total	19282,024	33			

Table N° 15. ANOVA results for Performance variable, H-C

Since Sig = 0.051 is higher than $\alpha = 0.05$, the Null Hypothesis "Ho" cannot be rejected, which means that there is no significant difference between the means of both distributions at this significance level.

We state that the performance of Group 1 EDGE NO CIP is not significantly superior to the performance of Group 3 HIERARCHY NO CIP, within a confidence interval of 95%.

The following is a result summary for Performance variable:

Performance	EDGE NO CIP	HIERARCHY NO CIP	Hypothesis Test	Confidence Interval
Mean	38.42	22.35	There exists **NO** significant difference	95%
Standard Deviation	27.28	17.98		
Comparison variable: Organizational configuration				

Table N° 16. Results summary for Performance variable, H-C.

f. ANOVA results for mean comparison Share, Post and Pull variables, H-C.

We practiced an ANOVA procedure to compare the means of the variables Share, Post and Pull of Groups 1 and 3; however no significant differences were detected.

D. TESTING OF HYPOTHESIS "D" (H-D)

1. COMPARING: EDGE USING CIP – HIERARCHY USING CIP

Dependent Variable : P = Group Performance
Independent Variable: Organizational configuration (Edge v/s Hierarchy)
Group 2: EDGE USING CIP
Group 4: HIERARCHY USING CIP

a. Performance variable distribution.

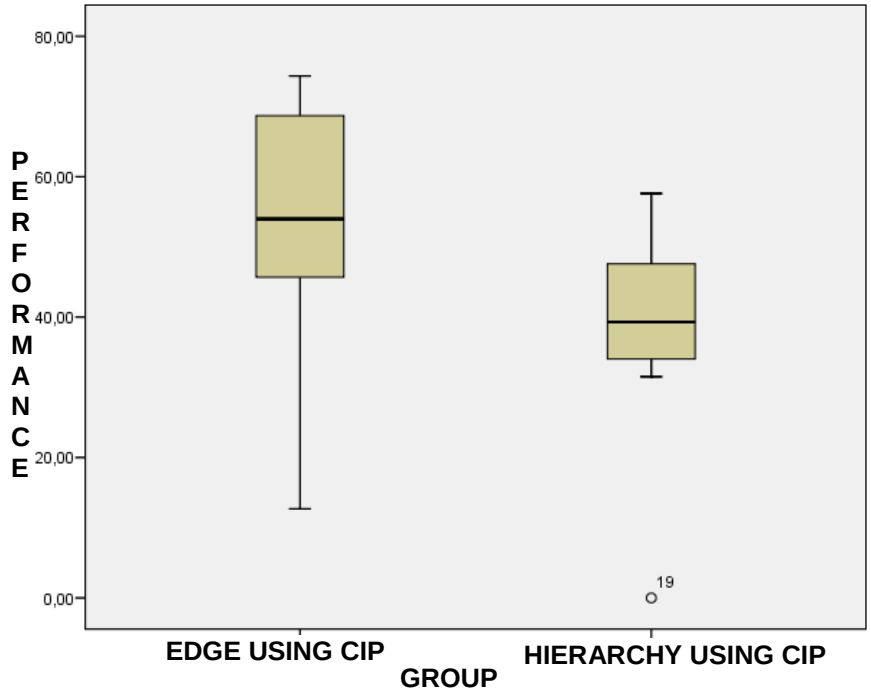

Figure N° 10. Boxplot of Performance variable Hypothesis D.

The boxplot above shows a graphical representation of the distribution data of both groups. It is evident that the "Edge USING CIP" group (Group 2) clearly outperformed the "Hierarchy USING CIP" group (Group 4).

From the boxplot, it can also be observed that the central quartiles of Group 2 span through higher values than those of Group 4, even though the dispersion of the former data set is greater.

The most relevant parameters of the distribution data are the following:

Performance

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Edge USING CIP	17	54,6935	16,66355	4,04150	46,1259	63,2611	12,68	74,35
Hierarchy USING CIP	17	39,5500	12,96281	3,14394	32,8851	46,2149	,00	57,60
Total	34	47,1218	16,58825	2,84486	41,3339	52,9097	,00	74,35

Table N° 17. Relevant parameters of Performance distribution, H-D

b. Compliance of conditions for ANOVA hypothesis test, Performance variable, H-D.

