

An Intelligent Debriefing System for Situation Awareness Training

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Abstract

An option to ensure that operators of complex systems have adequate situation awareness (SA) to support decision making and action is to train them to acquire and maintain SA. This paper expands upon an original approach to the problem of training and aiding SA skills in real-time operations by adding an intelligent debriefing capability. The system logs detected discrepancies from expected performance while the trainee performs a simulated mission. The system classifies the discrepancy data along multiple criteria so it can be viewed in many different ways according to the needs of the trainee and the instructor. When discrepancies occur, the system also saves the simulation state model so the trainee can request the detailed context.

Introduction

To become proficient, an operator of a complex system must know several types of knowledge: declarative knowledge (i.e., what to do), procedural knowledge (i.e., how to do it), and operational skill (i.e., when to do it) (Chu, Mitchell & Jones, 1995). Operational skills are especially important in a dynamic environment where the operator has to make decisions in time-critical situations. In order to make effective decisions in dynamic and risky domains, operators must acquire and maintain situation awareness (SA) (Endsley, 1988, 1995).

One strategy for helping operators achieve higher levels of SA is to design decision aids to support SA (c.f., Endsley & Selcon, 1997; Ernst-Fortin, Small, Bass & Hogans, 1997; Morrison, Kelly & Hutchins, 1996). Another option to ensure that operators have adequate SA to support decision making and action during performance is to train them to acquire and maintain SA. Training should highlight the role of SA in the operational environment. This training should focus on timely, critical, information seeking and processing behaviors needed for acquiring and maintaining SA (Salas, Prince, Baker & Shrestha, 1995). Such training may be accomplished by exposing trainees to scenarios through which they can develop the knowledge and skills necessary for SA (Shrestha, Prince, Baker & Salas, 1995).

This paper describes progress on an approach to the problem of training and aiding SA skills in real-time operations (Bass, Zenyuh, Small & Fortin, 1996; Bass, 1998). By integrating an expert model, an instructional

model, and a student model with a simulation, trainees learn about SA and other performance skills in a dynamic, interactive environment while they receive feedback during practice about deviations between the actual and the expected system state. Such guided practice with feedback in an authentic environment is critical for transfer to actual operations (Shrestha et al., 1995).

This paper expands upon the original approach by adding an intelligent debriefing capability. It is not desirable to present all of the information about deviations during performance. Training should support the student in developing the knowledge structures that are necessary for skilled performance (Stout, Salas & Kraiger, 1997). However, providing too much information during performance may distract the trainee. That is why instructors debrief trainees after practice. A debriefing capability provides the ability to help the student reflect on his performance and to develop required knowledge structures by elaborating the deviation data collected during performance with deviation cues information, consequences, and corrective actions.

Debriefing Approach

Based on a synthesis of the decision making and SA literature (c.f. Endsley, 1995; Gaba, Howard & Small, 1995; Klein, 1989, 1997; Orasanu & Fischer, 1997; Sarter & Woods, 1995; Stokes, Kemper & Kite, 1997), the process to be supported includes cue detection, cue interpretation, action planning, and action evaluation. The literature cited describes how experts, using cues in the controlled system and the environment, recognize the current situation, determine or prioritize the current goals, create expectations about the future system state, and choose the typical course of action to make the future system state meet the current goals.

A training system with coaching, scaffolding, fading, and reflection concepts from cognitive apprenticeship (Collins, Brown & Newman, 1989) and the lessons from feedback sequencing literature (e.g., Burton & Brown, 1982) can present the appropriate SA related information to the trainee during practice and during post-practice debriefing. For example, during practice, the system provides advice about the current state of the system and which states are not as expected. However, during debriefing, the system provides details about the particular SA problems the trainee had. For example, each time the controlled system deviated from the expected system state,

the debriefing system provides guidance about what cues to use to assess the state, how to recognize the current context, what to expect in that context, and what corrective action to take.

To support reflection on the trainee's performance and to aid an instructor in preparing and presenting a debriefing, the system summarizes the set of SA problems encountered during performance. This summary allows the trainee and/or the instructor to review progress and identify what type(s) of additional practice may be necessary.

To support debriefing, the system classifies the debriefing data along multiple criteria: time of the onset of the failed expectation, severity, type of deviation, context within which the deviation occurred, and type of skill with which the deviation is associated. In this way, the system captures the information surrounding the potential loss of SA.

The data can be viewed in many different ways according to the needs of the trainee and the instructor. Deviation resolution information is associated with each deviation so the trainee knows if he fixed the problem or the problem "went away" because the context changed or another activity superseded the current one. The deviations are available in multiple arrangements to support analysis in a variety of ways. For example, all failed expectations can be sorted in chronological order. They can be arranged by situation context. Alternatively, they can be grouped by the skill category of the deviation.

