Enabling Sensemaking for Intelligence Analysis in a Multi-user, Multimodal Cognitive and Immersive Environment

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Abstract— **This research proposes a user interface design for a collaborative, multimodal, multi-user cognitive and immersive environment for intelligence analysis, informed by sensemaking theory and scenario-based design. We have created a prototype software in a cognitive and immersive environment, which is designed to facilitate the structured brainstorming process. Part of our research goal is to determine whether this environment will better enable sensemaking compared to traditional pen and paper tools.**

Keywords- HCI; immersive environment; intelligence analysis; sensemaking; scenario-based design; multimodal interaction

I. Introduction

The intelligence community needs software which can help them to make sense of the information they are receiving through their work as analysts. The research in this paper addresses an important aspect of how technology and the ever-increasing availability of massive amounts of data [1] impact the national security domain, specifically how intelligence analysts are challenged when sorting through information, gathering evidence, and proposing hypotheses. According to Hutchins et. al, "currently available technology is not always effective in helping the analyst assimilate the huge amount of information that needs to be synthesized." [1]

Previous software for intelligence analysis has been discarded because of two major factors: the barrier of use of the software is too high, or the software does not meet the needs of the analyst. Our research takes a different approach to conceptualizing and designing software for analysts. We are developing software that will support analysts' sensemaking by integrating educational and training materials that are already used by analysts in their own domain, such as those described by Beebe and Pherson [2] or Hall and Citrenbaum [3]. We believe that this will create a more accessible interface and will provide affordances that are already familiar to the user base. Providing analysts with a tool that provides a similar interface has proven to have some success with analysts as users, as has been discussed by Smallman [4]. Our team is focusing on the structured analytic technique of brainstorming and how we can leverage the cognitive process to create a digital tool.

Through the lens of scenario-based design, we integrate the intended users' cognitive processes into the development of our software; to do this, we will adopt cognitive tools, such as the brainstorming tool, and techniques already utilized by intelligence analysts [2], to create a cognitive and immersive environment that supports multiple users and multimodal interactions in a way that is useful for intelligence analysis. By leveraging the capabilities of the cognitive and immersive room, we are aiming to reduce cognitive load inherent in intelligence analysis. The specific research questions formulated for this stage of our research are: 1.) How can we leverage brainstorming tools to expedite the foraging process as described by Pirolli and Card [5], and 2.) How can we utilize multimodal, multi-participant input to address cognitive load ? Our application of structured analytic techniques (which can be seen in Figure 2) is a new approach to the development of digital tools and software for intelligence analysis.

This paper will review historical trends among capabilities in previously released software and will suggest an application of sensemaking theory, participatory design, and scenario-based design to strengthen development of our software's capabilities. The framework for our research is based on the intelligence analysis sensemaking process (see Figure 1) as explained by Pirroli and Card [5]. Thorough integration of the respective iterative loops of foraging for information and sensemaking will also inform how a user interface and the system tools should support the intelligence process.

We propose that our software should be informed by direct feedback from analysts, scenario-based designs derived from existing structured analytic techniques, and associated resources that are currently used by intelligence analysts for training purposes, such as the tradecraft primer created by the CIA [6]. This is a novel approach to conceiving and designing software for intelligence analysis, as most existing software does not draw from the structured

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analytic techniques that we propose to build as a digital system. For future work, we will conduct user studies to determine the digital tool's utility and usability, as well as more in-depth studies to examine if it successfully enables the sensemaking process.

In Section 2 of this paper, we discuss previous literature in the following fields: state of the art of software developed for intelligence analysis, literature in sensemaking, user modelling, scenario-based design, and previous work in electronic brainstorming tools. In Section 3 of this paper we discuss our software and how we implemented user centered features informed by our research. In our final section, Section 4, we discuss limitations of our research, future work, and our conclusions.

II. LITERATURE REVIEW

This section covers literature discussing state of the art technologies for intelligence analysis, sensemaking theories, user modelling, and scenario-based design.

