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Hypothesis Testing of Edge Organizations: Laboratory Experimentation using the ELICIT Multiplayer Intelligence Game[1]

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Abstract

The *Edge* is a relative newcomer to organizational design--one that appears especially appropriate for contemporary military operations, but also raises issues regarding comparative performance of the Edge to alternate organizational designs, including more traditional hierarchal configurations. These issues suggest that laboratory experimentation, with coherently structured controls and manipulations and an appropriate data collection strategy, can offer substantive insights about the internal workings of the Edge organization with high levels of reliability and internal validity. Building upon prior command and control (C2) research, we report the preliminary results of our extension of our campaign of computational experimentation to series of laboratory experiments using the ELICIT multiplayer intelligence game. Our experiments confirm the results of earlier and companion computational experimentation – chiefly, that Edge organizations outperform Hierarchy organizations in certain task and environmental contexts, and in terms of certain performance measures. Our experiments also serve to inform future computational experimentation through noting: 1) Edge and Hierarchy organizations learn at the same rate, but with higher volatility within Edge configurations; 2) transforming from Hierarchy to Edge configurations results in either similar or improved performance on subsequent tasks; and 3) transforming from Edge to Hierarchy organizations results in degraded performance initially, with subsequent recovery to previous levels.

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INTRODUCTION

The *Edge* [1] is a relative newcomer to organizational design--one that appears especially appropriate for contemporary military operations, especially given expanding mission sets, such as natural disaster relief [2,3], pandemic response [4,5] and stabilization operations (see e.g., [6,7]). The Edge proposes to capitalize upon fully connected, geographically distributed, organizational participants by moving knowledge and power to the edges of organizations. These changes in information accessibility and organizational transparency, coupled with distributed decision rights and empowering what would traditionally be considered lower-level organizational members, highlight promising opportunities for enterprise efficacy. However, the Edge organization also raises issues in terms of comparative performance with respect to alternate organizational designs, including more traditional hierarchal configurations. Such comparisons are of particular interest in military and governmental contexts given continued prominence of the paradigmatic, perhaps tautological, concept of "unity of command," [8,9]—despite recognition that multinational coalition [10], interagency [11] and interorganizational networks (e.g., [12,13]) are a common situational context for defense officials and military personnel, particularly within the more senior ranks. Indeed, mounting anecdotal evidence suggests that a wide variety of US military organizations—Joint and Service—are testing new organizational forms, administrative controls, role assignments for senior officials, and communication protocols, albeit without the benefit of controls and manipulations inherent in more rigorous laboratory experimentation [14]. US Strategic Command, for example, has implemented a number of variants to the traditional continental staff structure (i.e., J-staff) typically found in the Strategic Apex [15] of combatant commands, with senior leader responsibilities spanning multiple administrative, functional, and cultural boundaries simultaneously [16,17]. Similarly, US Northern Command is actively pursuing new coordination mechanisms with outside agencies in order to execute its complex homeland security mission [12,13]. Senior defense officials have emphasized transformation – not just in weapon systems, but also organizational processes – as key to future viability of the US military. At least anecdotally, then, the Department of Defense is seeking to understand the utility of organizational forms other than traditional hierarchies.

Modern military organizations have adapted and evolved over many centuries (see, e.g., [19-22]). Hierarchical command and control (C2) organizations in particular have been refined longitudinally (e.g., through iterative combat, training and doctrinal development [23]) to become very reliable and effective at missions for which they were designed. In contrast, evidence to support the putative benefits and comparative advantages proposed for Edge organizations have begun to emerge only very recently (e.g., see [24]). Yet the complexity of military practice [25], previous exploration of virtual contexts [26], and situational contexts demanding high levels of interorganizational coordination (e.g., [27-30]) seem to indicate situational context in which hierarchal C2 structures appear mismatched or unsuitable.

These issues suggest that laboratory experimentation, with coherently structured controls and manipulations and an appropriate data collection strategy, can offer important insights about the internal workings of Edge organizations, with high levels of reliability and internal validity. Building upon early conceptualizations of Edge organizations (e.g., [1:20,39]), our campaign of experimentation has focused principally on the use of computational models, which McKelvey [31:771] suggests as "constructive substitutes" to lab studies of organizations. This campaign began with a paper presented at the 2004 CCRTS conference [32]. In that paper, the relative advantages and disadvantages of computational experimentation were presented, and this, computational research method was described in terms of a complementary, empirical approach. The 2005 ICCRTS paper followed [33], in which more than 25 diverse organizational forms were compared and analyzed, and the Edge configuration was shown to be theoretically distinct and uniquely differentiated from other organization forms grounded in both theory and practice. This 2005 paper also offered a theoretical discussion and set of hypotheses about the performance of Edge and Hierarchy organizational forms under different mission-environmental conditions, and provided some insight into relative characteristics and behaviors of Hierarchy and Edge organizations. The 2006 ICCRTS paper [34] expanded the study to specify and model four other, classic, theoretically grounded organization forms: Simple Structure, Professional Bureaucracy, Divisionalized Form (i.e., M-form, [35,36]), and Adhocracy [15,37]. We also employed computational experimentation to compare and contrast empirically the relative performance of Hierarchy and Edge organizational forms, using a multidimensional set of performance measures, under the mission-environmental conditions at two different points in history: 1) the Industrial Era, and 2) the 21st Century. Now, in a companion paper [38] to this present work, we are progressing systematically toward instantiation and analysis of the entire *organization design space* (i.e., in a contingency-theoretic sense) of organizational forms and mission-environmental contexts. This provides theoretically grounded, empirical results to complete the kind of “C2 approach space” conceptualized by Alberts and Hayes [39].

The research described in the present paper extends the campaign of computational experimentation through a series of laboratory experiments using the ELICIT multiplayer intelligence game [40]. ELICIT requires a team of subjects performing the roles of intelligence analysts to collaborate—in a network-centric, information-processing environment—and identify a fictitious and stylized terrorist plot. The laboratory setting enables the customary levels of control and manipulation expected with experimentation, which provides for excellent reliability and internal validity of results [41]. Additionally, we use the results of our prior computational experiments to suggest in part a candidate set of research hypotheses for testing; to identify a candidate set of dependent variables for measurement; and to establish an empirical basis for further validation and calibration of our computational models in this, intelligence-focused, C2 environment. Hence this part of our campaign of experimentation is explicitly model-driven (see McKelvey [31]), and reveals another, novel, powerful approach to C2 research. Results enable us to isolate some particularly powerful influences over and determinants of C2 efficacy—across organizational forms and contingency conditions—and to buttress the already solid foundation of external validation that supports our computational tools. Results should also help to illustrate the power of the ELICIT game to support compelling C2 research, and to contribute important, new knowledge in terms of both organization theory and C2 practice.

In the balance of the paper, we draw from the organization studies literature and prior computational experiments to motivate the set of research hypotheses examined through this study. We detail our research design, and report in turn the key findings and results. The paper closes with a set of conclusions, recommendations for practice, and topics for future research consistent with this campaign.

BACKGROUND

For more than a half century, Contingency Theory has retained a central place in organization studies research. Beginning with the seminal works by Burns and Stalker [42], Woodward [43], and Lawrence and Lorsch [44], organization theory has been guided by the understanding that no single approach to organizing is best in all circumstances. Moreover, myriad empirical studies (e.g., [43]; cf. [45, 46]) have confirmed and reconfirmed that poor organizational fit degrades performance, and many diverse organizational forms (e.g., Bureaucracy, see [69]; M-Form, see [35]; Clan, see [47]; Network, see [48]; Platform, see [49]; Virtual, see [50]) and configurations (e.g., Machine Bureaucracy, Simple Structure, Professional Bureaucracy, Divisionalized Form, Adhocracy, see [15]) have been theorized to enhance fit across an array of contingency factors (e.g., age, environment, size, strategy, technology).

In most of this research, the concept *organizational fit* has been treated in a relatively static manner, with a particular organizational form prescribed to fit well in a particular contingency context. For instance, *organizational technology and organizational environment* have been studied extensively as powerful contingency factors (e.g., [42,51,52]), with alternate technological and environmental characteristics (e.g., *comprehensibility, predictability, complexity, stability*) related contingently with different organizational forms (e.g., *craft, engineering*, see [53]). Indeed, organization scholars have come to understand well how various organizational forms should and do vary to fit diverse environmental contexts.

However, organizational scholars (e.g., [54-56]) have noted widely that the environmental contexts of many modern organizations are not static. Rather, organizational environments can change rapidly and unpredictably, due to multiple factors such as globalization [57], technology [58,59], hypercompetition [60], knowledge-based innovation [61], mounting competition from co-evolutionary firms [62], and others. Hence an organization that achieves good fit with its environment at one point in time may not be able to retain such fit longitudinally, unless it changes structure in order to maintain fit—dynamically—across changing environmental conditions.

Indeed, an organization facing a constantly changing environment could fall into a condition of continuous (disruptive) change [63], or it might take the opposite approach, striving instead toward a single form that is flexible and robust to environmental change [64]. Alberts and Hayes [1,39] refer to such latter organizational form in terms of *agility.* In either case—and in most cases in between—leaders’ and policy makers’ focus on static organizational fit is incommensurate with the dynamics of contingent organization demanded by disruptive environmental change [65:Ch. 9].

The campaign of computational experimentation summarized above has addressed this issue directly, examining systematically the comparative performance of various organizational forms across abruptly changing environmental conditions. In essence, we are looking to identify the best organizational fit for abruptly and disruptively changing environments. This campaign leads us to a set of model-driven research hypotheses meriting further testing through experimentation with human subjects. In particular, Orr and Nissen [34] conclude the following from their computational experimentation that compares Edge and Hierarchy organizational forms. Each of the hypotheses summarized below derives from Alberts and Hayes [1], and most include quotations to point the interested reader directly to the original motivation.

> *H0. Edge organizations can outperform Hierarchy organizations in demanding mission environmental contexts.*

Through computational experimentation, the Edge organization is shown to outperform the Hierarchy in the less-familiar, less-predictable, more-challenging environment referred to as the "21st Century Era." The previous authors conclude that the agility of this Edge form enables it to be more robust to demanding mission-environmental changes. This omnibus hypothesis is supported strongly by the results of the prior study.

> *H1. "Power to the Edge is the correct response to the increased uncertainty, volatility, and complexity associated with [21st century] military operations" [1:6].*

Similar to the omnibus hypothesis summarized above, manipulation of the organizational environment in computational experiments provides considerable support for this hypothesis. The Edge organization exhibits considerably greater agility, and hence is more robust to the challenges and demands of the 21st Century Era than the Hierarchy (e.g., consider how most, current, military C2 is organized) is.

