AFRL-RH-WP-TP-2023-0001

ENHANCING DETECTION OF ESSENTIAL ELEMENTS OF INFORMATION (EEI) THROUGH STRUCTURED ANALYTIC TECHNIQUES (SAT) AND VISUAL NETWORK TEXT ANALYSIS TO AUGMENT DECISION-MAKING OUTCOMES: AN ANALYTIC HIERARCHY APPROACH

Justin M. Nelson / Anna Maresca / Mary Frame
Bradley Schlessman / Samantha Perry
711th HPW/RHWAS
2255 H. Street, Building 248
Wright-Patterson AFB, OH 45433

TECHNICAL PAPER

March 2023

DISTRIBUTION A – Approved for public release. distribution unlimited.

AIR FORCE RESEARCH LABORATORY
AIRMAN SYSTEMS DIRECTORATE
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE

NOTICE AND SIGNATURE PAGE

Using Government drawings, specifications, or other data included in this document for any purpose other than Government procurement does not in any way obligate the U.S. Government. The fact that the Government formulated or supplied the drawings, specifications, or other data does not license the holder or any other person or corporation; or convey any rights or permission to manufacture, use, or sell any patented invention that may relate to them.

This report was cleared for public release by the AFRL Public Affairs Office and is available to the general public, including foreign nationals. Copies may be obtained from the Defense Technical Information Center (DTIC) (http://www.dtic.mil).

AFRL-RH-WP-TP-2023-0001 HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION IN ACCORDANCE WITH ASSIGNED DISTRIBUTION STATEMENT.

NELSON.JUSTIN.MICHAEL.1406840863 Digitally signed by NELSON.JUSTIN.MICHAEL.1406840863 Date: 2023.04.11 08:01:27 -04'00'

JUSTIN M. NELSON, DR-II, Ph.D.
Work Unit Manager
Mission Analytics Branch
Airman Systems Directorate
711th Human Performance Wing
Air Force Research Laboratory

MURDOCK.WILLIAM.P.1048742161 Digitally signed by MURDOCK.WILLIAM.P.1048742161 Date: 2023.04.10 15:57:59 -04'00'

WILLIAM P. MURDOCK, DR-IV, Ph.D.
Chief, Mission Analytics Branch
Airman Systems Directorate
711th Human Performance Wing
Air Force Research Laboratory

CARTER.LOUISE.ANN.1230249128 Digitally signed by CARTER.LOUISE.ANN.1230249128 Date: 2023.04.12 08:16:30 -04'00'

LOUISE A. CARTER, DR IV, Ph.D.
Chief, Warfighter Interactions and Readiness Division
Airman Systems Directorate
711th Human Performance Wing
Air Force Research Laboratory

This report is published in the interest of scientific and technical information exchange and its publication does not constitute the Government's approval or disapproval of its ideas or findings.

REPORT DOCUMENTATION PAGE

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED START DATE	END DATE
03-20-2023	Technical Paper	01 January 2022	28 December 2022

3. TITLE AND SUBTITLE

Enhancing Detection of Essential Elements of Information (EEI) through Structured Analytic Techniques (SAT) and Visual Network Text Analysis to Augment Decision-Making Outcomes: An Analytic Hierarchy Approach

5a. CONTRACT NUMBER	5b. GRANT NUMBER	5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER	5e. TASK NUMBER	5f. WORK UNIT NUMBER

6. AUTHOR(S)

Justin M. Nelson, Anna Maresca, Mary Frame, Bradley Schlessman and Samantha Perry

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

711th HPW/RHWAS
2255 H. Street, Building 248
Wright-Patterson AFB, OH 45433

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory
711th Human Performance Wing
Airman Systems Directorate
Warfighter Interactions and Readiness Division
Wright-Patterson Air Force Base, OH 45433

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'SREPORT NUMBER(S)

AFRL-RH-WP-TP-2023-0001

12. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution A. Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

AFRL-2022-3739; 4 Aug 2022

14. ABSTRACT

Implementing an appropriate analytical approach has the potential to augment and enhance the decision-making process for military analysts within an Intelligence, Surveillance, and Reconnaissance (ISR) environment leading to high confident, future recommendations. Currently, there is not a standardized approach when processing complex, military scenarios. Moreover, structured analytic techniques (SAT) coupled with information workflow methodologies have been shown to improve critical thinking and logical reasoning during decision-making, even when confronted with ill-defined intelligence. The objective of this study was to evaluate the effectiveness of SATs as a decision-support tool by correlating identified essential elements of information (EEI) with solution accuracy through visual network text analysis. The study consisted of 150 participants who were randomly assigned to one of two SATs with intelligence information provided in either incremental or complete sections. The SATs included a method for defining analytical questions (MDAQ), a scaffolding approach, and a control condition. The findings indicate that providing participants with the MDAQ approach significantly enhanced EEI detection and solution accuracy compared to scaffolding and control. This discovery provides underlying evidence that implementing a MDAQ approach as a decision-support tool has the potential to enhance critical thinking and relational EEI correlation resulting in improved performance.

15. SUBJECT TERMS

Structured Analytic Techniques (SATs); Essential Elements of Information (EEI); Intelligence, Surveillance, and Reconnaissance (ISR); Decision-Making; Visual Network Text Analysis

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
U	U	U	SAR	22

19a. NAME OF RESPONSIBLE PERSON	19b. PHONE NUMBER *(Include area code)*
Dr. Justin M. Nelson	

PREVIOUS EDITION IS OBSOLETE.

STANDARD FORM 298 (REV. 5/2020)
Prescribed by ANSI Std. Z39.18

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 EXECUTIVE SUMMARY

Implementing an appropriate analytical approach has the potential to augment and enhance the decision-making process for military analysts within an Intelligence, Surveillance, and Reconnaissance (ISR) environment leading to high confident, future recommendations.

Currently, there is not a standardized approach when processing complex, military scenarios. Moreover, structured analytic techniques (SAT) coupled with information workflow methodologies have been shown to improve critical thinking and logical reasoning during decision-making, even when confronted with ill-defined intelligence. The objective of this study was to evaluate the effectiveness of SATs as a decision-support tool by correlating identified essential elements of information (EEI) with solution accuracy through visual network text analysis. The study consisted of 150 participants who were randomly assigned to one of two SATs with intelligence information provided in either incremental or complete sections. The SATs included a method for defining analytical questions (MDAQ), a scaffolding approach, and a control condition. The findings indicate that providing participants with the MDAQ approach significantly enhanced EEI detection and solution accuracy compared to scaffolding and control. This discovery provides underlying evidence that implementing a MDAQ approach as a decision-support tool has the potential to enhance critical thinking and relational EEI correlation resulting in improved performance.

