# Establishing Trust in Decision-Aiding: The Role of a Visualization of Agent Decision-Space in Improving Operator Engagement with Reduced Cognitive Load

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### ABSTRACT

Decision recommendation systems relieve operators from high cognitive-load during stressful situations. However, automation over-trust can disengage complacent operators from the task leading to lower situation awareness and inability to intervene and override incorrect recommendations. Our recent research effort was focused on a visualization of agent decision-space to improve automation transparency and aid the operator's perception of the environment. We describe specific properties of the interface and their anticipated benefits such as improved situation-awareness and expectancy. The visualization is compared with an alternative static representation with an emphasis on how the visualization improves expectancy. An experiment was conducted with a command and control simulation environment to compare the two representations. The results of the experiment have been encouraging. Observed performance improvements in specific scenario conditions, are in accordance to anticipated benefits of the visualization.

**Keywords:** Decision-aids, Human-automation-interaction, Automation-transparency, Multi-dimensional scaling, Cognitive-load.

#### INTRODUCTION

Decision-aids for assisting commanders in uncertain and time-constrained environments are becoming ubiquitous in the military. They relieve operators from the mental burden of handling large amounts of information. However, decisionaids are often inaccurate, and can sometimes provide operators with incorrect recommendations. Our problem context is the scenario of a military commander dealing with large amounts of incoming reports in a socially unstable, urban environment. The operator's task in our study involves receiving information about active-crowds in the environment, and making decisions to deploy resources to mitigate or combat hostile crowds. We particularly discuss the design features of a visualization and how it augments the operators situation-awareness in order to better interact with a recommending system. As crowds can have a large number of attributes, identifying their qualitative nature can be mentally challenging in a timeconstrained and noisy environment. Decision-recommendations are made using R-CAST, an intelligent-agent based on the Recognition Primed Decision model (Fan, Sun, Sun, McNeese, & Yen, 2006). However, decision recommendation systems can throw operators out of the loop as a result of over-trust and vigilance decrement (Endsley & Kiris, 1995). The visualization of agent decision-space which we hereafter refer to as the VADS, was designed to make operators perceive the link between the experience-space of the intelligent-agent and, the nature of the crowd target (Hanratty, et al., 2009). This strategy is intended to keep operators engaged and maintain situation awareness.

The next section provides the reader with the description of the VADS. This is followed by a section that describes properties of the interface and the potential advantages they may have in augmenting situation awareness. The experimental-design and results are discussed on the 4<sup>th</sup> and 5<sup>th</sup> sections respectively. Finally, we conclude with a discussion of the implications of the study and potential directions for future research.

#### VADS: THE ESSENTIAL IDEA

The VADS displays a fixed number of prototypical events indicated by solid circles as shown in figure 1. Their positions on the two dimensional space are based on their attributes, and these positions are calculated by multi-dimensional scaling (Cox, 2000). When an active crowd-target appears, its qualitative-nature can be interpreted by its position on the display. The 'nearness' to prototypical crowds makes the operator perceive the qualitative-nature of the target. When a large number of targets appear, that awareness is critical in prioritizing targets in order to optimally and appropriately allocate resources. Green prototypes as shown in Figure 1 represent crowds that are typically not hostile, and they are perceived as nonevents. The yellow, orange and red prototypes represent crowd-targets in increasing order of threat-level. An active crowd-target can undergo transitions across these threat levels. In our simulation environment, crowd-targets can either be fastburners or slow-burners. Fast-burners are quicker in progressing to higher threatlevels than slow-burners. Representing an active crowd-target on the VADS is an alternative to listing its attributes on a table along with its threat-level. Attributes to a crowd-target include details such as size, proximity to a military-significantobject, presence of a key-insurgent etc. We refer to this tabular representation of crowd target attributes as the Agent Decision Table (ADT) (Hanratty, et al., 2009). The next section discusses potential merits of the VADS over the ADT.



Figure 1. Visualization of Agent Decision-Space (VADS)

## INTERFACE PROPERTIES FOR IMPROVED AWARENESS

R-CAST in our simulation environment only recommends the number of resources that need to be allocated to handle an active crowd-target. However, the prioritization of targets, or, the order in which they receive attention is solely decided by the operator. Additionally, R-CAST does not consider the travel time a dispatched resource would take until it reaches its crowd-target. Sometimes, this causes R-CAST to recommend an insufficient number of resources. This is a problem especially when a crowd-target is progressing in threat-level over time, resulting in an increased resource demand. Therefore, the operator is left with the onus to change resource allocation decisions when necessary. These two issues of prioritization, and the anticipation of resource requirements for a progressing target, are both linked to the ability to project a targets future status. Acquiring the ability to project the outcome of a resource allocation decision, or to discriminate between slowly-progressing targets and quickly-progressing targets, is dependent on sufficient comprehension of crowd-relevant data at an early stage. This ability to

make predictions is better known as level-3 SA (Endsley & Garland, 2000). Therefore, an important consideration of interface design is providing more information about the dynamics of the environment. Crowd-targets progressing to higher threat-level should be identified by the operator at an early stage. However, on the ADT, information about threat-level is static and is abruptly replaced by a new threat-level when a target completes transition. This is a problem when a large number of active targets are present on the ADT as more targets would fall outside the immediate visual focal attention of the operator. Peripheral vision cannot detect color (Wyszecki & Stiles, 1982), and abrupt transitions in the periphery of vision would go unnoticed during saccadic shifts or rapid eye movements (Burr & Ross, 1982; Ware, 2004).