> *H2. "The correct C2 approach depends on [five] factors": 1) shift from static/trench to mobile/maneuver warfare; 2) shift from cyclic to continuous communications; 3) volume and quality of information; 4) professional competence; and 5) creativity and initiative [1:19].*

Similar to manipulation of the organizational environment, the previous authors demonstrate that improving the network architecture and enhancing professional competency increase organizational performance considerably. However, this result pertains to the Edge and Hierarchy organizational forms alike. Hence improving network architecture and enhancing professional competency exert performance-enhancing effects across organizational forms, supporting elements 2) and 3) in the hypothesis stated above.

> *H3. "Given a robustly networked force, any one of the six effective command and control philosophies proven useful in the Industrial Era is possible" [1:32].*

The network architecture manipulation addresses this hypothesis in part, and the previous authors find evidence that improving network architecture increases organizational agility, and makes the organization more robust to challenges and demands of the 21st Century Era. However, their computational models do not represent each of six different C2 philosophies explicitly; hence support for this hypothesis is limited.

> *H4. People who work together, over time, and learn to operate in a "post and smart-pull" environment, will outperform similarly organized and capable people who do not.*

The professional competency manipulation addresses this hypothesis in large part, but the network architecture manipulation plays some role too (e.g., post and smart-pull environment). When focusing on professional competency effects, which include people working together over time, the previous authors find substantial support for this hypothesis. A worthwhile companion to the experimentation discussed in this piece could be exploration of alternative information dissemination techniques, such as "smart push" and others.

> *H5. "The more uncertain and dynamic an adversary and/or the environment are, the more valuable agility becomes" [1:124].*

Manipulation of the organizational environment addresses this hypothesis in part, and results above in terms of comparisons across abrupt environmental changes provide considerable support for this hypothesis. The Edge organization exhibits considerably greater agility, and hence is more robust to the uncertainties and dynamics of the 21st Century Era than is the Hierarchy.

> *H6. "An organization's power can be increased without significant resource expenditures" [1:172].*

This hypothesis is difficult to assess via computational results developed by the previous authors, for they do not represent resource expenditures explicitly, nor do they have variables to measure *organizational power*. However, individual, agent-level empowerment within an organization can be operationalized using the previous computational techniques by varying the level of professional competence that an agent holds relative to a particular task, as well as manipulating the probability that an agent seeks guidance from another in the event that an exception, or problem, is generated and noted. Indeed, the kinds of network architecture effects represented in their model demand huge resource investments in global communications infrastructure. Such investments provide some evidence against this hypothesis. Alternatively, the kinds of professional competency effects represented in their model do not demand large resource investments, as simply changing policy to reduce job and personnel turnover can bring about considerable improvements in knowledge flows—and in turn organizational performance.

To summarize the results from computational experimentation, empirical evidence suggests that the novel, poorly understood, Edge organizational form outperforms the traditional, well-known Hierarchy across abrupt environmental shifts (H0). The Edge organization exhibits considerably greater agility (H1, H5) than the Hierarchy does, which makes it more robust to the challenges and demands of abrupt environmental change. Additionally, improving network architecture and enhancing professional competency increase organizational performance considerably, but this result pertains to the Edge and Hierarchy organizational forms alike (H2, H3, H4). However, whereas network architecture enhancements demand huge resource investments in global communications infrastructure, professional competency improvements do not (H6); hence the latter may represent a more prudent focus of attention and resources than the former does.

In terms of our current experimentation with people in the laboratory, we focus principally upon the omnibus hypothesis (H0) from above pertaining to organizational form, and we concentrate on comparison between the Edge and Hierarchy. This appears to represent the most pressing issue in terms of leaders and policy makers, who must organize enterprises to fit well in the currently changing environment. This issue offers considerable theoretical insight as well, for the organization studies field continues to search for agile organizational forms. Restating this hypothesis in terms appropriate for human experimentation in the laboratory:

> *Hypothesis 1. People working together in an Edge organization will outperform those who perform the same work in a Hierarchy.*

Additionally, we focus on the professional competency results from above, for this appears to be a cost-effective approach to increasing the performance of any organizational form. Summarized simply:

> *Hypothesis 2. Organizations comprised of people with greater professional competence will outperform those with less-competent people, regardless of organizational form.*

Finally, expanding upon the model-driven hypotheses above, we draw from the literature on knowledge management and organizational learning (e.g., see [95]) to hypothesize that organizations—regardless of form—will learn over time and through task repetition, and that Edge organizations will learn more quickly than Hierarchies:

> *Hypothesis 3. Performance of an Edge or Hierarchy organization will increase over time and through task repetition.*

> *Hypothesis 4. Performance of an Edge organization will increase more quickly than that of a Hierarchy.*

RESEARCH DESIGN

In this section, we summarize the research design used to guide this series of laboratory experiments. Building directly upon the work accomplished by Parity [40], we employ the ELICIT multiplayer intelligence game to examine how people working together on an information-sharing and –processing task perform across organizational configurations. ELICIT requires a team of subjects performing the roles of intelligence analysts to collaborate—in a network-centric, information-processing environment—and identify a fictitious and stylized terrorist plot. We begin by describing this ELICIT environment, and then outline the subjects, protocols, controls, manipulations and measurements used for experimentation.

ELICIT Environment

The intelligence game involves a fictitious terrorist plot, about which a set of 68 informational clues called "factoids" have been developed. Each factoid describes some aspect of the plot, but none is sufficient to answer all of the pertinent questions (i.e., who, what, where, when). The factoids are distributed among the 17 players in a series of steps: each player receives two clues initially, followed by one after five minutes of play and another after ten minutes have elapsed. The factoid distribution is designed so that no single player can solve the problem individually, and so that the team of players cannot solve the problem until after the final distribution. In other words, the players must collaborate to solve the problem, and they are required to do so for a minimum of ten minutes. Evidence from previous experiments (e.g., [40]) suggests that play requires substantially more time (e.g., an hour or more).

Subjects play the game via client applications on separate, networked computer workstations. Each subject has access to a set of five functions supported by the client: 1) List, 2) Post, 3) Pull, 4) Share, and 5) Identify. The List screen displays all factoids that a particular player has received. For instance, after the initial distribution, a player's List screen would display the two factoids distributed by the server. Post enables a player to have one or more factoids displayed on a common screen that can be viewed by other players. This represents one of two mechanisms for sharing information in the game (e.g., verbal and like communication is prohibited generally in most experiment protocols). Pull represents the complement to Post, as a player can display on his or her List screen common information that has been posted. These post-pull functions are associated with four, separate screens, each corresponding to the pertinent questions (i.e., who, what, where, when) regarding the terrorist plot; that is, one screen includes information regarding who (e.g., which terrorist organization) might be involved, another includes information regarding what (e.g., which target might be attacked), and so forth for information regarding where and when the attack might occur. Share represents the second mechanism for sharing information in the game, and enables players to send factoids directly to one another. Finally, Identify represents the manner in which subjects communicate their "solutions" to the problem, indicating via the software their conclusions regarding the pertinent questions (i.e., who, what, where, when) regarding the terrorist plot.

Multiple versions of the game have been created, each of which is structurally similar but distinct. For instance, each version includes 17 players (and pseudonyms) and a set of 68 factoids. However, the factoids—and hence details of the terrorist plot—are unique to each version. Hence the potential exists to play the game multiple times, even with the same group of subjects. Although time-consuming and tedious, additional, structurally equivalent versions of the game can be created as well. At the present time, four different versions have been created and shared.

After the game has completed, the moderator shuts down the server application, and researchers begin to analyze the transaction data captured by the server in text-file logs. Such data include time stamped entries for nearly every activity in the networked ELICIT environment, including, for instance, when and which factoids are distributed to each player, when and which factoids are posted to which common screens, when and which common screens are viewed by each player, when and which factoids are shared between each player, and the time stamped results of each player's Identify attempt. The game requires considerable cognitive and collaborative effort to play well (i.e., identify the pertinent details of a terrorist plot), but such effort is within the capabilities of many people and groups.

Subjects

Subjects in this experiment represent a combination of (mostly) masters and PhD students and (a few) faculty members in at a major US university. Subjects are grouped into four sections: 1) Group A is comprised principally of PhD students in information science; 2) Group B is comprised principally of masters students enrolled in an advanced C2 course; 3) Group C is comprised principally of masters students enrolled in an introductory C2 course; and 4) Group D is comprised principally of masters students with a special operations and/or intelligence background.

A total of 68 subjects range in age from 22 to 62 years (μ = 35.8, σ = 8.52), and possess between 1 and 38 years of work experience (μ = 11.82, σ = 8.41). All subjects have undergraduate college degrees, and 42% have graduate degrees. Hence the subjects are representative in part of the kinds of relatively experienced and well-educated people who serve as professional intelligence analysts, particularly in national intelligence agencies. Further, all of the subjects have direct military or government service, and some have worked professionally in military or government intelligence organizations. Hence the subjects are also representative military and government employees who serve as professional intelligence analysts. This representative sample serves to enhance the external validity of the study.

However, none of the subjects works currently as a professional intelligence analyst, and none of the three groups of subjects has worked together previously in an intelligence capacity. In this regard, the laboratory introduces some artificiality into the experiment. Additionally, despite the considerable level of realism designed into the ELICIT game, the information-sharing and -processing task is limited intentionally, so that people can play the game within an hour or two, and the networked-computer, ELICIT-mediated task environment does not enable all of the same kinds of media-rich communication modalities (e.g., telephone, video teleconference, face-to-face interpersonal and group interaction) likely to be found in operational intelligence organizations in the field. These factors serve to limit the external validity of the study. Limitations such as these are inherent within laboratory experimentation [32], and call for the use of other, complementary research methods (e.g., fieldwork, see [66]).

Protocols

Subjects are pre-assigned to play specific roles (e.g., as identified via pseudonyms) in the game, and to the extent possible, each subject plays the same role in every experiment session. In this particular experiment, subjects are pre-assigned to roles based upon their level of work experience. This is similar to the manner in which professional analysts are assigned to specific roles in operational intelligence organizations in the field, and hence helps to ground this experiment though conformance to practice. This approach contrasts a bit with that of randomized assignment imposed in some prior studies (cf. [40]), emphasizing our concern for realism over replication.