We practiced the Kolmogorov-Smirnov and the Shapiro-Wilk tests for normality check. We also verified homogeneity of variances through the Levene test. For all tests we used 95% of confidence ($\alpha = 0.05$). Our results turned out satisfactory as indicated in the following tables.

Tests of Normality

GROUP	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Perf. N° 2	,131	17	,200*	,919	17	,141
N° 4	,209	17	,047	,851	17	,011

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table N° 18. Test of normality results, H-D.

Test of Homogeneity of Variances

PERF

Levene Statistic	df1	df2	Sig.
1,437	1	32	,239

Table N° 19. Test of homogeneity of variance results, H-D

The value of the parameter Sig = 0.239 is greater than $\alpha = 0.05$. This verifies the homogeneity of variance of the distribution.

c. ANOVA results for mean comparison of Performance variable, H-D.

In this section we check whether the mean values of Performance variable of both groups differ significantly as a consequence of having different organizational structures.

Null Hypothesis "Ho": The means of the distribution of Performance variable in both groups are equal (similar).

ANOVA results:

ANOVA

PERF

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1949,275	1	1949,275	8,747	,006
Within Groups	7131,332	32	222,854		
Total	9080,607	33			

Table N° 20. ANOVA results for Performance variable, H-D

Since Sig = 0.006 is much lower than $\alpha = 0.05$, the Null Hypothesis "Ho" must be rejected, which means that there exists a difference between the means of both distributions at this significance level.

We state that the performance of Group 2 EDGE USING CIP is significantly superior to the performance of Group 4 HIERARCHY USING CIP, within a confidence interval of 95%, which is legitimately attributable to the difference in organizational structure between both groups.

The following is a result summary for Performance variable:

Performance	EDGE USING CIP	HIERARCHY USING CIP	Hypothesis Test	Confidence Interval
Mean	54.69	39.55	There exists significant difference	95%
Standard Deviation	16.66	12.96		
Comparison variable: Organizational configuration				

Table N° 21. Results summary for Performance variable, H-D.

g. ANOVA results for mean comparison Share, Post and Pull variables, H-D.

We practiced an ANOVA procedure to compare the means of the variables Share, Post and Pull of Groups 2 and 4; however no significant differences were detected.

E. TESTING OF HYPOTHESIS "E" (H-E)

1. COMPARING: EDGE NO CIP – HIERARCHY USING CIP

Dependent Variable : P = Group Performance
Independent Variable: Organizational configuration (Edge v/s Hierarchy); CIP usage.
Group 1: EDGE NO CIP
Group 4: HIERARCHY USING CIP

d. Performance variable distribution.

