Available online at www.sciencedirect.com

ScienceDirect

IFAC-PapersOnLine 49-19 (2016) 031–035

A Comparison of Methods for Assessing Situation Awareness in Current Day and Future Air Traffic Management Operations: Graphics-Based vs Text-Based Online Probe Systems

Thomas Z. Strybel*, Dan Chiappe*, Kim-Phuong L. Vu*, Adriana Miramontes*, Henri Battiste* and Vernol Battiste**

*California State University Long Beach, Long Beach, CA 90840 USA (email: thomas.strybel@csulb.edu)
**San Jose State Foundation and NASA Ames Research Center, Moffett Field, CA, USA (e-mail: vernol.battiste@NASA.gov)

Abstract: Operator situation awareness can be measured by examining operator response time and accuracy to online queries or probes. We compared an existing, text-based query method with a new graphics-based method. The text-based method presented multiple-choice queries to air traffic controllers (ATCos) on a display next to the DSR. Responses were entered by selecting one of the response alternatives presented with the query. The graphics-based method presented the query along with a screen shot of ATCo's current traffic on the DSR. The ATCo responded by touching the symbol of the aircraft that was the subject of the question. These methods were compared in a simulation involving student ATCos currently enrolled in an Aviation Sciences program.

Keywords: situation awareness, SPAM, air traffic control, workload.

1. INTRODUCTION

Airspace modernization programs such as the Next Generation Air Transportation System (NextGen) in the U.S., and the Single European Sky Air Traffic Management Research program (SESAR) in Europe, are being designed to meet the growing demand for air travel. Modernization of the airspace will require new automation tools and new concepts of operation, yet the optimal mix of automation tools and novel concepts has yet to be determined. Strategies for modernizing airspace systems must ensure that operator workload and situation awareness (SA) are optimized, meaning that valid and reliable methods for assessing these constructs are essential.

The construct of SA has been a major topic of interest for theorists, researchers, designers and operators for over 25 years. SA refers to the operator's understanding of an evolving situation that he or she is in, or "what's going on" for the purpose of projecting system states into the near future. The importance of this construct has led to diverse theoretical perspectives that have been debated over the years (e.g., Endsley, 2015; Chiappe, Strybel & Vu, 2015; Stanton Salmon & Walker, 2015), and these have been recently debated in a special issue on SA in *The Journal of Cognitive Engineering and Decision Making* (Pritchet, 2015). Despite these fundamental differences in the conception of SA, Wickens (2015), points out that the construct ". . . cannot easily be defined/discussed in the abstract, devoid of a context any more than we can talk about 'a situation' without saying what that situation is" (p. 90). In other words, it is difficult to debate the nature and processes involved in acquiring and maintaining SA without referencing a specific work environment.

The diverse approaches to SA have implications for how the construct is measured. SA measurement methods are generally categorized into subjective, performance, physiological and probe techniques. Probe techniques, the focus of this paper, assess an operator's awareness of specific information needed for adequate performance. Two methods for asking questions have been developed, both of which have evidence of reliability and validity. Endsley's Situation Awareness Global Assessment Technique (SAGAT; Endsley, 1995b) is an offline method because the operator is queried about task information when a scenario is frozen and the displays are blanked. SA is measured by the number of correct responses to probe queries. Evidence for the criterion validity of SAGAT has been reported (e.g., Endsley, 2000; Endsley, 1990b; Gronlund et al., 1998), and SAGAT has been used in a variety of settings such as air traffic control, aviation, and nuclear power plant operations. It is the most widely used probe technique for SA assessment to date. Online probe techniques such as Durso and Dattell's (2004) Situation Present Assessment Method (SPAM), query the operator about task information in real time while he/she is performing a task. With SPAM, the operator can rely on information from displays, as they remain active when a question is asked. Consequently, with SPAM, SA is measured as both response accuracy and response latency. To ensure that the response latencies are due to SA and not operator workload, SPAM provides a "ready for question" prompt prior to presenting a question. The operator responds to the ready prompt only when he or she has sufficient excess capacity to answer question; the SA question is presented

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.10.457

immediately after an affirmative response. The ready latency is a measure of momentary operator workload (e.g., Strybel et al., 2013) and the probe latency measures SA. Evidence for the reliability and validity of SPAM has been accumulating in recent years (e.g., Durso and Dattel, 2004; Durso, et al., 2006; Bacon et al., 2011; Strybel et al., 2011; 2013). However, some criticize SPAM as being intrusive to the operator (e.g., Pierce et al., 2012) and others (e.g., Strybel et al., 2008) have shown changes in workload or performance with SPAM. Consequently, we have developed methods of presenting probe questions and collecting operator responses in real time that minimally impact on the operator (Strybel et al., 2010).