Subjects read about the experiment, and consent formally to participate in it. When all ELICIT clients have connected with the server, subjects sit down at the appropriate workstations, are informed verbally about the nature of the experiment, and are asked to read a set of instructions pertaining to both the experiment and the ELICIT environment. The instructions for Group A subjects are included in Appendix A for reference. Subjects are encouraged to ask questions throughout this process. When subjects have read the instructions, and have had their questions answered satisfactorily, they indicate via the ELICIT client that they are ready to begin.

In this particular experiment, each of the four subject groups participates separately (e.g., on a different day of the week), and each group participates in a total of four experiment sessions, each time playing a different version of the game (i.e., Versions 1 – 4). For Groups A, B, and C, each of the four experiment sessions is spaced roughly one week apart; for Group D, experiment sessions are conducted twice a week for two weeks. This provides time for subjects to reflect upon the game, and to interact with one another outside of the laboratory (e.g., as collaborating professional intelligence analysts do), but given that the subjects have many responsibilities outside of the laboratory experiments, this provides time also for subjects to forget about specific aspects of each session (e.g., as multitasking professional intelligence analysts do). Hence some learning and forgetting outside of the laboratory environment takes place between experiment sessions. The specific schedule of play is described below.

Subjects are instructed not to reveal their pseudonyms to one another during the game. Indeed, they are instructed not to talk or communicate with one another during the game via any mechanism outside of the two summarized above (i.e., post-pull, share). This simulates the kind of globally distributed, network-centric environment in which much intelligence work takes place operationally today. Additionally, subjects are allowed to send handwritten “postcards” directly to one another at periodic intervals in two of the four groups. Postcards contain the same information associated with an Identify function (i.e., who, what, where and when details). This enriches the communication media available to the subjects beyond the artificially limiting factoid distribution enabled by the ELICIT software. To preserve anonymity, subjects send such postcards via the Experiment Moderator, who shuffles and delivers them to their intended recipients. Hence the sender of a postcard knows only the pseudonym of the receiver, and vice versa. In addition to enriching the communication media, such postcards also capture in part the mental models [96-101] of subjects at various points of game play. A total of one postcard is allowed at each interval, with four or five intervals, coinciding approximately with the 15-, 25-, 35-, 45- and 55-minute marks in the game. Mental models, captured on the experimental postcards, are collected from each player, regardless of group, by the Experiment Moderator. However, as described in the manipulations section below, in only two of the four groups are the "postcards" delivered to their intended recipients.

Subjects are given incentives to play the game well, as participation and performance are factored into the evaluation of students' coursework. Subjects are given incentives also for personal gain (e.g., a "point" is awarded for an individual person that identifies the plot correctly in the shortest period of time) as well as for group gain (e.g., a "point" is awarded for all members of the team that identify the plot correctly in the shortest period of time). This is intended to mimic the dual nature of incentives that exist in professional intelligence environments, where people must cooperate for the organization to perform well, but who also compete against one another for limited rewards such as wage increases, promotions, desirable job assignments, and like intrinsic and extrinsic factors. The incentive structure is thus somewhat analogous to the profit-sharing incentive system described by Groves [67]. Further, of the 44 team-individual reward strategies identified by Cacioppe [68], the game incentive structure provided public recognition (R10), praise (R11), feedback (R12), team-building (R19) and team attention (R20). Cacioppe [68] describes these reward and recognition strategies as falling between extrinsic and intrinsic rewards, and specifically ascribes their utility for the two phases of the team life cycle most critical to the experiment—establishing itself (stage 2) and performing the task (stage 3).

Each subject is instructed to use the Identify function only once during game play. This represents the manner in which *formal* conclusions about terrorist plots in practice are taken very seriously, and how they impact other organizations (e.g., an operational organization may declare a state of emergency in preparation for or response to a suspected terrorist plot). Hence each player in the game is expected to wait until he or she is relatively confident about the plot before sending an "official" notice. Alternatively, the use of postcards above allows subjects to exchange the same information informally with select other players. This represents the manner in which *informal* hypotheses are discussed and compared frequently within operational intelligence organizations.

The game can end in either of two ways: 1) when all players make their identification, or 2) when the Moderator must end the game due to time constraints. Generally, subjects are not told the results of the game (e.g., plot details) until after all four versions of the game have been played. This represents in part the kind of equivocality inherent in intelligence work: analysts are rarely certain about any suspected plot, and many are required to work on multiple plots either simultaneously or sequentially. Again, we go to considerable lengths to enhance the realism of the game—and hence external validity of the results.

Finally, multiple instruments are administered to the subjects, at various points in time during the series of experiments. None of these instruments is administered during game play. They are described in the measurements section below.

Controls

As noted above, each subject is pre-assigned a specific role to play, and is intended to play such specific role through each version of the game. Each version of the game is structurally equivalent, and both the ELICIT software and physical laboratory environments are invariant across experiment sessions. Further, via the instruments administered to the subjects and enacted within the ELICIT environment, researchers have the ability to control for myriad factors (e.g., personality, information-sharing, experience) *ex-post* to the experiment sessions. In general, we strive to control every aspect of the environment and experiment that is not manipulated expressly as described below. To the extent possible, we also match teams for gender, Service, military rank, and age, achieving the greatest uniformity between Groups B and C.

To replicate real-world organizations, more experienced personnel are given roles of greater perceived responsibility – i.e., cross-team coordinator, team leader – in the Hierarchy configuration, as operationalized in the pseudonyms and role assigned to each player in the ELICIT environment. This preference for assigning more experienced personnel is continued into the Edge configurations to provide consistency across all four groups and all 16 experimental sessions. In the case of an absent player in one of these five key positions in the Hierarchy configuration, an experienced subject was promoted to fill the vacancy in a style similar to real-world organizations. A team leader, for example, would serve as the cross-team coordinator in his or her absence; similarly, the most experienced team member would serve for the team leader in his or her absence. Less experienced subjects and those with known absences during the experimental period are assigned to team member positions under both configurations in order to minimize the impact of missing or transitory players on the experimental design. If the group played with fewer than 17 subjects, the experiment moderator would ensure that the missing player's factoids (4 in total) are available to the other players via the software.

On occasion, the same subject plays with two different experimental groups. To minimize the effect of this play, the factoid sets are manipulated such that they are structurally equivalent, but cosmetically unique (e.g., Blue Group → Green Group), during each round. Any errors or misspellings noted in the factoid sets are repeated in the homomorphic substitutes to ensure one-to-one correspondence of all factoid sets used during a particular round of experimentation. Repeat subjects are assigned positions of lowest relative responsibility in the Hierarchy configuration, as well as a new pseudonym (which ensures a different distribution of factoids) during repeat play.

Manipulations

The manipulations center on the research hypotheses motivated and summarized above. To test the first hypothesis about comparative performance of Edge and Hierarchy forms, subjects are assigned to corresponding experimental environments. No specific manipulations are associated with the second hypothesis. Rather, we intend to gauge professional competence of the subjects outside of the game play, and to seek correlation and understanding via *ex-post* analysis. The two hypotheses regarding learning are addressed via the Hierarchy-Edge manipulation described above.

Hierarchy

In the Hierarchy organization manipulation, subjects are assigned to play roles within a three-level, functional, hierarchical organization as depicted in Figure 1. An overall leader (i.e., labeled "1") is responsible for the intelligence organization as a whole, and has four functional leaders (i.e., labeled "2," "6," "10," "14") reporting directly. Each such leader in turn has three analysts (e.g., labeled "3," "4," "5") reporting directly, and is responsible for one set of details associated with the terrorist plot. For instance, Subleader 2 and team would be responsible for the "who" details (e.g., which terrorist organization is involved) of the plot, Subleader 6 and team would be responsible for the "what" details (e.g., what the likely target is), and so forth for "when" and "where." Subjects are shown this organization chart, told of their responsibilities within the organization, and provided with a short description of the hierarchy.

Additionally, the ELICIT software limits subjects' Post and Pull access to specific common screens within this manipulation. Specifically, those players in the "who" group, for instance, are allowed to Post to and Pull from only one of the four common screens (i.e., the "who" screen) noted above. Comparable restrictions apply to players in the other three functional groups. The only exception applies to the Leader 1, who has post-pull access to all four common screens. Further, we limit postcards to immediate superiors and subordinates within the organization. These manipulations reinforce the functional and hierarchical nature of the Hierarchy organizational form represented.

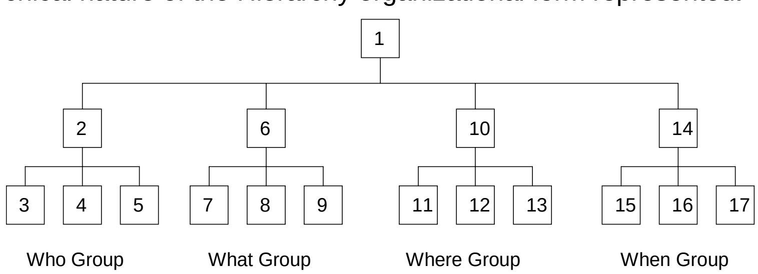

Figure 1: Hierarchy Organization

Alternatively, players are allowed to use the Share function to send factoids to any of the 16 other players in the entire organization. This serves to capture the "flattening" effect of e-mail and like, now-ubiquitous communication modes that enable peer-to-peer collaboration across formal organizational boundaries. We note, however, that such Share function is limited to sharing factoids only: no free-form or other information can be exchanged in this direct manner.

In terms of the game ending, in this manipulation, the game ends when all the players identify the plot details, or when the game times out. However, the incentive structure ensures such that players *other* than the leader receive individual recognition *if and only if* his or her pre-selected leader identifies the plot correctly and in less time than the other two teams. This represents the manner in which leaders of many hierarchical organizations speak for the organization as a whole, and it captures the important information-sharing task of ensuring that such leader is informed well.

Edge

In the Edge organization manipulation, there are no pre-assigned leaders or functional groups established in advance of the experiment. Rather, consistent with current Edge conceptualizations, the group is leaderless and without form—what Mintzberg terms *Adhocracy*. As noted above, the players are pre-assigned to specific roles (i.e., pseudonyms) within the game, but the various roles reflect no hierarchical or functional differences from one another. As with the hierarchy manipulation above, subjects are told about this organizational arrangement, and are provided with a short description of the Edge as an organizational form. We characterize the nature of this Edge manipulation in Figure 2.