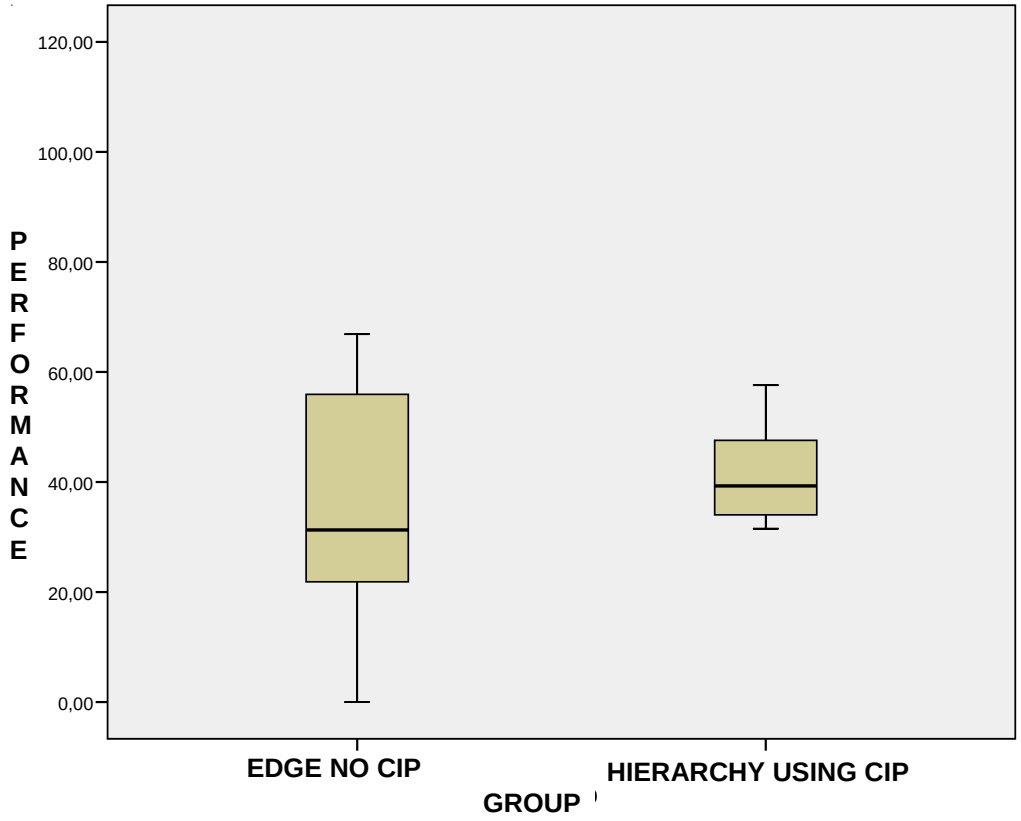

Figure N° 11. Boxplot of Performance variable.

The boxplot above shows a graphical representation of the distribution data of both groups. It is evident that the "Edge NO CIP" group (Group 1) exhibits A performance that is similar to that of the "Hierarchy USING CIP" group (Group 4).

From the boxplot, it can also be observed that the central quartiles of Group 1 span through similar values than those of Group 4, however the data dispersion of the former group is greater.

The most relevant parameters of the distribution data are the following:

Descriptives

Perform

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Edge NO CIP	17	38,4188	27,28475	6,61752	24,3903	52,4473	,00	111,36
Hierar USING CIP	17	39,5500	12,96281	3,14394	32,8851	46,2149	,00	57,60
Total	34	38,9844	21,04163	3,60861	31,6426	46,3262	,00	111,36

Table N° 22. Relevant parameters of Performance distribution, H-E.

e. Compliance of conditions for ANOVA hypothesis test, Performance variable. H-E.

We practiced the Kolmogorov-Smirnov and the Shapiro-Wilk tests for normality check. We also verified homogeneity of variances through the Levene test. For all tests we used 95% of confidence ($\alpha = 0.05$).

Tests of Normality

	Group	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Perform	Edge NO CIP	,132	17	,200(*)	,927	17	,191
	Hierar USING CIP	,209	17	,047	,851	17	,011

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

Table N° 23. Test of normality results, H-E.

Test of Homogeneity of Variances

PERF

Levene Statistic	df1	df2	Sig.
7,106	1	32	,012

Table N° 24. Test of homogeneity of variance results, H-E.

The value of the parameter Sig = 0.012 is lower than α = 0.05. This indicates that there is no homogeneity of variance of the distribution. Therefore it is not possible to use ANOVA to compare the performance of these two groups. Alternatively, we applied the "non parametric" Kruskal-Wallis Test for mean comparison, as recommended in Camacho, 2006.

f. Kruskal-Wallis Test results for mean comparison of Performance variable, H-E.

In this section we check whether the mean values of Performance variable of both groups differ significantly as a consequence of having different organizational structures and using different interaction tools.

Null Hypothesis "Ho": The means of the distribution of Performance variable in both groups are equal (similar).

Kruscal-Wallis Test results:

Test Statistics[a,b]

PERF

	Perform
Chi-Square	,428
df	1
Asymp. Sig.	,513

a. Kruskal Wallis Test

b. Grouping Variable: Group

Table N° 25. Kruscal-Wallis Test results for Performance variable, H-E.

Since Sig = 0.513 is much higher than α = 0.05, the Null Hypothesis "Ho" cannot be rejected, which means that there exists no difference between the means of both distributions at this significance level.

We state that the performance of Group 1 EDGE NO CIP is similar to the performance of Group 4 HIERARCHY USING CIP, within a confidence interval of 95%, which is legitimately attributable to the combined differences in organizational structure between both groups and the usage of the CIP tool.

The following is a result summary for Performance variable:

Performance	EDGE NO CIP	HIERARCHY USING CIP	Hypothesis Test	Confidence Interval
Mean	54.69	39.55	There exists no significant difference	95%
Standard Deviation	16.66	12.96		
Comparison variable: Organizational configuration				

Table N° 26. Results summary for Performance variable, H-D.

h. ANOVA results for mean comparison Share, Post and Pull variables, H-E.

We practiced an ANOVA procedure to compare the means of the variables Share, Post and Pull of Groups 1 and 4; however no significant differences were detected.