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Metrics, Analysis and Methods for the Exploitation of ELICIT Experimental Data

Topic: Network-Centric Experimentation and Analysis

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Title:

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Abstract:

The Command and Control Research Program (CCRP) has been involved in experimentation activities to investigate the C2 impact of cognition and collaboration processes, the distribution of decision rights, patterns of interaction, the structures of information flow, and other net centric related concepts. As a part of that effort, the CCRP has sponsored the design and development of a software environment for conducting human-in-the-loop experiments focused on information- and social-domain phenomena. This experimental environment, named ELICIT (Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust), presents a group of 17 players with an information distribution and assembly problem to explore how people share information and generate shared awareness. Experiments conducted to date using the ELICIT platform have generated a rich set of data, which, given current and emerging interest, is expected to continue to accumulate. To help the community effectively exploit these data, we have conducted illustrative analysis that suggests useful metrics for quantities of interest and methods for data extraction, analysis and visualization. This paper describes a set of metrics, analyses, and methods that may be useful to other members of the ELICIT community of interest, and that demonstrate the types of insights that can be gleaned from ELICIT experimentation.

Background

The Command and Control Research Program (CCRP) is involved in experimentation activities to investigate the C2 impact of cognition and collaboration processes, the distribution of decision rights, patterns of interaction, the structures of information flow, and other net centric related concepts. The CCRP has sponsored the design and development of a software environment for conducting human-in-the-loop experiments focused on information- and social-domain phenomena. This experimental environment, named ELICIT (Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust) will provide the community with the capability to analyze the cognitive and social impacts of C2 approach and organizational structure, primarily focusing on information sharing, trust, shared awareness, and task performance.

Objectives

Over the last year, the ELICIT experimentation environment has matured and gained a great deal of interest. Several data sets already exist and more are expected to accumulate. The CCRP wishes to exploit these data to begin harvesting illustrative research results. By exploring these data, analysts can gain insights into the factors influencing important aspects of command and control (C2) quality, particularly the generation of shared awareness. This effort begins to build organized knowledge about information sharing and shared awareness under different organizational conditions and with different types of participants. More importantly, it demonstrates the value of the information that can be gained by conducting experiments using the ELICIT platform.

The primary purpose of this work was not to draw conclusions, but to provide illustrative and exemplar analyses to demonstrate what can be done with the data that arises from the ELICIT experiment and to provide and identify tools to facilitate future analyses.

A great deal of interesting and rich analyses can be conducted using the ELICIT platform and experiment metadata. This paper summarizes our raw data manipulation, illustrative analysis, and statistical studies to give examples for future work. Our hope is that the community as well as others such at the Naval Postgraduate School[1] and the US Military Academy[2], will build upon these technologies to enrich ELICIT.

What is ELICIT?

The ELICIT experimentation environment presents a group of 17 players with an information distribution and assembly problem to explore how people share information

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[1] 12th International Command & Control Research & Technology Symposium, June 2007
Tara A. Leweling and Dr. Mark E. Nissen. Hypothesis Testing of Edge Organizations: Laboratory Experimentation using the ELICIT Multiplayer Intelligence Game

[2] 12th International Command & Control Research & Technology Symposium, June 2007
Joshua Lospinoso and Dr. Frederick Moxley. The ELICIT Experiment: Eliciting Organizational Effectiveness and Efficiency under Shared Belief

and generate shared awareness. In the experimental scenario, subjects receive information about a future attack. Sixty eight information factoids containing information related to the party carrying out the attack, the form the attack will take, the time of the attack, and the location of the attack, namely the who, what, when, and where of the problem. Factoids are introduced into the system by the server operating the experiment. Two factoids are distributed to each participant at the start of the game. A third factoid is distributed to each participant after 5 minutes and a fourth after ten minutes. Each factoid contains key, supportive, or extraneous information; no factoid contains false information. The information is structured so that various sets of factoids combine to allow one of the four information areas to be solved.

The participant's mission is to gain a sufficient amount of knowledge to solve or identify each of the four question areas by combining and sharing the information to which they have access. Each subject is able to transmit his known facts in two ways. Peer-to-peer sharing allows a participant to share a factoid directly with another participant. Factoids may also be broadcasted by posting a factoid to a commonly available website. Participants can check the websites and view posted factoids. The act of viewing a website is referred to as a pull, given the assumption that a participant views a website to search for factoids and extract information from postings. When a participant feels they have seen/collected enough factoids to develop an understanding of the solution, they can identify a four part answer. The number of ID attempts can be controlled by the experiment facilitator. In the existing data sets, the number of ID attempts is restricted to single submission in some runs, while other runs allow an unlimited number of IDs.

Networked Organization

The C2 approach for the series of experiments analyzed as part of this effort were designated prior to the start of each run. These organizational structures are a traditional hierarchy and an edge or fully connected network. The control variables used in the experiment are expressed as part of these network structures. Each organization is made up of seventeen participants. Communication lines exist between participants (peer-to-peer) and between participants and websites. In each organizational structure, the peer-to-peer communication capabilities are the same, in other words every participant can communicate directly with all other participants. However the two structures largely differ in website accessibility. In the hierarchy, participants are divided into four task groups each having access to only one website. The seventeenth participant in the hierarchy is the cross team coordinator or the commander who has access to all four task websites. Unlike the hierarchy, all participants in the edge network have access to all four task websites. Website accessibility is depicted in the diagrams below.

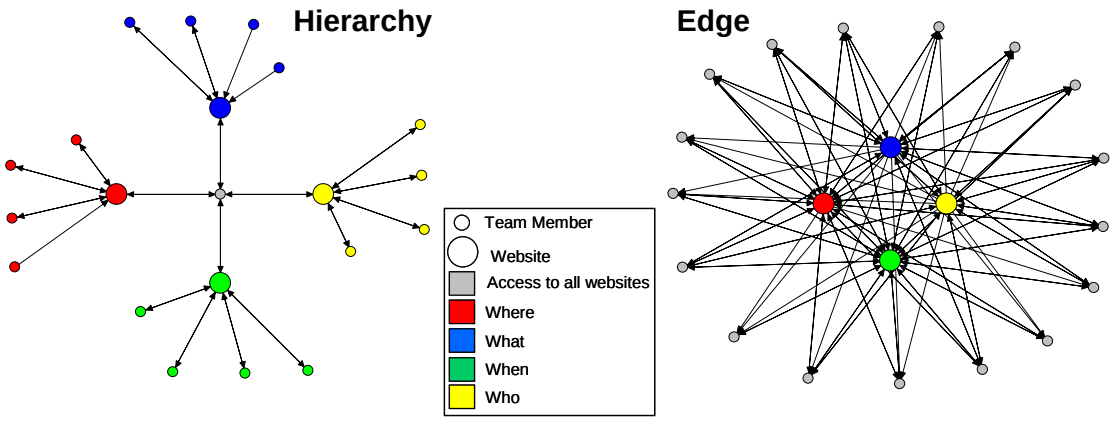


Figure 1. Website Access by Organization Type

Data Collection

Analysis was conducted using output from the ELICIT experimentation platform, including data about the participants and the transaction log generated by the software. The computers used during the experiment record data pertaining to each participant's actions in a transaction log. Metadata is also obtained from the experiment facilitator or gleaned from a post-experiment survey. The metadata pertains to both the experiment itself (location, date, time, number of participants, factoid set, etc.) and the individual participants (experience, expertise, age, level of education, etc.). When assessing the results of these live experiments it is important to view the data in context to be able to attribute certain results to characteristics of the group and/or its constituents.

