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# **Can You DIG It? Dynamic InfoGraphics (DIG) Capstone: A Concept for Transparency of Intelligent Agent Systems Using Augmented Reality**

**by Gina Hartnett, Jamison Hicks, and Derek Millard**

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by Gina Hartnett, Jamison Hicks, and Derek Millard  
*DEVCOM Analysis Center*

## REPORT DOCUMENTATION PAGE

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| 13. SUPPLEMENTARY NOTES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                             |                                     |                            |                                                                       |                               |
| 14. ABSTRACT<br>The future battlefield is becoming an exceedingly complex environment that is often difficult for a Soldier to digest fully. Soldiers will need to understand their environment as quickly as possible with the help of intelligent agents (IAs). This influx of information leaves operators with decreased situation awareness (SA) and user trust in these systems. Using the Dynamic InfoGraphics (DIG) concept increases user SA and trust in automation because it provides the user with rapid understanding of the battlefield and mission-relevant entities and transparency of autonomous or IA systems' actions and decisions. A total of 54 rotary wing pilots, flight medics, non-rated crew, and civilian aviation subject-matter experts participated in this 2 (display presentation type) × 2 (level of transparency) within-subjects design study. Results indicate the DIG presentation type outperformed the text presentation type with improved accuracy and response time in answering real-time SA queries, and improved trust and workload was noted in after-action surveys. In addition, the more transparency the system showed, the more user trust occurred. |                             |                                     |                            |                                                                       |                               |
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## (U) Table of Contents

|                                                     |     |
|-----------------------------------------------------|-----|
| List of Figures .....                               | v   |
| List of Tables .....                                | vi  |
| Acknowledgments .....                               | vii |
| 1. INTRODUCTION .....                               | 1   |
| 2. BACKGROUND .....                                 | 3   |
| 2.1 Proposed Model of DIG-LoSA .....                | 5   |
| 2.2 General Problem Statement .....                 | 9   |
| 3. METHODS, ASSUMPTIONS, AND PROCEDURES .....       | 10  |
| 3.1 Flight Scenario Development.....                | 10  |
| 3.1.1 Programming.....                              | 10  |
| 3.1.2 Mission Profile.....                          | 11  |
| 3.1.3 Tasks .....                                   | 12  |
| 3.1.4 Measures .....                                | 17  |
| 3.1.5 Research Questions.....                       | 19  |
| 4. CONSTRAINTS, LIMITATIONS, AND ASSUMPTIONS .....  | 20  |
| 4.1 Assumptions .....                               | 20  |
| 4.2 Scope of Research .....                         | 20  |
| 4.3 Limitations.....                                | 20  |
| 4.4 Delimitations .....                             | 21  |
| 4.5 Reliability .....                               | 21  |
| 4.6 Validity .....                                  | 22  |
| 5. RESULTS AND DISCUSSION .....                     | 24  |
| 5.1 Demographics.....                               | 24  |
| 5.2 Mission Response Time Data .....                | 24  |
| 5.3 Mission Accuracy Data .....                     | 25  |
| 5.4 Enemy Response Time Data .....                  | 26  |
| 5.5 Enemy Accuracy Data .....                       | 26  |
| 5.6 Situation Awareness by Condition .....          | 27  |
| 5.7 Trust by Condition.....                         | 28  |
| 5.8 Workload by Condition.....                      | 29  |
| 5.9 Usability by Condition .....                    | 30  |
| 6. CONCLUSION AND RECOMMENDATIONS .....             | 31  |
| 6.1 Effective Human-Agent Collaborations .....      | 31  |
| 6.2 Effective Intelligent Agents Transparency.....  | 31  |
| 6.3 Effective Intelligent Agents Forecasting .....  | 31  |
| 6.4 Future Research.....                            | 32  |
| 6.4.1 Future of Transparent IA Collaborations ..... | 32  |
| 6.4.2 Future IA Interface Control.....              | 32  |

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---

## (U) Table of Contents

|                         |    |
|-------------------------|----|
| 7. REFERENCES .....     | 33 |
| List of Acronyms .....  | 37 |
| Distribution List ..... | 38 |

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## List of Figures

|            |                                                                                                                                                                                   |    |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Figure 1.  | Current 9-Line MEDEVAC format .....                                                                                                                                               | 7  |
| Figure 2.  | 9-Line MEDEVAC message as spoken or heard via verbal<br>communications .....                                                                                                      | 8  |
| Figure 3.  | 9-Line DIG .....                                                                                                                                                                  | 8  |
| Figure 4.  | 9-Line DIG with Levels 1, 2, and 3 of SA .....                                                                                                                                    | 9  |
| Figure 5.  | Unreal Engine's blueprint visual scripting language.....                                                                                                                          | 11 |
| Figure 6.  | All FARP DIG in AR .....                                                                                                                                                          | 13 |
| Figure 7.  | All FARP JVMF text messages presented on the panel mounted display<br>.....                                                                                                       | 14 |
| Figure 8.  | Enemy threat outside the window .....                                                                                                                                             | 14 |
| Figure 9.  | Enemy threat AR icons without metadata (less condition) and with<br>metadata (more condition), respectively .....                                                                 | 15 |
| Figure 10. | Mission and enemy threat JVMF text alerts on PMD .....                                                                                                                            | 15 |
| Figure 11. | Enemy threat JVMF text message on PMD .....                                                                                                                                       | 15 |
| Figure 12. | Mission-related PQs example .....                                                                                                                                                 | 16 |
| Figure 13. | Enemy threat questions; UAS = unmanned aircraft system.....                                                                                                                       | 16 |
| Figure 14. | Screenshot of the scenario video with a 9-Line and patient DIG displayed<br>in AR, enemy in the real world with enemy AR symbol, and the PMD<br>screens in the bottom center..... | 17 |
| Figure 15. | Screenshot of the scenario video with an All FARP DIG displayed in AR<br>and a mission-related PQ in the middle right of the environment.....                                     | 17 |
| Figure 16. | ANOVA for mission response time data.....                                                                                                                                         | 25 |
| Figure 17. | ANOVA for mission response accuracy data .....                                                                                                                                    | 25 |
| Figure 18. | ANOVA for ER time data .....                                                                                                                                                      | 26 |
| Figure 19. | ANOVA for ER accuracy data.....                                                                                                                                                   | 27 |
| Figure 20. | Overall SA by condition.....                                                                                                                                                      | 28 |
| Figure 21. | Overall trust by condition .....                                                                                                                                                  | 28 |
| Figure 22. | MR times ANOVA by variable.....                                                                                                                                                   | 29 |
| Figure 23. | ER times ANOVA by variable .....                                                                                                                                                  | 29 |
| Figure 24. | Workload by condition.....                                                                                                                                                        | 30 |
| Figure 25. | Usability by condition .....                                                                                                                                                      | 30 |

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## List of Tables

|          |                                                                |    |
|----------|----------------------------------------------------------------|----|
| Table 1. | Hartnett's DIG-LoSA model .....                                | 6  |
| Table 2. | Scenario sections and objective data points .....              | 13 |
| Table 3. | Objective data points per participant for one condition .....  | 18 |
| Table 4. | Objective data points per participant for all conditions ..... | 18 |
| Table 5. | Objective data points for all 54 participants .....            | 18 |
| Table 6. | Demographics table .....                                       | 24 |

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# 1. INTRODUCTION

Autonomous and artificial intelligence (AI) systems are beginning to inundate almost all industries, including military operations, providing humans with enormous amounts of sensed information and aid or replacement with complex and rapid decision making. It becomes challenging for humans to decipher the plethora of sensed information (Ha et al., 2019; Holzinger et al., 2019), which makes decision making even more complex and time consuming. This is true for operators of many Army systems in which decisions, actions, and mistakes happen quickly. The rapid and complex actions these systems take often make it difficult for a human to understand the vast amount of sensed information, the *what* and the transparency of system reasoning, or the *why* of a system's specific action. Currently, in Army rotary wing platforms, automated systems make some decisions and take various actions to alleviate workload (Crawford & Neal, 2006). Often, however, no explanations are provided to the pilot or crew. This lack of reasoning frequently leads to uncertainty in users (Bobek & Nalepa, 2021; Zhang & Hußmann, 2021; Jiang et al., 2022). This uncertainty will likely exacerbate the situation when intelligent agents (IAs), such as AI, are introduced into the cockpit (Sutthithatip et al., 2021). This information gap leaves operators with decreased situation awareness (SA) and user trust in these systems, especially if the system makes an obvious error (Pomranky et al., 2001; Pak et al., 2017; Schmitt et al., 2018).