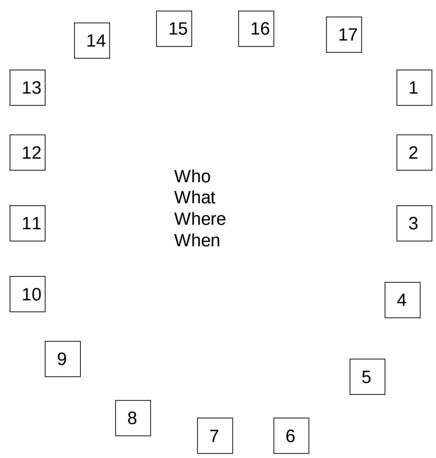

Figure 2 Edge Organization

Without an overall leader or functional groups, subjects must decide for themselves who works on which aspects of the problem, and who posts, pulls and exchanges information with whom. With this manipulation, the ELICIT software does not limit subjects' Post and Pull access to specific common screens; that is, in contrast to the hierarchy manipulation above, any player can post to and pull from any of the four common screens (i.e., "who," "what," "when," "where"). In further contrast, any player can send a postcard to any other player, albeit within the same format, frequency and number constraints established for the hierarchy manipulation. Consistent with the other manipulation is the Share function, through which any player can share factoids directly with any other.

In terms of the game ending, in this manipulation, the game ends when all players Identify the plot details, or when the game times out. This represents the manner in which flat, leaderless organizations require some consensual decision making, and it captures the important information-sharing task of ensuring that all participants are informed well. To ensure comparability with the hierarchy results, however, after the game has completed, participants are asked to elect *an emergent leader*, and this subject's game performance (e.g., evidenced via the Identify function) is used for comparison with that of the leader (i.e., Leader 1) in the hierarchy manipulation.

Manipulation Sequence

Each of the three subject groups is assigned to a unique manipulation sequence as summarized in Table 1, and each group plays all four versions of the game once (i.e., each group plays a total of four times). Group A plays according to the Edge manipulation all four times. Because we know relatively little about Edge organizations—particularly how they form and learn over time—this manipulation provides longitudinal data for exploration. Groups B and C play twice each in the Hierarchy and Edge manipulations, but the order of play is reversed. This reduces potential confounding from learning effects associated with order of play. These groups also play twice within each manipulation (e.g., twice in Hierarchy, then twice in Edge) before reversing. This allows two experiment sessions for learning within a particular organizational form to occur. The contrast between Group B and Group C performance reveals between-subjects effects; the contrast between Hierarchy and Edge manipulations reveals both within- and between-subjects effects; and both individual and organizational learning over time reveals within-subjects effects. Group D plays according to the Hierarchy manipulation all four times, offering a contrast to Group A. As a note, the individual player represents the primary unit of analysis, but both individual and organizational levels of analysis are considered in this experiment. A second manipulation involves allowing or disallowing each subject to share his or her evolving mental model of the impending terrorist attack via a highly structured data collection mechanism and timing criterion—operationalized as the sharing or withholding of "postcards" as outlined above. Further details about this manipulation are available from the authors, and results from this manipulation are reserved primarily for discussion in future work, with some limited explication offered in this paper.

Group	**Session 1 V4**	**Session 2 V3**	**Session 3 V2**	**Session 4 V1**
A – PhD	E – no MM	E – no MM	E – no MM	E – no MM
B – Advanced C2	H – MM	H – MM	E – MM	E – MM
C – Introductory C2	E – MM	E – MM	H – MM	H – MM
D – SOF / Intel	H – no MM	H – no MM	H – no MM	H – no MM

Key:
V1-V4: Elicit Version 1-4
H: Hierarchy manipulation
E: Edge manipulation
MM: Mental models distributed between players
No MM: Mental models *not* distributed between players

Table 1: Manipulation Sequence

Measurements

This section describes our operationalization schema for performance, professional competence, and organizational learning.

Performance. The first hypothesis addresses comparative organizational performance of Hierarchy and Edge organizations, and the performance of individuals within Hierarchy and Edge organizations. In this experiment, *performance* is operationalized as a two-dimensional dependent variable comprised of: 1) time to identify plot details correctly; and 2) accuracy of the plot identification. This measurement construct is informed by our computational experiments (e.g., see [33, 70-72]), in which *time* and *accuracy* (related to *risk*) reveal consistently insightful results. The measurement construct is also informed by literature in the psychological and organizational domains that suggest a trade-off exists between time and accuracy in tasks requiring high cognition and/or advanced motor skills (e.g., see [73-78]) at both the individual and team/group levels of analysis.

In the first component, *time* pertains to when a subject submits his or her identification of the terrorist plot, with group performance with respect to time operationalized as the mean submission time of all subjects participating during the experimental session. For ease of comparison, the scales for both measurements are normalized to a 0-1 scale, with 1 being more desirable in both cases (e.g., faster, more accurate). Measuring and normalizing time is straightforward, as the time for each subject's identification is logged to the nearest second by the software. To ensure that the measurements are meaningful when compared against values from all 16 experimental sessions, we determine that identifications made at the same 'clock' time during two different sessions (e.g., after 2200 seconds has elapsed since the start of Session 1 and after 2200 seconds has elapsed since the start of Session 2) are to be considered exactly equal. Each subject's identification time is thus calculated using Equation 1:

$$T = \frac{3896 - identification\_time}{3896} \qquad \text{Eq. (1)}$$

In Equation 1, 3896 represents the maximum time elapsed (in seconds) during all 16 experiments. An example in which *any* subject identifies at 2200 seconds after *any* experimental session begins becomes:

$$\frac{3896-2200}{3896}=0.44$$

In the second component of performance, *accuracy* refers to when the subject has identified the specific details of an impending terrorist attack – i.e., who, what, where and when, with group performance for accuracy operationalized again as the mean accuracy of identifications provided by subjects during the experimental session. Sufficient information is contained within the factoid sets such that the subjects can discern the group responsible for the attack ("who"), the target of the attack ("what"), the country in which the attack will take place ("where") and the month, date and time of the terrorist attack ("when"). For the results reported here, we operationalize accuracy according to strict criteria, with a subject receiving a high score on accuracy if his or her identification of the terrorist attack reduced decisionmaker uncertainty *exactly*. Our model is thus consistent with Heuer's [79,80] description of intelligence analysts as agents that filter and make sense of scattered and potentially incomplete information on behalf of policy makers, informing policy makers by reducing uncertainty about complex topics. A subject receives credit for his or her identification under this strict schema if it matches the correct response exactly, with some reasonable exceptions for natural language equivalents and use of "military time" (i.e., 24-hour clock) by many respondents. A point is awarded for each component of the correct answer – group, target, country, month, date, and time of day – and then normalized to a scale from 0 to 1, with equal weighting for the who, what, where, and when components. No points are awarded for blank (i.e., non-) answers. An illustration of the operationalization is provided at Appendix E.

Professional competence. The second hypothesis addresses professional competence. We capture demographic and experiential information (e.g., education, work experience, intelligence experience) from subjects in order to pre-assign them to roles in the ELICIT game. Such demographic information is used to correlate and understand the role and distribution of professional competence on individual and organizational performance. This knowledge inventory instrument is included in Appendix B for reference. Measures used in this section focus on the subjects' work experience (years), military/government experience (years), and intelligence experience (years).

Learning. The third and fourth hypotheses address learning. We operationalize *learning* as the change in performance over time and repetition, and use the same, two-dimensional dependent variable summarized above. Specifically, we measure the change in performance across the four experiment sessions—blocking by organizational form.

RESULTS

We discuss the results of our laboratory experiments in the order outlined above: performance, professional competence, and learning.

Consistency of Observations with Proposed Design

We first check that our experimentation follows our research design. Basic correlations reveal that our primary manipulations–organizational form and mental models–are not highly correlated, a condition important to simplifying the interpretation of results from multivariate research designs [81:775]. Given the design as described in Table 1, the Spearman's Rho coefficients for our independent variables are as expected (Appendix D) and confirm the robustness of our basic factorial design for the stated hypotheses.

Organizational Form and Mental Models

We conduct experimentation during 16 sessions over a 36 day period. Groups occasionally play ELICIT with fewer than the requisite 17 players, but our experimental protocol ensures that in all but one case, subjects can access all information needed to completely discern all details about the impending terrorist attack.[2] A total of 68 unique subjects play the game from 1 to 8 times (μ = 3.51, σ = 1.71), with 90% of subjects submitting an identification during game play and thus providing 210 cases for evaluation at the individual level of analysis. The authors play ELICIT with Group A (PhD Group), however, the analysis omits any associated data. Subjects occasionally submit their identification of the terrorist attack more than once, but for consistency in the analysis and with the instruction set to the players, all results reflect only the subject's *first* identification, regardless if a subsequent identification was more accurate. The

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[2] The exceptional case represents the pilot experiment in which the subjects do not receive a factoid related to the exact hour of the impending attack. All other information, however, is available to the players during this session.

distribution of these 210 cases between and within the two manipulations is provided in Table 2 below. More detailed descriptive statistics are provided in Appendix D (Table 4).

		Organizational Form		Total
		Edge	Hierarchy	
Mental Model	Exchanged	66	62	128
	Not Exchanged	46	36	82
Total		112	98	210

Table 2: Cross-tabulation of Observations

The two components of the dependent variable *performance* (i.e., time and accuracy) are checked for normality using probability plots, with acceptable results, and interestingly, are not correlated (r = -0.058, p>0.40). Normal distribution of and lack of covariance between the dependent variables supports the appropriateness of utilizing ANOVA to determine if the manipulations resulted in statistically significant differences among the sample populations. Coupled with the low correlation between the primary manipulations (0.044, p>0.52), the normality of distribution also supports use of MANOVA techniques for assessing our results [81].

Within and between the two manipulations, the means of the two performance factors are different, and for half of the groups, the difference of the means appears significant. For example, when mental models are exchanged, players in the Edge configurations, on average, score 0.47 on the time of their identifications (recall that 0 would represent the slowest time for any player to identify the details of the terrorist attack in any experimental round, while 1 would represent the fastest time for any player to identify details about the terrorist attack in any experimental round). Under the same condition, however, players in Hierarchy configurations, on average, score 0.25 for time of their identifications, or 0.47 – 0.25 = 0.22 *slower* than Edge groups on our normalized scale.[3]

Similarly, players in the Hierarchy configurations, when allowed to exchange their mental models of the terrorist attack (even in the very limited, structured manner provided by the experimental protocol), score, on average, 0.68 for accuracy (recall that 0 would represent a completely inaccurate identification, while 1 would represent a completely accurate identification). Players in Hierarchy configurations, when *not* allowed to exchange mental models, score, on average, 0.56 for accuracy – a difference of 0.68 – 0.56 = 0.12 *slower* than with the exchange of mental models on our normalized, dimensionless scale. One reasonable interpretation of these results is that the exchange of knowledge (operationalized as "postcards") among the players slows the hierarchy, but yields greater accuracy over the case of simply exchanging information (operationalized as "factoids"). The Edge, however, demonstrates no degradation in time when mental models are exchanged, with a nearly similar improvement in accuracy. The Edge, it appears at first glance, can absorb a higher-level cognitive task (i.e., exchange of interpretation vs. exchange of existing data) more easily than the Hierarchy, although both forms benefit in terms of improved accuracy.