The illustrative analysis detailed in this paper was accomplished by leveraging data collected during past experimentation efforts to analyze factors affecting shared awareness and suggest how new data might be generated that will increase the value of ELICIT to the community. EBR collected twenty six transaction logs, generated scripts to manipulate and parsed these data to conduct several statistical comparisons to draw preliminary conclusions about the effectiveness of each C2 approach (hierarchy and edge) and demonstrate our analysis approach.

The ELICIT Value Chain

In an effort to organize our effort and covey our analysis process to the larger community, an ELICIT Value Chain was developed. The network structure enables information sharing which allows individuals to develop situational awareness and facilitates mission effectiveness. In order to quantify the organizational structures, and measure the behaviors described in the value chain, we developed a set of metrics. These behaviors measures and indicators of awareness are listed to the right of the value chain.

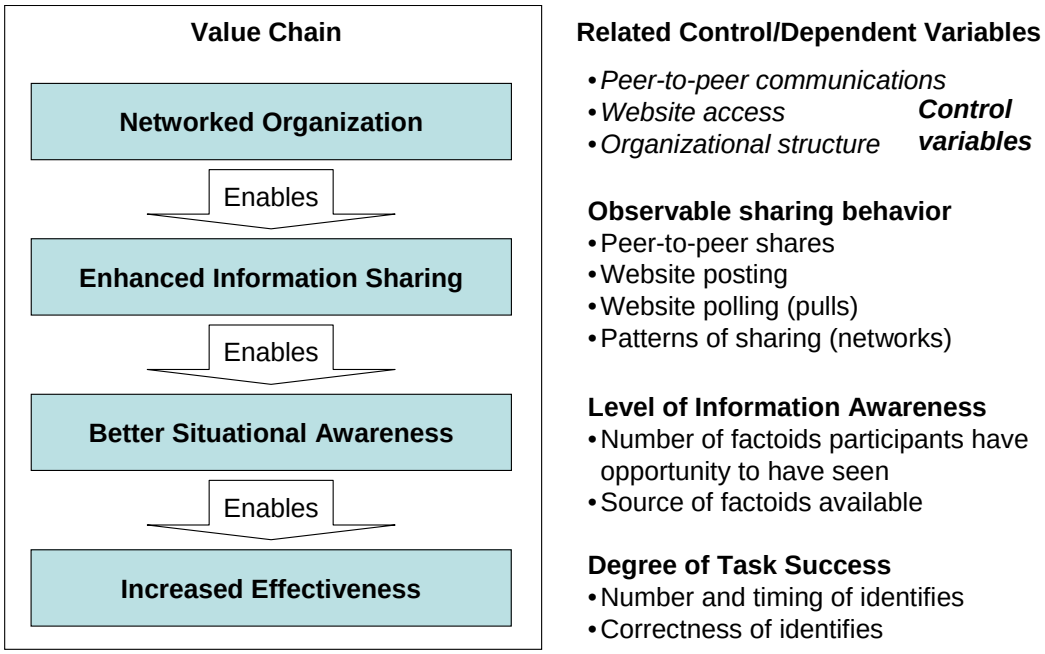


Figure 2. NCO Value Chain for ELICIT and Related Metrics

When possible, these metrics directly map to experimental data, otherwise indirect measures were used. Metrics were developed for information dissemination behaviors, network characteristics, and task success as listed above.

Illustrative Statistical Comparisons

As part of our approach, EBR performed illustrative analyses to examine metrics for different pairs of trials. These analyses enable statistical comparisons and demonstrate how each link of the value chain may differ. The illustrative analysis focused on the following three cases:

- Non-Military v. Military
  - Runs conducted using the edge organization type and factoid set 1.
  - Each set of participants were undergraduate students:
    - Non-Military: Boston University
    - Military: U.S. Military Academy
- Comparisons between national cultures
  - Runs conducted using the hierarchy organization type and factoid set 2.
  - US participant group v. Portuguese participant group
- Undergraduates v. Graduates
  - Runs conducted using the edge organization type and factoid set 1.
  - Undergraduates: U.S. Military Academy
  - Graduates: NPS

Each of these runs was chosen to enable specific comparisons. Our team tried to identify pairs of runs with similar trial factors except for the subject of comparison to draw meaningful conclusions.

Once our three statistical comparisons were complete we conducted an overall analysis to compare the behaviors, awareness levels, and performance measures for the two network structures (hierarchy v. edge) across twelve data sets (baseline runs).

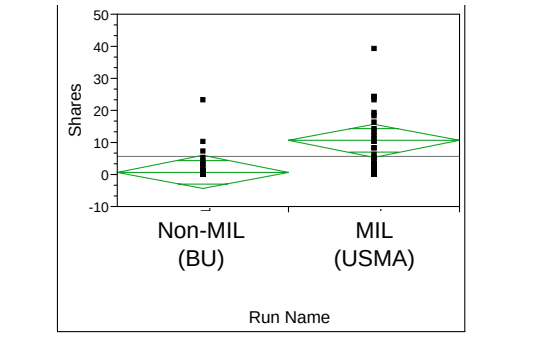
Illustrative Analysis

Enhanced Information Sharing

Information sharing was measured using data collected on information dissemination behaviors. These data are comprised of sharing actions such as peer-to-peer share, website posting (posts), website polling (pulls), and patterns of sharing (network measures). The number of posts, pulls, and peer-to-peer shares, were measured over time in ten minute intervals.

<u>Analysis of Direct Sharing Data (Peer-to-peer Sharing)</u>

When analyzing the direct sharing actions in the Non-Military v. Military comparison, the Military participants performed significantly more peer-to-peer sharing than the Non-Military participants as shown in the first figure below. The second figure shows that the direct sharing rate of the Military group increases over time while the rate remains fairly low and steady for the Non-Military run.



Oneway Anova

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Run Name	1	4140.71	4140.71	7.1257	0.0083*
Error	168	97623.81	581.09		
C. Total	169	101764.52			

Note: USMA shares range up to 200

Figure 3. Shares by Individuals (Non-military vs. Military) (Edge)

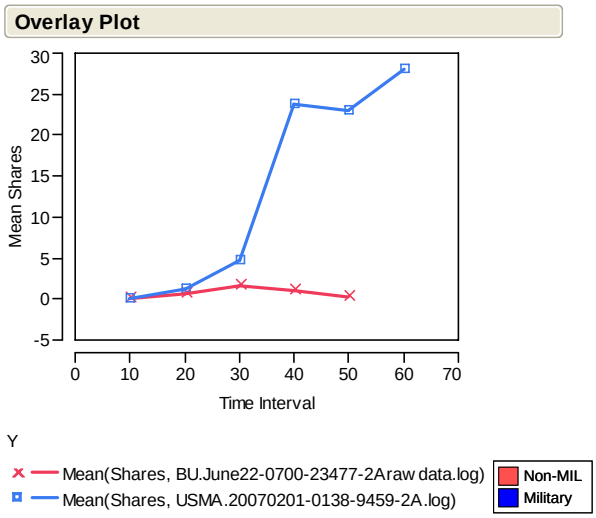


Figure 4. Mean Shares by Time Interval (Non-military vs. Military) (Edge)

Using the graphs below, a comparison of direct sharing among national cultures (US v. Portugal) can be made. The US group performed significantly more peer-to-peer sharing

actions than the Portuguese group. The sharing rate decreases for both groups during the course of the run.