Dynamic InfoGraphics (DIG) seeks to provide the user transparency and rapid understanding of autonomous or IA system actions and decisions, thereby increasing user trust through increased SA. This concept combines intuitive graphics with bits of textual information that are dynamic and quickly understood by the user. The goal is to present relevant informational DIGs in augmented reality (AR) to the user. The use of autonomous and IA systems is growing in almost all military operations, providing aid to the Soldier or replacement with complex, rapid decision making and actions that become extremely difficult for humans to quickly understand (Ha et al., 2019; Holzinger et al., 2019; Le Roux, 2010) and, if needed, intervene. This lack of understanding presents a human factors need to the military. This study presents a solution that increases SA and user trust in the system and improves user workload and overall mission performance as Soldiers are given a tool to facilitate a new capability in understanding.

A total of 54 rotary wing pilots, medics and crew, and civilian aviation subject matter experts (SMEs) participated in this 2 (display presentation type: DIG [in AR], text [on an aircraft inside screen]) × 2 (level of transparency: less [L1 sense and display {what}]; more [L1/sense and display {what}, L2/transparency through XAI {why}, L3/trend forecasting through trend analysis {next}]) within-subjects design study. Results

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indicated that the DIG presentation type outperformed the text presentation type with increased accuracy, SA, user trust, and decreased decision time and workload. In addition, the more transparency the system shows, the higher the users' trust.

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## 2. BACKGROUND

Transparency of the system is crucial to understanding the *what* and the *why*, which will increase user trust and ensure effective collaboration within this human–system team. Research conducted to ensure humans understand the *how* and *why* of intelligent systems through explainable AI (XAI) (Gunning, 2016) supports the importance of transparency. A model of human trust in autonomous systems, Situation Awareness-based Agent Transparency (SAT) (Chen & Barnes, 2014), was developed to describe user trust issues in these systems. Situation awareness is defined by Endsley (1995) as the perception of environmental elements, understanding the meaning of those elements, including how they relate to each other, and what might occur in the near-term future given the current status of the environment.

Following these elements, a model of DIG levels of SA (DIG-LoSA) was created to demonstrate the transparency of a system by visually displaying the sensed information (*what*), the transparency of the system’s reasonings or explanations (XAI) (*why*), and trend forecasting based on trend analysis (*next*) for actions and decisions made by those systems. Lin & Lu (2016) suggest helicopter pilots need situational awareness in the cockpit to mitigate the accidents that pilots have incurred due to the lack of SA. Parnell et al. (2022) cited that a lack of pilot SA affected decision making during a dual engine failure on take-off. Choi et al. (2007) state that a lack of SA caused 80% of accidents between 1989 and 1992. In addition, research shows that visual ideas in graphical format are easier to understand than those presented with words (Lemke, 1998). The DIG concept provides user transparency of IA systems, thereby increasing user trust through increased SA.

The use of AR in the military is in full swing as well. The concept is that systems would be worn on a dismount Soldier’s head and provide augmented information on top of the real world on the battlefield in both day and night operations to provide enhanced SA (Gans et al., 2015). One issue to consider is the amount of information provided to the user. Too much augmentation is likely to lead to cluttering their view and increasing workload of the user (Tatzgern et al., 2016). In the commercial world, the use of AR to aid the driver user interface is a heavily researched area (Schömig et al., 2018). In fact, Lindemann et al. (2018) found that the use of an AR windshield display for autonomous driving significantly enhanced driver’s SA. Most researchers agree that it should be kept simple. Goldiez (2004) reports that AR systems have the potential to enhance user performance in a wide variety of domains, including the military, for a multitude of tasks, including training and decision support before and during military operations. Brandão & Pinho (2017) found that the use of AR can improve dismounted operators’ SA on the battlefield.

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Since the caveman days, humans have been drawing images on cave walls to represent ideas and concepts he wishes to communicate (Kennedy, 1974). If sketching an object or scene can overcome the communication barrier, what other benefits might the picture provide over words (Gauker, 2011)? Previous research into images versus words suggests that humans better understand and easily digest images (Epstein et al., 1960; Lemke, 1998; Kliegel et al., 2007). They found that picture material was learned better than concrete or abstract nouns. Take, for example, a language barrier between humans. One speaks French, and the other speaks English. Trying to convey a thought or idea through verbal language would be difficult and time consuming if they had to look up each word from English to French and vice versa. However, suppose the English-speaking individual simply draws a picture of a toilet or beer mug. In that case, the French-speaking individual can grasp the meaning of that image and translate it into the correct idea much more quickly and with greater ease. Similarly, if the French-speaking individual were then to give directions using language, it would be very confusing and take much time to translate each word, but if those directions were given, for example, in a simple strip map with arrows, streets, and buildings, the intent would be clear, concise, and well understood much more quickly.

Dewan (2015) points out that incorporating graphics into our primarily text-based communications will allow us to communicate more effectively. According to Paivio (1990), pictures are processed cognitively with less effort than words. He describes that when words go into long-term memory, they do so with a single code, but images enter long-term memory with a dual code, one visual and one verbal, and each is stored in different areas of the brain, allowing easier recall.

What is needed is the adoption of a framework for combining intuitive graphics with minimal textual information that is dynamic, quickly absorbed, and provides SA. Just as the National Football League example provides a pertinent, quick dynamic snapshot of SA of the status of the game, so too can the concept of a DIG provide the relevant SA of the battlefield, as well as provide the transparency and forecasting needed to improve user SA and trust in IA systems, while reducing user workload. To build an effective DIG, one must consider the most pertinent information to the mission. What information does the operator or commander need to have constant or immediate knowledge? The design of the DIG should highlight the most critical information (i.e., more prominent, a different color, bold, or in the middle) of the situation.

Note that all information the IA senses about the environment should not be displayed in the DIG. That would be information overload. Based on the mission and the users' needs, the IA system should display the most relevant pieces of sensed information (*what*) to the users and any explanations necessary (*why*) to fully understand that

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information. In combination with the *what* and the *why* of a DIG, these systems' trend forecasting (next) should be integrated as the systems learn through trend analysis and determine what could happen next.

## 2.1 Proposed Model of DIG-LoSA

This research proposes Hartnett's model of DIG-LoSA (Table 1) to support SA of the mission environment, based on the original model of SA (Endsley, 1995) and SAT model (Chen et al., 2014) as well as other previous work (Chen & Barnes, 2014; Chen et al., 2018), combined with research of XAI. The proposed model of DIG-LoSA creates requirements for DIG creation to obtain appropriate and necessary SA and is presented in Table 1.

The first level of the DIG-LoSA, in which the IA system senses and displays information to the user, provides both the status of the environment and system transparency of current and ongoing status, actions, and decisions in real time. The *what* level or sense and display provides information related to a specific event, entity, status, or multisystem and includes information such as location, communications, counts, times, conditions, identifications, threats, battle-damage assessment, and collaboration lanes. At the second level, transparency through XAI, in which the IA system is completely transparent with all relevant information, also known as the *why*. At this level, explanations or reasonings as to why the system took specific actions or made specific decisions are provided to facilitate user understanding of the system's behaviors and processes. Level 3 provides trend forecasting based on trend analysis or the *next*, in which the IA system should forecast user needs, near-term future behaviors, and task or mission confidence. Specifically, forecasting should occur in three areas. First, this level should communicate what the IA system forecasts, the actions, and the decisions the user would likely make based on machine learning. Second, the DIG should be used to present the IA's forecast of the behaviors of, for example, other entities, systems, statuses, and missions on the battlefield based on its actions and decisions through trend analysis. Third, it should display forecasting of task and or mission effectiveness and success or failure, preferably in the form of confidence levels. In a related area of forecasting, the DIG should be well designed such that the user can forecast what actions or decisions the IA systems might make based on coded algorithms, known learned behaviors, and user familiarization with the system. For the effective development of DIGs, each of the three levels should be integrated and dynamically updated throughout the mission. The integration of these levels should increase user SA and user trust as well as decrease user workload.

**Table 1. Hartnett's DIG-LoSA model**

|         | Endsley's 3 Levels of SA Model                | Chen's SAT Model                                                                                           | Hartnett's DIG-LoSA Model<br>System transparency through graphical representation of an element's current and future status |
|---------|-----------------------------------------------|------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| Level 1 | Perception of the elements in the environment | Support Operators Level 1 SA<br>What's going on and what is the agent trying to achieve?                   | <i>Sense and Display (What)</i><br>Current and dynamic sensed status of the environment and system actions and decisions    |
| Level 2 | Comprehension of the current situation        | Support Operators Level 2 SA<br>Why does the agent complete a specific action or make a specific decision? | <i>Transparency through XAI (Why)</i><br>Explanation or reasoning of system actions and decisions                           |
| Level 3 | Projection of future status                   | Support Operators Level 3 SA<br>What should the operator expect to happen?                                 | <i>Trend Forecasting (Next)</i><br>Forecasting of near-future status, actions, and decisions based on trend analysis        |

In the future, an IA may be responsible for sensing the injuries via wearable devices (watches, sensor sewn in clothing, electrocardiogram sensors worn, digital Band-Aid, etc.) worn by each Soldier, building the 9-Line request and sending it to the closest medical evacuation (MEDEVAC) helicopter. Imagine a wearable device that can sense an injury, provide the exact location, automatically dial in the correct frequency, and provide the relevant information regarding the landing site (security, nuclear, biological, chemical status, etc.) and information about the patients (patient status, nationality, injuries, etc.). Some of this information would already be in a database a system might

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use, and some of the data would be gathered from other sources or sensed using the Internet of Battlefield Things (IoBT). In Figure 1, the information required for each line of the 9 Lines is explained.