For several years, we have used a text-based technique in which probe questions and possible responses are presented on a touch-screen display next to airspace operators (ATCos and pilots). The operator responds to the query simply by touching the answer from a set of possible answers. In this respect, the probe technique can be viewed as presenting multiple choice queries which may limit the types of SA information that can be asked. In this paper we report on a refinement of the online query technique. We compared this traditional text-based query method with a new graphics-based method.

The graphics-based method presented queries with a screen shot of ATCo's current traffic on the DSR. The ATCo response was made by touching the symbol of the aircraft on the screen shot that was the answer to the question. The potential advantages of this technique are that the types of questions asked can be expanded, and may resemble more open-ended queries (similar to those used in SAGAT). For example, instead of asking "Which aircraft will be in conflict in the next two minutes" and providing a set of possible aircraft, with the graphics-based technique, the question can be written, "Select the aircraft that will be in conflict in the next two minutes." This expands the possible answers to include all aircraft currently in the controller's sector.

Other practical advantages can be realized by this graphics-based approach. If questions can be designed without reference to a specific call sign, probe queries can be less dependent on a specific traffic scenario. This should reduce the time required to develop probe questions for SA measurement. In fact, it may be possible to develop standardized probe questions that would apply to any simulation evaluation of SA in some operational context. Moreover, the intrusiveness of the online probe method should be lower because the ATCo does not have to translate call signs that are part of a probe question into spatial locations on the radar display.

2. METHOD

2.1 Participants

Ten student air traffic controllers (ATCos) from the Aviation Sciences Program at Mount San Antonio College, an FAA College Training Initiative (CTI) institution participated in this study. All students previously participated in a 16-week radar simulation internship at the Center for Human Factors in Advanced Aeronautics Technologies (CHAAT) at California State University, Long Beach. This internship trained students on current day and NextGen air traffic management procedures. All participants had experience with the text-based probe technique as part of the course, but none had experience with the graphics-based probe technique. Participants were compensated $160 for completing the two-day simulation experiment.

Table 1. Sample Questions for Text and Graphic Probe Methods

Text (Yes/No Response)	Graphic
If no further action is taken with AAL123, will the next LOS take place in the SW quadrant?	Select an AC that will be in conflict in the next 2 minutes if no further action is taken.
Is AAL123 currently climbing?	Select the AC that you will descend next.
Will any co-altitude AC be within 5nm of each other in the next 2 min if no further action is taken?	Select an AC that will be within 5nm of another co-altitude AC in the next 2 minutes (20nm).
Will any AC be within 20nm of PXV in the next 5 min if no further action is taken?	Select an AC that is within 20 nm of PXV.
Will your next frequency change be given to an AC in the SW quadrant?	Select the AC that you will next issue a frequency change to.

2.2 Materials

Participants were tested using the Multi Aircraft Control System (MACS) software (Prevot, 2002). MACS is a medium fidelity simulator that simulated sector ZID-91, which includes overflights as well as departures from and arrivals to Louisville International (SDF) airport.

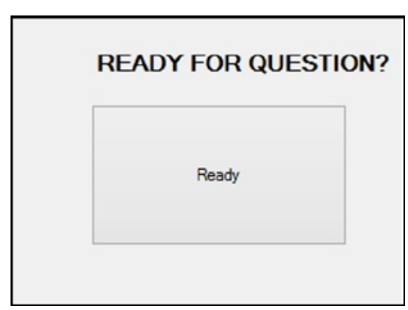

Figure 1. Ready Prompt Screen for Both Probe Methods.

The SPAM probe technique was presented on a touchscreen located to the right of the DSR display in two different formats. For the text-based format, a "Ready for Question" prompt was presented at the specified time interval, as shown in Figure 1. This ready prompt was paired with an auditory alert in the participant's headset. Participants were instructed to press the "Ready" button only when their workload allowed time to answer the probe question. Once the