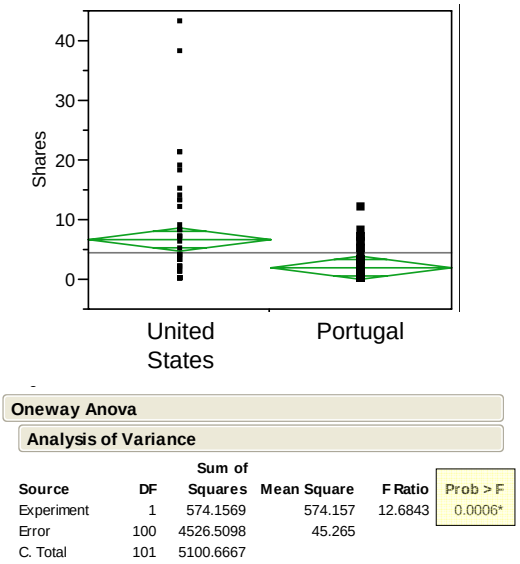


Figure 5. Shares by Individuals (US vs. Portugal) (Hierarchy)

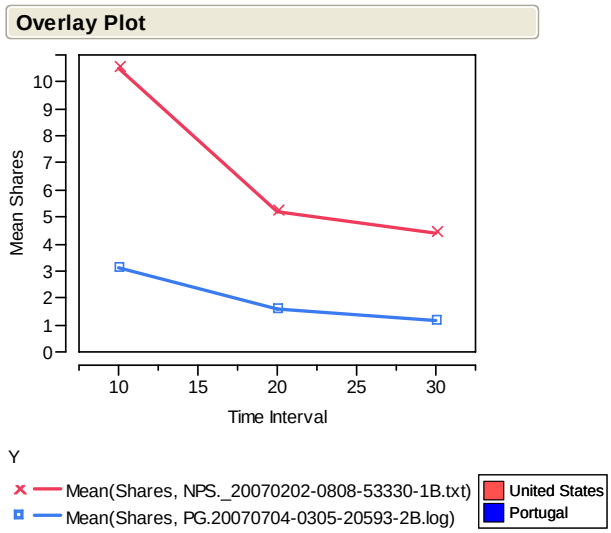


Figure 6. Mean Shares by Time Interval (US vs. Portugal) (Hierarchy)

And finally in the Undergraduates v. Graduates case pictured below, the sharing rate increased over time for both groups. The Undergraduates performed significantly more peer-to-peer sharing actions than the Graduate group.

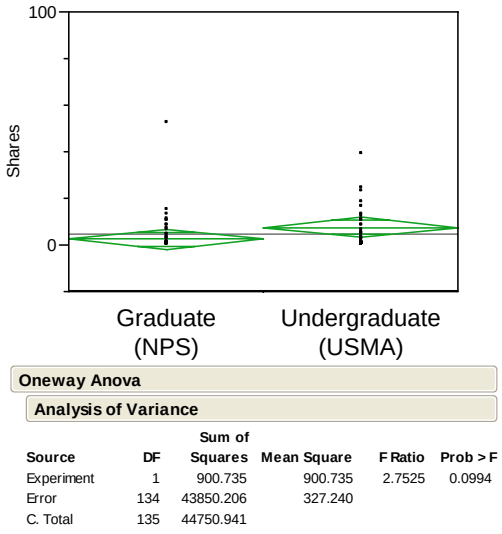


Figure 7. Shares by Individuals (Undergraduate vs. Graduate) (Edge)

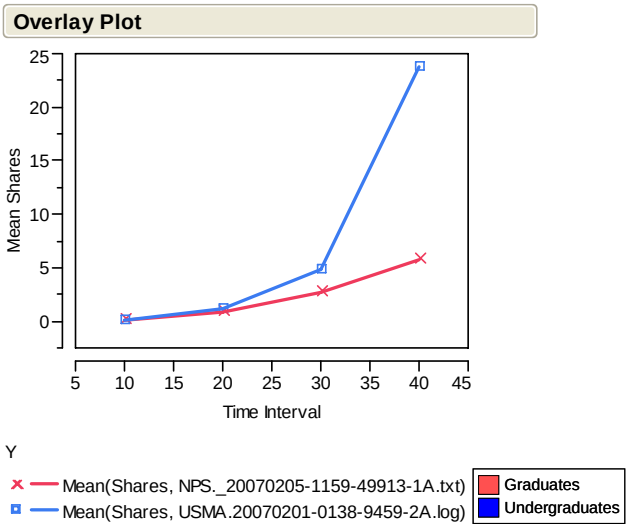


Figure 8. Mean Shares by Time Interval (Undergraduate vs. Graduate) (Edge)

In general the Military group performed more peer-to-peer sharing actions than any other group. In addition, for those illustrative trials where peer-to-peer sharing was present, the

number of shares increased over time in the edge trials and decreased over time in the hierarchy trials.

When reviewing the overall analysis of Edge v. Hierarchy, there is not a significant difference in peer-to-peer sharing for the two organization types. However peer-to-peer sharing in the hierarchy organization declines over time while sharing increases over time in the Edge organization runs as pictured below.

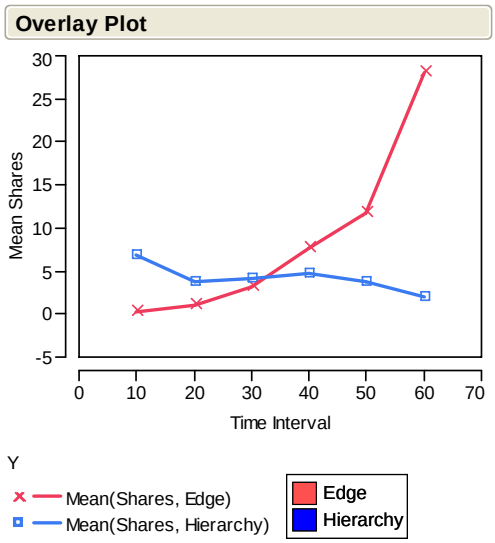


Figure 9. Peer-to-peer Sharing by Time Interval (Hierarchy vs. Edge)

Analysis of Website Posting Data

Analysis of posting actions revealed no significant difference in either the Non-Military v. Military case or the US v. Portugal comparison. There was a statistically significant difference in the Undergraduates v. Graduates case, as the Undergraduate group data reflected a greater number of posting actions as shown in the graphs below.