2.0 INTRODUCTION

2.1 ISR Overview

ISR military operations collect vital information with respect to our near-peer adversaries' ground locations, movement patterns, and threat capabilities in order to support future forecast predictions and enhance situational awareness (Pawgasame 2016; Liu et al. 2019). These operations require Joint All-Domain Command and Control (JADC2) cooperation across air, land, maritime, cyberspace, and space domains in order to properly assess the situation and reduce uncertainty (Caballero et al. 2021). There are five key intelligence collection disciplines (Multi-INT) to support the mission. This includes: open-source intelligence (OSINT), human intelligence (HUMINT), signals intelligence, (SIGINT), geospatial intelligence (GEOINT), and measurement and signature intelligence (MASINT) (Lowenthal & Clark 2015; Mugavero et al. 2015; Stottlemyre 2015). Individually, each discipline represents their own storyline and narrative aligned with the information collected. However, the aggregation of all the available collected intelligence from each discipline enhances transparency, reduces tunnel-vision, and supports ISR requirements.

Although obtaining multiple sources of information can help support high confidence predictions of future events, there are still several obstacles that can influence and deter the decision-making process. One of the biggest obstacles for ISR analysts and strategic planners is data processing and comprehension (Novák & Burita 2019). ISR collections capture a tremendous amount of data from imagery, full-motion video, and technical reports which requires synchronization and validation across multi-INTs. In addition to the large quantity of collected intelligence data, the findings can be ill-defined, incomplete, inaccurate, or vague. This is a crippling problem for analysts, resulting in increased lead times (Hersey & Wang 2013). With the real-world

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

constantly changing, if there is a significant time delay in the data processing phase, the intelligence may no longer be reliable at a decision-critical time.

In order to combat this obstacle, ISR analysts implemented the processing, exploitation, and dissemination (PED) phase of the intelligence cycle into their workflow process (see Figure 1). In all, there are five main phases of the intelligence cycle which includes (1) planning, (2) collection, (3) processing and exploitation, (4) analysis, and (5) dissemination (Johnson 1986; Herring 1999). The planning and collection phase refers to the mission and operational environment to answer intelligence gaps requested by leadership to gain an advantage in the battlefield. During the processing and exploitation phase, analysts are required to clean and structure the data into a readable format. This phase takes the greatest amount of time as it is absolutely essential that the data is accurate and can be analyzed in order to detect relational indicators and observables to support the decision-making process for future military actions (Scarff et al. 2013). The analysis phase is when the data is examined and correlated to answer the intelligence gaps. Lastly, the data is disseminated to the stakeholders and military leadership.

Over the past few decades, the Department of Defense (DoD) has made it a priority to implement the PED phase of the intelligence cycle into ISR platforms in an effort to augment and enhance the decision-making process (Haugh & Douglas 2017; Schoening et al. 2015; Wollocko et al. 2015). However, until a standardized decision-support tool can be leveraged by analysts, data overload and processing time will remain to be an issue leading to under-informed decisions. Previous research has discovered that incorporating analytic tool suites, software programs, and automation coupled with PED could reduce data overload and support analysts' future prediction accuracies (Dominguez et al. 2005; McFarlane et al. 2016; Yang et al. 1998; Lusher & Stone 1997). Granted, improvements can still be made, as it is not yet clear which methodologies or technologies will afford the greatest benefits in operational environments.

Figure 1. The Five Phases of the Intelligence Cycle with focus on the PED Phase 2.

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

2.2 SAT

One concept that has been employed within academia and industry when assessing complicated, vague information to support the decision-making process is SATs (O'Hare & McGuinness 2015; Lin et al. 2012; Belland et al. 2017). SATs were originally developed as a support tool to help students mitigate errors and reduce pre-existing biases during cognitive tasks (Dhami et al. 2016). Previous research has discovered that incorporating SATs in an academia setting enhanced critical thinking, logical reasoning, decision-making rationale, and output performance metrics (Hiedemann & Jones 2010; Richards 2016; Brunzel 2021).

SATs are developed based on three main categories which include diagnostic techniques, contrarian techniques, and imaginative thinking (Scott 2020; Dhami et al. 2019; Artner et al. 2016). Diagnostic techniques are designed to formulate analytic statements, assumptions, and gaps into clearly identifiable statements. The analysis of competing hypotheses (ACH), scaffolding, and key assumption check are examples of diagnostic techniques. Contrarian techniques are aimed to diminish pre-existing biases and modify the current thought process. Devil's advocate, team a/team b, and high-impact/low-probability analysis are examples of contrarian techniques. Imaginative thinking engages a new perspective that can lead to alternative outcomes. Brainstorming, red team analysis, and alternative futures analysis are examples of imaginative thinking (Gaeta et al. 2021; Chang et al. 2018).

While these techniques and many more can support and facilitate operators' decision-making characteristics during an intricate task, the scaffolding technique closely aligns with the strategic guidelines' intelligence analysts are familiar with when performing their assessments. The scaffolding technique focuses on strategic learning and metacognition to enhance content comprehension (James & Okpala 2010). The foundation is structured upon identifying a problem statement, generating and selecting possible solutions, justifying the selection, testing and evaluating the results, and incorporating feedback into the system (Nelson 2022). Previous research has discovered a change in baseline performance when operators integrated a scaffolding technique leading to improved content comprehension and mitigating previously existing assertions (Gelder et al. 2020; Dabarera et al. 2014; George 2010). More recently, SATs have been embedded into military environments to improve output performance metrics (Coulthart 2017; Pherson & Heuer 2020). However, very little research has been conducted to determine the effectiveness of the scaffolding technique on decision-making within an emulated ISR setting (Nelson et al. 2022).

The question remains, can a current SAT be an effective decision support tool for ISR operations in theater? With that, a group of ISR subject matter experts (SME) came together at Wright-Patterson Air Force Base (AFB) to discuss the current SAT options. The outcome was the development of a new SAT known as the MDAQ. MDAQ is a structured approach which enables operators to assess the problem statement, process and identify EEI, hypothesize and create relational correlations, and convey a decision with high confidence. It is a continual-loop process that aims to induce active deep thinking and logical reasoning, leading to an increase in detection of EEIs to enhance the decision-making process. The ability to accurately detect subtle, embedded EEIs and indicators that are not immediately obvious or comprehensible within muddled intelligence could significantly improve ISR decision-making capabilities regarding future planning. To obtain greater understanding on the efficacy of SATs as a decision support tool within military ISR operations, further investigation on granular level needs to be conducted

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

in order to gain insight into the operators' decision-making process (Coulthart 2016).

2.3 Visual Network Text Analysis

There are several empirical approaches that can be used to determine the effectiveness of SATs as a decision support tool which include comparable discoveries, quality of information, and output performance metrics (Sharma et al. 2013; Eierman et al. 1995; Udo & Guimaraes 2017). Although these approaches can provide valuable insight, they do not detect and identify essential observables and indicators that are the foundation of how the results are quantified. To clearly understand the sentiment behind decision-making outcomes based upon open-field text and speech-to-text responses, visual network text analysis needs to be performed.