To make clear the usefulness of the multiple representations, we present an aviation example for training instrument landing system (ILS) approaches. During the descent, the pilot must descend at the appropriate rate to reach the initial approach fix (IAF), the beginning of the approach, at the proper altitude. When descending below the transition altitude (TA), 18,000 feet in the US, the pilot must set the altimeter to the local setting. During the approach, the pilot must set the navigational equipment to the settings compatible with the approach and must meet all published altitude and course restrictions. By the final approach fix (FAF), the pilot should be configured for landing (e.g., flaps out, landing gear down, and spoilers out). Also the pilot should be using the localizer and glideslope for horizontal and vertical guidance. If the runway is not in sight by the decision height (DH), the pilot should not attempt to land, but rather execute a missed approach.

During a practice session, if the system detects deviations in the trainee's performance, a profile is displayed portraying the deviations and when they occurred

(Figure 1). The intent of this display is to portray when the deviations occurred with respect to time. The length of the box is determined by the onset and correction of the deviation.

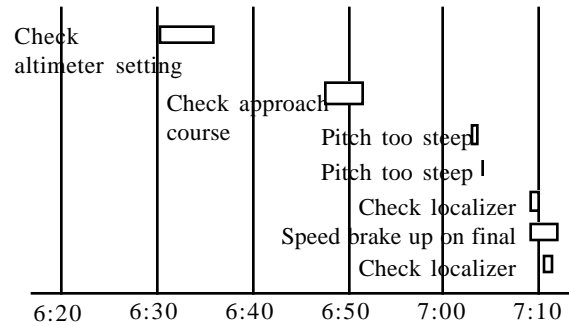
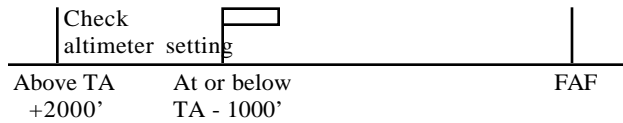


Figure 1. Chronological Deviation Display

The chronological presentation may not provide enough contextual information for the trainee to understand how he allowed the deviations to occur or what else was happening. A second display separates deviations by context in order to provide the trainee with the ability to understand what was happening when the deviations occurred (Figure 2). In this example, the altimeter setting messages are linked to an altitude based context while the other messages are linked to where in the approach the deviation occurred. In this way, the trainee gets a better sense of when the deviation occurred. The deviation is presented relative to the relevant context. Also, when repeated feedback is displayed, it is indicated by multiple boxes in the same row as the label. This presentation makes repeated problems more obvious, thus making trends more noticeable.

A third display groups the deviations by skill category (Figure 3). The idea here is that each activity is composed of a set of skills. For example, in aviation, a common categorization of the skills are aviate, navigate, communicate, and manage systems. For ILS approaches, the aviate category includes continuous aircraft control. Discrete configuration issues (i.e., gear, flaps, speed brake, lights, etc.) are generally treated separately. The ability to group deviations allows the trainee to see where he is having trouble with a particular skill instead of one particular expectation. This presentation also allows the debriefing to proceed in a threaded manner (i.e., by each skill).

Altimeter Setting



Approach

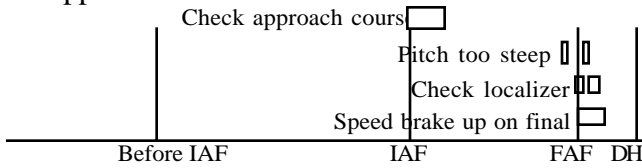


Figure 2. Deviation Grouped by Deviation Display

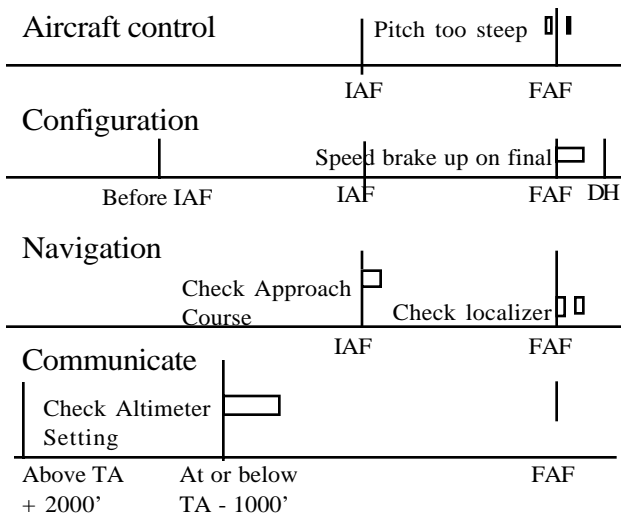


Figure 3. Deviation by Skill Category

During debriefing, detailed explanation is available for every deviation, regardless of the display on which it occurs. The information includes:

- < Deviation cues (how to tell that a deviation has occurred)
- < Consequence (future result if the deviation is left uncorrected)
- < Severity level (a measure of the priority)
- < Corrective action (action to take to return to the expected state)
- < Evaluation criteria (if applicable) to assess student performance

Similarly, cue detection and interpretation information will be available for recognizing relevant contexts (e.g., before the initial approach fix).