- Line 1.** Location of the pick-up site.
- Line 2.** Radio frequency, call sign, and suffix.
- Line 3.** Number of patients by precedence:  
A - Urgent  
B - Urgent Surgical  
C - Priority  
D - Routine  
E - Convenience
- Line 4.** Special equipment required:  
A - None  
B - Hoist  
C - Extraction equipment  
D - Ventilator
- Line 5.** Number of patients:  
A - Litter  
B - Ambulatory
- Line 6.** Security at pick-up site:  
N - No enemy troops in area  
P - Possible enemy troops in area (approach with caution)  
E - Enemy troops in area (approach with caution)  
X - Enemy troops in area (armed escort required)  
\* In peacetime - number and types of wounds, injuries, and illnesses
- Line 7.** Method of marking pick-up site:  
A - Panels  
B - Pyrotechnic signal  
C - Smoke signal  
D - None  
E - Other
- Line 8.** Patient nationality and status:  
A - US Military  
B - US Civilian  
C - Non-US Military  
D - Non-US Civilian  
E - EPW
- Line 9.** NBC Contamination:  
N - Nuclear  
B - Biological  
C - Chemical\* In peacetime - terrain description of pick-up site

**Figure 1. Current 9-Line MEDEVAC format**

Currently, when a 9-Line request is transmitted and viewed on the Panel Mounted Display (PMD) of the aircraft, it will be displayed with only the choices for each line or verbally spoken via the radio (Figure 2).

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Line 1: 4QFJ12345678  
Line 2: 121.500 MHZ / Badger6  
Line 3: 2R/1C  
Line 4: C  
Line 5: 1A  
Line 6: X  
Line 7: C  
Line 8: 1C / 2E  
Line 9: B

**Figure 2. 9-Line MEDEVAC message as spoken or heard via verbal communications**

Either the pilot has an excellent memory of what the choices in a 9 Line are, or the pilot will need to refer to the 9-Line guide to determine the complete picture, which increases the time for the crew to become fully aware of the situation, and it may increase mission completion time. For the 9-Line DIG concept, each of the 9 Lines is graphically represented to be easily digestible by the user (Figure 3). With very little to no training, this format is intuitive and easily understood by experienced and novice pilots.



**Figure 3. 9-Line DIG**

It is equally as important for the IA to show the why and the next of the IA actions, decisions, and recommendations, as well as the predictions based on trends. In Figure 4, the 9-Line Event DIG, a why and next is displayed to provide additional information to the user. Obviously, it is clear why MEDEVAC was requested. Troops have been injured and require medical attention and evacuation. However, additional information can be relayed that may explain why a patient is classified as urgent or why an armed escort is required. The additional information can give the crew a better understanding of what they will be dealing with when they land or may provide insights into the near future of the battle. As previous research suggests, the IA should not only

be transparent with *what* information it has sensed from the environment but should provide its explanations (XAI) for its actions, decision, and recommendations by providing a *why* to the user to build user confidence and trust in the system. In this case, the IA generating the 9-Line DIG also provides a why statement as to why an armed escort is required and what the top factor (recent SPOT report of enemy troops) was in making that determination. The system should also provide its forecasting of possible upcoming next events to the user based on any trends in the data that can be quickly analyzed by the system at a much faster pace than its human teammate. In this example, the forecasting is provided by the system in the form of Predictions/Advice/Decisions/Suggestions, which makes a prediction that, based on intelligence gathered, the security at the pickup site will change from Red to Green within 90 s. The top factor in this prediction is the information known to the system that an Apache gunship has been dispatched to eliminate the enemy troops in the area.

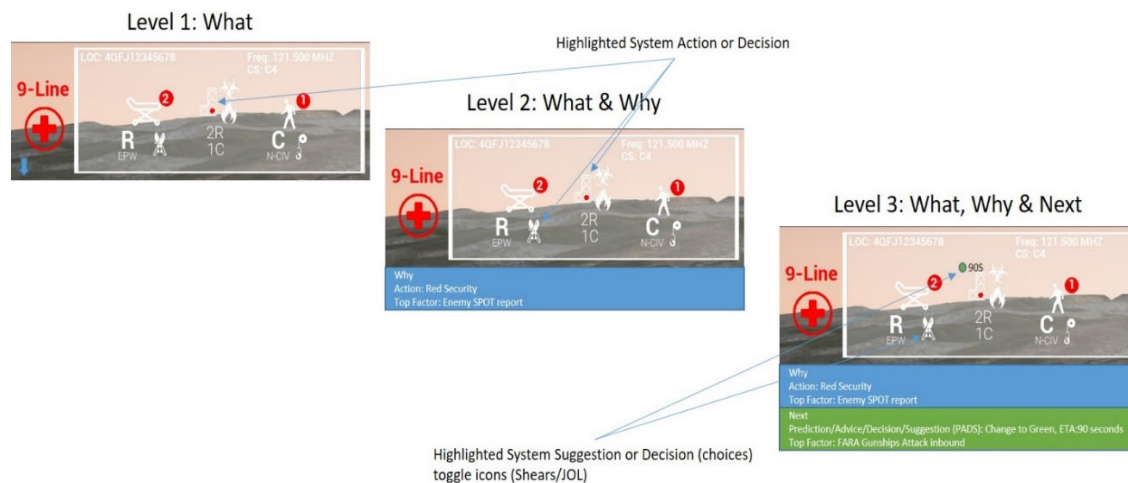


Figure 4. 9-Line DIG with Levels 1, 2, and 3 of SA

## 2.2 General Problem Statement

The IA systems are growing in almost all military operations, providing aid to the Soldier or replacement with complex, rapid decision making and actions that become extremely difficult for humans to understand quickly. This lack of understanding is a gap within the military, and it can lead to decreased SA and user trust in the system, increased user workload, and decreased overall mission performance as they attempt to build and maintain that understanding. This research was conducted to understand the importance of this information by examining various levels of transparency and how and how to effectively display that information and its effect on SA, user trust, user workload, and overall user performance.

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### **3. METHODS, ASSUMPTIONS, AND PROCEDURES**

A 2 (display presentation type: DIG [in AR], text [on an aircraft inside screen]) × 2 (level of transparency: less [L1 sense and display {what}]; more [L1/sense and display {what}, L2/transparency through XAI {why}, L3/trend forecasting through trend analysis {next}]) within-subjects design was used to examine system transparency. This study was executed using a MEDEVAC scenario-based mission created using Unreal Engine software. Scenarios were developed for each of the four conditions. This mixed methodology study will collect both objective (response times and accuracy) and subjective (surveys: SA, usability, user trust, workload, user preference, and training) data and demographic information (age, gender, years in service, military experience, flight hours, aircraft expertise, and heads-up display [HUD] and gaming experience) data. Rotary wing pilots, medics and crew, and civilian aviation SMEs were recruited.

Participants in the study participated over a period of 2 h. Each condition took 8.5 mins. Participants completed all four conditions (randomized). They provided accuracy and response time to mission-related probing questions (PQs) and accuracy and response times for enemy threat identification (TID) questions during the scenario to ascertain objective SA and workload measurements. After each condition, participants completed subjective surveys in which they rated their perceived SA, trust, usability, and workload. Breaks were given after each condition or at the request of the participant. At the completion of the study (all four conditions), participants completed the remaining subjective measures on their preference of display type and level of information as it related to their SA, trust, usability, and workload. In addition, the participants rated their perceived preparedness for the study based on the training they received.

#### **3.1 Flight Scenario Development**

All scenarios were developed using Unreal Engine and conducted by the U.S. Army Combat Capabilities Development Command (DEVCOM) Analysis Center (DAC) to simulate a Blackhawk MEDEVAC helicopter.

##### **3.1.1 Programming**

As shown in Figure 5, to create the DIG, Unreal Engine 5 (UE5) (owned by Epic Games, 2022) was used. UE5 is a game engine designed to allow companies and individuals to build video games and simulations rapidly (there are also uses for things such as architecture and other model showcasing). UE5 tries to simplify the coding process and make it a more visual experience with visual scripting or node diagrams that they call Blueprints (Epic Games, 2022).