Text analysis is a widely used and extremely powerful technique that provides the capability to ingest, parse, and identify EEI within large unstructured communication datasets (Welbers et al. 2017; Popping 2015; DiMaggio 2015). However, there are challenges associated with open-field text and speech-to-text responses that need to be addressed. These challenges include grammatical errors, improper spelling, and word abbreviations, which are all too common within collected intelligence (Macdonald et al. 1982; Ittoo et al. 2016). To mitigate these challenges, fuzzy matching and logic can be used. This technique identifies semantic words based on similarities, rather than exact matches (Zhao & Mao 2017; Buckley et al. 2000; Mehl 2006). The output leads to clearly defined communication responses.

Once unstructured datasets have been cleaned, structured, and unified through fuzzy matching and logic, a visual network can be constructed. Visual network text analysis is a visual representation that supports analytic reasoning and decision-making outcomes assembled upon existing knowledge, understanding, and rationale through textual exploration (Brandes & Corman 2003; Saktheewaran et al. 2020; Goodall 2011; Drieger 2013). The visualization displays text mining features and nodes representing word frequency with respect to EEI identification and performance metrics. The display from the visual network can provide underlying evidence to support the effectiveness of SATs as an ISR decision support tool.

As previously mentioned, intelligence is collected across multiple INTs which then require analysts to validate, structure, analyze, and disseminate in near-real time to inform future military direction. The evaluation of SATs as an ISR decision support tool coupled with a visual network text analysis can provide invaluable insight that can help support military tool development and capabilities (see Figure 2). Therefore, the intention of the research study was to evaluate two SATs, the MDAQ and standard scaffolding, and a control condition as a foundational baseline for the development of current and future ISR decision support tools.

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

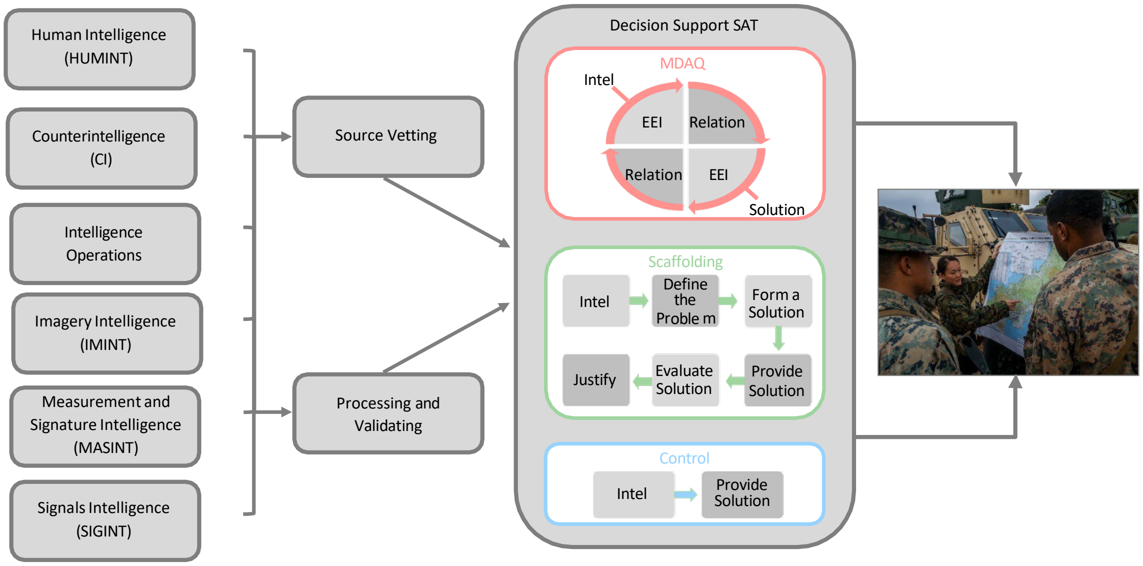


Figure 2. A Conceptual Decision Support Workflow for PED for Multi-INT Collections with regard to each SAT.

3.0 METHODS

3.1 Participants

The study protocol was approved by the U.S. Air Force Research Laboratory (AFRL) Institutional Review Board (IRB) (FWR20140043H). The goal of this effort was to evaluate the effectiveness of (SATs as a decision support tool for future ISR tool development. In order to obtain a foundational baseline for performance, the study was tested on individuals who had no prior military experience to reduce the effect of analytical training and pre-existing biases. A similar research study evaluating SATs on decision-making outcomes conducted by Belland et al. 2017 discovered a pairwise comparison of 0.27 for pooled standard deviation of subjects and a mean difference of 0.23. Using a standard power of 0.80, an effect size calculation was performed, resulting in a sample size of 25. Therefore, 150 participants recruited from Amazon's Mechanical Turk (MTurk™) completed the research study. MTurk™ is a widely used online survey creation and data collection tool where participants can support research activities. Participants were excluded from the study if they did not meet the following criteria: must be 18 years old or older, speak fluent English, retain basic computer skills, located within the U.S., obtain a 95% study approval rating or higher on MTurk™, and could not have previously participated in similar research studies involving SATs or have prior analytical training.

Participants who did not pass attention checks within the experiment or provided nonsensical long form responses were excluded.

Of the 150 participants who completed the study, 63 were male and 87 were female with an average age of 40 years old (SD = 10). Participants were randomly assigned to one of six groups (N = 25 in each): (1) MDAQ with intel presented incrementally ($MDAQ_{Inc}$), (2) MDAQ with intel presented in a complete section ($MDAQ_{All}$), (3) scaffolding with intel presented incrementally ($Scaffolding_{Inc}$), (4) scaffolding with intel presented in a complete section

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

(Scaffolding$_{All}$), (5) control with intel presented incrementally (Control$_{Inc}$), or (6) control with intel presented in a complete section (Control$_{All}$).

3.2 Task and Experimental Design

A between-subjects experimental design was implemented, where participants were randomly assigned to one SAT (MDAQ, scaffolding) or a control condition and given the content in either incremental sections or all at once (see Figure 3). All participants were provided with the same content containing one subtle EEI for each person of interest (four total EEIs within the intel). It is important to note that the task was reviewed and selected by our in-house ISR SMEs based upon similar characteristics and challenges intel analysts face within complex military operations. The ability to understand and measure analytical processes, logical reasoning, and attention to detail through EEI detection and decision-making based upon different SATs will be invaluable in supporting the development of current and future ISR tools that can be transitioned into military operations. If the participants were provided the content all at once, they would read the full intel and then provide open-ended text responses in an attempt to correctly identify EEIs and the associated relationship. If participants were provided the content in incremental sections, they would read the intel in five subsections. Following each subsection, they had the opportunity to provide an open-ended text response in an attempt to correctly identify EEIs and the associated relationship. After completing the main task, participants were provided demographic questionnaires to allow for a post-hoc correlation analysis. The task took approximately 20 minutes to complete but each participant was given up to one hour to finish. Participants were instructed to take their time and focus on decision- making accuracy over speed.