Because the high level debriefing displays may not provide enough context, the student can request complete state model information for any deviation. This may help the student better recall the situation.

Architecture

The architecture for the system is based on Hazard Monitor (HM), a real-time aid that provides feedback to pilots (Ernst-Fortin, et al., 1997). HM is a knowledge-based aid designed to reduce the rate of preventable accidents regardless of the source of the problem (i.e., human, machine, or external environment). In complex environments, hazards occur despite improvements in system design and advances in human-computer interaction. HM aids in these situations by enhancing the problem recognition and identification process so that operators recognize deteriorating situations in time to avoid adverse consequences.

HM, as an operational aid, helps to reduce preventable accidents by alerting the human operator to discrepancies between actual and expected system states -- a divergence that could lead to adverse consequences. Discrepancies are assessed as failed expectations in a situation within the context of goal-oriented activity. For example, during the final approach to an airport, one expectation is for the aircraft landing gear to be down and locked. Defining expectations in this way allows the aiding messages to be both timely and context-dependent as notifications are tied to the operator's current situation and goals plus the current system and environmental states.

A high-level overview of the system architecture is shown in Figure 4. The major components include the curriculum, state model, expert model, instructional model, and instructional interface. The external simulation is included in the figure for completeness. The simulation represents the host environment with which the decision support system must be integrated.

Externally, a simulation periodically provides system and environmental state data to the state model as the student performs the simulated mission.

The curriculum component specifies the training objective and other knowledge bases to use for training. This component is a data file used by both the expert model and the instructional model.

The expert model instantiates a normative model of the skills to be trained. It also includes the explanation or "tutoring" knowledge available during debriefing.

The highest-level element of the expert model knowledge structures is the "network". Different tasks are modeled in separate networks (e.g., descent and approach). All other knowledge is organized within the network. The structure of the tutoring and expert knowledge within a network is detailed in Figure 5.

Figure 5. Structure of Network Knowledge

The network specifies when monitoring a particular activity should initiate and terminate. It points to a collection of situational contexts. Networks are augmented with “N tutor” or network level tutoring knowledge which will help students recognize and interpret the cues related to the initiation and the termination of an activity.

Situation nodes specify the context within an activity for monitoring (e.g., for the ILS approach, situation contexts include inside the IAF, inside the FAF, and at the DH). Each situation node has “S tutor” or situation node level tutoring knowledge specifying the cues, interpretation, and reasons why the situated context is important. Situation nodes point to a collection of expectations for that context (Figure 5 depicts the expectations for only one situation node).

Expectations specify conditions for comparing expected and actual system states (i.e., the normative model vs. current state model). Expectations include references to other tutoring knowledge (“E tutor”) which describes among other things:

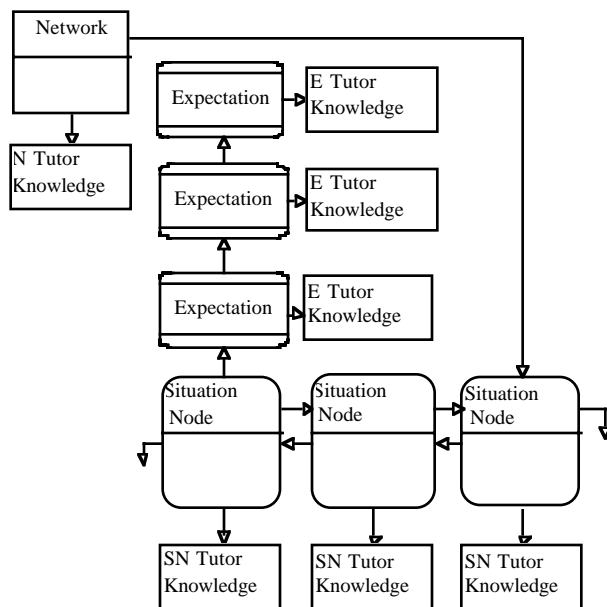
The instructional model depicted in Figure 4 processes the discrepancies detected by the expert model. For debriefing, the instructional model also invokes state model snapshots when discrepancies are detected. Therefore the student can request complete state model information for any deviation displayed on the instructional interface.

The instructional interface has three components to support debrief:

1. The high level debriefing displays illustrated in Figures 1, 2, and 3
2. The state model snapshots
3. Explanatory information for selected deviations: cue detection and interpretation, action planning, and consequence information.

Conclusion

There is a need to train operators of complex systems to acquire and maintain SA. However, the method for conducting this training remains a current operational and research issue. Intelligent learning environments with knowledge-based models and real-time simulations offer an attractive addition to the existing methods of on-the-job training, traditional classroom training and simulator time.



We have described an approach to provide intelligent debriefing in a SA training environment. This approach begins to address the problem of training SA.

However, even if it were implemented as described, there would still be outstanding research and evaluation questions. Implementation and evaluation are required steps to increase our understanding of how to train SA. We have begun to implement the system and we plan to evaluate it with student pilots.

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