A. *State of the Art*

Wright et al. [7] introduce Sandbox, which is the successor to the analysis tool nSpace. Their paper explains human information interaction capabilities, such as 'put this there' cognition, automatic process model templates, gestures for fluid expression of thought, assertions with evidence, and scalability metrics. The authors use cognitive task analysis to identify a number of techniques used by analysts. The authors take note of the use of Post-its by analysts in order to organize and sort ideas. The authors translated this into a feature called MindManager, which employed concept map strategies to allow diagrammatic visual representations. The activities the software is designed to support are visual thinking and working with evidence. They designed the software to be flexible to adapt to different types of analysts and analytical styles. The software also incorporates a source attribution and context function. Another interesting feature is that the software can provide automatic evidence fitted to templates of analytic framework.

Pioch and Everett [8] describe the Polestar intelligence analysis toolkit, which is one of the earliest software suites designed for intelligence analysis. Polestar included a snippet view of texts, where users could highlight and drag text to the portfolio view for later analysis. This portfolio view also records metadata about the text. Polestar also included a way to start knowledge structuring, such as a wall of facts similar to the sticky-note exercise taught in intelligence analysis classes. This software included a timeline feature, to allow analysts a way to visualize relationships in data. Polestar included an argument tree editor, allowing analysts to structure and formulate hypotheses in a visual fashion. The dependency viewer allowed users to trace back where a document or object was found in the dependency network.

Eccles et al. [9] explore part of intelligence analyst' process of using narration to make sense of events of interest and how the authors, themselves, use a software system called GeoTime to map geo-temporal events for easier access. The authors discuss the major features of GeoTime: the space-time pattern finding system, the theory behind which is that it relieves the analyst from effort of searching for common patterns and events. The second part of the system relies on visual annotations, which takes the visual information and appends relevant information. The final part of the software is a text editor that allows analysts to make relevant comments on the found information. GeoTime uses a collaborative environment but also emphasizes a data-aware object, where annotations are embedded in time and space, so these become a new piece of information connected to the found information. GeoTime is also interested in allowing analysts to work on a meso-level, such as behavioral trends, events, and plots, rather than an individual unit.

Keel [10] introduces E-Wall, which is a visual analytic environment design to support remote sensemaking. It is designed around object focused thinking, where information is represented as an object, and users construct semantic relations between them. The E-wall layout is designed to allow users to collaborate while working on information and to allow users to manipulate data in object-like chunks. The E-Wall uses two computational agents to manage information flow, and infers relationships among data types, and another that evaluates databases and suggests data to the user. The E-Wall allows users to navigate large amounts of data independently and minimizes the need for verbal interaction. Our research anticipates that communication between users is an important part of the collaborative process and therefore our tool integrates deliberate periods of interaction among users to collaborate on theories.

Rooney et al. [11] discuss INVISQUE (an abbreviation of INteractive VIsual Search and QUery Environment), a tool that allows searching, automated clustering of data, automated entity extraction, and manual manipulation of data on an infinite canvas. Users can initiate a search to look for articles related to a topic or create clusters of their own. The authors here discuss the way that users would group documents in a way that had semantic meaning to them, that the software would not have been able to infer and then group. The authors use Pirolli and Card's sensemaking model, along with Klein's Data/Frame extension. The software we are developing has superficial similarities to INVISQUE, however we propose a more structured method that is aligned with the formalized structured analytic technique of brainstorming to encourage analysts to develop topic ideas and clusters before they seek for more data. This should allow for users to experience a more focused search for data during the foraging process.

Jigsaw is another piece of software designed for intelligence analysis. Gorg et al. [12] discuss the capabilities of the software in their article. Jigsaw is designed to support the sensemaking activities surrounding collecting and organizing textual information by intelligence analysts. The Jigsaw system is designed to provide visualization for different perspectives on information in documents and it supports evidence marshalling through a Shoe Box view. The earliest version of the software focused heavily on visual representation of relationships between entities but did not provide any kind of text analysis. One of the major findings of creating this software was that software functions cannot replace the reading of reports. Repeated careful reading of selected texts tended to be the preferred method to understand the information in texts. As a result, the Jigsaw system incorporated the ability to summarize and cluster similar important text information. From there, the software used packages such as GATE, LingPipe, the OpenCalais system, and the Illinois Named Entity Trigger, to import data from documents.