3.3 Data Analysis

Statistical analysis and visual network text analysis were performed using R Statistical Analysis Software Program (R version 4.1.2). R is an open-source programming language for statistical computing and visual representation of datasets (Wessa 2009; Goslee 2011). An analysis of variance (ANOVA) was conducted comparing SATs and information workflow (i.e., incremental vs complete) focusing on (1) overall correctly identified EEIs and solution accuracy (2) correctly identified EEIs based on person of interest. A visual network text visualization was generated to represent EEI identification by SAT and solution accuracy. The independent variables were SATs (MDAQ, scaffolding, control) and the information workflow methodology (increment, complete). The dependent variables were EEI identification performance and solution accuracy.

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

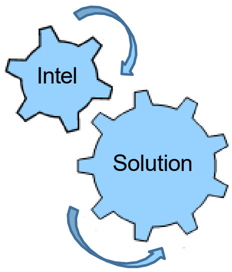
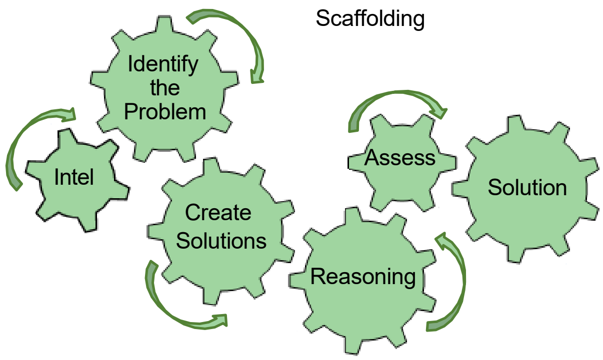
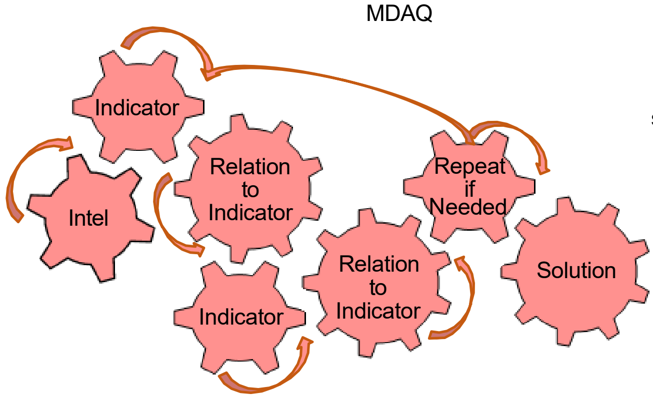
SAT	Methodology	Information Workflow
Control 	In the Control Group, participants were given the content and asked to provide a solution without being presented a structured approach	If the information was complete, the entire intel was given at once followed by the SAT. If the information was incremental, the intel was divided into five subsections and the participants had to complete the SAT after each subsection
Scaffolding 	In the Scaffolding Group, participants were given the content and asked to follow a specified structured approach. After reading the intel they had to identify the problem, create solution(s), provide reasoning, assess the situation, and provide a solution	If the information was complete, the entire intel was given at once followed by the SAT. If the information was incremental, the intel was divided into five subsections and the participants had to complete the SAT after each subsection
MDAQ 	In the MDAQ Group, participants were given the content and asked to follow a specified structured approach. After reading the intel they had to identify indicators/ EEI and provide the relational component. This process was repeated until they felt they had enough information to provide an educated solution	If the information was complete, the entire intel was given at once followed by the SAT. If the information was incremental, the intel was divided into five subsections and the participants had to complete the SAT after each subsection

Figure 3. SAT Methodology and Information Workflow Process.

4.0 RESULTS

4.1 Solution Accuracy: EEI Identification based on SATs and Information Workflow

First, we wanted to determine if solution accuracy was derived from coupling SATs and information workflow. An ANOVA was conducted and revealed a statistically significant difference between SATs and information workflow with respect to solution accuracy ($F5{,}144 = 4.13$, $p < 0.01$) as seen in Table 1. Moreover, it was discovered that providing MDAQInc lead to the highest solution accuracy compared to all other conditions (17 out of 25 participants – 68%).

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

Next, we wanted to determine if EEI identification was the foundational reasoning resulting in greater solution accuracy between conditions. Therefore, open-field text analysis was conducted focusing on EEI identification between SATs and information workflow. An ANOVA revealed there was a statistically significant difference between SATs and information workflow when participants identified 0 EEIs ($F_{5,144} = 10.55$, $p < 0.01$) and four EEIs ($F_{5,144} = 11.70$, $p < 0.01$). The majority of the participants assigned to the control and scaffolding groups were unable to identify an EEI within the intel (Control$_{All}$ 19 of 25 (76%), Control$_{Inc}$ 13 of 25 (52%), Scaffolding$_{All}$ 17 of 25 (76%), Scaffolding$_{Inc}$ 19 of 25 (76%)). Only the MDAQ groups had participants who were able to correctly identify all 4 EEIs (MDAQ$_{All}$ 6 of 25 (24%), MDAQ$_{Inc}$ 11 of 25 (44%)). This discovery provides validity to the concept that SATs and information workflow does significantly influence EEI identification leading to improved solution accuracy. The bar chart represents the number of correctly identified EEIs with respect to SATs, information workflow, and solution accuracy (see Figure 4).

Table 1. An ANOVA was conducted comparing SATs and Information Workflow for Correctly Identified EEI. Statistical Significance at an Alpha of 0.05.

Comparison of Structured Analytic Technique and Information Workflow for Identified EEIs								
EEIs	Control All	Control Inc	MDAQ All	MDAQ Inc	Scaffolding All	Scaffolding Inc	Between Groups F-Test	p-value
0	19 (76%)	13 (52%)	5 (20%)	3 (12%)	17 (68%)	19 (76%)	10.55	<0.01
1	3 (12%)	8 (32%)	7 (28%)	4 (16%)	6 (24%)	3 (12%)	1.11	0.36
2	1 (4%)	3 (12%)	3 (12%)	3 (12%)	2 (8%)	3 (12%)	0.30	0.91
3	2 (8%)	1 (4%)	4 (16%)	4 (16%)	0 (0%)	0 (0%)	2.04	0.08
4	0 (0%)	0 (0%)	6 (24%)	11 (44%)	0 (0%)	0 (0%)	11.70	<0.01
Solution Accuracy	4/25 (16%)	10/25 (40%)	7/25 (28%)	17/25 (68%)	6/25 (24%)	7/25 (28%)	4.13	<0.01

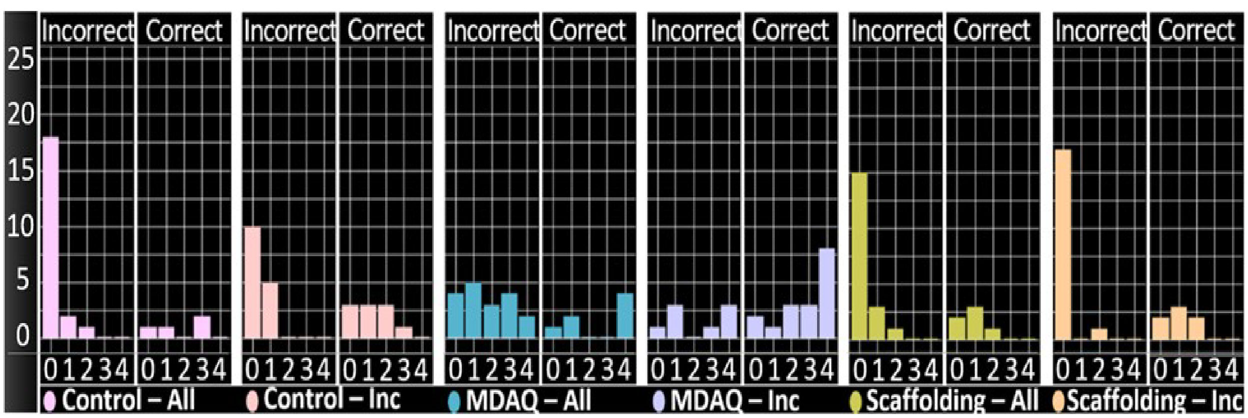


Figure 4. Visual Representation for Correctly Identified EE) and SATs coupled with Solution Accuracy.