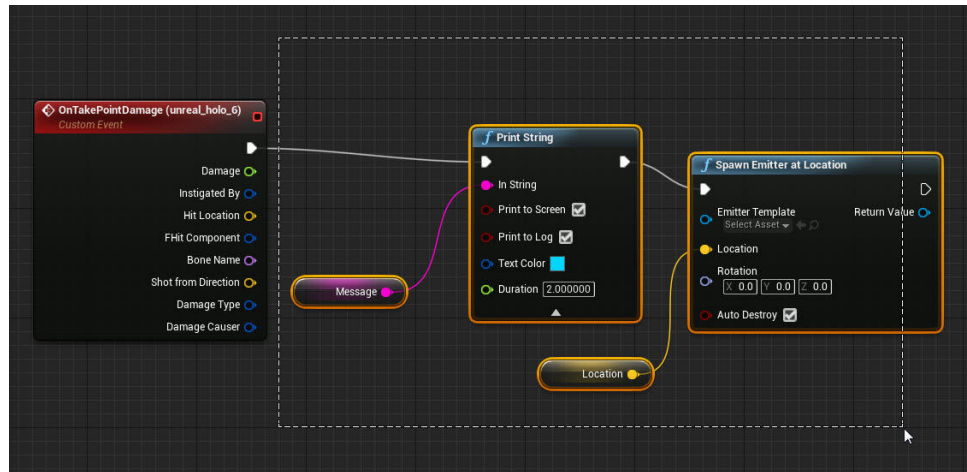


**Figure 5. Unreal Engine’s blueprint visual scripting language**

These simplifications are geared toward artists who do not have a strong coding background, and it allows them to integrate their art more easily with a traditional programming team. UE5 is free to use when no profit is being made and is a great resource for military and civilian applications (Epic Games, 2022). DIGs are designed such that they can be displayed in four categorized ways: on a head-mounted display (HMD) or AR device, on a heads-up (AR windshield or HUD or PMD, on a 2D computer screen as a standalone widget or integrated as part of another program, or on a handheld device like a tablet. This means that they will either be in a fixed location in the pilot’s field of view (HMD), a fixed location on the cockpit’s dashboard (on the glass for HUD or on a screen for PMD), a fixed location on a 2D monitor, or a mobile location given by a tablet.

UE5 allows a programmer to design the DIG on what they call widgets (Epic Games, 2022). These widgets can then be placed in the simulated environment by attaching them to the Viewport (like an HMD) or by placing them in the simulated environment (to mimic being displayed on the cockpit glass or panels). Widgets are very useful because UE4 offers premade tools that help a programmer size, shape, and organize the information and symbols present in the infographic. It also allows things to be changed dynamically during a simulation, such as fuel quantity depleting or hiding certain symbols with the press of a button. The events that cause these changes are programmed through UE5’s visual scripting language.

### **3.1.2 Mission Profile**

Four flight scenarios were created for this study using Unreal Engine. These scenarios are 8.5 mins long. One additional scenario (~2.5 mins long) was used for the training runs. All the mission scenarios, other than those used for training, were of the same

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length and time. However, the location and types of enemies and PQs were different so that pilots did not become familiar with the events.

### **3.1.3 Tasks**

#### ***3.1.3.1 Dynamic InfoGraphics and Text Supervision and Queries***

The participants were presented with incoming information from the IA either by DIG in AR or in a text format in 2D. If the participants were in the DIG condition, the information was displayed using pseudo-AR in a DIG graphical format. If the participants were in the text condition, this information was displayed to the participant via Joint Variable Message Format (JVMF) messages, which used a text format. This text format required the participant to look down at the simulated PMD to read the message. When this happened, the participant's gaze was on the inside of his aircraft and not on the outside world; as such, the view of the outside world through the aircraft window was partially occluded while viewing the text messages they received. This simulated the user bringing his attention from outside the aircraft to inside the aircraft to view and read a message on his/her PMD screen. Each change during the mission generated a new text message.

These messages, whether in graphical format in AR (DIG) or in text format on their virtual PMD, provided all the information as described under each section (forward arming and refueling point [FARP], 9-Line, all Casualties, Patient, Medical Treatment Facility [MTF]) description to include, for example, in the FARP section, location (by Military Grid Reference System), availability/waiting time, and fuel and ammunition/air-launched effects (ALE) resources. If the participant was in the AR DIG condition, the FARPs, for example, were displayed to the participant using AR symbology (providing the exact location of the entity or event) in an out-the-window view as if they were looking through their HMD as well as the AR DIG displaying all the information as described under the FARP description. In addition to the information provided, the system displayed a recommendation to the user. If the participant was in the Less: Level 1 condition, they only received entity status information and system decision or recommendation. If the participant was in the More: Level 1, 2, and 3 conditions, the system also provided information for why the system made a decision or recommendation and a projection or prediction about the near future. Again, depending on whether the participant was in the text or AR DIG condition dictated the way in which the information was presented to the user.

The AI displayed FARP choices and its recommendation to the user. Once the AI recommended FARP A, for example, the aircraft landed at the point indicated and onboarded fuel and ammunition/ALE.

During each presentation of DIG or text, the participant was asked mission-related queries regarding the information presented. Accuracy and response times were collected. In the same fashion described in the Methods section (Section 3), the participant received either a 9-Line DIG or text message and an All Patient/Patient DIG or text message. Finally, the participant received MTF choices and recommendations and the chosen MTF either by DIG or text message. As shown in Table 2, each 8.5-min scenario appeared as one continuous scenario to the user but was broken up into five distinct sections for data collection purposes.

**Table 2. Scenario sections and objective data points**

| Each condition | Section     | PQs | PQ timing | TID | TID timing | Threat type (TT) | TT timing | Total |
|----------------|-------------|-----|-----------|-----|------------|------------------|-----------|-------|
| Section 1      | FARP        | 5   | 5         | 2   | 2          | 2                | 2         | 18    |
| Section 2      | 9-Line      | 5   | 5         | 2   | 2          | 2                | 2         | 18    |
| Section 3      | All Patient | 5   | 5         | 2   | 2          | 2                | 2         | 18    |
| Section 4      | Patient     | 5   | 5         | 2   | 2          | 2                | 2         | 18    |
| Section 5      | MTF         | 5   | 5         | 2   | 2          | 2                | 2         | 18    |
| Total          |             | 25  | 25        | 10  | 10         | 10               | 10        | 90    |

### 3.1.3.2 FARP DIG and Text

Examples of the FARP DIG and corresponding text messages created for this study are shown in Figures 6 and 7.



**Figure 6. All FARP DIG in AR**

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| COA           | A             | R       |
|---------------|---------------|---------|
| Type:         | Active        | Rolling |
| COA Selected: | Rolling FARP★ |         |
| Distance:     | 13km          | 13km    |
| ETA:          | 2:35          | 2:45    |
| Direction:    | ESE           | N       |

Figure 7. All FARP JVMF text messages presented on the panel mounted display

### 3.1.3.3 *Enemy Threat Identification Task*

In addition to the main task of flight supervision and mission-related queries about the information contained in the DIGs or within the text messages, a secondary task was implemented. The secondary task consisted of the detection of enemy entities and the selection of the type of threat (i.e., personnel, vehicles, weapons, or explosives).

The entities were displayed on the terrain during the flight scenario. Figure 8 shows an example of an enemy entity as seen on the ground by an un-aided participant. In the DIG condition, an AR symbol (Figure 8) highlighted the enemy threat and provided metadata on the type of enemy threat. In the text condition, a JVMF message was sent and included the enemy TT. The participant was asked to hit the space bar as soon as they detected the threat and then select the type of threat from multiple-choice options. In the text, more conditions and additional information about the enemy was available for viewing by the participant, such as the enemy entity’s direction, heading, and distance (Figures 9–11).



Figure 8. Enemy threat outside the window

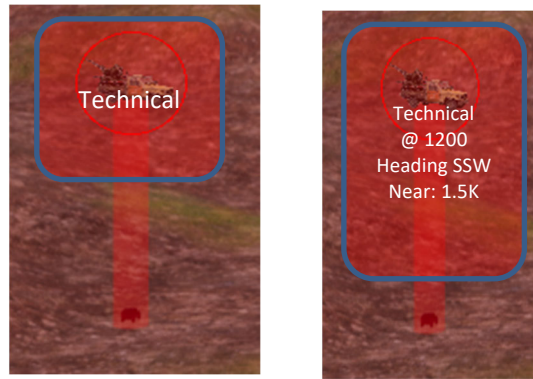


Figure 9. Enemy threat AR icons without metadata (less condition) and with metadata (more condition), respectively

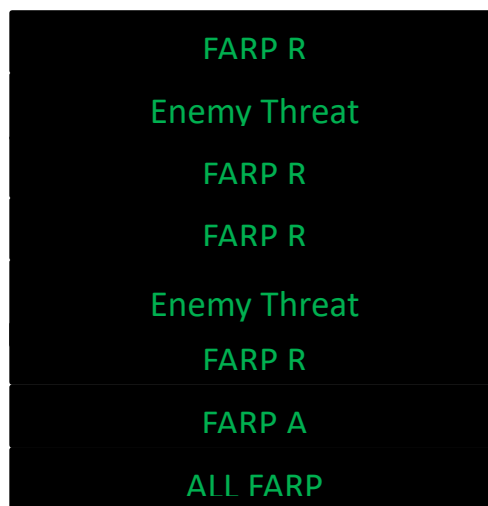


Figure 10. Mission and enemy threat JVMF text alerts on PMD

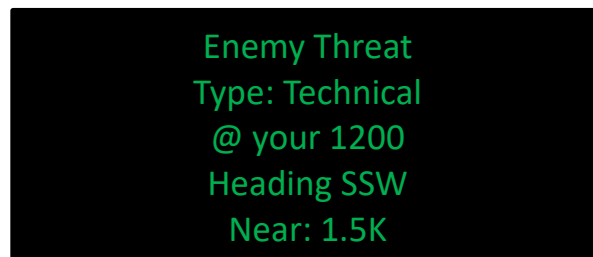


Figure 11. Enemy threat JVMF text message on PMD

Participants then participated in the four conditions (randomized) by viewing each scenario condition, providing answers to PQs (Figure 12), and identifying enemy threats and types (Figure 13) on the battlefield to ascertain objective SA.