Organizational Form

Hypothesis 1 suggests that people working together in an Edge organization will outperform those who perform the same work in a Hierarchy. To test this hypothesis, we use univariate ANOVA to determine whether the differences in the means of individuals working in an Edge and individuals working in a Hierarchy are significant. For example, the mean *time* for players working within Edge configurations, regardless of the exchange of mental models, is 0.47. This result appears to contrast with the mean *time* of 0.33 for players working with Hierarchy configurations (regardless of the exchange of mental models), suggesting that persons in a Hierarchy configuration identified the terrorist attack details more slowly than their Edge counterparts. Similarly, the mean *accuracy* for players working within Edge configurations is 0.69, while the mean *accuracy* for players working within Hierarchy configurations is 0.66, a lesser

[3] To convert from the normalized scale to seconds, one would multiply by 3869 seconds. Thus the difference described here is 0.22 * 3869 = 851 seconds, ~ 14 minutes. Thus, on average, Hierarchy groups require 14 additional minutes to complete the task over Edge counterparts, with a total task period of 37 to 60 minutes.

difference. A one-way ANOVA reveals that the difference in the means for *time*, is significant ($p<0.001$), while the difference in the means for *accuracy* is not ($p>0.38$).

Given these results, Hypothesis 1 is partially supported. Persons working in an Edge organization, on average, perform their work *faster*. However, persons working in Edge and Hierarchy configurations produce *equally accurate* results. This finding leads to our first proposition.

> ***Proposition 1. For complex tasks requiring high collaboration among a mid-sized group of professional knowledge workers, persons working in Edge organizations, on average, perform faster than persons within Hierarchy organizations, with no discernible change in accuracy.***

In short, the Edge outperforms the Hierarchy, given the same complex task (see [102, 103] for a discussion objective task complexity). However, we suggest further experimentation be undertaken to assess whether this postulate can be generalized to other types of tasks and task environments.

Exchange of Mental Models

We then again apply univariate ANOVA to compare the sample performance means related to the exchange or lack of exchange of mental models. We note that the mean *time* for subjects in groups that exchanged mental models is 0.37 (slower), while the mean time for subjects in groups that did not exchange mental models is 0.45 (faster). We also note that mean *accuracy* for subjects in groups that exchanged mental models is 0.72 (more accurate), while the mean accuracy for subjects that did not exchange mental models is 0.61 (less accurate). Both differences in the means are significant ($p<0.01$). For organizational designers, this result suggests that relative to complex tasks requiring high collaboration, a trade space for performance exists between allowing organizational members to share *only* information (operationalized as “factoids” about the impending terrorist attack) and allowing them to share information <u>and</u> knowledge (operationalized as person’s emerging mental model of the terrorist attack). While the sharing of mental models results in a more accurate performance, the sharing of mental models also results in a slower performance.

However, a more careful examination of the data suggests that for persons in a Hierarchy configuration, the exchange of mental models slows performance on average (mean time is 0.47–0.25 = 0.22 slower with exchange of mental models, $p<0.01$) but also increases accuracy (mean accuracy is 0.69–0.60 = 0.09 more accurate with exchange of mental models, $p<0.08$) Yet the Edge configuration appears sufficiently robust such that it can absorb the added work of exchanging mental models and thereby gain improved accuracy (mean accuracy is 0.75-0.61 = 0.14 more accurate with exchange of mental models, $p<0.02$) *without suffering slower performance* (mean time is 0.47-0.45 = 0.02 slower with exchange of mental models, $p>0.55$). Thus our preliminary work suggests the following propositions.

> ***Proposition 2. For complex tasks requiring high collaboration among a mid-sized group of professional knowledge workers, persons given the opportunity to exchange mental models about the task solution provide more accurate results.***
>
> ***Proposition 2a. For persons operating within the Edge, the exchange of mental models enhances accuracy without degrading speed.***
>
> ***Proposition 2b. For persons operating within the Hierarchy, the exchange of mental models degrades speed while improving accuracy.***

We caution the reader that given the emphasis on accuracy in the instructions to the subjects (and by extension, the incentive structure posed to the subjects), proposition 2b requires further evaluation.[4] To spare the reader, detailed statistical discussion is not provided as we test our remaining three hypotheses. Additional detail can be obtained from the authors.

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[4] The careful reader will also note that in the above calculations, we ignored subjects who failed to respond. If these 24 cases were included with an assignment of 0 for time (slowest) and 0 for accuracy (least accurate), the levels of significance are nearly identical, suggesting that our results are robust across two very reasonable operationalizations of the data.

Professional Competence

Our second hypothesis suggests that organizations comprised of people with greater professional competence will outperform those with less competent people, regardless of organizational form.

At the individual level of analysis, two proxies for operationalizing professional competence are 1) subjects' prior familiarity with intelligence analysis and 2) subjects' years of work experience.

Intelligence experience. Of our observations, 48 are associated with persons who self-report some experience with intelligence functions, while 137 are associated with persons who self-report no experience with intelligence functions. We omit the 49 cases for which no data about experience with intelligence functions is available. A MANOVA reveals no significant difference in the performance of those possessing or lacking intelligence experience.

Work experience. We next correlate work experience (in years) against both performance factors, time and accuracy. There exists a weak positive correlation between work experience and speed ($r = 0.17$, $p < 0.02$) and a weak negative correlation between work experience and accuracy ($r = -0.18$, $p < 0.02$). These findings suggest that more experienced workers identify the details about the terrorist attack more quickly, but are more prone to inaccurate identifications.

We also consider Hypothesis 2 at the organizational level of analysis. In the context of this experimentation, we can consider professional competence as experience with command and control, and we compare the average performance of Group B (undertaking advanced C2 coursework) against average performance of Group C (undertaking introductory C2 coursework) in order to test this hypothesis. Since we wish to compare the groups as a whole, and not just individuals, we include data from subjects who did not identify in the analysis as time = 0 and accuracy = 0. Again, a MANOVA reveals no significant difference in performance between Group B and Group C. Thus Hypothesis 2 has mixed support depending on the proxy used for professional competence and the level of analysis explored.

We caution the reader, however, that all of the subjects hold baccalaureate degrees, and nearly all possess or are working toward a masters or doctoral degree. Further, the selection process for attending or teaching at the university is competitive, indicating that all subjects are likely to possess a level of professional competence equal to or surpassing various peer groups. We thus acknowledge mixed support for this hypothesis, but suggest that further, more specific testing is required to ensure adequate controls and manipulations for professional competence can be incorporated into the ELICIT campaign of experimentation.

Task Repetition

Hypothesis 3 suggests that as organizations repeat tasks, performance will improve, regardless of organizational configuration. We expect that time and accuracy within our four experimental groups will improve during each round of experimentation – i.e., performance in Round 2 will improve over Round 1, performance in Round 3 will improve over Round 2, and so on.

Interestingly, our plots for all four Groups (see Appendix C) challenge this hypothesis – in three of our four groups (Groups A, B, and C), time improves mildly between Rounds 1 and 2 and Rounds 3 and 4, but degrades mildly between Rounds 2 and 3. Only one group (Group D) shows improvement or near similarity for time between Round 2 and Round 3. For accuracy, the graph is even less illuminating. Groups A and D appear to hover at about the same accuracy throughout the experiment, with slight degradation or improvement from one round to the next. Group B improves, degrades and then improves, while Group C degrades, improves, and improves.

We are interested in each group's performance relative to itself over time, so we isolate the data and perform four unique MANOVA calculations followed by Scheffe post-hoc analyses, one for each group and including non-answers (time = 0, accuracy = 0). Thus time and accuracy are the dependent variables and round of play is the independent variable. For groups that play all rounds in either the Hierarchy (Group D) or Edge (Group A) configuration, the differences in *time* are not significant. In Group C, the degradation in time when the group switches from Edge to Hierarchy (from 0.50 to 0.15, ~22.5 minutes slower over Round 2) is significant ($p<0.05$) when compared to all other rounds of play. Similarly, in Group B, the improvement in time when the group switches from Hierarchy to Edge (from 0.16 to 0.40, ~14 minutes faster) is significant ($p<0.05$), as is Group B's subsequent improvement in time between Round 3 and 4 (from 0.40 to 0.64, ~ 15 minutes faster).

The results are thus mixed. If the organizational form is unchanging, the time of the group changes negligibly. However, if the organizational configuration changes from Edge to Hierarchy, the group suffers performance degradation (i.e., a reconstitution period) before recovering to its “normal” level of performance. If the organizational configuration switches from Hierarchy to Edge, the group improves at the point of the configuration change and continues to improve subsequently--not only is no recovery period required when transitioning from Hierarchy to Edge, but the transformation results in improved performance immediately that continues into subsequent tasks, at least relative to time. These findings lead us to reject Hypothesis 3 and replace it with the following, more refined postulates.

Proposition 3a. Over time, neither Edge nor Hierarchy organizations improve their speed on complex, highly cognitive tasks requiring significant collaboration.

Proposition 3b. Edge organizations that are re-configured into Hierarchy organizations suffer a significant degradation in speed before recovering to previous levels of performance.

Proposition 3c. Hierarchy organizations that are re-configured into Edge organizations enjoy immediate and continual improvements in speed, with no need for a recovery period.

On the accuracy dimension of performance, a slightly different pattern emerges. In the group that plays the game in the Edge configuration all four times (Group A), accuracy improves from Round 1 to Round 2 ($p<0.05$), degrades from Round 2 to Round 3 ($p<0.05$) and improves from Round 3 to Round 4 (p not significant). This group struggles with the Edge configuration, and reaches its peak performance with respect to accuracy during Round 2. In the group playing in the Hierarchy configuration all four times (Group D), accuracy improves steadily over time, with significant improvement ($p<0.05$) from Round 1 to Round 2. For Group C, the pattern of performance found with time repeats itself for accuracy – i.e., accuracy improves from Round 1 to Round 2 when the Edge configuration remains stable, degrades at the transformation to Hierarchy (Round 2 to Round 3), and then recovers to its previous level of performance during Round 4 while remaining in the Edge configuration. All changes are significant. For Group B, only the improved accuracy between Rounds 1 and 4 is significant ($p<0.05$). This finding indicates that Group B shows similar or improved performance over all four rounds, *despite the transformation from Hierarchy to Edge* at the midpoint. Since we are concerned that our strict interpretation of accuracy may affect these results, we repeat the analysis using a relaxed coding schema for accuracy. The results for the second analysis are generally similar (see Appendix C for details). We thus feel confident offering the following refinements to Hypothesis 3.