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

4.2 Visual Network Text Analysis: Which EEIs were Correctly Identified based on SATs and Information Workflow

Lastly, we investigated the correlation between each of the four EEIs (labeled based on their chronological order within the intel as EEI 1-4) and SATs using a visual network text analysis. When correctly identified, each EEI embedded within the intel provided the participant with critical information directed towards the appropriate solution. An ANOVA was conducted and revealed there was a statistically significant correlation between SAT and EEI 1 ($F_{5,144} = 10.04$, $p < 0.01$), EEI 2 ($F_{5,144} = 9.22$, $p < 0.01$), EEI 3 ($F_{5,144} = 10.22$, $p < 0.01$), and EEI 4 ($F_{5,144} = 13.10$, $p < 0.01$) as seen in Table 2. In addition, it was discovered that the MDAQ group was able to identify and correlate the detection of EEI 1 ($F_{2,147} = 19.97$, $p < 0.01$), EEI 2 ($F_{2,147} = 20.38$, $p < 0.01$), EEI 3 ($F_{2,147} = 25.73$, $p < 0.01$), and EEI 4 ($F_{2,147} = 31.98$, $p < 0.01$) more efficiently compared to the control and scaffolding group leading to higher solution accuracy during the decision-making process (see Figure 5).

Table 2. An ANOVA was conducted comparing SATs and Information Workflow for Identification for Each EEI.
Statistical Significance at an alpha of 0.05.

Comparison of Structured Analytic Technique and Information Workflow for Each EEI								
EEI	Control All	Control Inc	MDAQ All	MDAQ Inc	Scaffolding All	Scaffolding Inc	Between Groups F-Test	p-value
1	4 (16%)	7 (28%)	12 (48%)	18 (72%)	3 (12%)	2 (8%)	9.22	<0.01
2	3 (12%)	3 (12%)	11 (44%)	19 (76%)	4 (16%)	5 (20%)	10.04	<0.01
3	3 (12%)	5 (20%)	15 (60%)	15 (60%)	2 (8%)	2 (8%)	10.22	<0.01
4	1 (4%)	2 (8%)	11 (44%)	14 (56%)	1 (4%)	0 (0%)	13.10	<0.01

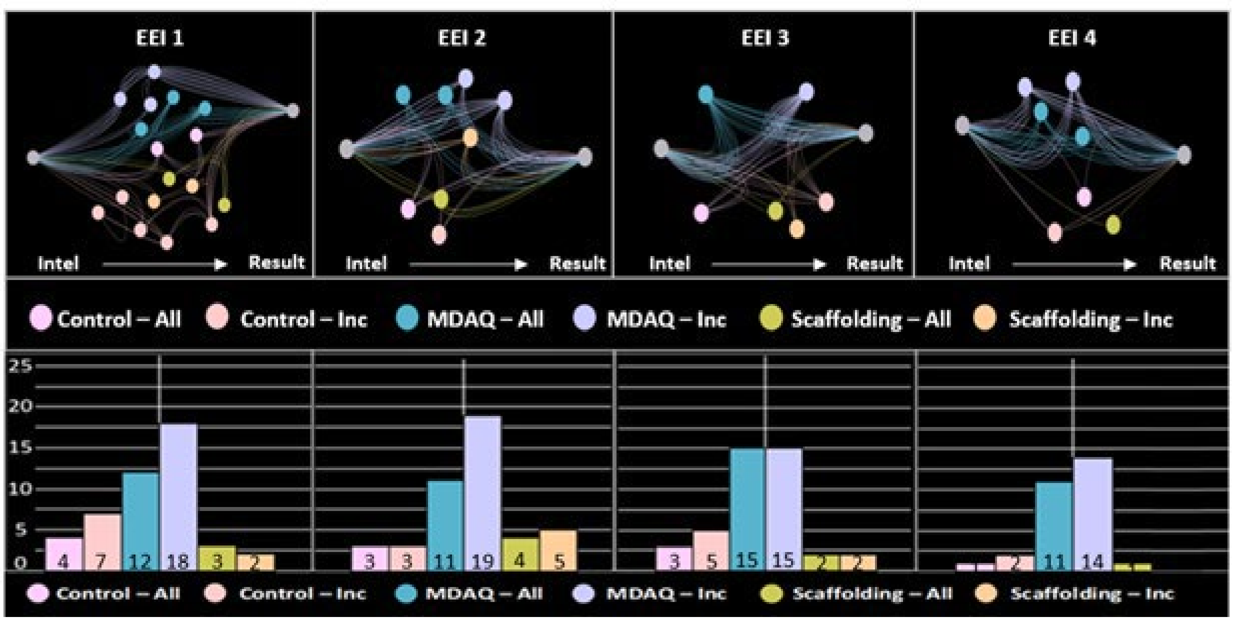


Figure 5. Representation of a Visual Network Text Analysis Displaying Identified EEIs by SAT and Information Workflow leading to Solution Accuracy.

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

4.3 Demographics and Personal Characteristics

There were no statistically significant correlations between demographics (i.e., age, gender, education level, gaming experience) and detection of essential elements of information leading to performance enhancement.

5.0 DISCUSSION

The U.S. military relies heavily on ISR collections to derive decision-making assessments with respect to our adversaries' ground movement patterns, threat level capabilities, and future allocation of resources (Karvetski et al. 2020). If intel analysts misconstrue subtle information within ISR collections, it can produce an increase in errors, an increase in lead time, and induce pre-existing biases resulting in poorer decision-making outcomes. Moreover, multi-domain collected intelligence is commonly ill-defined, incomplete, or vague, resulting in operators relying on intuition instead of data-driven evidence. Therefore, it is imperative that a decision-making tool can be leveraged to combat these issues and enhance future military decision recommendations.

Prior research has shown that implementing SATs when confronted with complex, convoluted information can improve decision-making outcomes (Covey & Lovie 1998; Miller 2017).

