Detecting a Loss of Situational Awareness

Stephen R. Pickard

Ami Eidels

Eric J. Beh

Leslie M. Blaha

DETECTING A LOSS OF SITUATIONAL AWARENESS

Stephen R. Pickard, Ami Eidels, Eric J. Beh
University of Newcastle, Australia

Leslie M. Blaha
711th Human Performance Wing, Air Force Research Laboratory
Pittsburgh, PA, USA

Based within the aviation context, this research is attempting to detect a loss of situational awareness (SA) using Detection Response Tasks (DRT). The research is in two phases: an initial survey and then an experimentation phase. A survey has been distributed attempting to gain an understanding of what current aviation personnel understand of the construct of SA and how it is currently taught and assessed, and what are the observed indicators of a loss of SA. The survey results will be used to validate some previously identified elements of SA around the link between SA and cognitive capacity and workload, and the cognitive and physical indicators of SA loss. The survey results have provided input into the experimentation phase of the research project. In the experimentation phase, a DRT-style experiment using Modifiable Multitasking Environment (ModME) software will simulate pilot workloads and behaviours, and through gradual increases in workload, use the DRT responses as a cognitive performance indicator of a loss of SA.

Situation awareness (SA) is loosely defined as the perception of events and elements in time and space (Endsley, 1990). Though the term is commonly used in aviation, transportation, and other critical industries, there is still debate around the most appropriate formal and operational definitions (Endsley, 1993). In this paper, we investigated pilots' understanding of SA, their SA experiences through training and assessment, and the signs of SA loss via an online survey. We analysed the data using a specialised statistical technique, correspondence analysis, to identify the structure of the association between categorical variables using data visualization. We explain how survey outcomes are used to develop a methodology to investigate SA in the laboratory.

THE SITUATION AWARENESS SURVEY

The survey, containing 76 items in 6 sections, was implemented online through LimeSurvey. Five sections were multiple choice questions; the sixth section allowed free-form comment. Section 1 identified demographic data around an individual's current role, measures of experience (years of flying and number of flying hours), the types of aircraft flown, and whether their experience was civil, military or both. Section 2 questions pertained to the participant's background of SA training and assessment through their initial pilot training. Section 3 asked about the participant's current understanding of SA. The questions were modelled on descriptions identified in a literature review of contemporary, scientific descriptions of SA. Section 4 contained similar questions to Section 2, but relating to training and assessment in the respondents current environment. Section 5 asked questions related to the respondent's observations of when someone is losing situational awareness. Section 6 was a free-form question to allow the respondents to include any additional pertinent information. A four point Likert scale was used for most questions with response options: Strongly Disagree, Disagree, Agree, Strongly Agree. A 'Not Applicable' option was provided for some questions. A neutral or middle option was not provided; respondents had to answer in either a negative or positive way. At points in the survey, negative questions were used to discourage response bias. These negative items' responses were reversed during analysis.

The target survey participants were pilots and aircrew members who were either: currently employed as a pilot, recreational pilot, flying instructors, or undergoing pilot training. The target population also covered fixed wing, rotary wing (Helicopter) and operators of unmanned aircraft systems (UAS). To simplify the approach to potential respondents, organisations with access to pilots were approached to have them distribute the survey to employees or members. The organisations approached included: Regular Public Transport (RPT) operators, The Australian Defence organisation, civil flying clubs and associations, Defence Industry organisations, other commercial aircraft operators in the general aviation space, and Emergency Services. These organisations potentially provided access to approximately 12,000-15,000 respondents. Over the 12 months the survey was open, 15 organisations distributed the survey and we received 26 responses, and of those, only 24 were complete.