Proposition 3d. Over time, both Edge and Hierarchy organizations will improve their accuracy on complex, highly cognitive tasks requiring significant collaboration.

Proposition 3e. Edge organizations that are re-configured into Hierarchy organizations suffer a significant degradation in accuracy before recovering to previous levels of performance.

Proposition 3f. Hierarchy organizations that are re-configured into Edge organizations absorb the change without any degradation in accuracy, and then continue to improve over time.

Combining propositions 3b and 3e, as well as 3c and 3f, leads to the following propositions.

Proposition 3g. Edge organizations that are transformed into Hierarchy organizations suffer a significant degradation in performance before recovering to previous levels of performance.

Proposition 3h. Hierarchy organizations that are transformed into Edge organizations immediately operate faster, without any degradation in accuracy, and subsequently continue to improve on both aspect of performance.

We note, too, that the two groups playing the same organizational configuration four times (i.e., E-E-E-E & H-H-H-H) generally improve from one round to the next, although the Edge group performs exceptionally and unexpectedly well in Round 2. We defer comments on this observation until the discussion.

Organizational Learning

Our final hypothesis suggests that performance by an Edge organization will improve more quickly than that of a Hierarchy organization. We operationalize learning as the improvement (or degradation) in average performance from one round of play to the next, given the same organizational configuration. For example, if an Edge Group performed at a time of 0.24 during Round 1 and a time of 0.36 during Round 2, the learning would be measured as 0.36 – 0.24 = 0.12, or an improvement of 0.12 during the later round. In the experimentation, we have five observations that reflect learning by Edge groups and five observations that reflect learning by Hierarchy groups.

As expected, the Edge groups learn slightly faster than the Hierarchy groups, as evidenced by performance on both the time and accuracy dimensions (μ: 0.064 > 0.05 for time, μ: 0.188 > 0.158 for accuracy). However, these differences are not significant ($p>0.80$), leading us to reject Hypothesis 4. We also note that in terms of accuracy, the Edge group experiences greater volatility than the Hierarchy (σ: 0.28 > 0.12), leading us to offer the following propositions:

Proposition 4. Over the same period of time, Edge and Hierarchy organizations achieve approximately the same level of learning.

Proposition 4a. Compared to Hierarchy counterparts, Edge organizations may experience greater volatility as they learn.

DISCUSSION

In this section, we discuss implications of the results of our laboratory experiments for both organizational design and future research.

Implications for Organizational Design

The Edge [1,39] is an emerging concept within organizational design, and our companion piece [38] to this work suggests that the Edge resembles and performs as a composite of other forms, notably elements of Mintzberg's [37] Adhocracy, Professional Bureaucracy and Simple Structure. The Edge's low centralization, low formalization, and high probability of lateral communication suggests it may share critical characteristics with network organizations [48], particularly as viewed through the lens of organizational information-processing theory [82-84]. Indeed, our laboratory experimentation offers an instantiation of organizational information-processing theory in an experimental laboratory environment with human subjects, It complements existing computational [24,33,34,38] and field research [70] on Edge organizations. Specifically, we manipulate organizational form by imposing or removing controls on the manner in which subjects are permitted to access, share or exchange information (e.g., "factoids") and knowledge (e.g., "postcards").

Comparing Results of Computational and Laboratory Experimentation

Our laboratory experiments suggest that generally speaking, Edge organizations outperform Hierarchy organizations when given similar tasks and opportunities for organizational learning. Learning within Edge organizations can be more volatile and inconsistent than in Hierarchy organizations, but *on average*, the two organizational forms learn at the same pace. Our experimentation thus intimates that for complex tasks requiring high interdependence and high cognitive skill, the Edge organization is the superior form. More specifically, in our two-dimensional performance model, the Edge outperforms the Hierarchy on time without sacrificing accuracy, while improving its performance at an approximately equivalent rate. This finding buttresses the validity of our previous and current computational modeling, which suggests that the Edge outperforms other organizational configurations but with higher project and function risk, resulting in more volatile, but superior, results than when a Hierarchy performs similar tasks.

This work also extends our previous computational experimentation by examining the relationship between the exchange of information and knowledge and performance within the two organizational forms. Our laboratory experimentation intimates that the Hierarchy organizations may suffer performance degradation when its members are asked to share *both* information and knowledge; specifically, the Hierarchy's performance lessens when its members are asked to share their *interpretations* of available information (i.e., knowledge) rather than simply share available information. For the Edge, however, sharing information and knowledge does not result in performance degradation—in fact, performance is enhanced. While preliminary, our results continue to extend the margins of information-processing theory by suggesting that the *content* of the information to be processed by an agent may affect the observed result of processing efforts. Agents that exchange filtered, synthesized and summarized information may outperform those working with information that has not been arranged into a more coherent whole.

Evaluating Performance

To compare the performance of our four organizational form–mental model pairs, organizational designers may find it helpful to envision the two dimensions of performance on a grid, with time on the *x*-axis and accuracy on the *y*-axis (Figure 3). Three unique $y = -x + b$ indifference curves are included, with b_1, b_2, and b_3 as unspecified constants. The indifference curves represent levels of relative performance (i.e., closest to the origin = worst performance, farthest from the origin = best performance) in which the evaluator has equally weighted time and accuracy (e.g., 0.10 improvement in time is equal to 0.10 improvement in accuracy). Any point along an indifference curve would be considered as providing comparable performance. In such an evaluation space, the Hierarchy *with* the exchange of mental models underperforms all others, while the Edge *with* the exchange of mental models outperforms all others. When mental models are not exchanged, our observations suggest that the Edge and Hierarchy would fall along a nearly similar indifference curve – i.e., they are interchangeable in terms of observed performance. While preliminary, this finding suggests that for complex tasks in which the network architecture allows only for the formal or informal exchange of unprocessed information, neither the Edge nor Hierarchy outperforms. For complex tasks in which the network architecture allows for sharing of interpretations of this information, the Edge outperforms the Hierarchy.

We caution that the indifference curves described here are useful for discussing and evaluating organizational performance, but are tautological in nature. The curves provide a means for *evaluating* the observed performance of various organizational form-mental model pairings *relative to each other* and *laden with stakeholder values time and accuracy as equally important performance factors*. If values associated with the performance factors were changed by the stakeholders, one might draw different comparative conclusions. Also, our data offers no reason to suspect that the relationship between time and accuracy is linear, and in fact, contradicts any such assertion.

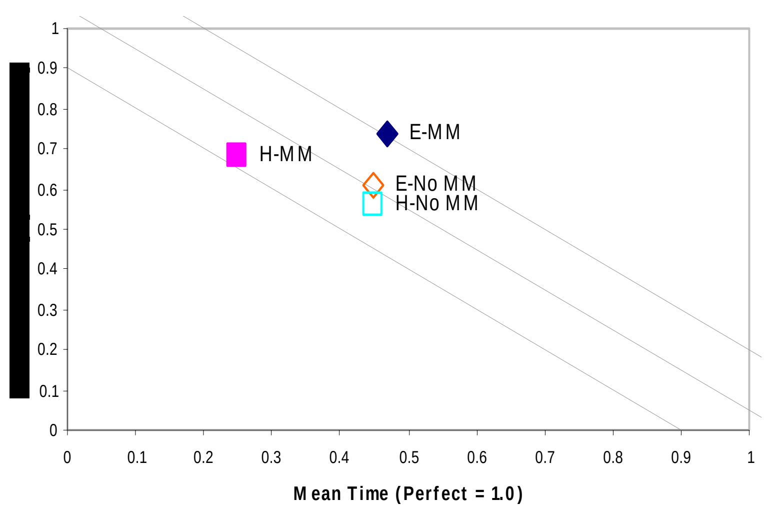

Figure 3: Evaluating Observed Performance via Indifference Curves

Measuring the Cost of Organizational Transformation

One of the more important aspects of our experimental protocol is providing a means to measure the switching cost associated with organizational transformation—i.e., initiating exploration of the extent by which performance is degraded when an organization switches from Edge to Hierarchy, or from Hierarchy to Edge. The research thus demonstrates a complexity beyond simple comparison of two organizational forms relative to organizational performance—it provides an empirical investigation of the cost of *dynamically* reconfiguring an organization at the midpoint of its life cycle. Our results are both surprising and illuminating. While one would expect that dynamically reconfiguring an organization would generally lead to a degraded performance followed by recovery to previous performance levels after some time lag, we discover that this pattern occurs only when the Edge reconfigures into Hierarchy, not when the Hierarchy reconfigures into an Edge. The Hierarchy, reconfigured into an Edge, suffers no degradation in performance (as defined by time and accuracy), and in fact, appears to thrive and excel in its new Edge configuration.

The implications of these two results could conceivably have extensive ramifications for the design of command and control processes, and deserve both further experimental scrutiny and careful consideration by policymakers. Consider, as an example, disaster relief operations. For those at or first to arrive on the scene of a disaster, rescue and relief efforts are often characterized as chaotic, uncertain, and complex. Previous and concurrent computational modeling suggests Edge configurations are preferable in such contexts [34,38]. During relief operations, stakeholders surface to make demands on already stretched resources, while service providers arrive and attempt integrate their capabilities into ongoing rescue/relief efforts [85-87]. Although military organizations have long been involved in disaster relief efforts [88-90], few, if any, laboratory experiments have informed senior defense officials as more optimal command and control structures for integrating military capabilities into disaster relief operations. While nascent and preliminary, our empirical investigations suggest that given overarching goal clarity, military units assigned to disaster relief missions and vested with Edge-like characteristics could outperform similar military units assigned to disaster relief missions and managed via a more traditional Hierarchy command and control structure. Certainly, this assertion is broad and sweeping, and instantiation of Edge-like command and control processes versus Hierarchal command and control processes for military units requires further reflection and discourse that would not prove insignificant. At an abstract, basic level, however, our findings suggest that wholly antithetical thinking about traditional military command and control processes may be a useful step toward designing high-performance organizations for complex, chaotic environments.