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**How far away (in distance) (in time)  
is the selected FARP?**

1. 10
2. 6
3. Don't Know
4. Not Provided

**Figure 12. Mission-related PQs example**

**The Enemy Threat is a**

1. Personnel
2. Technical
3. Tank
4. UAS
5. Don't know

**Figure 13. Enemy threat questions; UAS = unmanned aircraft system**

During each session, the participants were asked mission-related PQs to objectively measure their SA. This method was used so the missions were not paused during PQs and answers. Additionally, during the entire simulation, the participants searched the external environment for enemy threats along the route and identified any threats and selected the type of threat from multiple-choice options. After each of the four, 8.5-min scenario simulations, the participants were asked to complete subjective surveys regarding the condition they had just completed.

For this study, the AR condition was simulated through the virtual reality (VR) video and presented on a gaming laptop screen. An associated PMD screen was inserted into the VR helicopter cockpit.

Object icons and DIGs (Figure 14) appeared in AR along the predetermined route. Participants observed the event-generated 2D/3D objects and were asked to answer mission-related probes (Figure 15) and simultaneously identify enemy threats along the route.



Figure 14. Screenshot of the scenario video with a 9-Line and patient DIG displayed in AR, enemy in the real world with enemy AR symbol, and the PMD screens in the bottom center



Figure 15. Screenshot of the scenario video with an All FARP DIG displayed in AR and a mission-related PQ in the middle right of the environment

### 3.1.4 Measures

Objective and subjective measures were collected during and after this study. After Action Reviews and interviews were conducted for iteration purposes.

### 3.1.4.1 Objective Measures

Responses to scenario-based probes were collected to ascertain accuracy. Response times were also collected. Responses to enemy TID, TT, and response times to both were collected as objective data.

Each of the four conditions elicited 90 objective data points (Table 3) for a total of 360 data points for each participant (Table 4). The total study objective data points for all participants elicited 19,440 data points (Table 5).

**Table 3. Objective data points per participant for one condition**

| Each condition | Section     | PQs | PQ timing | TID | TID timing | TT | TT timing | Total |
|----------------|-------------|-----|-----------|-----|------------|----|-----------|-------|
| Section 1      | FARP        | 5   | 5         | 2   | 2          | 2  | 2         | 18    |
| Section 2      | 9-Line      | 5   | 5         | 2   | 2          | 2  | 2         | 18    |
| Section 3      | All Patient | 5   | 5         | 2   | 2          | 2  | 2         | 18    |
| Section 4      | Patient     | 5   | 5         | 2   | 2          | 2  | 2         | 18    |
| Section 5      | MTF         | 5   | 5         | 2   | 2          | 2  | 2         | 18    |
| Total          |             | 25  | 25        | 10  | 10         | 10 | 10        | 90    |

**Table 4. Objective data points per participant for all conditions**

| All 4 conditions per participant | Section     | PQs | PQ timing | TID | TID timing | TT | TT timing | Total |
|----------------------------------|-------------|-----|-----------|-----|------------|----|-----------|-------|
| Section 1                        | FARP        | 20  | 20        | 8   | 8          | 8  | 8         | 72    |
| Section 2                        | 9-Line      | 20  | 20        | 8   | 8          | 8  | 8         | 72    |
| Section 3                        | All Patient | 20  | 20        | 8   | 8          | 8  | 8         | 72    |
| Section 4                        | Patient     | 20  | 20        | 8   | 8          | 8  | 8         | 72    |
| Section 5                        | MTF         | 20  | 20        | 8   | 8          | 8  | 8         | 72    |
| Total                            |             | 100 | 100       | 40  | 40         | 40 | 40        | 360   |

Each participant was assigned a code number (P#), which was applied to each file (questionnaires and data files) generated by the participant. All files are stored in a password-protected computer, only accessible to individuals involved with the project.

**Table 5. Objective data points for all 54 participants**

| Total study data points | Section     | PQs   | PQ timing | TID   | TID timing | TT    | TT timing | Total  |
|-------------------------|-------------|-------|-----------|-------|------------|-------|-----------|--------|
| Section 1               | FARP        | 1,080 | 1,080     | 432   | 432        | 432   | 432       | 3,888  |
| Section 2               | 9-Line      | 1,080 | 1,080     | 432   | 432        | 432   | 432       | 3,888  |
| Section 3               | All Patient | 1,080 | 1,080     | 432   | 432        | 432   | 432       | 3,888  |
| Section 4               | Patient     | 1,080 | 1,080     | 432   | 432        | 432   | 432       | 3,888  |
| Section 5               | MTF         | 1,080 | 1,080     | 432   | 432        | 432   | 432       | 3,888  |
| Total                   |             | 5,400 | 5,400     | 2,160 | 2,160      | 2,160 | 2,160     | 19,440 |

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#### **3.1.4.2 Subjective Measures**

A total of 10,250 self-reported responses to questionnaires were collected. After the completion of each condition, subjective measures were completed to assess the impact of the DIGs on each participant's user experience, training, workload, SA, usability, and user trust in the IA. The following measures were used: the Bedford Workload Rating Scale (Roscoe, 1984); Situation Awareness Rating Scale (developed by DAC); System Usability Scale (DIG and JVMF Text) Questionnaire (developed by DAC); Trust in Automated Systems Test Less and More (Wojton et al., 2020); Operational Assessment of Training Scale (developed by Director Operational Test and Evaluation, Air Education and Training Command, and Joint Interoperability Test Command; Usability Metric for User Experience (UMUX-Lite) (Lewis et al., 2013); and Trust in Automation questionnaire (developed by DAC).

#### **3.1.5 Research Questions**

Does the level of system transparency result in an increase in user SA and trust? Are graphics or text better at quickly relaying information to a user? What is the most effective method of providing system transparency (i.e., system actions and decisions) to the users (pilots, medics, and crew)? These general questions are best answered with more specific research questions listed below.

##### **Research Question 1:**

Will presentation type (DIG or Text) and level of information (less [1] or more [1, 2, and 3]) affect user SA and user Trust?

##### **Research Question 2:**

Will presentation type (DIG or Text) affect user workload?

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## **4. CONSTRAINTS, LIMITATIONS, AND ASSUMPTIONS**

### **4.1 Assumptions**

Assumptions are things accepted as true, or at least plausible, by researchers and peers. All participants are assumed to be honest and truthful in their self-reported responses to the surveys they completed. It is also assumed that the results of this study are generalizable to Army Aviation pilots and crew, possibly other military operators using a plethora of systems, and perhaps other industries using IA systems (like AI), such as the automotive and medical industries.

### **4.2 Scope of Research**

The scope of research details how in-depth your study is to explore the research question and the parameters in which it will operate in relation to the population and time frame. The scope of this research is limited to the effect of transparency and level of information on user SA, trust, and workload in the U.S. Army Aviation population within a 4-month time frame. This study focuses on Army aviation pilots, medics, and crew (active duty or retired), as well as civilian aviation SMEs who range in age (20–61) and experience/flight time. This study uses a randomized design and relies on participants' electronically collected objective and self-reported subjective data. The intent of this research was to collect as much data as possible within the Army Aviation community with an expectation of 40–50 participants (acquired 54). The minimum number is derived from the Latin Square design where 40 participants would create an equal number of participants completing each condition (i.e., 4 conditions completed 10 times). Additionally, a G\*Power calculation was completed with an effect size  $f$  of 0.05. The total sample size required for sufficient power was calculated at 38.