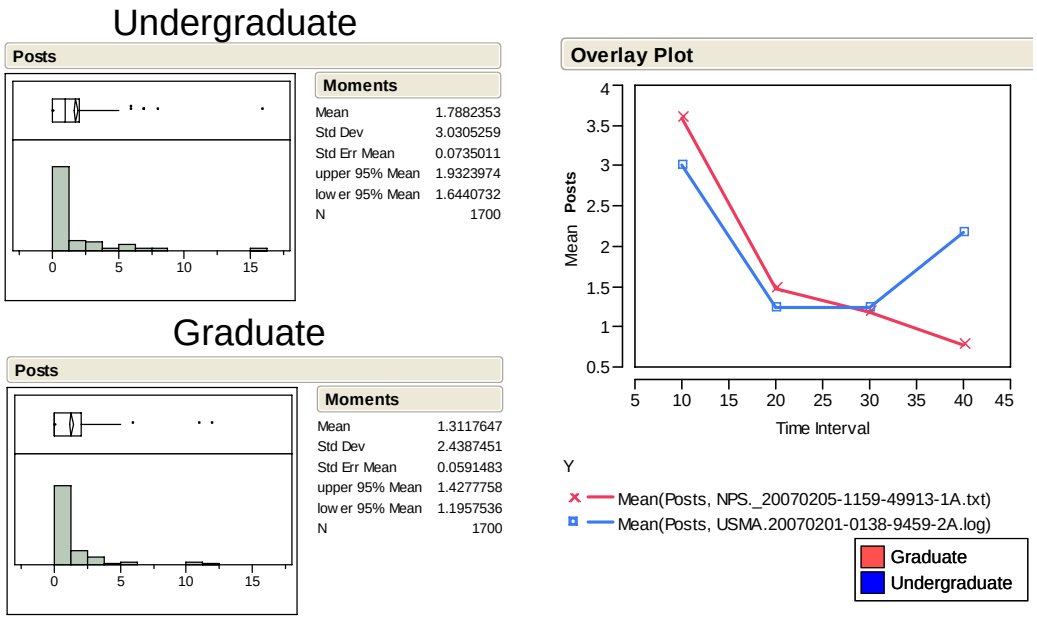


Figure 10. Distribution of Posts and Posts Over Time (Undergraduate vs. Graduate) (Edge Network)

In general, the posting actions were fairly consistent across the organization types in these illustrative analyses. The team observed that in each case participants performed the greatest number of posting actions in the first ten minutes of the run. This may be explained by the time intervals at which new factoids are introduced into the experiment. As stated in the ELICIT description, there are sixty eight factoids in total. At the start of the run, the system server provides each of the seventeen participants with two factoids and so fifty percent of the factoids are released at t = 0 minutes. Five minutes later the server gives each participant a third factoid, thus seventy five percent of the factoids are released at t = 5 minutes. Finally, at t = 10 minutes the server provides each participant a fourth factoid, releasing all sixty eight facts into the system. While participants can perform sharing actions throughout the entire length of the experiment, posting may be more prevalent during the first ten minutes as all participants are guaranteed to have received at least four factoids during that time interval.

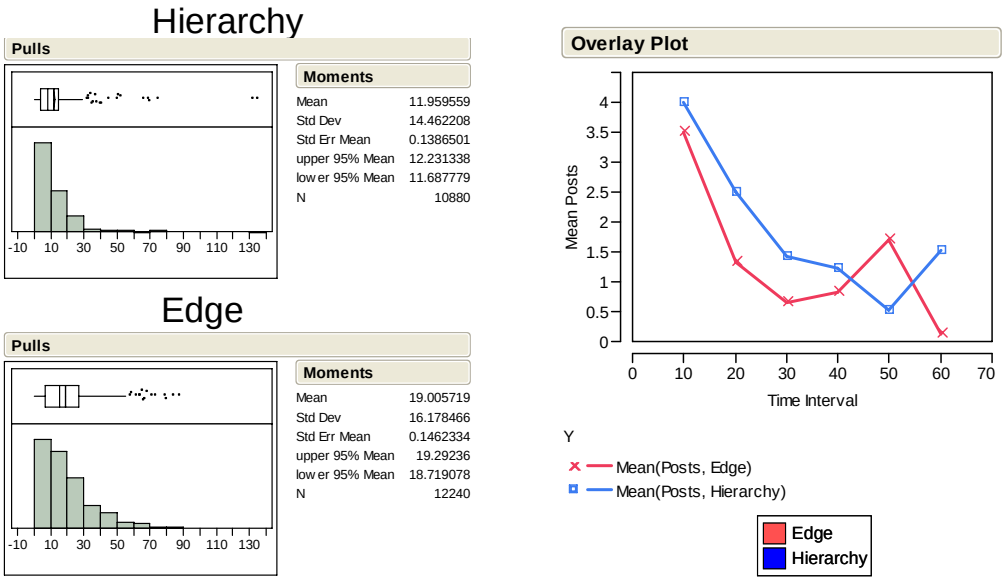


Figure 11. Distribution of Posts and Posts Over Time (Hierarchy vs. Edge)

While there is no significant difference in the posts actions by organization type, this pattern of more frequent website posts in the first ten minute interval holds true in the overall analysis of the Edge v. Hierarchy.

<u>Analysis of Web Pull Data</u>

As explained earlier, the term website pulls refers to the action of a participant viewing a website. Since it is impossible to record what factoids a participants reads or learns from a website, the frequency of website views is assumed to be the act of pulling or seeking information. In the Non-Military v. Military comparison, the Military group pulls are significantly higher than the Non-Military group. In the graph below, we observe a decreasing trend in the rate of pulls performed by each group over time.

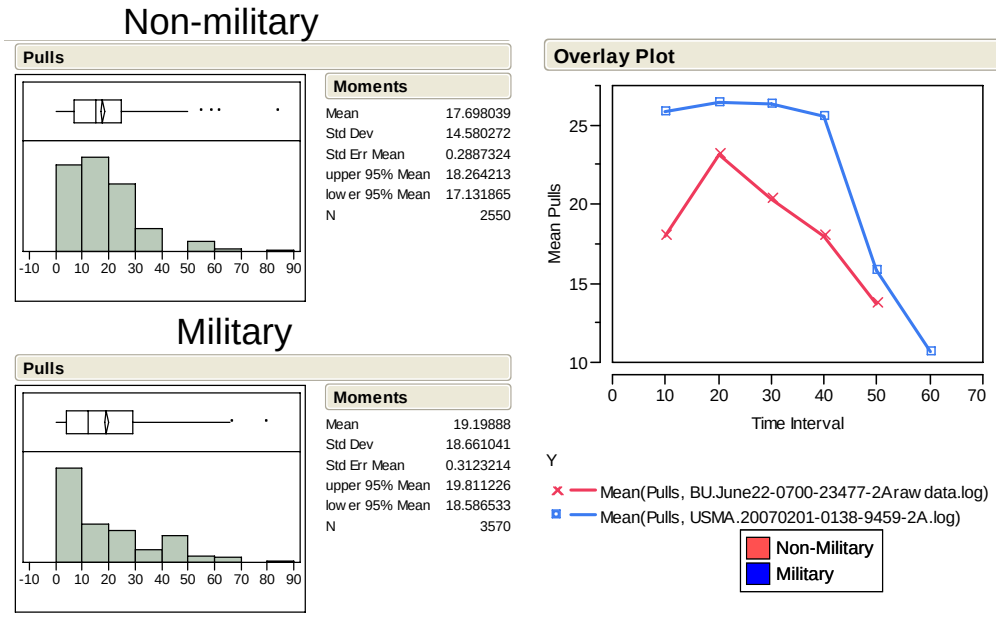


Figure 12. Distribution of Pulls and Pulls Over Time (Non-military vs. Military) (Edge)

No significant difference is apparent in the US v. Portugal comparison. The pull rate of Portuguese participants increases over time while the pull rate remains fairly stable in the US run.