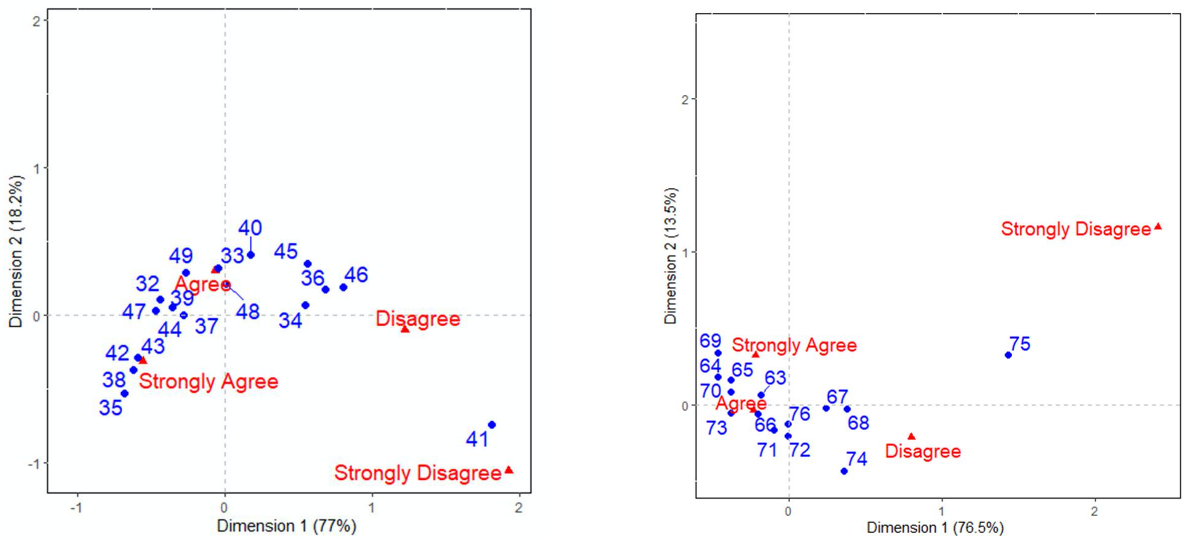
Analysis of Survey Results

Demographics showed that all respondents had civil flying backgrounds (no military); respondents were predominantly pilot or pilot instructors with only two registering as student pilots; all flew fixed wing with two having also flown rotary wing; experience levels ranged from >3 years to >21 years and from >50 to >5,000 flyer hours.

We used correspondence analysis (CA) to explore the survey results and visualize the associations between the outcomes. The technique is described in detail in a number of textbooks (Beh & Lombardo, 2014), whereas here we provide only a concise description. Pearson's χ^2 statistic is typically used to assess statistical significance of the relationship between two or more categorical variables; when such an association is statistically significant, this measure is used in CA to examine its structure in a low (two, or three) dimensional graphical format using a correspondence plot. To perform the CA, the Likert scales were converted into numerical values, and a table of response frequencies was constructed for each question. Correspondence plots were then constructed using R code on the table of counts for each section of data. Each correspondence plot provided an excellent visual summary of the association, explaining at least 80% of the association in the table as measured using Pearson's χ^2 statistic. The survey results validated the use of the negative questions to identify participants completing the survey correctly and not just ticking the same response. The participants generally answered as expected for positive and negative questions. Key results are reported below.

Training of Situational Awareness

Of the 24 respondents, 21 reported that they received SA training and assessment during their initial pilot training. Results showed a strong alignment with questions relating to the focus on SA training in contemporary training environments. Respondents agreed or strongly agreed that SA is presented as a critical aviator skill and was taught throughout elements of the course. Similar responses were received for the questions relating to SA assessment in that, SA assessment was conducted throughout the course and was assessed against established criteria to provide objective assessment.



(a) Q32-49 Understanding of SA

(b) Q63-76 Detecting a loss of SA

Figure 1: Correspondence Bi-Plots

Understanding of Situational Awareness

The first 3 questions in this section referred to the respondents' assessment of their own understanding of SA and their evaluation of their colleagues' understanding of SA. There was a high level of agreement that respondents (24 of 24 Agree or Strongly Agree) and their colleagues (21 of 24 Agree or Strongly Agree) had a good understanding of SA, but then the responses to a check question (Q36) are somewhat contradictory and more than half indicated that, 'it was not a well understood concept'. The remaining questions in this section were developed around the contemporary description of SA from the literature. A correspondence plot was developed for the remaining questions in this section (Q32-49), as shown in Figure 1(a). Each point on the plot corresponds to a survey question and the proximity of the dot to the four options shows their association. As can be seen in the CA plot, there is a strong association across the responses to the 'Agree' and 'Strongly Agree' options. For example Q49, 'Situational Awareness is making decisions on available information', responses were Agree (16), Strongly Agree (8) and Disagree (1), hence the location of the dot in relation to 'Agree' on the plot. The responses to Q41 were more closely associated with 'Strongly Disagree'. Overall, the CA plot shows that the respondents generally Agree or Strongly Agree with contemporary construct of SA as identified in the literature, for example Endsley's 3-stage definition of SA (Endsley, 1995) and the link to cognitive processes (Durso et al., 2006; Flach & Rasmussen, 2017).