Implications for Future Research

The ELICIT laboratory environment, coupled with robust research design, offers an opportunity for researchers to explore organizational dynamics in microscopic detail, particularly at the size of a mid-sized workgroup or even small firm. With a sizable portion of experimental findings about team performance derived from experimentation on groups sized at two to nine individuals ([104-109]), , incorporating 17 players in the ELICIT environment provides *laboratory* experimentation with group sizes that have generally been reserved for field studies (see, e.g., cf. [110] for a field study involving multi-sized groups from under 5 to over 20) or computational experimentation (see, e.g., [38]). Log files automatically scribe essential data that could assist researchers with exploring hypotheses from a plentitude of theoretical domains, and additional data collection can complement software logs as the research design requires. In this section, we offer some initial thoughts about extending this research program.

Edge vs. Hierarchy

The Hierarchy, often considered an instantiation of Weber's [69] bureaucratic structures and Mintzberg's [37] Machine Bureaucracy, is a long-studied phenomenon within social science. Yet other forms of organizing clearly exist, and the study of these organizational forms materializes as a diverse and sometimes even contentious stream of research within organizational studies [e.g., 47,48,49,50]. Further, recent advances in our conceptions and instantiations of self-organization [91,92], complexity theory, worker/employee empowerment [93] and innovation labs [94] point to a growing body of empirical studies and theoretical frameworks that can serve to inform investigation of Edge, or Edge-like, organizations. The research presented in this work, coupled with our complementary computational experimentations, draws from and extends upon these traditions, and we ground our efforts in organizational theory by instantiating differences between the two organizational forms from an information-processing perspective [52]. We thus contend that one manner in which researchers can differentiate organizational forms is through a detailed understanding of how the agents within each form receive, process, store and exchange available information.

The ELICIT framework is particularly suited to investigations grounded in this framework, as the primary manipulations relate to the exchange and storage of information, and to some extent, knowledge, among the participants. The results presented in this paper, however, merely scratch the metaphorical surface of the investigations made possible with the data, and in particular, offer coarse (albeit important baseline) insights into how the Edge performs compared to a more traditional and well-known organizational form, the Hierarchy. Realizing the full potential of this information processing perspective toward organizational design in general and comparing organizational forms in particular, however, requires a commitment to cogently expressing high-level, but often nebulous, concepts into experimental observables. For example, the terms "decision rights" and "distribution of power" are often articulated as varying among organizational forms. However, how these and like concepts can (and should) be instantiated in the ELICIT environment remains an area for future consideration. We are hopeful, however, that our results serve as encouragement for considering the ELICIT laboratory experimentation as an opportunity for both mid-range theory testing and finely honed micro-theorizing, particularly as these investigations relate to Hierarchy and Edge forms.

Incentives

The relationship between incentive structures and both organizational performance and organizational learning, for example, represent major unknowns with regard to Edge organizations. Our analysis considers time and accuracy as separate dimensions of performance, and we normalize both factors across all 16 groups. We discover that variance in time from one round to the next for the two groups that played a single organizational configuration consistently (i.e., Edge-only or Hierarchy-only) is not significant. At first glance, these findings appear surprising, but we attribute the results as evidence that our incentive structure emphasizes accuracy over time. A subject "wins" the game if he or she offers the most correct solution among his or her peers, regardless of how quickly he or she provides the details about the terrorist attack. The findings suggest that unearthing incentives that emphasize accuracy *and* time in mid-sized groups is a challenging task, and our work to date requires significant refinement. However, the results reported in this paper offer a baseline against which other experimentation on incentive structures could be referenced.

Motivation and Organizational Learning

For our experimentation, evidence of organizational learning thus becomes primarily instantiated in improved accuracy– i.e., since is time is relatively stable, we expect each group's *accuracy* to improve over the previous round of play as evidence of group learning. In both our strict and relaxed criteria,[5] the Edge-only and Hierarchy-only groups demonstrate a steady improvement in accuracy, excepting Round 2 with the Edge group. In this one case, the accuracy appears abnormally high compared to measured, steady improvement (for detail, see Figure 4 in Appendix C). One plausible explanation for this spike in improved performance is the possibility that ELICIT version 3 is less difficult compared to the others. This assertion is buttressed by observing that two of our four groups demonstrate peak performance when playing version 3, and yet is contradicted by two of the four groups demonstrating their peak performance during play of version 1. Another plausible explanation is that if performance is related to motivation, perhaps motivation is highest once the purpose and format of the game is well understood (i.e., when

[5] Generally speaking, the relaxed criteria described here accepts linguistically similar answers as correct across all four rounds, and thus ignores some of the nuance available in current versions of ELICIT. For example, in two of the ELICIT versions, articulating the fully correct answer of the intended target of the terrorist attack (i.e., the "what") involves subjects providing a modifier-noun combination (e.g., "corporate headquarters," "subsidiary headquarters") instead of providing an unmodified noun (e.g., "headquarters"). Under our strict schema, the answer of "headquarters," if the correct answer is "subsidiary headquarters," is considered incorrect. Under our relaxed schema, "headquarters" is considered correct. The relaxed schema thus provides greater between-group consistency for evaluating subject responses among all four ELICIT versions. The experimental trade off is reducing our ability to explore how the various groups respond to variance in task complexity.

task clairty is high) and the experience is still somewhat novel (i.e., when the task appears non-routine and/or out of ordinary)—i.e., during Round 2, when version 3 of the game is played. We leave the answers to such questions to future researchers, but offer that the results presented in this work could serve as a baseline for a family of research questions related to the relationship between motivation theory and performance.

CONCLUSION

The *Edge* is a relative newcomer to organizational design, but it is emerging as an important organizing concept for contemporary military operations. Little is known, however, about the performance of Edge organizations relative to alternatives, leading to the current campaign of Edge research. The campaign investigates the Edge using complementary computational, field, and laboratory techniques, and the work presented here offers preliminary analysis of our laboratory experimentation. The experiments lead us to refine our hypotheses about the Edge, its learning curve, and its performance through direct comparison against the better-known Hierarchy in a laboratory setting. The laboratory setting allows us to adequately control for many variables—such as rank, gender, assignment of persons to particular roles, allowable patterns of communication—that field experimentation does not. Our results are thus based on the carefully executed manipulations of experimental research.

In the course of experimentation, we discover unexpected attributes of both Edge and Hierarchy organizations, including empirical measures of the costs associated with transforming from one form to another. In so doing, we contribute an empirical baseline for ongoing discussions about resource ramifications associated with *dynamically* transforming organizations. Parts of our analysis confirm the results of earlier and companion computational experimentation – chiefly, that Edge organizations outperform Hierarchy organizations in certain task and environmental contexts, and in terms of certain performance measures. Yet, our experimentation also serves to inform future computational experimentation and extend existing computational models through our observations that: 1) Edge and Hierarchy organizations learn at the same rate, but the Edge experiences greater volatility in its learning, 2) transforming from Hierarchy to Edge results in either similar or improved performance on subsequent tasks, and 3) transforming from Edge to Hierarchy results in degraded performance initially, with subsequent recovery to previous levels.

Beyond testing a series of hypotheses and refining our predictions about the Edge with greater clarity and detail, we suggest that the ELICIT experimental environment, coupled with a fastidious research design, provides the opportunity to investigate research questions related to team decisionmaking at well beyond the usual team investigative size of two to six individuals. Our work is grounded in information processing theory, and we suggest that the ELICIT environment is particularly suited to this theoretical framework. Our operationalization of important concepts (e.g., Edge and Hierarchy in a complex collaborative task, bi-dimensional performance) contributes to both the empirical and theoretical literatures. It also suggests further opportunities for organizational theorists to define more abstract concepts (e.g., “decision rights” or “empowerment”) in the context of Galbraith’s conceptions about how organizations process information. Such clarification and understanding will greatly assist efforts to bridge latent variables with experimental observables, and advance our understanding of the internal organizational dynamics of Edge and other organizational forms. We recognize that other areas of organizational theorizing (e.g., studies on leadership, motivation, incentives, etc) could be easily incorporated into the Edge campaign of experimentation, and we hope we have provided a sound empirical baseline against which such discussions can continue to unfold.

APPENDIX A – PARTICIPANT INSTRUCTIONS (GROUP A)

Instructions

You have been assigned to an Edge organization. Your goal is to identify details about an impending terrorist attack. You may communicate to other players in two ways: 1) sharing and posting factoids via the software posting factoids to websites, and 2) sending "postcards." You may also pull factoids from websites. Verbal communication is not permitted during the game.

Sharing, posting and pulling factoids via the software

The software supports two ways of informing group members about factoids you have "discovered." You can **Share** a factoid directly with another group member using the Share tab. You can also **Post** a factoid to or **Pull** a factoid from any website. Other group members can do the same.

There are four websites: Who, What, Where and When. Though these areas are called websites, the information display is provided by the experiment software and not by the Internet.

- Factoids in your inbox can be copied into your MyFactoids list by selecting the factoid and clicking on the **Add to MyFactoids** action.
- To **Share** a factoid, select the factoid from either your inbox or your MyFactoids list that you wish to share. Click on the **Share** action, and select the pseudonym of the person with whom you want to share. This sends the factoid to the selected player's inbox message list.
- To **Post** a factoid, select the factoid from your inbox or MyFactoids list. Click on the **Post** action, and select the website you wish to post to.
- To **Pull** a factoid, select the factoid you wish to copy from the website and click on the Add to MyFactoids action. The **Add to My Factoids** action can be used to copy a factoid from a website to your MyFactoids list.

Sending "Postcards"

Periodically during the experiment, you will be asked to send a "postcard" to one other player of your choosing. You do NOT have to send the postcards to the same player each time. The postcard should reflect your assessment of the attack details at that point in time. Your postcards must have the following format:

Postcard

From: <your pseudonym> Date:
To: <addressee's pseudonym> Time:

My assessment of the attack is:	Certainty			
Group: ________________________	High	Moderate	Low	None
Target: ________________________	High	Moderate	Low	None
Country: _______________________	High	Moderate	Low	None
Month: ________________________	High	Moderate	Low	None
Day: __________________________	High	Moderate	Low	None
Time of day: ____________________	High	Moderate	Low	None
Method of attack: ________________	High	Moderate	Low	None

Other software tools

Some other tools are available to you in the software:

- To get a summary list of all the factoids in your MyFactoids list, click on the MyFactoids tab in the middle of your screen.
- To find out your role information and how other members of your group see you, click on the "How I'm seen" tab.
- To get a list of all the members in your group, with information about their role and country, click on the "What I see" tab.
- To access information from a team website, click on the website that you wish to view. To update the website with the latest information that has been posted to it, click on the Refresh action at the top of the screen, while viewing the website.