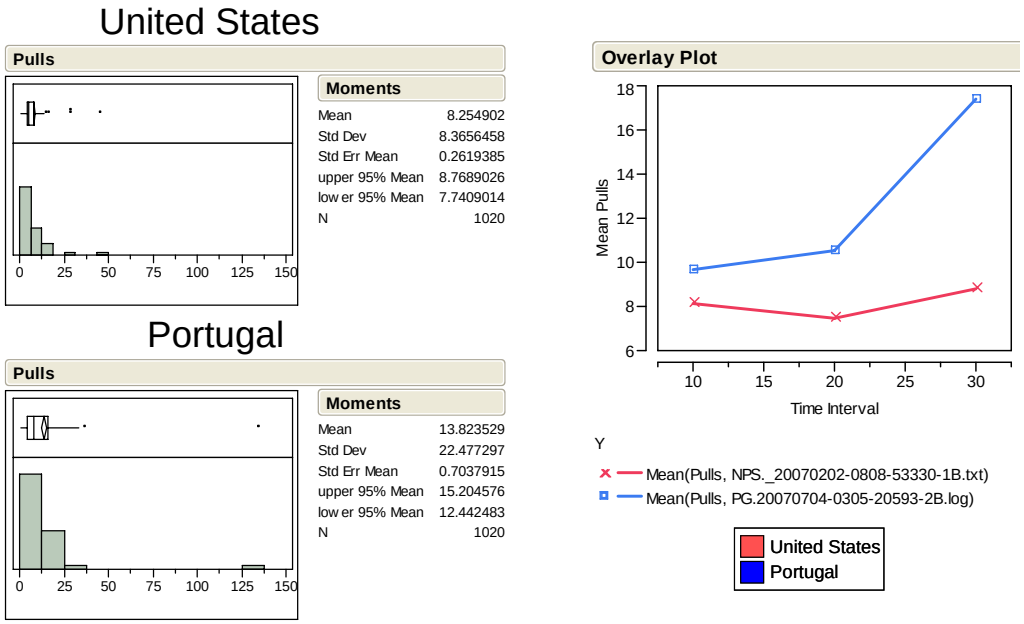


Figure 13. Distribution of Pulls and Pulls Over Time (US vs. Portugal) (Hierarchy)

When analyzing the Undergraduates v. Graduates pulls, the Undergraduates performed significantly more pulling actions than the Graduate group. The pull rate of the Undergraduates remains steady throughout the run, while the pull rate of the Graduate group increases over time.

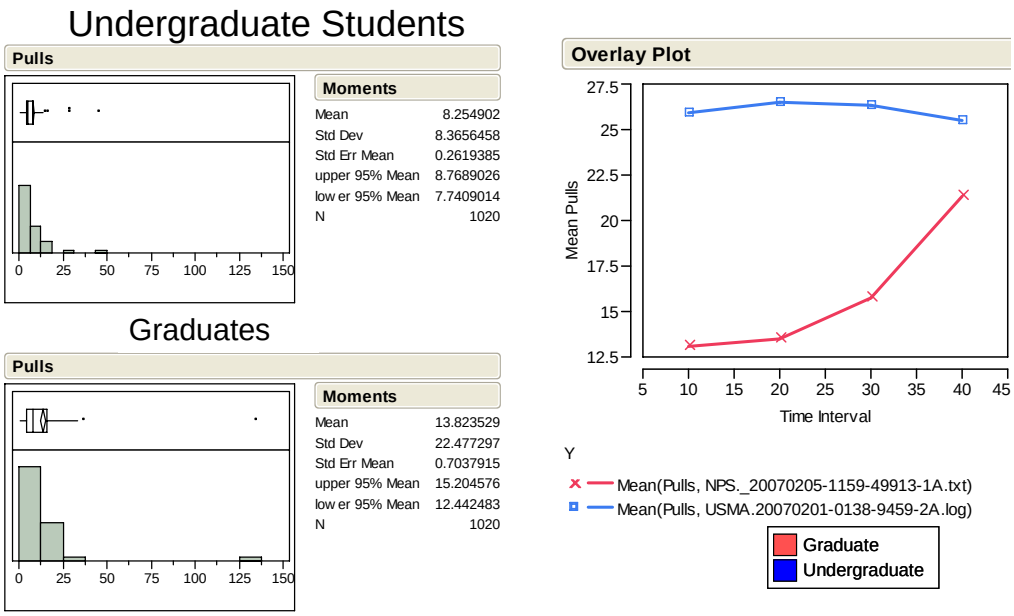


Figure 14. Distribution of Pulls and Pulls Over Time (Undergraduate vs. Graduate) (Edge)

The comparisons between trials display some significant differences, however no dominant pattern emerges. Overall analysis shows a greater number of website pulls occur in the Edge over the Hierarchical organization as displayed below.

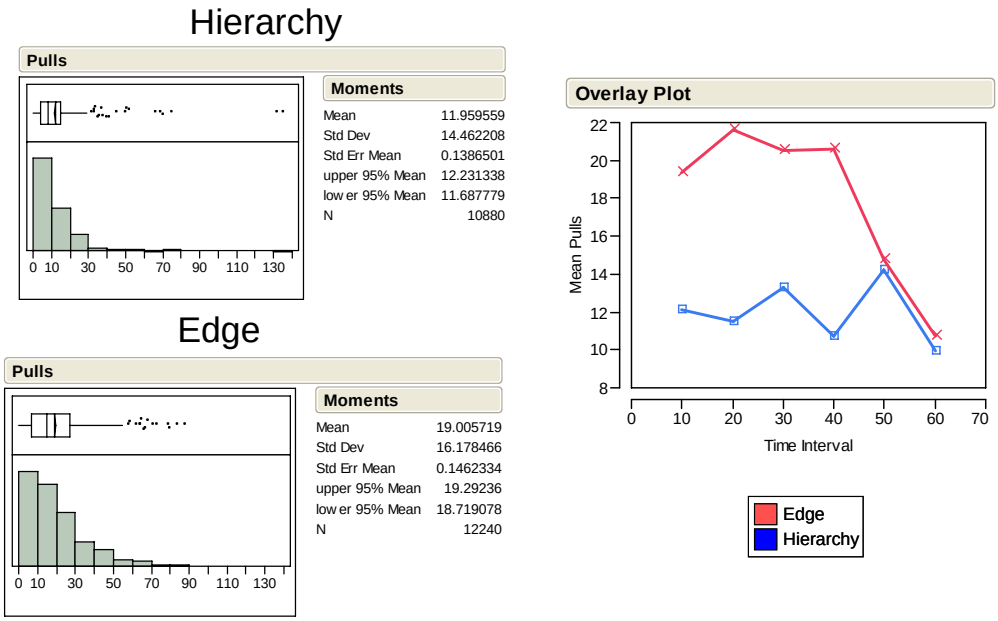


Figure 15. Distribution of Pulls and Pulls Over Time (Hierarchy vs. Edge)

<u>Summary of Information Dissemination Behaviors</u>

When observing all three information dissemination behaviors, we can draw conclusions about which groups performed more sharing actions.

- More information dissemination behaviors exist in the Military group than the Non-Military group.
- The US participants engage in more information dissemination behaviors earlier while the Portuguese group increased information sharing behaviors over time.
- The Undergraduates engage in more information dissemination behaviors while the Graduates increase behaviors over time.

Overall the Edge organizations display more information sharing behaviors than the Hierarchy organizations as shown in Figure 3 below. This is especially true when looking at website polling. It is important to note that the ability for edge participants to access all four websites (three more than sixteen of the seventeen hierarchical participants) may have some bearing on this result.