Murdock and Roth [13] use the lens of Pirroli and Card's sensemaking theory to examine a map-based prototype system called Basic Ordnance Observation Management System (BOOMS), developed at the Penn State GeoVISTA center. The aim of the paper is to explore how visuo-spatial contexts and maps contribute toward the intelligence analysis understanding of the events in their field. The authors focus on the capabilities of the software and how it offers users context to understand details concerning specific events within a one-year time period. The authors use sensemaking to model the technical concerns that must be addressed for technology that is used for gathering information. The mapping software is interactive and includes a structured top down navigation system. The aim of the software is to be able to provide insight for operational and policy decision makers through pattern finding abilities in the software.

Petersen et al. [14] discuss the software CrimeFighter, an analysis tool designed for criminal investigators. The authors introduce the concept of applying sensemaking to counter terrorism and criminal networks, and a software tool called CrimeFighter Investigator. The challenges outlined in the article concerning criminal investigation are also relatively similar to challenges in intelligence analysis. Several specific elements are information volume, information complexity, and information sharing. The authors discuss the capabilities of the software, and how they support the investigation process. The authors describe how the history function helps to allow for revisiting and revising the information in the software for further consideration. The software also has some prediction features possible, which are supported by social network analysis, decision making, and hypothesis making. The tool also has a storytelling feature, which allows for the grouping of elements of the investigation on the timeline that seem related to the analyst.

Chung et al. [15] discuss VisPorter, a collaborative text analytics tool aimed toward allowing sensemaking in a collaborative environment. The software is meant for multi-user engagement and the designers focused on different elements such as haptic touch, lighting, and to explore how people forage for information to share hypotheses. The VisPorter software includes the Foraging tool, which contains the document viewer and the concept map viewer, and the Synthesis tool, which allow users to share information found individually with the foraging tools. Some of the features included in this software was gesture-based interaction, with an example of someone with a small display flipping a document off the left side of their device, and having it be shared and dropped on the right side of a synced large display. Our brainstorming software is situated in an immersive environment that also uses multimodal input on an immersive display that allows multiple users to collaborate, but our software recognizes users' body frames and allows users to interact with the system using only physical gestures. We anticipate this should allow users to spend more cognitive energy on analysis than on interacting with the system.

Benjamin et al. [16] describe the capabilities of an analytic software tool called DIGEST. Its main capabilities are extracting data from text, such as sentiments, social influence, and information flow structures; the tool also has exploratory data analytics, and finally it uses the stored results to create various knowledge products. After the data collection and processing stage, where analysts can configure the tool to collect data on specific topics, the tool develops a template for information reporting. Finally, the analyst can populate the template with the information the tool has collected. The analyst can choose what information they want included, as well as add any of their own insights to the product.

While several features of our software have been present in the software discussed above, the underlying concept for all of our features is to enable human collaboration during sensemaking; by applying the intended users' domain knowledge to our software development we hope to achieve create a cognitively more accessible product. The process that we are proposing of retrospectively consulting and integrating educational materials into the software design is novel for this problem. This novelty is partly due to the fact that the users' requirements as intelligence analysts might be too rigorous for a generic brainstorming software to be useful; to address this special user need, we are implementing the structured brainstorming process developed by intelligence analysts. The specific process for this tool is a structured analytic technique called brainstorming, where a group of analysts record salient pieces of data on sticky notes and creates topic groups from these notes. Our software design is using a blended approach of interviews and integration of source material from the intelligence analysis domain.

B. Sensemaking theory

Sensemaking theory is well represented in human-computer interaction studies on user interface design for intelligence analysis [5][7]–[9][11][13][14][17]–[22]. Pirolli and Card introduce the concept of the sensemaking process in intelligence analysis as a cognitive schema operating on expert level behavior [5]. Given this assumption, the authors also prelude their article with the understanding that expertise and experience will form a series of behavioral patterns that will inform how the intelligence analysts behave.