Specifically, scaffolding has been shown to improve content comprehension, critical thinking, and decision-making rationale. Previous literature has discovered that promoting scaffolding as an instructional framework enhances an operators' ability to understand and translate complicated content into simplified information. In this example, the instructional framework initiated probing questions in an effort to increase active deep thinking and problem-solving characteristics. Although this concept manipulates the operators' thought process through a structured approach, the framework allows for the operator to continually engage and construct their own problem statements and recommendation (Clark & Graves 2005). Another study conducted by Pata et al. 2006, discovered that employing scaffolding within a collaborative workspace can augment and enhance decision-making skills. In this effort, the operator had to progress through the scaffolding approach multiple times to generate situational awareness and invoke relational decisions based on the content fragments. The results displayed improved decision-making recommendations through enhancing pattern recognition (Pata et al. 2006).

Unlike previous literature discoveries, incorporating a scaffolding approach coupled with either incrementally or complete intelligence, did not enhance decision-making outcomes when confronted with simulated ISR content. In addition, there was not a significant enhancement in detection of EEI. This discovery provides further support to the thought that there may be limitations to the effectiveness of scaffolding on cognitive processing and decision-making when confronted with complex military environments (Xun & Land 2004; Doo & Heo 2020). We anticipated that there may be limitations associated with current SATs which led to the development of the method for MDAQ by ISR SMEs at Wright-Patterson AFB.

This study investigated if incorporating SATs, specifically scaffolding and MDAQ, could augment the decision-making process by improving detection of EEI. We believed this would lead to higher solution accuracy when provided with unstructured, emulated ISR intelligence in both incremental and complete sections. Since MDAQ is a newly developed SAT, there is little previous literature on the effectiveness of the design and approach. Nevertheless, the findings provided underlying evidence that when participants were instructed to follow the MDAQ

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

approach, there was a significant enhancement in EEI detection compared to scaffolding and control. $MDAQ_{Inc}$ and $MDAQ_{All}$ identified approximately four times as many EEIs compared to $Scaffolding_{Inc}$, $Scaffolding_{All}$, $Control_{Inc}$, and $Control_{All}$. The enhancement in detection of EEIs improved decision-making outcomes resulting in a significant performance difference. In addition, the majority of the participants within the control and scaffolding groups were unable to identify a single EEI embedded within the intelligence. On the other hand, the MDAQ group was the only group that was able to correctly identify all four EEIs (11 of the 25 participants in the $MDAQ_{Inc}$ and 6 of the 25 participants in the $MDAQ_{All}$). MDAQ may be demonstrating these difference by driving deeper cognitive engagement and processes. This discovery provides valuable insight that following the MDAQ approach, an in-house ISR developed SAT, enables critical thinking and logical reasoning leading to improved decision-making outcomes.

Previous research has shown that quantified performance metrics were the key indicators when evaluating SAT efficacy during the decision-making process (Friedman & Zeckhauser 2016). However, little to no research has been conducted evaluating critical thinking and logical reasoning collected from open-field responses when providing an SAT. Therefore, this study not only focused on output performance metrics but also the relational aspects of open-field inputs and the decision-making process using visual network text analysis. A visual network text analysis is a representation displaying the relational component between key works and indicators (Yoon & Park 2004; Saura 2021). The findings showed that the MDAQ group was able to accurately identify EEIs and show a direct relationship/correlation to the solution compared to both, scaffolding and control. Incorporating a visual network text analysis to represent EEI detection and solution accuracy for SATs strengthens the argument that the MDAQ group was able to process, comprehend, and disseminate information more effectively leading to improved decision accuracy.

Lastly, there were limitation with this research study that need to be addressed in the next iteration which include the evaluation of additional SATs, physiological measurements to evaluate workload and cognitive stressors, and including military personnel as participants to determine if this research can be transitioned into a military environment. However, the discoveries from this study are very promising and provided valuable fundamental insight that incorporating MDAQ could improve detection of subtle EEIs leading to improved performance compared to a scaffolding and control approach.

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

6.0 REFERENCES

Artner, S., Girven, R., & Bruce, J. (2016). Assessing the Value of Structured Analytic Techniques in the U.S. Intelligence Community. *RAND National Defense Research Institute*. doi.org/10.7249/rr1408

Belland, B., Walker, A., Kim, N., & Lefler, M. (2017). Synthesizing Results from Empirical Research on Computer-Based Scaffolding in STEM Education: A Meta-Analysis. *Review of Educational Research*, 87(2), 309-344. doi.org/10.3102/0034654316670999

Belland, B., Walker, A., & Kim, N. (2017). A Bayesian Network Meta-Analysis to Synthesize the Influence of Contexts of Scaffolding Use on Cognitive Outcomes in STEM Education. *Review of Educational Research*, 87(6), 1042-1081. doi.org/10.3102/0034654317723009

Brandes, U., & Corman, S. (2003). Visual Unrolling of Network Evolution and the Analysis of Dynamic Discourse. *Information Visualization*, 2(1), 40-50. doi.org/10.1057/palgrave.ivs.9500037

Brunzel, J. (2021). Making Use of Quantitative Content Analysis: Insights from Academia and Business Practices. *Business Horizons*, 64(4), 453-464. doi.org/10.1016/j.bushor.2021.02.010

Buckley, J., Buckles, B., & Petry, F. (2000). Processing noisy Structured Textual Data Using a Fuzzy Matching Approach: Application to Postal Address Errors. *Soft Computing*, 4, 195-205. doi.org/10.1007/s005000000054

Caballero, W., Friend, M., Blasch, I. (2021). Adversarial Machine Learning and Adversarial Risk Analysis in Multi-Source Command and Control. *International Journal of Optics and Photonic Engineering*, 11756, 117560L. doi.org/10.1117/12.2589027

Change, W., Berdini, E., Mandel, D., & Tetlock. (2018). Restructuring Structured Analytic Techniques in Intelligence. *Intelligence and National Security*, 33(3), 337-356. doi.org/10.1080/02684527.2017.1400230

Clark, K., & Graves, M. (2005). Scaffolding Students' Comprehension of Text. *The Reading Teacher*, 58(6), 570-580. doi.org/10.1598/rt.58.6.6

Coulthart, S. (2017). An Evidence-Based Evaluation of 12 Core Structured Analytic Techniques.