Detecting a loss of Situational Awareness

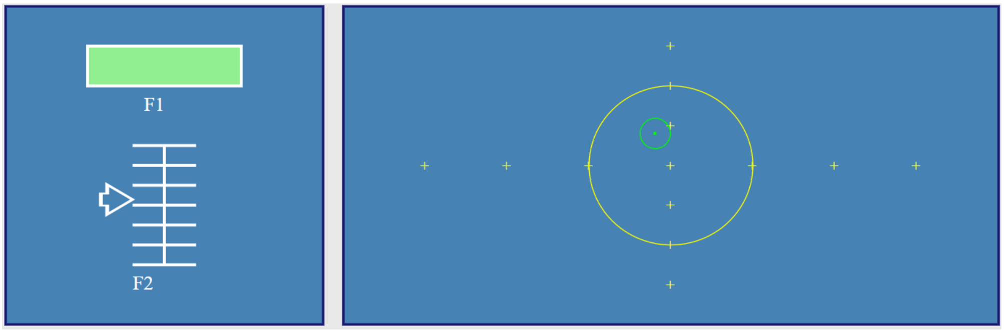
The questions in this section referred to physical and cognitive indicators of a loss of SA. Figure 1(b) shows the CA plot for this section. Again, there was strong association between the responses and indicators of loss of SA identified in the literature. The respondents indicated Agree or Strongly Agree to the questions; it was easy to detect a loss of SA (Q63) the cognitive indicators questions; not detecting threats (Q65), loss of scanning technique (Q66), poor decision making (Q69), not following procedures (Q71) and inability to recall basic information (Q72). This cognitive element of SA is most interesting and steers toward the concept that experiments that measure cognitive performance and workload can also be used to measure SA, or a loss of SA as identified by various authors (Endsley, 1990; O'hare, 1997; Wickens, 1999).

EXPERIMENTAL PLATFORM FOR ASSESSING SA

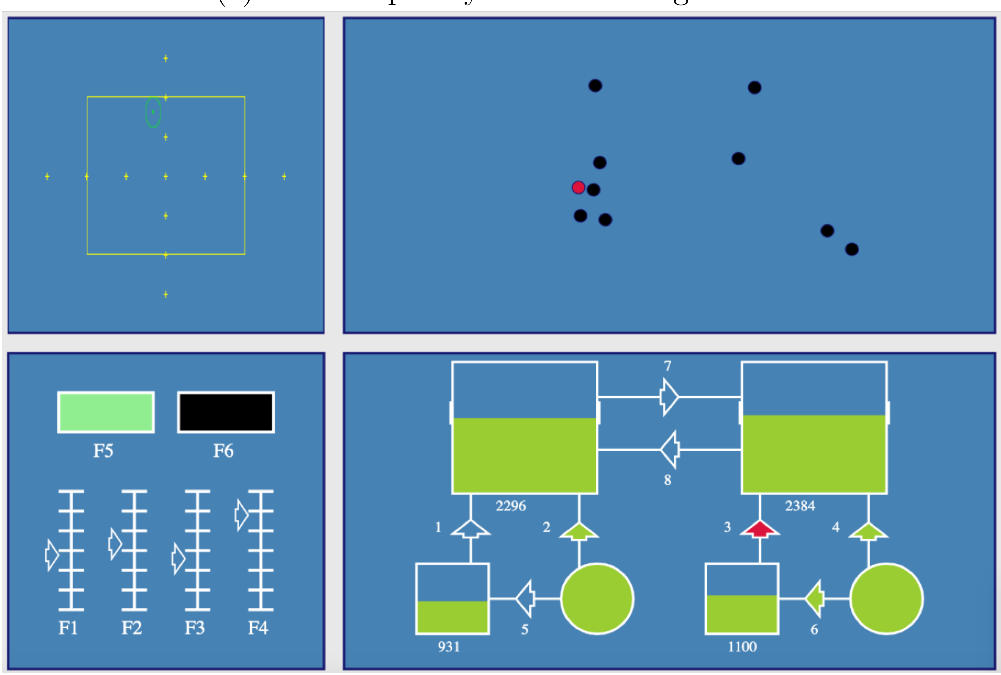
From the analysis of the survey and the literature review the nexus between cognitive capacity, workload, and the indicators of a loss of SA should be explored through experimentation. Such an experiment has two main requirements: First, an experimental platform that allows to systematically change the complexity, or load, of the task (Howard et al., 2020) and second, an objective way for measuring operators' workload. The Detection Response Task (DRT) is a well established methodology for observing changes in cognitive workload and capacity, especially in the automotive industry (Strayer et al., 2006; Conti et al., 2012). Yet, there has been limited use of the DRT methods to measure or detect a loss of SA as experienced by an aircraft pilot.