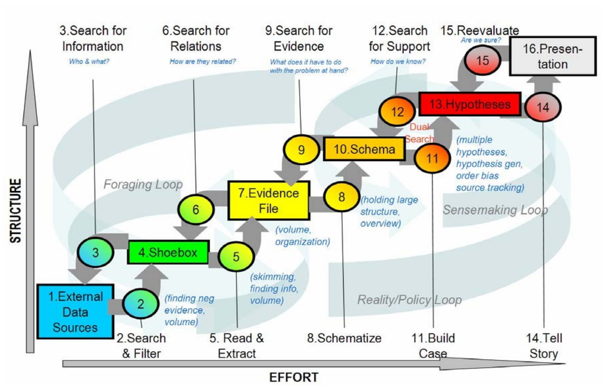

Figure 1 The sensemaking process and leverage points for analyst technology as identified through cognitive task analysis [5].

The authors state that analysts would restructure incoming information to fit previously built organizational formats, to aid in planning, evaluation, and reasoning. Pirolli and Card posit that the intelligence process can be divided into two loops: 1) the foraging loop, where analysts seek out and sort information, and 2) the sensemaking loop, where analysts pinpoint the best evidence, and building a mental model from the evidence. Our digital tool is intended to facilitate this process, more specifically, the foraging loop.

C. User modelling

We have studied structured analytic techniques in educational materials that were created for use in the intelligence analysis field. These techniques include but are not limited to: brainstorming, what-if analysis, and multiple scenario generation [6]. We are transforming these techniques into digital tools for our cognitive immersive environment. Currently, while there are many digital tools and software that have been created for the intelligence analysis domain, few of these tools use structured analytic techniques in their design or operation, or they fail to account for the user in system designs [23]. Gotz et al. [24] detail the intelligence analysis process, conducted an experiment concerning intelligence analysis, behavioral modeling, and user interface implications. Based on their findings, the authors argue for a flexibility in computer tools available to analysts, as analysts have a varied method of collecting and recording information. One of their final conclusions is user interface design should have some amount of user centered design and modelling, because analysts create information models when none are present, and they expressed appreciation when the models were available [24]. Perhaps the most well-known structured analytic tool that has been transformed into a digital tool is the Analysis of Competing Hypothesis tool, initially created by Richard Heuer [25].

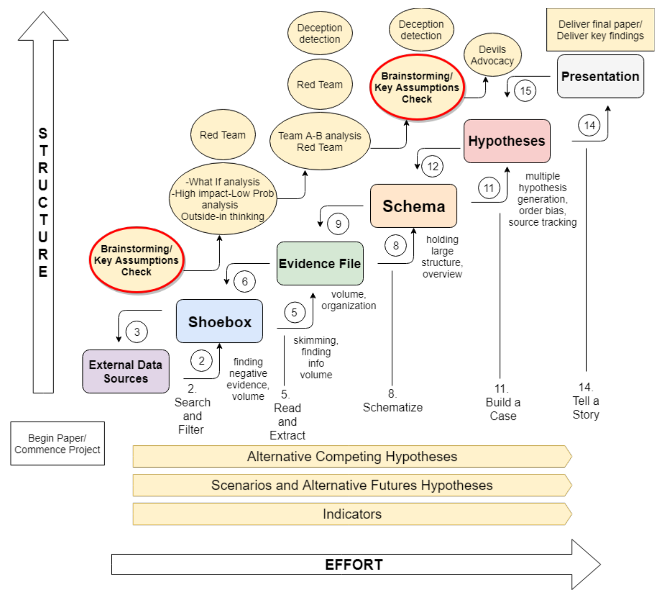

Figure 2 Pirolli and Card's sensemaking model with structured analytic techniques superimposed

One challenge in successfully creating a digital tool for intelligence analysis is identifying the specific information demands of the operations analysts use to support their work. We consult intelligence analysis training materials, manuals, and final products, such as briefs, to understand the steps taken by analysts when conducting intelligence analysis.