### **4.3 Limitations**

Limitations are potential weaknesses in a study that are primarily out of the researcher's control, given limited funding, choice of research design, statistical model constraints, or other factors. In addition, a limitation is a restriction that cannot be reasonably dismissed and can affect your design and results. It is noted that a limitation of this study is that pilots were not tested using a real aircraft with an actual IA flying the aircraft. The use of computer laptops to simulate AR is also a limitation. The AR was simulated using VR viewed through a laptop screen. These limitations could not be overcome due to funding and resource limitations.

As a result of this simulation created through Unreal Engine software and conducted on gaming laptops, mimicking head movement was arduous and clunky. Participants used

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their mouse to click on arrows to simulate their head movements instead of merely moving their heads to look up or down as they would typically do in VR or a real aircraft using a HUD or HMD. Looking down did diminish the view of the outside world, which was intentional. It mimicked a pilot bringing his attention inside the aircraft and looking down to read messages on a monitor.

Another limitation of this study is possible learning effects from one scenario to another, because 40% of questions were the same for conditions 1 and 3 and 2 and 4. Using the same questions was intentional to directly compare accuracy and response time. Conditions were randomized to mitigate possible learning effects. This study also relied on self-reported data from the participants for user SA, trust, workload, and usability, which may be subject to bias and may not accurately reflect actual performance or implementation of the novel DIG concept. This study did not account for external factors that may have impacted participant performance, such as fatigue or concentration.

#### **4.4 Delimitations**

Delimitations are the definitions set as the boundaries of a study, so delimitations are in my control. Delimitations are set so that a researcher's goals do not become impossibly large to complete. Research questions and hypotheses were limited to focus on a few key aspects, such as user SA, trust, and workload. Additionally, this research was limited to Army aviation pilots, crew, and civilian aviation SMEs to obtain Army aviation-specific results that could be generalizable to the Army aviation population. Due to limited resources and time, the study only included a sample of 54 participants. This sample size is considered adequate for the purposes of this study. This study implemented a random design to limit bias and learning effects.

#### **4.5 Reliability**

Reliability in a research study refers to the degree to which the results are consistent and repeatable. In other words, it relates to the extent to which the measurements, procedures, and data collection methods used in the study are dependable and can be trusted to produce similar results if repeated under the same conditions. Overall, ensuring the reliability of a research study is essential for ensuring that the findings are accurate, dependable, and trustworthy. Researchers used standardized protocols and procedures, carefully selected and trained observers or raters, and established measurement tools and instruments to ensure reliability.

1. **Test-Retest Reliability:** This refers to the extent to which a measurement tool or instrument yields consistent results when administered multiple times to the same sample. To assess test-retest reliability, researchers may administer the

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same test to the same group of participants at two different points in time and compare the results.

2. **Inter-rater Reliability:** This refers to the extent to which different raters or observers who are measuring the same thing agree on their observations. To assess inter-rater reliability, researchers may have multiple raters observe the same phenomenon and compare their results.
3. **Internal Consistency Reliability:** This refers to the extent to which different items or questions on a questionnaire or survey measure the same construct or phenomenon. To assess internal consistency reliability, researchers may calculate Cronbach's alpha coefficient, which measures the degree to which the items in a scale are interrelated.
4. **Parallel Forms Reliability:** This refers to the extent to which two similar forms of a test or measurement tool produce similar results. To assess parallel forms of reliability, researchers may administer two versions of the same test to the same group of participants and compare the results.

Inter-rater reliability for this study was assessed by having various observers observe the experimental process over several participant runs and agree that the process and measurements were consistent across the participants they observed. Additionally, the observers and researchers examined the results of multiple participants within each condition and found them to be within an acceptable margin of error. Reliability was maintained by carefully controlling all variables and ensuring all methods were recorded correctly and adhered to so that results are repeatable. Threats were minimal.

## **4.6 Validity**

The validity of a research study refers to the degree to which the study accurately measures or reflects what it intends to measure or reflect. In other words, it refers to the extent to which the study's findings are based on sound evidence, free from bias or error, and applicable to the population of interest. Overall, ensuring the validity of a research study is crucial to producing meaningful and reliable results that can inform practice and policy.

1. **Internal Validity:** This refers to the extent to which the study design, methods, and procedures are free from bias and confounding factors that could impact the results. To ensure internal validity, researchers may use control groups, random assignment, and standardized protocols.
2. **External Validity:** This refers to the extent to which the findings of the study can be generalized to other populations or settings beyond the sample studied. To ensure external validity, researchers may use representative samples, random selection, and diverse settings.

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3. Construct Validity: This refers to the extent to which the study measures what it intends to measure. To ensure construct validity, researchers may use multiple measures or sources of data and conduct a pilot study to refine the research methods.
  4. Face Validity: This refers to the degree to which the study appears to measure what it intends to measure, as judged by the participants or other stakeholders. Face validity can be improved by using clear and appropriate research questions, measures, and procedures.
  5. Content Validity: This refers to the degree to which the study covers all aspects of the phenomenon under investigation. To ensure content validity, researchers may use a comprehensive literature review, expert input, or a systematic analysis of the relevant domains.

Internal validity was assessed and controlled by the random assignment of participants, and standardized protocols were used for this study. For example, the training was pre-recorded so that every participant received the exact same training. Additionally, face and content validity was assessed for this study using SMEs to rate the MEDEVAC flight scenario video as well as the DIG and text elements used in the scenario to determine internal validity and the DIG and text elements' validity to real-world MEDEVAC missions (Figure 1). Threats were minimal. Ratings from SMEs for the scenarios and elements of the scenario were rated medium (3.0) to very high (5) by all four SMEs with means of 3.5 for JVMF messages mission scenarios and TTs and locations and 4 for DIG and SA assessment questions.

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## 5. RESULTS AND DISCUSSION

### 5.1 Demographics

A total of 54 pilots, flight medics, crew (active or retired), and aviation SMEs (military or civilian) were used to execute the study and collect sufficient data points from which to draw conclusions—51 were males and 3 were females. As shown in Table 6, the mean age of participants was 41, with a range from 20 to 61. The military service mean was 16 years, with a range of 0 to 44. Primary and total flight hours means were 844 h and 1,569 h with ranges between 0 and 5,000 and 0 and 7,900 h, respectively. HUD hours averaged 234.2 h with a range of 0 to 2,500 h. Finally, the gaming experience mean was 2,073 h with a range of 0–10,000 h.

Table 6. Demographics table

| <b>Variable</b>      | <b>Mean</b> | <b>Median</b> | <b>Range</b> | <b>Variance</b> | <b>Standard deviation</b> | <b>Standard error</b> | <b>Skewness</b> | <b>Kurtosis</b> |
|----------------------|-------------|---------------|--------------|-----------------|---------------------------|-----------------------|-----------------|-----------------|
| Age                  | 41.00       | 40            | 20-61        | 125.8           | 11.2                      | 1.5                   | 0.160           | 2.31            |
| Military Service     | 16.0        | 16            | 0-44         | 95.5            | 9.8                       | 1.3                   | 0.317           | 2.82            |
| Primary Flight Hours | 844.0       | 500           | 0-5000       | 1252922.6       | 1119.3                    | 150.9                 | 1.9             | 6.24            |
| Total Flight Hours   | 1,569.5     | 896           | 0-7900       | 3094106.8       | 1759.0                    | 237.2                 | 1.6             | 5.35            |
| HUD Hours            | 234.2       | 15            | 0-2500       | 294563.8        | 542.7                     | 73.2                  | 3.0             | 11.77           |
| Gaming Hours         | 2,073.6     | 500           | 0-10000      | 8694415.6       | 2948.6                    | 397.6                 | 1.4             | 3.76            |

### 5.2 Mission Response Time Data

The mission response (MR) data were collected from 54 participants during the DIG study. Every participant sat through each of the four conditions and responded to questions based on the information provided. For each question, the participant's answer, response time, and accuracy were collected.

The MR data indicated a significant difference in presentation type and information-level variables as indicated in the analysis of variance (ANOVA) table (Figure 16). The DIG presentation type responded faster than the text presentation type and the less information level responded faster than the more information level.

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ANOVA of the Mission Response Time Data Analysis of Deviance Table
(Type III Wald chi-square tests) Response: Time.to.Respond
Chisq
(Intercept)      3165.9306      1      < 2.2e-16 ***
Presentation      204.5977      1      < 2.2e-16 ***
Info.Level        32.6905      1      1.081e-08 ***
Presentation:Info.Level  0.5249      1      0.4687
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

**Figure 16. ANOVA for mission response time data**

### 5.3 Mission Accuracy Data

Mission accuracy was also statistically significant for presentation type and information level, such that the DIG was 17% more accurate than the text and the less information was 7% more accurate than the more information, as seen in the ANOVA table (Figure 17).