International Journal of Intelligence and Counterintelligence, 30(2), 368-391. doi.org/10.1080/08850607.2016.1230706

Coulthart, S. (2016). Why do Analysts Use Structured Analytic Techniques? An In-Depth Study of an American Intelligence Agency. *Intelligence and National Security*, 31(7), 933-948. doi.org/10.1080/02684527.2016.1140327

Covey, J., & Lovie, A. (1998). Information Selection and Utilization in Hypothesis Testing: A Comparison of Process-Tracing and Structural Analysis Techniques. *Organizational Behavioral and Human Decision Processes*, 71(1), 56-74. doi.org/10.1006/obhd.1998.2782

Dabarera, C., Renandya, W., & Zhange, L. (2014). The Impact of Metacognition Scaffolding and Monitoring on Reading Comprehension. *System*, 43, 462-473. doi.org/10.1016/j.system.2013.12.020

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

Dhami, M., Belton, I., & Careless, K. (2016). Critical review of Analytic Techniques. *IEEE*, 152-155. doi.org/10.1109/eisic.2016.039

Dhami, M., Belton, I., & Mandel, D. (2019). The Analysis of Competing Hypotheses in Intelligence Analysis. *Applied Cognitive Psychology*, 33(6), 1080-1090. doi.org/10.1002/acp.3550

DiMaggio, P. (2015). Adapting Computational Text Analysis to Social Science (and vice Versa). *Big Data & Society*, 2(2), 2053951715602908. doi.org/10.1177/2053951715602908

Dominguez, C., Cox, D., Long, W., Moon, B., & Klein, G. (2005). Helping Analysts Deal with Data Overload: Profiling Profilers. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 3(4), 224-237. doi.org/10.1177/154193120504901008

Doo, B., & Heo, H. (2020). A Meta-Analysis of Scaffolding Effects in Online Learning in Higher Education. *International Review of Research in Open and Distributed Learning*, 21(3), 1-334. doi.org/10.19173/irrodl.v21i3.4638

Drieger, P. (2013). Semantic Network Analysis as a Method for Visual Text Analysis. *Procedia-Social Behavioral Sciences*, 79, 4-17. doi.org/10.1016/j.sbspro.2013.05.053

Eierman, M., Niederman, F., & Adams, C. (1995). DSS Theory: A Model of Constructs and Relationships. *Decision Support Systems*, 14(1), 1-26. doi.org/10.1016/0167- 9236(94)00012-h

Friedman, J., & Zeckhauser, R. (2016). Why Assessing Estimative Accuracy is Feasible and desirable. *Intelligence and National Security*, 31(2), 178-200. doi.org/10.1080/02684527.2014.980534

Gaeta, A., Loia, V., & Orciuoli, F. (2021). A Comprehensive Model and Computational Methods to Improve Situation Awareness in Intelligence Scenarios. *Applied Intelligence*, 51, 6585-66008. doi.org/10.1007/s10489-021-02673-z

Gelder, T., Kruger, A., Thomman, S., Rozario, R., Silver, E., Saletta, M., Barnett, A., Sinnott, R., Jayaputera, G., & Burgman, M. (2020). Improving Analytic Reasoning via Crowdsourcing and Structured Analytic Techniques. *Journal of Cognitive Engineering and Decision Making*, 14(3), 195-217. doi.org/10.1177/1555343420926287

George, R. (2010). Beyond Analytic Tradecraft. *International Journal of Intelligence and Counterintelligence*, 23(2), 296-306. doi.org/10.1080/08850600903566124

Goodall, J. (2011). An Evaluation of Visual and Textual Network Analysis Tools. *Information Visualization*, 10(2), 145-157. doi.org/10.1057/ivs.2011.2

Goslee, S. (2011). Analyzing Remote Sensing Data in R: The Landsat Package. *Journal of Statistical Software*, 43(4), 1-25. doi.org/10.18637/jss.v043.i04

Haugh, T., & Douglas, L. (2017). Improving Outcomes: Intelligence, Surveillance, and Reconnaissance Assessment. *Air and Space Power Journal*, 31(4), 4-17. link.gale.com/apps/doc/A522758596/AONE?u=anon~de7754b7&sid=googleScholar&xid=ef3a26c1

Herring, J. (1999). Key Intelligence Topics: A Process to Identify and Define Intelligence Needs. *SCIP*, 10(2), 4-14. doi.org/10.1002/(sici)1520-6386(199932)10:2<4::aid-cir3>3.0.co;2-c

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

Hersey, P., & Wang, M. (2013). Composable, Distributed System to Derive Actionable Mission Information from Intelligence, Surveillance, and Reconnaissance (ISR) Data. *IEEE*, 460-467. doi.org/10.1109/syscon.2013.6549923

Hiedemann, B., & Jones, S. (2010). Learning Statistics at the Farmers Market? A Comparison of Academia Service Learning and Case Studies in an Introductory Statistics Course. *Journal of Statistics Education*, 18(3), 20-33. doi.org/10.1080/10691898.2010.11889584

Ittoo, A., Nguyen, L., & Bosch, A. (2016). Text Analysis in Industry: Challenges, Desiderata and Trends. *Computers in Industry*, 78, 96-107. doi.org/10.1016/j.compind.2015.12.001

James, I., & Okpala, C. (2010). The Use of Metacognitive Scaffolding to Improve College Students Academic Success. *Journal of College Teaching & Learning*, 7, 11. doi.org/10.19030/tlc.v7i11.251

Johnson, L. (1986). Making the Intelligence Cycle Work. *International Journal of Intelligence and Counterintelligence*, 1(4), 1-23. doi.org/10.1080/08850608608435033

Lin, T., Hsu, Y., Lin, S., Changlai, M., Yang, K, & Lai, T. (2012). A Review of Empirical Evidence on Scaffolding for Science Education. *International Journal of Science and Mathematics Education*, 10(2), 437-455. doi.org/10.1007/s10763-011-9322-z

Liu, Y., Luo, Z., Liu, Z., Shi, J., & Cheng, G. (2019). Cooperative Routing Problem for Ground Vehicle and Unmanned Aerial Vehicle: The Application on Intelligence, Surveillance, and Reconnaissance Missions. *IEEE*, 7, 63504-63518. doi.org/10.1109/access.2019.2914352

Lowenthal, M., & Clark, R. (2015). The Five Disciplines of Intelligence Collection, Sage.

Lusher, R., & Stone, G. (1997). A Prototype Report Filter to Reduce Information Overload in Combat Simulations. *IEEE*, 2788-2793. doi.org/10.1109/icsmc.1997.635374

Karvetski, C., Mandel, D., & Irwin, D. (2020). Improving Probability Judgement in Intelligence Analysis: From Structured Analysis to Statistical Aggregation. *Risk Analysis*, 40(5), 1040-1057. doi.org/10.1111/risa.13443

Kusmaryono, I., Gufron, A., & Rusdiantoro, A. (2020). Effectiveness of scaffolding strategies in learning against decrease in mathematics anxiety level. *Journal of Mathematics Education*, 13-22. doi.org/10.25217/numerical.v4i1.770

Macdonald, N., Frase, L., Gingrich, P., & Keenan, S. (1982). The writers workbench: Computer aids for text analysis. *IEEE*, 30(1), 105-110. doi.org/10.1109/tcom.1982.1095380

McFarlane, D., Doig, A., Agutter, J., Mercurio, J., Mittu, R., Brewer, L., & Syroid, N. (2016). Defeating Information Overload in Health Surveillance using Metacognitive Aid Innovation from Military Combat Systems. *The Journal of Defense Modeling and Simulation*, 14(4), 371-388.