However, on the VADS, transition information is shown by motion, which should help in attracting attention, and reducing the reaction-time in responding to a crowdtarget (Peterson & Dugas, 1972). Crowd-target motion can also help in the perception of transition-rate which would eventually be helpful in discriminating between slow-burners and fast-burners. Although the ADT can facilitate much of this information as the user gets accustomed to using it, affordances on the VADS facilitate this with less mental-workload resulting from the vigilance aspect of the task.

On a real-world task, the selection of targets and resource allocation can depend on the qualitative-nature of the targets as well. External representations should match internal representations of how crowd-targets are perceived, for more efficient perceptual processing and reduced cognitive-load (Zhang, 2001). Crowds of the same threat-level that indeed differ in terms of how they are qualitatively perceived are associated to different types of resource requirements in a real-world setting.

The VADS facilitates this perception of qualitative-type as its representational layout is designed on the basis of prior experience. On the ADT, crowd attributes can indirectly facilitate this perceptual process in a similar way, however, interpreting the qualitative-nature can be mentally challenging or may require significant prior experience in the environment, due to a large number of attributes.

The ability to predict future status can also depend on the qualitative-nature of the target, as some prototypical crowds have a higher probability to progress to a higher threat-level than other ones. It is also important to consider that changes in the environment during a period of long term usage of the agent, can lead to predictable errors in the agents recommendation. Such errors, that have fixed patterns, can be linked to the qualitative-nature of crowd-targets. Thus, displaying this qualitative information can improve the ability to change agent-recommendations about resource-type when necessary. Predicting future target status based on the dynamics

of progressing targets and developing expectancies towards errors in recommendation are also potential advantages of the VADS.

These design decisions are intended to make the operator perceive the environment differently, with better situation awareness. Promoting transparency in automation is intended to engage the operator into the loop without increasing cognitive-load.

#### **EXPERIMENTAL DESIGN**

We will only provide an overview of the experimental design in this paper. Hanratty et al (2009), describe the experiment in greater detail. Our simulation of an urban command and control environment based on the three-block-challenge problem (Fan, et al., 2005) was the test-bed for the experiment. The experiment was a between subjects design with a total of 32 participants recruited from the Army ROTC at the Pennsylvania State University. Both groups were presented with the display of the battlefield environment. However, the presentation of crowdtarget information differed between groups where the experimental group received the VADS, and the control group received the ADT. Four scenarios were developed that were presented in random order to each participant. Scenarios differed in workload and the proportion fast-burners to slow-burners.

#### RESULTS

Hanratty et al(2009), reported the initial results of the experiment. For each scenario, a one-way ANOVA was conducted to compare scores between the two groups. Score differences were insignificant with the exception of scenario 3. In the case of scenario 3, the experimental group scored significantly higher than the control group (F(1,30) = 6.370, p = .017). A possible explanation is that scenario 3, that was designed for higher workload had an equal proportion of slow-burners and fast-burners. Therefore, the ability to discriminate between fast and slow burners became more critical in order to predict future threat level of targets. The VADS possibly facilitated participants for meeting this requirement. Our analyses revealed that SAGAT scores did not significantly differ between the two groups. RT-SA scores was higher for the experimental group although this difference was not statistically significant (p = .1424).

#### **DISCUSSION AND FUTURE WORK**

Design decisions for the VADS were made with the objective of improving operator situation awareness relevant to the task environment. We discussed how various

properties in the design are aimed at reducing the mental effort required to identify crowd-targets making transitions, and in projecting their future threat-level. Our experimental results are encouraging. Even though the VADS did not improve overall performance, it appears to have facilitated the scenario in which the ability to predict future threat-level was a necessity. Our analyses on situation awareness measures did not reveal statistically significant differences, however, an experiment with a larger sample size may lead to more convincing results.

The inherent nature of VADS that abstracts crowd information, aids the operators interpretation of the qualitative-nature of targets. Although experimental results may not reflect on the direct advantages of this property, it has the potential to provide the necessary awareness to an operator interacting with automation. We hope that future experimental studies on this concept may throw more light on its effects in naturalistic decision-making.

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