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ANOVA of the Mission Response Accuracy Data Analysis of Deviance Table (
Type III tests) Response: Surv(Time.to.Respond, Response)

MR Accuracy
Df Chisq Pr(>Chisq)
Presentation      1 223.3957 <2e-16 ***
Info.Level        1  4.4698  0.0345 *
Presentation:Info.Level  1  1.8813  0.1702
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

**Figure 17. ANOVA for mission response accuracy data**

Overall, the response times for the DIG condition appear to be lower than the text condition overall levels of the information level condition. The Cox regression indicates that the response rate is generally higher in the DIG condition in comparison to the text condition, which suggests that the participants are responding to the prompted questions more (more right answers) in the DIG conditions as compared to the text conditions. The timing data of the accurate responses indicate that the DIG conditions result in faster response times in comparison to the text conditions. Similarly, the

response times for the less conditions were generally lower than the more conditions over all levels of the presentation condition. The Cox regression indicates that the response rate is generally higher in the less comparison to the more condition, which suggests that the participants are responding to the prompted questions more (more right answers) in the less conditions compared to the more conditions. The timing data of the accurate responses indicate that the less conditions result in faster response times in comparison to the more conditions.

## 5.4 Enemy Response Time Data

The enemy response (ER) data were collected from 54 participants during the DIG study. The participant sat through each of the four conditions and responded to questions based on their awareness of their surroundings. For each question, the participant's answer, the time it took the participant to notice the enemy, the following time it took to identify the enemy, and accuracy were collected.

The ER data indicated statistically significant differences for the presentation type and information level, such that the DIG was faster at identifying enemy threats than the text and the more information level was faster at enemy identification than the less information level as indicated by the ANOVA table (Figure 18).

ANOVA of the Enemy Response Time Data Analysis of Deviance Table  
(Type III Wald chi square tests) Response: Time.to.Respond

**ER Time**

|                         | Chisq    | Df | Pr(>Chisq)    |
|-------------------------|----------|----|---------------|
| (Intercept)             | 991.8408 | 1  | < 2.2e-16 *** |
| Presentation            | 26.8455  | 1  | 2.204e-07 *** |
| Info.Level              | 12.3798  | 1  | 0.000434 ***  |
| Presentation:Info.Level | 2.7282   | 1  | 0.098588 .    |

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Figure 18. ANOVA for ER time data

## 5.5 Enemy Accuracy Data

The enemy accuracy data indicated statistically significant differences in presentation type and level of information, such that those in the DIG condition accurately identified 40% more enemy threats than those in the text condition, and those in the More information condition about the enemy accurately identified 7% more enemy threats than those in the Less information condition as seen in the table (Figure 19).

ANOVA of the Enemy Response Accuracy Data Analysis of Deviance Table (Type III tests) Response: Surv(Time.to.Respond, Response)

**ER Accuracy**

|              | Df | Chisq   | Pr(>Chisq)    |
|--------------|----|---------|---------------|
| Presentation | 1  | 309.377 | < 2.2e-16 *** |
| Info.Level   | 1  | 13.212  | 0.0002782 *** |

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

**Figure 19. ANOVA for ER accuracy data**

Overall, the response times for the DIG condition appear to be lower than the text condition over all levels of the information-level condition. The Cox regression indicates that the response rate (accuracy/correctness) is generally higher in the DIG condition in comparison to the text condition, which suggests that the participants are correctly responding to the prompted questions more in the DIG conditions in comparison to the text conditions. The timing data of the accurate responses indicate that the DIG conditions result in faster accurate response times in comparison to the text conditions. Unlike with the mission response, the ER times for the less conditions were generally higher than the more conditions over all levels of the presentation condition. The Cox regression indicates that the response rate (accuracy/correctness) is generally higher in the more conditions in comparison to the less conditions, which suggests that the participants are correctly responding to the prompted questions more in the more conditions in comparison to the less conditions. The timing data of the accurate responses indicate that the more conditions result in faster response times in comparison to the less conditions.

## **5.6 Situation Awareness by Condition**

Testing of the medians indicates that all conditions appear to be statistically significant (602.21, 3df, p-value of  $< 2.2 \times 10^{-16}$  \*) from one another. Based on this, the best indication of which conditions the participants preferred would come from the mean, median, mode, and range. The participants seem to prefer the DIG presentations and appear to favor more information rather than less (Figure 20).

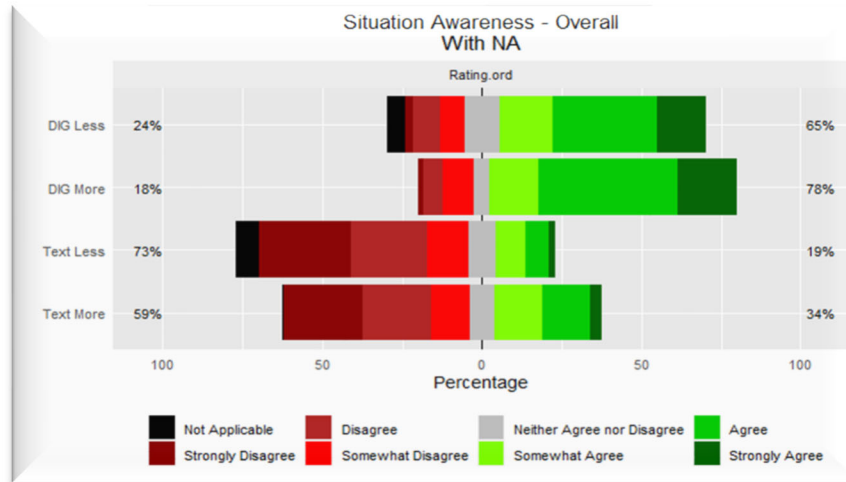


Figure 20. Overall SA by condition

## 5.7 Trust by Condition

Unlike the previous surveys, the mean, median, mode, and range table is not as helpful. However, based on the  $Z$  statistic (246.98, 3df,  $p$ -value of  $< 2.2 \times 10^{-16} *$ ) from the Dunn Test and the effect sizes, we can deduce that the participants rated the DIG more condition the highest, followed closely by the DIG less condition, and the text conditions were rated approximately the same and were rated lower than the DIG conditions (Figure 21). When comparing the information-level variables, the less information level was rated lower than the more information level, and the more information level was rather higher than the less information level.

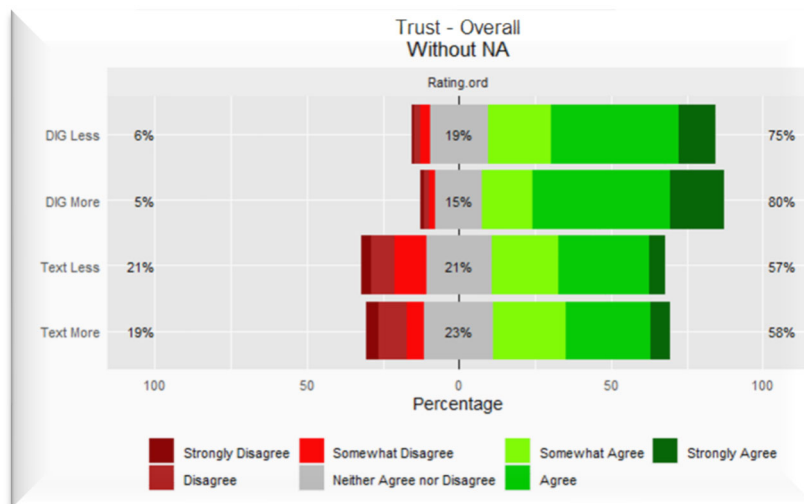


Figure 21. Overall trust by condition

## 5.8 Workload by Condition

Assessing workload objectively, we look back to the ANOVAs for MR and ER times (Figures 22 and 23). As noted earlier, there is a statistically significant difference in the presentation type and information level, such that the those presented with the DIG format responded faster than those presented with the information in text format. Additionally, those presented with enemy information while in the DIG format were faster at enemy identification that those presented with enemy information while in the text format.

ANOVA of the Mission Response Time Data Analysis of Deviance Table (Type III Wald chisquare tests) Response: Time.to.Respond

| MR Time                                                       |           |    |               |
|---------------------------------------------------------------|-----------|----|---------------|
|                                                               | Chisq     | Df | Pr(>Chisq)    |
| (Intercept)                                                   | 3165.9306 | 1  | < 2.2e-16 *** |
| Presentation                                                  | 204.5977  | 1  | < 2.2e-16 *** |
| Info.Level                                                    | 32.6905   | 1  | 1.081e-08 *** |
| Presentation:Info.Level                                       | 0.5249    | 1  | 0.4687        |
| Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 |           |    |               |

Figure 22. MR times ANOVA by variable

ANOVA of the Enemy Response Time Data Analysis of Deviance Table (Type III Wald chisquare tests) Response: Time.to.Respond

| ER Time                                                       |          |    |               |
|---------------------------------------------------------------|----------|----|---------------|
|                                                               | Chisq    | Df | Pr(>Chisq)    |
| (Intercept)                                                   | 991.8408 | 1  | < 2.2e-16 *** |
| Presentation                                                  | 26.8455  | 1  | 2.204e-07 *** |
| Info.Level                                                    | 12.3798  | 1  | 0.000434 ***  |
| Presentation:Info.Level                                       | 2.7282   | 1  | 0.098588 .    |
| Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 |          |    |               |

Figure 23. ER times ANOVA by variable

Additionally, subjective results (553.28, 3df, p-value of  $< 2.2 \times 10^{-16} *$ ) were statically significant and indicated that those in the DIG format with more information presented to them rated their workload as 69% lower (better) than those in the text format with less information presented to them (Figure 24).