As structured brainstorming is a standard structured analytic technique in the sensemaking process, we are developing a digital tool in a cognitive and immersive environment for brainstorming in the intelligence analysis domain. We aim to create an environment that will facilitate sensemaking during the brainstorming process, and therefore it is imperative that we understand how analysts identify important evidence, discuss ideas, and how they interact with each other as a team in order to identify how to proceed with analysis. As mentioned above, our research team conducted several pen and paper brainstorming sessions and observed brainstorming sessions conducted in an intelligence analysis class at a local university, using direct feedback from analysts and integrating material from the domain.

The structured brainstorming process is explained in Beebe and Pherson’s 2014 book, “Cases in intelligence analysis” [2]. The process begins with a group of analysts reading a document individually and then recording pieces of evidence they find most salient on sticky notes. After a predetermined amount of time, the recording portion of the brainstorming process ends, and the group puts their sticky notes up on a wall or other surface. After the notes are put up, the group members rearrange the notes into topic groups, initially with no discussion. Lastly, the group discusses the emerging topics to determine which are most relevant to their project. We have created a user model off of this process using the principles of scenario-based design, which are discussed below section D. Scenario based design.

The practice of examining users’ work routines to construct a model of how software should be developed for the user base is known as scenario-based design [26]. There are established benefits of scenario based-design, as it examines and seeks to model the real-world processes undergone by the users. The core concept is to examine how people use technology and then to more deeply examine how technology impacts or shapes their activities. Another feature of scenario based design is applying user scenarios for interface and technology design in order to mold the technology to the users' needs and situation [26].

The scenario-based design process is intended to examine the potential stakeholders, as well as develop claims about the current practices of the potential users, which will inform how user scenarios are developed. Once the user analysis is developed, it is utilized in design analysis. Design analysis focuses on user activities, information design, and interaction scenarios. These are all developed, further shaped, and informed by information on the projected user and their needs and use of the software. Usability claims and analysis are also reiterated during design analysis. Then, a prototype is prepared, where more specific usability specifications are developed and programmed. The process of reshaping the software to reflect user needs is re-iterated as necessary. However, the process that we are proposing of retrospectively consulting and integrating educational materials into the software design is novel for developing software for intelligence analysis.

E. Electronic brainstorming tools

Electronic sticky notes are not uncommon in digital brainstorming literature. Previous works have looked at the use of sticky note tools in group and collaborative settings [27] and in remotely mediated group work, as well as, how sticky notes can be used to define affinity groups in collaborative work [28]. Jensen et al. [29] compare the use of traditional analog sticky notes to a digital sticky-notes tool, and concludes that the digital sticky notes were superior in terms of increased note interaction, clustering, and labelling. Existing digital sticky note tools can be found in examples such as Discusys [28], ECOPack [30], Padlet [31], and Quickies [32].

More closely aligned to the focus of our research, a sticky-notes brainstorming tool known as RAMPARTS has been designed for criminal investigations. The study by Wozniak et al. [33] found that “...RAMPARTS spatial awareness decreased task completion time when compared to a paper-based system, without any adverse effect on task completion time compared to a tabletop, and without increasing perceived cognitive workload” [33]. Investigating task completion time and spatial awareness aspects will be important to consider for future user testing with our own software, in order to determine if our digital tool will be able to enable sensemaking during intelligence analysis.

III. Implementing user Centered Features

This project seeks to extend existing research by incorporating scenario-based designs into the software interface, as informed by sensemaking theory. We are using a blended approach of including direct feedback from former analysts at a local university, as well as cognitive analytic techniques created by the domain experts [2][3]. Intelligence analysis classes are available in some universities, and they often teach techniques that widely used in the intelligence domain. We conducted several of our own pen-and-paper brainstorming sessions and observed an intelligence analysis class at a local university to better understand the methods used in the field of intelligence analysis. These sessions further motivated the behavior and capabilities of our software.

In order to enable sensemaking for analysts, we have taken the pen-and-paper brainstorming exercise as described by Beebe and Pherson [2] and implemented it into an immersive, digital tool that can be used collaboratively in a multi-user context. The research project will incorporate feedback from analysts, both through direct feedback and user studies, and is currently informed by documents from the training and educational literature that has been produced by the intelligence field. The goal of integrating training and educational materials into the software capabilities and interactions is to make the tool accessible to a majority of the users, as they will have had previous exposure to these materials in their domain experience. Furthermore, it is important for our tool to support human interactions individually and as a group, and enable fluid manipulation of the users' ideas as sticky notes to reduce cognitive effort and bias.