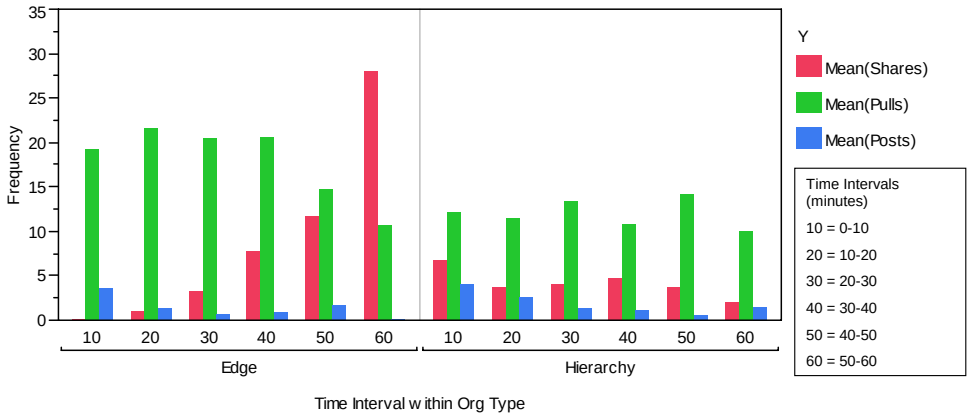


Figure 16. Peer-to-peer Sharing, Pulls, Posts (Hierarchy vs. Edge)

Patterns of Sharing

Network visualizations and metrics can enable insight into differences in the structure of networks that emerge from interactions taking place during the experiment. As part of our analysis we studied transaction networks. In such a network, a link is present between two participants A and B, if at least one factoid from A was passed to B sometime during the course of the experiment, as represented by an arrow. If information transfer also occurred from participant B to participant A, the link would be represented by a double headed arrow. Such a link represents reciprocal transactions within the network. Websites are also included in these transaction networks. A link between participant A and a website exists if at least one factoid from A was posted to that respective website. A link can also exist pointing from a website to participant A if at least one polling action was performed by participant A on that respective website. The width of each link (or line) depicts the arc strength which related to the number of transactions which occurred between the sender and recipient. “Spring-embedding” visualization methods were used

in the transaction networks to help build insight into the differences between the networks being compared. Such differences can help generate hypotheses which can be used in formulating future experimental designs.

For example, below we examine the transaction networks of the Military v. Non-Military Edge Organizations.

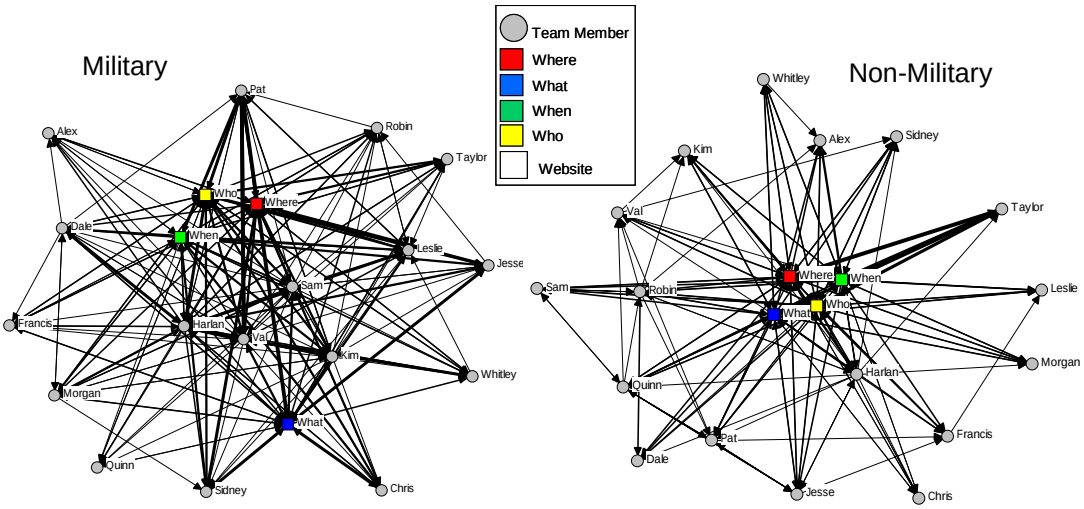


Figure 17. Network Comparisons: Edge Org. (Military v. Non-Military)

There are a greater number of links or transactions in the Military group when compared to the Non-Military group. In addition, the websites are less centrally located within the Military group than in the Non-Military group.

The transaction networks of the US v. Portugal Hierarchy Organizations are pictures below. There are fewer transactions in these experiments. The commander is centrally located within the Hierarchy network while the websites appear along the periphery.

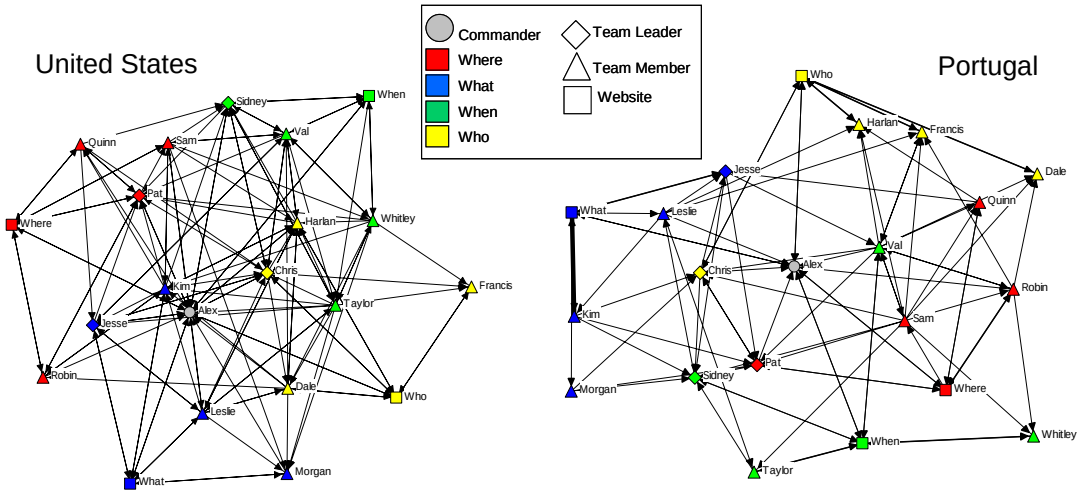


Figure 18. Network Comparisons: Hierarchical Org. (US v. Portugal)

In reviewing the network visualizations for these illustrative cases, the Edge organizations are more richly connected than the Hierarchy organizations. The Edge organizations have a greater number of links and those links are more heavily weighted signifying multiple transactions between entities.

Network metrics were also calculated to help reveal nodes (participants or websites) with relative importance from a network perspective. These metrics can help characterize the nature and symmetry of the network. Network metrics include degree centrality, degree centralization, betweenness centrality, and betweenness centralization. Below we examine these measures for the four illustrative trials used in the example above.