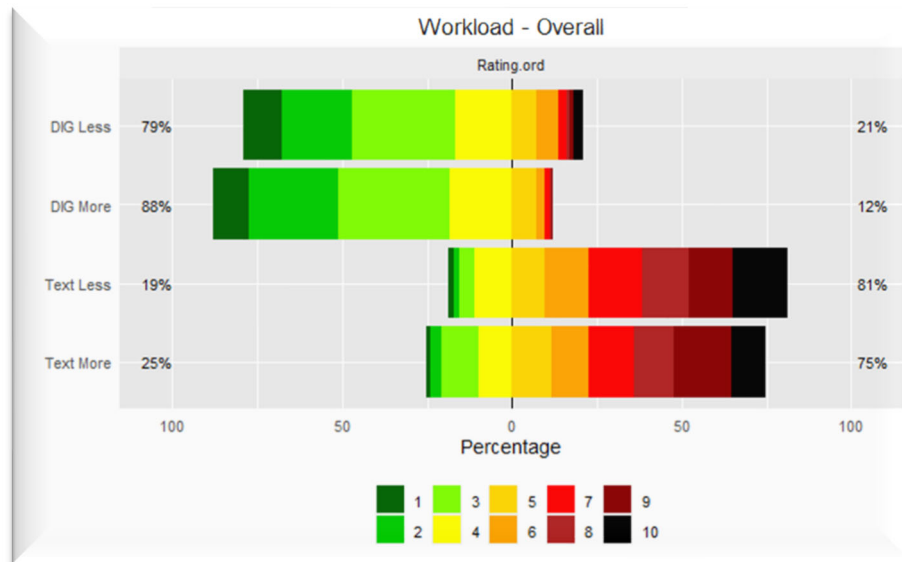


Figure 24. Workload by condition

## 5.9 Usability by Condition

Testing of the medians indicates that the only difference in the rating comes from the presentation conditions or the DIG or text conditions. This indicates that the perceived usability of more or less information is negligible to the participants. These results were statistically significant (511.45, 3df, p-value of  $< 2.2 \times 10^{-16}$  \*). The participants seem to prefer the DIG presentations over the text presentations (Figure 25).

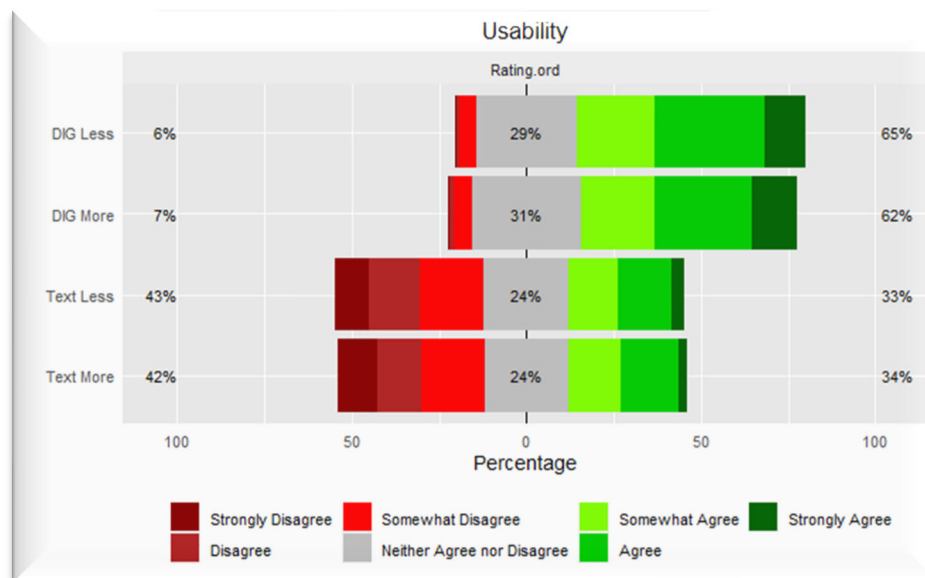


Figure 25. Usability by condition

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## **6. CONCLUSION AND RECOMMENDATIONS**

### **6.1 Effective Human–Agent Collaborations**

Based on the results and analysis of this study, providing mission information to users must be done in a clear, concise way by an IA. Breaking the paradigm of the relay of information in a pure text format is not conducive to quick comprehension of information. Users not only prefer but need that information provided in an easily comprehensible way. This study demonstrates that way could be the IA's use of graphical representations of that data that is dynamic in nature, providing the users with real-time or near-real-time data, keeping them fully situationally aware of the current mission and situation. Additionally, if the IA system provides the necessary information to the user in AR, it will reduce the workload of their human counterpart, especially with respect to pilots in the cockpit who need to remain heads up and eyes out.

### **6.2 Effective Intelligent Agents Transparency**

Users will continue to increasingly work with IAs that sense and make sense of the environment. The IA will be designed to take actions and make decisions and recommendations based on what they *see* and *understand* about the environment. It is imperative that those IA are completely transparent with their human teammates about what they see and understand as well as the actions, decisions, or recommendations that they make so that their human counterparts know what is happening and why the system acted or made a recommendation. This transparency is required for human users to trust their IA system counterparts.

For the IA systems and users to work together efficiently and effectively, a basic level of transparency must be presented in the form of the system's current state, actions, and decisions, which will need to be clearly and concisely conveyed and understood by the user. Moving forward, not only will the user require current system status, actions, and decisions to acquire the necessary SA and build user trust, the systems must be able to graphically demonstrate its reasoning and predictions, specifically the reason why the IA teammate took specific actions or made specific decisions and provided near-term predictions based on trends in the sensed data.

### **6.3 Effective Intelligent Agents Forecasting**

Additionally, to build the maximum amount of user trust, the behavior must be predictable and the environment forecastable. The behavior of the system, including the progress of the mission and the probability of success for the task or mission, as well as environment forecasting, are necessary requirements that must be conveyed. The

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model of DIG-LoSA proposed accomplishes these levels for effective SA. Developers of these systems and algorithms should be encouraged to design these systems by integrating user interfaces that will incorporate this concept to increase system transparency and forecasting, resulting in increased user SA and user trust while decreasing user workload while working with these system teammates.

## **6.4 Future Research**

### **6.4.1 Future of Transparent IA Collaborations**

Future studies will look at the benefits of DIGs by examining the differences in the exchange of information between the standard text method (current) and the DIG concept method. Additionally, future studies will seek to (1) develop visualization guidelines based on emerging research in AR, user interface design, and human factors and (2) develop methods/frameworks of design development for the types of DIGs.

### **6.4.2 Future IA Interface Control**

Finally, additional DIGs will be developed for a wide range of military operations and users. Future research should include the use of voice commands and hand gestures to initiate DIG views of the data required. Additionally, for users that use their hands during normal operations and/or in noise-constrained environments, research should include DIG initiation by eye gaze.

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## LIST OF ACRONYMS

|          |                                                   |
|----------|---------------------------------------------------|
| 2D/3D    | 2-/3-dimensional                                  |
| AI       | artificial intelligence                           |
| ALE      | air-launched effects                              |
| ANOVA    | analysis of variance                              |
| AR       | augmented reality                                 |
| DAC      | DEVCOM Analysis Center                            |
| DEVCOM   | U.S. Army Combat Capabilities Development Command |
| DIG      | Dynamic InfoGraphics                              |
| DIG-LoSA | DIG levels of situation awareness                 |
| ER       | enemy response                                    |
| FARP     | forward arming and refueling point                |
| HMD      | head-mounted display                              |
| HUD      | heads-up display                                  |
| IA       | intelligent agent                                 |
| ID       | identification                                    |
| IoBT     | Internet of Battlefield Things                    |
| JVMF     | Joint Variable Message Format                     |
| MEDEVAC  | medical evacuation                                |
| MR       | mission response                                  |
| MTF      | Medical Treatment Facility                        |
| PMD      | Pre-warning Message for Departure                 |
| PQ       | probing question                                  |
| SA       | situation awareness                               |
| SAT      | Situation Awareness-based Agent Transparency      |
| SME      | subject matter expert                             |
| TID      | threat identification                             |
| TT       | threat type                                       |
| UE5      | Unreal Engine 5                                   |
| VR       | virtual reality                                   |
| XAI      | explainable AI                                    |

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