Identifying the Who, What, Where, and When of the Attack

When you think that you have identified the who, what, where and when of the adversary attack, click on the **Identify** tab at the top of your screen and enter free text messages that identify the who, what, where and when of an adversary attack. **Partial answers are accepted, but you may Identify only one time**.

- The who is a group (for example the blue group).
- The what is a type of target (for example an embassy or religious school or dignitary)
- The where is the country in which the attack will take place (for example Alphaland)
- The when is the month, day and time of day on which the attack will occur (for example December 15, at 3:00 a.m.)

During the game

During each experiment round, you are free to work on any aspect of the task.

Winning the Game

Once all the players have identified a solution and the surveys are complete, you will be asked to determine who emerged as the 'team leader' during this round. Your selection should reflect a group consensus. After the game has been played, you may talk amongst each other to select the emergent team leader. Verbal communication is not permitted during the game, but is permitted once all of the surveys are complete and you are selecting your emergent team leader.

The games are structured as a tournament that recognizes the contributions of both individuals and groups. You receive one individual point **if you identify the correct solution and your emergent group leader identifies the correct solution**. Your group receives a group point if your emergent **group leader identifies the correct solution**. After the four games are played, the points will be totaled. You can receive a maximum of four individual points during the tournament, and your group can receive a maximum of four group points. In the event of an individual tie (e.g., 11 players identify four correct solutions and the emergent group leader identifies the correct solution in all cases), the fastest individual average time to identify wins. In the event of a group tie (e.g., all group leaders identify the correct solution), the fastest average time for the group to identify will win. **Therefore, it is in your best interest to identify the correct solution as quickly as possible while also ensuring that your emergent group leader identifies the correct solution as quickly as possible.** You may only use the 'identify' function in the software one time.

Game Over

The game is over when all players have made their identification, or 60 minutes have elapsed (whichever is sooner). You will also be asked to complete a different short survey at the end of the experiment.

Summary

You have been assigned to an edge organization. This assignment affects how you can communicate with other players.

- Sharing factoids: You may share factoids with any player of your choosing, and you may share any single factoid as many times as you wish. Factoids are shared via the ELICIT software.
- Sending postcards: You may send a postcard to any player of your choosing at specified intervals.
- Posting to websites: You can post any factoid to any website of your choosing.
- Pulling from websites: You may pull factoids posted on any website.

You can refer to these instructions during the course of the experiment by clicking again on the URL in the moderator message.

When you have finished reading this important group background information and are ready to begin, click the Ready button in the upper left corner of your screen.

Thank you for playing, and good luck!

	Edge
I want to:	
Share a Factoid	Factoids can be sent to any other player via the software
Send a Postcard	Handwritten postcards can be sent to any other player
Post a factoid to a website	Factoids can be posted to any website via the software
Pull a factoid from a website	Factoids can be pulled from any website via the software

Table 3: Quick Reference Table -- Edge

Note 1: Instructions were adapted from those originally created by Parity Communications
Note 2: Groups B, C and D, as listed in Table 1, were provided short descriptions of Edge or Hierarchy organizations in the instructions.

Appendix B – Subject Demographics

ELICIT Knowledge Inventory Questionnaire

Directions
Please complete this questionnaire candidly. Your information will kept in confidence, and will be used for anonymous statistical analysis and reporting purposes only. If you have any questions or concerns, please consult the Experiment Moderator.

Your name: ____

Today's date: ____

1. What is your age in years? ______________________

2. How many years of work experience do you have since college graduation? ______________

3. Please list each college degree, major, institution and date separately (e.g.,
BS, Economics, UC Berkeley, 2000
MS Information Sciences, Naval Postgraduate School, 2004)

____

____

____

____

4. How many years of military/government experience do you have? _____________________

5. In which military/government branch do you work (e.g., Army, Navy)? ___________________

6. What is your current rank (e.g., O4/LCDR, GS13)? ______________________________

7. What is your area of greatest military expertise (e.g., artillery, aviation) _________________

____

8. How many years' experience do you have in this area? _____________________________

9. How many years' experience in the intelligence field do you have? ____________________

10. What is the greatest number of people that you have supervised? ____________________

Appendix C – Performance by Experimental Group

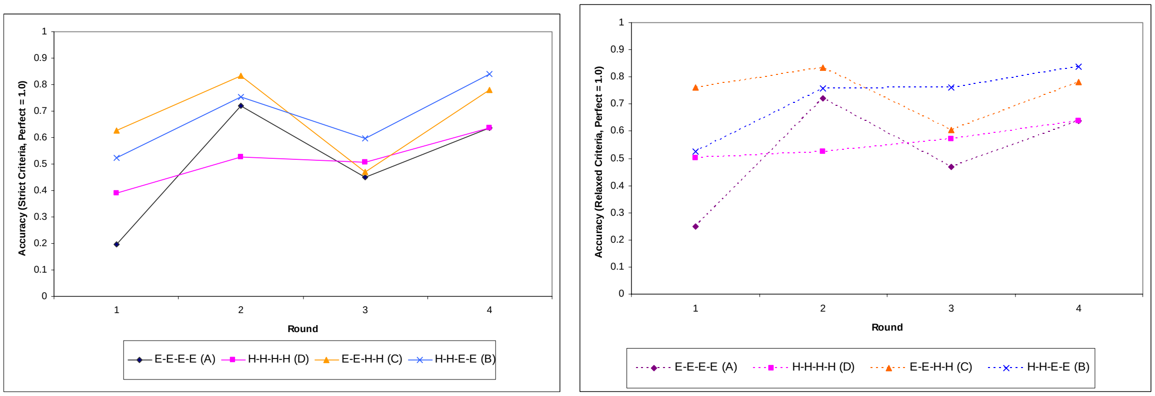

Figure 4: Observed Accuracy (Strict Criteria – left, Relaxed Criteria - right), Groups A-D

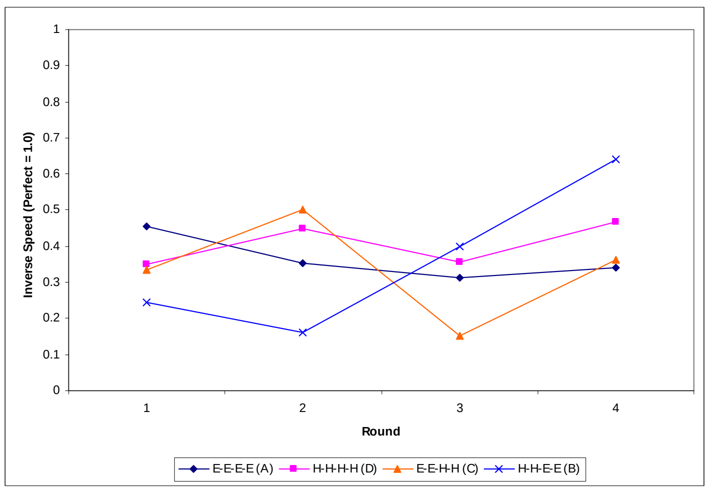

Figure 5: Observed Time, Groups A-D

Appendix D – Performance by Primary Manipulations

			Organizational Form		
			Edge	**Hierarchy**	**All**
Mental Models	**Exchanged**	*Time*	μ : 0.47 σ: 0.19	μ : 0.25 σ: 0.19	μ : 0.37 σ: 0.22
		Accuracy	μ : 0.75 σ: 0.27	μ : 0.69 σ: 0.26	μ : 0.72 σ: 0.26
		No response	1	6	
	Not Exchanged	*Time*	μ : 0.45 σ: 0.17	μ : 0.47 σ: 0.10	μ : 0.45 σ: 0.14
		Accuracy	μ : 0.61 σ: 0.35	μ : 0.60 σ: 0.25	μ : 0.61 σ: 0.31
		No response	11	6	
	All	*Time*	μ : 0.47 σ: 0.18	μ : 0.33 σ: 0.20	
		Accuracy	μ : 0.69 σ: 0.31	μ : 0.66 σ: 0.26	

Table 4: Descriptive Statistics for Two Dimensional Performance

	Form	Mean	Std. Deviation	N
Learning - Time	Edge	.0640	.13202	5
	Hierarchy	.0500	.13058	5
	Total	.0570	.12401	10
Learning - Accuracy	Edge	.1880	.27779	5
	Hierarchy	.1580	.12357	5
	Total	.1730	.20331	10

Table 5: Learning vs. Organizational Form

		Organizational Form	Mental Model	Experimental Group	ELICIT Version
Organizational Form	Correlation Coefficient	1.000	.044	.185**	-.008
	Sig. (2-tailed)	.	.523	.007	.906
Mental Model	Correlation Coefficient		1.000	.877**	.016
	Sig. (2-tailed)		.	.000	.815
Experimental Group	Correlation Coefficient			1.000	.001
	Sig. (2-tailed)			.	.994
ELICIT Version	Correlation Coefficient				1.000
	Sig. (2-tailed)				.
	N	210	210	210	210

** Correlation is significant at the 0.01 level (2-tailed).

Table 6: Spearman's Rho Correlation Coefficients for Independent Variables

Appendix E – Operationalization of Accuracy

	Correct answer	**Subject 1 identification**	**Accuracy (points)**	**Subject 2 identification**	**Accuracy (points)**
Who (Group)	Tan	Tan or Blue	0	Tan	1
What (Target)	Omegaland's chancery	Chancery	0	Chancery of Omegaland	1
Where (Country)	Betaland	Omegaland	0	Betaland	1
When (Month)	June	June	1	May or June	0
(Date)	15	15	1		0
(Time)	3 p.m.	1500	1	3	0
	Normalized Accuracy measure		$A=\frac{0+0+0+\frac{(1+1+1)}{3}}{4}=0.25$		$A=\frac{1+1+1+\frac{(0+0+0)}{3}}{4}=0.75$

Table 7: Illustration of Accuracy Measurement (Strict Criteria)

	Correct answer	**Subject 1 identification**	**Accuracy (points)**	**Subject 2 identification**	**Accuracy (points)**
Who (Group)	Tan	Tan or Blue	0	Tan	1
What (Target)	Omegaland's chancery	Chancery	1	Chancery of Omegaland	1
Where (Country)	Betaland	Omegaland	0	Betaland	1
When (Month)	June	June	1	May or June	0
(Date)	15	15	1		0
(Time)	3 p.m.	1500	1	3	0
	Normalized Accuracy measure		$A=\frac{0+1+0+\frac{(1+1+1)}{3}}{4}=0.50$		$A=\frac{1+1+1+\frac{(0+0+0)}{3}}{4}=0.75$

Table 8: Illustration of Accuracy Measurement (Relaxed Criteria)

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