We use the Pirolli and Card sensemaking notational model (Figure 1) to develop the structure and behavior of our software. This model depicts the cognitive tasks completed by intelligence analysts, and it includes a foraging phase and a sensemaking phase. The brainstorming tool is informed by the foraging phase from Pirolli and Card’s model to allow analysts to search, discover, and filter

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information during the shoebox phase. The tool is also derived from structured analytic techniques already in use by intelligence analysts. Our hypothesis is that the software should be informed by cognitive processes that intelligence analysts undergo during the intelligence process, as well as the cognitive analytic tools currently used by intelligence analysts. It is imperative to leverage these techniques to create a useful and usable cognitive, immersive environment.

The sticky notes brainstorming tool is situated in a cognitive immersive environment in the Cognitive Immersive Systems Lab (CISL). This environment is comprised of a 360-degree panoramic display that stands at 14 feet tall. The brainstorming tool is comprised of a personal view and a global view to accommodate individual and group brainstorming. We have integrated verbal and gestural commands into the software that equate with the actions in the analog brainstorming exercise, and we have enabled a personal view and a global view (see Figure 4). We believe informing the software with techniques already familiar to the user will create a more usable interface [4], and will enable sensemaking during the analysis process.

Digital sticky notes are created and edited on the personal view with a personal device, such as a laptop or a tablet. Then, the personal view is synced to a web server, allowing notes to transfer to the global view. The personal view includes an area to create new notes that are only shown within the personal view, an uncategorized area where notes can be sent to the blank space on the global view, and an area that reflects all of the other created categories and notes of the session. Our personal view (see Figure 3) is accessed through a web browser, allowing it to work on a wide variety of devices. Users can send notes from the personal view to the global view by tapping on a note and then tapping into the uncategorized area.

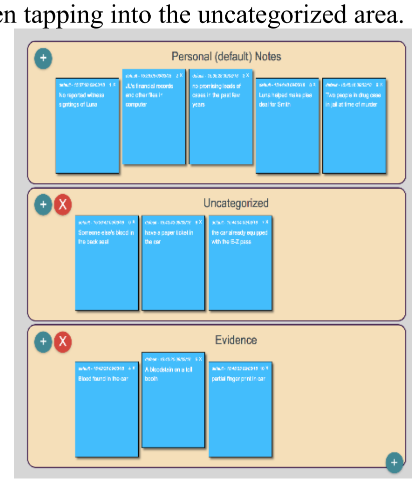

Figure 3 Personal view of sticky notes brainstorming tool.

Once notes are on the shared screen, users can discuss with each other and interact with the global and personal views (see Figure 3) to create categories from their ideas.

The cognitive and immersive system is equipped to handle gestural commands and verbal commands, either separately or in tandem for multimodal interactions. The technologies that enable multi-user input are Kinects [34], which are used to detect body frames and spatial information. This information allows users to make gestural commands as input to the system. Lapel microphones allow multiple users to give verbal commands to the system. The system output is projected via five projectors onto the 360-degree screen. The system can also speak to users through a synthesized voice. This environment creates an immersive and interactive workspace for analysis.

In order to support a cognitive and immersive environment, we enabled verbal and gestural commands for the user to interact with the global view of the system. Verbal commands relayed through the lapel microphone currently consist of: 1) Create note, 2) Edit note, 3) Delete note, 4) Move note, 5) Create category, 6) Rename category, 7) Add note to category. Gestural commands are recognized by the Kinect sensors [34]. The gestures recognized by the global view in the brainstorming environment are pointing to select a note, grasping with a hand to pick up a note, and releasing a hand to drop a note elsewhere on the screen.