Edge Organization

Military (USMA - 0201)		
	Degree	NrmDegree
Val	20	100
Sam	20	100
Harlan	20	100
Kim	19	95
Where	17	85
Who	17	85
What	17	85
When	17	85
Leslie	14	70
Dale	13	65
Pat	11	55
Robin	11	55
Sidney	10	50
Morgan	10	50
Jesse	9	45
Taylor	9	45
Francis	9	45
Whitley	9	45
Chris	8	40
Alex	8	40
Quinn	8	40

Civilian (BU - 0622)		
	Degree	NrmDegree
Who	17	85
What	17	85
When	17	85
Where	17	85
Harlan	16	80
Robin	12	60
Quinn	10	50
Pat	10	50
Val	9	45
Jesse	8	40
Francis	8	40
Kim	7	35
Alex	7	35
Dale	6	30
Sam	6	30
Sidney	6	30
Taylor	5	25
Leslie	5	25
Chris	5	25
Whitley	5	25
Morgan	5	25

Websites
Where
What
When
Who

Table 1. Degree Centrality (Military vs. Civilian)

In the table above, degree is a measure of how many other entities each participant (denoted by game assigned name) and website (denoted by What, When, Where, Who) interacted with. With twenty one entities in the experiment any one participant can interact with a maximum of twenty other entities. We know that participants post and pull information from websites, but websites do not interact with each other, therefore the maximum degree for an Edge network website is seventeen, the number of experiment participants. The NrmDegree in the tables above normalizes degree to measure degree centrality for each entity. In the Military group, we see that three individuals interacted with all other entities in the experiment, while in the Non-Military group no individual has a greater degree centrality than the websites. Degree centralization measures the heterogeneity of degree centrality. The degree centralization of the Military group is 37.89%, while the Non-Military group is 41.84%.

Hierarchical Organization

United States (NPS - 0202)		
	Degree	NrmDegree
Alex	16	80
Chris	13	65
Taylor	13	65
Kim	13	65
Pat	12	60
Harlan	12	60
Dale	11	55
Sidney	10	50
Val	10	50
Leslie	10	50
Sam	10	50
Whitley	10	50
Jesse	9	45
Quinn	7	35
Morgan	7	35
Robin	5	25
What	5	25
Where	5	25
Who	5	25
When	5	25
Francis	4	20

Portugal (0604)		
	Degree	NrmDegree
Sam	12	60
Val	11	55
Chris	9	45
Sidney	9	45
Pat	9	45
Alex	9	45
Leslie	8	40
Robin	7	35
Jesse	7	35
Harlan	5	25
Where	5	25
Kim	5	25
When	5	25
Francis	5	25
What	5	25
Quinn	5	25
Who	5	25
Dale	4	20
Taylor	4	20
Morgan	4	20
Whitley	3	15

Commander
Team Leaders
Where
What
When
Who
Websites
Where
What
When
Who

Table 2. Degree Centrality (United States vs. Portugal)

In the Hierarchy organization examples, Alex, the cross team commander with the same potential communication lines as the Edge participants, communicates with the greatest number of entities in the US group. In the Portuguese group, the commander only interacted with nine other entities, while two other participants had a greater degree measure. The Portuguese participants interacted with fewer entities than the US group. The degree centralization of the US group is 37.89%, while the Portuguese group is 30.53%.

Degree centrality can best be described as a measure of an entity's opportunity to influence others. In these examples, the Edge organization appears to have a greater level of degree centrality than the Hierarchy.

Edge Organization

Military (USMA - 0201)		
	Betweenness	NrmBetweenness
Where	33.845	8.907
Who	33.304	8.764
When	31.927	8.402
What	31.054	8.172
Harlan	30.29	7.971
Val	9.449	2.487
Sam	9.421	2.479
Pat	3.953	1.04
Kim	3.847	1.012
Leslie	3.612	0.951
Morgan	1.801	0.474
Francis	1.72	0.453
Sidney	1.634	0.43
Robin	1.527	0.402
Taylor	1.387	0.365
Chris	1.387	0.365
Alex	1.321	0.348
Dale	1.254	0.33
Whitley	1.079	0.284
Jesse	0.593	0.156
Quinn	0.593	0.156

Civilian (BU - 0622)		
	Betweenness	NrmBetweenness
Who	95.726	25.191
Where	74.543	19.617
What	32.393	8.524
When	29.41	7.739
Harlan	5.999	1.579
Robin	5.642	1.485
Quinn	5.558	1.463
Kim	3.699	0.973
Pat	3.608	0.95
Dale	2.199	0.579
Leslie	2.143	0.564
Morgan	2.032	0.535
Whitley	2.032	0.535
Sidney	1.832	0.482
Jesse	1.676	0.441
Val	1.576	0.415
Francis	1.093	0.288
Sam	0.776	0.204
Chris	0.443	0.117
Taylor	0.443	0.117
Alex	0.176	0.046

Websites
Where
What
When
Who

Table 3. Betweenness Centrality (Military vs. Civilian)

Betweenness centrality measures the connectedness of the network. Using this measure we can tell how a participant affects communication path length determining the number of shortest paths a participant or website lies on. In other words, if a node is removed, how severely will the absence of that node impact the communication network? In our example tables above, the websites largely affect the connectedness of each network. Removing the website would severely affect the path length between entities. In the Military organization we can see that one participant, Harlan, impacts network connectivity more than all other participants. In the Non-Military case, all participants scored low on betweenness centrality; however we observe that some websites play a more dominant role than others in the connectedness of the Non-Military network. Betweenness centralization in a measure of the heterogeneity of betweenness centrality for each network. The betweenness centralization index is 6.65% for the Military group and 22.86% for the Non-Military group.

Hierarchical Organization

United States (NPS - 0202)		
	Betweenness	NrmBetweenness
Alex	72.843	19.169
Kim	28.933	7.614
Who	24.45	6.434
Chris	23.831	6.271
Pat	22.954	6.041
Sam	20.033	5.272
Harlan	18.945	4.986
Val	18.88	4.968
Dale	14.745	3.88
Taylor	13.863	3.648
Sidney	12.433	3.272
Leslie	12.169	3.202
Jesse	9.463	2.49
What	9.034	2.377
Whitley	7.307	1.923
Where	7.23	1.903
When	6.63	1.745
Quinn	4.063	1.069
Robin	2.293	0.603
Morgan	1.367	0.36
Francis	0.533	0.14

Portugal (0604)		
	Betweenness	NrmBetweenness
Alex	82.836	21.799
Val	68.423	18.006
When	65.151	17.145
Who	56.286	14.812
What	41.561	10.937
Where	33.883	8.917
Sidney	32.931	8.666
Chris	27.644	7.275
Leslie	24.133	6.351
Jesse	21.467	5.649
Pat	16.893	4.445
Sam	11.943	3.143
Francis	10.892	2.866
Robin	6.183	1.627
Quinn	5.15	1.355
Kim	5	1.316
Harlan	3.058	0.805
Taylor	1.583	0.417
Morgan	1.167	0.307
Dale	0.908	0.239
Whitley	0.908	0.239

Commander
Team Leaders
Where
What
When
Who
Websites
Where
What
When
Who

Table 4. Betweenness Centrality (United States vs. Portugal)

In the Hierarchy examples, Alex, the Commander, is critical in minimizing the path length of the network. The websites play a larger role in the connectedness of the network in the Portuguese group. The betweenness centralization index is 15.76% for the US group and 16.07% for the Portuguese group.

In general the data analysis reflects that the Edge organizations are more richly connected than the Hierarchy because the Edge organizations have a greater number of arcs and those arcs are more heavily weighted signifying multiple transactions between pairs of participants.

Better Situational Awareness

The level of information awareness was analyzed by measuring the number of factoids participants have the opportunity to have seen and by reviewing the sources of available factoids. As explained earlier, participants in both organizations receive the four factoids via server distribution.