The planned DRT experiment aims to replicate pilot behaviours in operating an aircraft as much as possible in a simple interface. The types of behaviours would cover the fine and gross motor-skills (i.e., use of a joystick), use visual scanning techniques to switch between stimuli, mimic some of the stimuli types commonly seen inside and outside the cockpit, and use cognition to detect error or threat conditions and project future potential outcomes. The DRT should also use an inexpensive and easily accessible, simple to use interface that minimises variables, reduces or minimises practice effect, allows a primary task that employs fine and gross motor skills that can be easily automated by the participant, and contains a secondary visual/cognitive task to measure workload.

For experimental testing, we will use the ModME platform, illustrated in Figure 2, which provides a suitable interface and allows manipulation of task complexity. According to Jones, as task complexity increases, performance will be relatively linear to a threshold where SA will be impacted and there will be a relatively rapid drop-off in performance (Jones & Endsley, 1996). It is anticipated that this drop in performance will be observable as a rapid increase in response times and error rate in the DRT, and serve as an indicator of a loss of SA. By using the stair-casing technique to increase the task complexity within the DRT, it should be possible to identify the threshold where performance degrades for individuals and use this as a baseline for further experiments.



(a) Low complexity SA task configuration



(b) High complexity SA task configuration

Figure 2: ModME interface configurations for a low and high complexity SA task concepts. (a) uses a low-load Monitoring (left) and Cross-hair Tracking tasks (right). (b) uses (clockwise from upper left) Cross-hair Tracking, Multi-object Tracking, high-load Monitoring, and Resource Management tasks.

For the initial experimentation phase, a lower complexity ModME configuration, shown in Figure 2(a), will be used. This configuration, with relatively slow-moving stimuli, would be relatively easy to complete and provide a baseline in which participants can complete the task with minimal errors and fast RTs. Over subsequent trials, the speed and complexity of the stimuli will increase in a stair-cased manner to track how RT and errors change as indicators of overload and loss of SA. This would validate the first level of SA as identified by Endsley (1995). Later experiments would use a similar methodology but a more complex set of tasks to measure a loss of SA at the 2nd and 3rd level of SA. For the 2nd and 3rd level of SA experiments, we will use increasingly complex ModME configurations containing up to four subtasks, similar to Figure 2(b). This will require scanning of frequent events occurring in multiple screen locations and monitoring to identify threats and potential future states.

References

Beh, E. J., & Lombardo, R. (2014). *Correspondence analysis: Theory, practice and new strategies*. John Wiley & Sons.

Conti, A., Dlugosch, C., Vilimek, R., Keinath, A., & Bengler, K. (2012). An assessment of cognitive workload using detection response tasks. In *Proceedings of the fourth international conference on applied human factors and ergonomics.*

Durso, F. T., Bleckley, M. K., & Dattel, A. R. (2006). Does situation awareness add to the validity of cognitive tests? *Human Factors*, *48*(4), 721–733.

Endsley, M. R. (1990). *Situation awareness in dynamic human decision making: Theory and measurement* (Unpublished doctoral dissertation). University of Southern California Los Angeles, CA.

Endsley, M. R. (1993). A survey of situation awareness requirements in air-to-air combat fighters. *The International Journal of Aviation Psychology*, *3*(2), 157–168.

Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human factors*, *37*(1), 32–64.

Flach, J. M., & Rasmussen, J. (2017). Cognitive engineering: Designing for situation awareness. In *Situational awareness* (pp. 333–360). Routledge.

Howard, Z. L., Evans, N. J., Innes, R. J., Brown, S. D., & Eidels, A. (2020). How is multi-tasking different from increased difficulty? *Psychonomic Bulletin & Review*, *27*, 937–951.

Jones, D. G., & Endsley, M. R. (1996). Sources of situation awareness errors in aviation. *Aviation, space, and environmental medicine*.

O'hare, D. (1997). Cognitive ability determinants of elite pilot performance. *Human factors*, *39*(4), 540–552.

Strayer, D. L., Drews, F. A., & Crouch, D. J. (2006). A comparison of the cell phone driver and the drunk driver. *Human factors*, *48*(2), 381–391.

Wickens, C. (1999). Cognitive factors in aviation. *Handbook of applied cognition*, 361–389.