Additionally, the system is able to handle a multimodal approach of input allowing a combination of verbal and gestures to make up a command, such as a user pointing at a note and saying, "Delete that note." These technologies enable multimodal interactions which we hypothesize will help reduce the cognitive load of analysts, which has been documented in previous work through interviews with analysts and experiments involving intelligence analysts [1] [33][35]–[37].

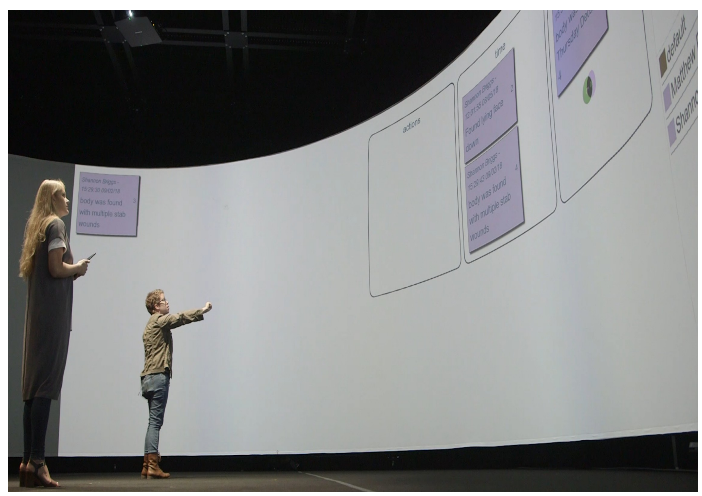

Figure 4 User interaction with point/select system in brainstorming tool.

The interactions between the global view and the personal view are designed to be faithful to the structured analytic brainstorming process, and to match the sensemaking process outlined by Pirolli and Card. Analysts create notes solitarily before they share the notes with the

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group, and then spend time discussing the shared notes as a group. To facilitate collaboration, our technology allows multiple users to interact with the global view at the same time.

IV. CONCLUSION AND FUTURE WORK

This paper has introduced our sticky notes brainstorming tool, as informed by cognitive tools from intelligence analysis, which is aiming to better enable sensemaking for analysts. The underpinnings for our research are brought in from sensemaking theory, scenario-based design, and user modelling research on intelligence analysis, and considers prior research in electronic sticky notes. Our prototype tool, situated in CISL, is comprised of a personal view accessible on personal devices, and a global view that is projected onto a screen viewable by all users. We have integrated multimodal input for the system through gestural and verbal commands.

We have found that designing software for intelligence analysis has presented a number of challenges, which has informed the limitations of our current research. The accessibility of the intended user is generally less than other user groups, as by nature of their work they cannot divulge sensitive information. Similarly, accessibility of accurate and relevant source material to inform the design of the software has been challenging for the reason discussed above. On a more technical note, the range of input we are enabling in a multimodal environment is in a conceptual phase, and we are designing and carrying out user studies to understand the potential impact on users.

For future work, we will conduct user studies to examine the usability and utility of the brainstorming tool. We use Pirolli and Card's sensemaking theory and notational model [5] to understand how their representation of how the cognitive tasks of intelligence analysis might be supported by the brainstorming tool in our cognitive immersive environment. Our tool will be used to run mock intelligence exercises to determine if it can produce results that will be considered useful to an analyst. Failure or success will be determined by how many unique ideas are generated during the brainstorming session, the quality of the ideas, the length of the session, how many topic clusters are generated, and the perceived quality of the discussion. Based on future user studies with our tool, we can identify modifications to create a more usable product for the user base. If the software is more usable with these modifications, and returns useful information, then we can determine that including educational and training materials is a necessary step in designing the software. Our first user study will compare the actions and interactions between groups using traditional pen and paper tools compared to our digital brainstorming tool. The subject pool will be college students. We will do multiple rounds of studies and will improve the tool capabilities and user interface after each round. A future user study will include former intelligence analysts as subjects in order to give us domain specific feedback for the tool.

Our prototype of a digital brainstorming tool is motivated by a scenario-based design, as well as, existing intelligence analysis resources and materials Future work includes creating more personalized experiences for users, developing and researching new gestures and multimodal interactions, and extending the tool to other structured analytic techniques (see Figure 2).

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