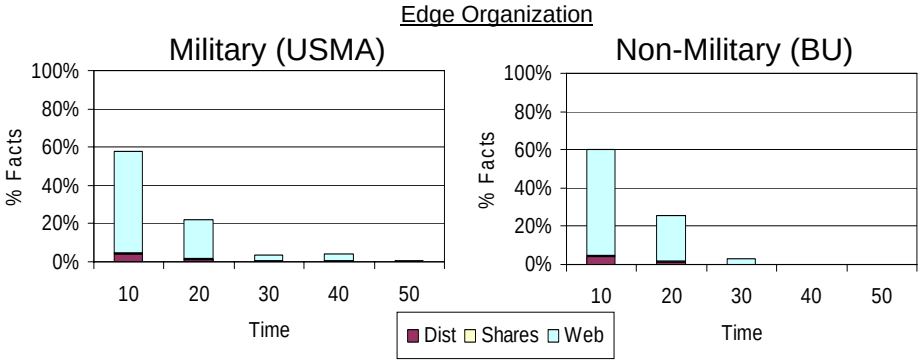


Figure 19. Average access to new facts over time by source (Non-military vs. Military)

In reviewing the illustrative cases, participants in the Edge runs have access to a large number of facts early in the run (on average about 60% of all facts are available to each participant in the first ten minutes). The majority of these new facts are made available to participants through the four websites.

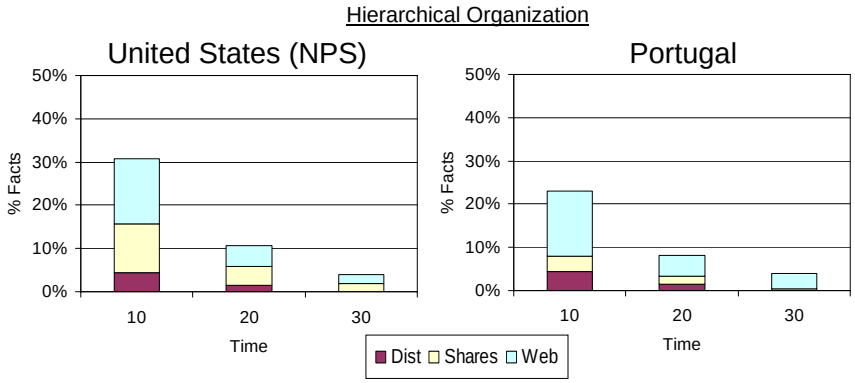


Figure 20. Average access to new facts over time by source (United States vs. Portugal)

Participants in the Hierarchical trials have access to fewer facts in the first 10 minutes (on average about 25% of all facts) and these new facts are gained through website use and direct sharing.

As expected the websites play a large role in information dissemination and increase situational awareness. In general participants in the Edge network have access to more factoids than the Hierarchy, and they receive the factoids earlier, and therefore have the potential to build greater levels of situational awareness quickly.

Degree of Task Success

Task success is a Measure of Performance (MOP). As part of this analysis task success is measured by the timing and correctness of identification attempts. The identification attempts were reviewed in ten minute time intervals and the latest attempt in each time interval was scored for correctness. Correctness is calculated by evaluating how many elements of the four part ID (What, When, Where, Who) are correct.

In exploring IDs made in the six data sets used in the comparative analysis, the two organizations performed differently. Eight completely correct IDs were made in the Non-Military group while only seven were made in the Military group. Another important observation is that the participants in the military group identified a greater number of solution elements correctly throughout the trial.

US participants identified a greater number of solution elements correctly when compared to the Portuguese group. Only one participant, a member of the US group, had a completely correct ID.

Eight completely correct IDs were made in the Graduate group while only seven were made in the Undergraduate group. However at the end of the trial, the Graduate

participants had a greater number of correct elements while many of the Undergraduate participants had changed their answers.

Identification scores improve over time in the Edge organization while correctness level out in the Hierarchy organization. In general the Edge organization achieves a greater level of task success. Edge participants identified more correct elements than the Hierarchy and therefore have a greater level of understanding as shown in the graphs below.

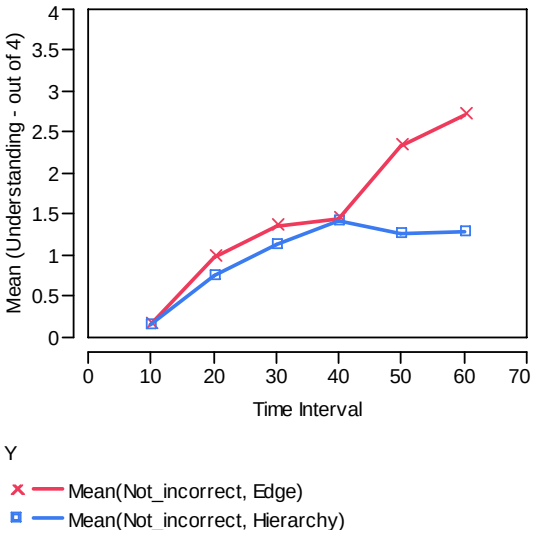
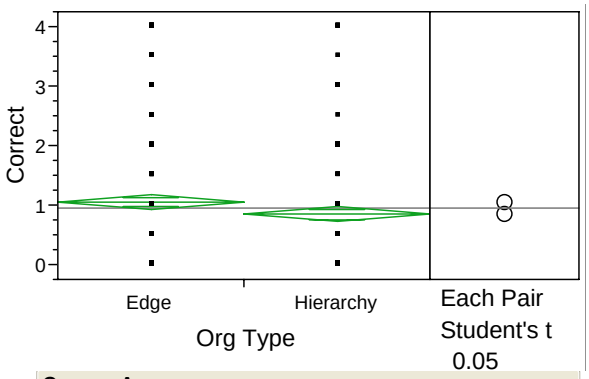


Figure 21. Correctness over Time



Oneway Anova

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Org Type	1	8.5784	8.57843	5.3996	0.0204*
Error	814	1293.2129	1.58871		
C. Total	815	1301.7914			

Figure 22. Hierarchy vs. Edge Comparison: Correctness Scores

Conclusions

Through this analysis, our team was able to draw conclusions about the comparison studies and observe how communication network structures affect information sharing, situational awareness, and effectiveness. There appears to be a statistically significant difference in the Edge trials when compared to the Hierarchy trials. While this work explores several variables and concepts to examine comparative cases and the impact of organizational structures, ELICIT can be used in numerous analytical initiatives.

The primary purpose of this analysis is to demonstrate the utility of these methods to provide insight into the kind of analysis that can be done with a large amount of ELICIT data. We hope the community will take use the display tools and methods identified as part of this effort and apply them to conduct future analyses.

During the course of this illustrative study a great deal more analysis and comparisons were done. Due to time and space constraints, only a selected portion of the work is shown here. The complete analysis can be found at: http://www.dodccrp.org/html4/elicit.html.

Additional information on the ELICIT software platform, existing data, and the ELICIT User Group can be found at: http://www.dodccrp.org/html4/elicit.html.

Tools and Methods

As mentioned above, particular scripts and tools were used to parse the transaction logs into time phased data tables and assist in scoring participant ID attempts. Assorted Python™[3] scripts assisted with data manipulation to extract key data for detailed review. JMP™[4] and Excel™ were used to manipulate, visualize, calculate statistics and analyze the data tables. NetDraw™[5] was used to visualize the network structures and UCINET™[6] was used to calculate network metrics.

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[3] G. van Rossum et al., Python Language Website, http://www.python.org/
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