Mehl, M. (2006). Quantitative Text Analysis, Handbook of Multimethod Measurement in Psychology, 141-156. doi.org/10.103711383-011

Miller, D. (2017). Strategy Making and Structure: Analysis and Implications for Performance. *Academy of Management Journal*, 30(1), 7-32. doi.org/10.5465/255893

Mugavero, R., Benolli, F., & Sabato, V. Challenges of Multi-Source Data and Information New Era. *Journal of Information Security and Applications*, 11(4), 230-242.

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

doi.org/10.1080/15536548.2015.1105617

Nelson, J., Maresca, A., Schlessman, B., Holt, J., Kegley, J., & Boydstun, A. (2022). Evaluating the Efficacy of Structured Analytic Approaches as a Support System to Enhance Decision-Making within intelligence, Surveillance, and Reconnaissance (ISR) Mission Environment.

Nelson, J., Maresca, A., & Schlessman, B. (2022). Can Structured Analytic Techniques Enhance Intelligence, Surveillance, and Reconnaissance (ISR) Assessments when Provide Incremental Essential Elements of Information (EEI).

Novák, A., & Burita, L. (2019). Business Intelligence and ISR Data Processing. *IEEE*, 1-8. doi.org/10.1109/miltechs.2019.8870135

O'Hare, L., & McGuinness, C. (2015). The Validity of Critical Thinking Tests for Predicting Degree Performance: A Longitudinal Study. *International Journal of Educational Research*, 72, 162-172. doi.org/10.1016/j.ijer.2015.06.004

Pata, K., Lehtine, E., & Sarapuu, T. (2006). Inter-Relations of Tutor's and Peers' Scaffolding and Decision- Making Discourse Acts. *Instructional Science*, 34, 313-341. doi.org/10.1007/s11251-005-3406-5

Pawgasame, W. (2016). A Survey in Adaptive Hybrid Wireless Sensor Network for Military Operations. *IEEE*, 78-83. doi.org/10.1109/acdt.2016.7437647

Person, R., & Heuer, R. (2020). Structured Analytic Techniques for Intelligence analysis. *Cq Press*

Popping, R. (2015). Analyzing Open-Ended Questions by Means of Text Analysis Procedures. *Bulletin of Sociological Methodology*, 128(1), 23-39. doi.org/10.1177/0759106315597389

Richards, J. (2016). Intelligence Studies, Academia and Professionalization. *The International Journal of Intelligence, Security, and Public Affairs*, 18(1), 20-33. doi.org/10.1080/23800992.2016.1150683

Saura, J. (2021). Using Data Sciences in Digital Marketing: Framework, Methods, and Performance Metrics. *Journal of Innovation & Knowledge*, 6(2), 92-102. doi.org/10.1016/j.jik.2020.08.001

Saktheewaran, A., Srinivasan, A., & Stasko, J. (2020). Touch? Speech? Or Touch and Speech? Investigating Multimodal Interaction for Visual Network Exploration and Analysis. *IEEE*, 26(6), 2168- 2179. doi.org/10.1109/tvcg.2020.2970512

Scarff, L., Burke, D., Jones, E., Gilfillan, L., Pratt, S., Jackson, C., Weil, S., & Fiore, S. (2013). Measuring Knowledge: Investigative Research into the Quantification of Performance within a Contextual Multi-Source PED Fusion Process. *IEEE*, 8756, 235-249. doi.org/10.1117/12.2015303

Schoening, J., Duff, D., Hines, D., Riser, K., Pham, T., Stolovy, G., Houser, J., Rudnicki, R., Ganger, R., James, A., & Nagler, E. (2015). PED Fusion via Enterprise Ontology. *IEEE*, 9464. doi.org/10.1117/12.2182064

Scott, B. (2020). Red Teaming Financial Crime Risks in the Banking Sector. *Journal of Financial Crime*, 28(1), 98-111. doi.org/10.1108/jfc-06-2020-0118

Sharma, M., Singh, G., Virk, R., & Singh, G. (2013). Design and Comparative Analysis of DSS

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022

Queries in Distributed Environment. *IEEE*, 73-78. doi.org/10.1109/icsec.2013.6694756

Stottlemyre, S. (2015). HUMINT, OSINT, or Something New? Defining Crowdsourced Intelligence. *International Journal of Intelligence and Counterintelligence*, 28(3), 578-589. doi.org/10.1080/08850607.2015.992760

Udo, G., & Guimaraes, T. (2017). Empirically Assessing Factors Related to DSS Benefits. *European Journal of Information Systems*, 3(3), 218-227. doi.org/10.1057/ejis.1994.22

Welbers, K., Atteveldt, W., & Benoit, K. (2017). Text Analysis in R. *Communication Methods and Measures*, 11(4), 245-265. doi.org/10.1080/19312458.2017.1387238

Wessa, P. (2009). A Framework for Statistical Software Development, Maintenance, and Publishing within an open-Access Business Model. *Computational Statistics*, 24, 183-193. doi.org/10.1007/s00180-008- 0107-y

Wollocko, A., Farry, M., Voshell, M., Jenkins, M., & Pellicano, M. (2015). Supporting Common ground across multiple operator perspectives – creating collaborative solutions for Distributed Processing, Exploitation, and Dissemination (PED). *IEEE*, 82-88. doi.org/10.1109/cogsima.2015.7108179

Xun, G., & Land, S. (2004). A Conceptual Framework for Scaffolding Ill-Structured Problem-Solving Processes using Question Prompts and Peer Interactions. *Educational Technology Research and Development*, 52, 5-22. doi.org/10.1007/bf02504836

Yang, J., Honavar, V., Miller, L., & Wong, J. (1998). Intelligence Mobile Agents for Information Retrieval and Knowledge Discovery from Distributed Data and Knowledge Sources. *IEEE*, 99-102. doi.org/10.1109/it.1998.713391

Yoon, B., & Park, Y. (2004). A Text-Mining-Based Patent Network: Analytical Tool for High-technology Trend. *The Journal of High Technology Management Research*, 15(1), 37-50. doi.org/10.1016/j.hitech.2003.09.003

Zhao, R., & Mao, K. (2017). Fuzzy Bag-of-Words Model for Document Representation. *IEEE*, 26(2), 794- 804. doi.org/10.1109/tfuzz.2017.2690222

7.0 ACRONYM LIST

ACH	Analysis of Competing Hypotheses
AFRL	Air Force Research Laboratory
ANOVA	Analysis of Variance
DoD	Department of Defense
EEI	Elements of Information
GEOINT	Geospatial Intelligence
HUMINT	Human Intelligence
INT	Intelligence Collection Disciplines
IRB	Institutional Review Board
ISR	Intelligence, Surveillance, and Reconnaissance

JADC2	Joint All-Domain Command and Control
MASINT	Measurement and Signature Intelligence
MDAQ	Method for Defining Analytical Questions
MTurk	Mechanical Turk
OSINT	Open-Source Intelligence
PED	Joint All-Domain Command and Control
SAT	Structured Analytic Techniques
SIGINT	Signals Intelligence
SME	Subject Matter Expert

Distribution A. Approved for public release; distribution unlimited.
AFRL-2022-3739; 4 Aug 2022