Measuring Situation Awareness in Command and Control: Comparison of Methods Study

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ABSTRACT

Motivation – This research sought to compare three different approaches for measuring Situation Awareness (SA) during a command and control scenario.

Research approach – A total of 20 participants undertook question one of the Combat Estimate, a military planning process, in an experimental command and control test bed environment. Participant SA was measured using three different SA measures: a freeze probe technique, a post trial subjective rating technique, and a critical incident technique interview approach. Comparisons were then made between the measures of SA obtained during the study.

Findings/Design – The results show that the freeze probe measure (SAGAT) was the only measure that had a statistically significant correlation with participant performance. The findings also demonstrate that there was no significant correlation between the three SA measures used.

Research Implications – The findings offer validation evidence for the SAGAT approach when used to measure participant SA during a command and control task and suggest that the three approaches used view SA in a different manner.

Originality/Value – The research explores the measurement of SA during command and control activity and makes judgements on the suitability of each method for application in this context.

Take away message – Analogous to the different theoretical perspectives on SA presented in the literature, these findings suggest that the methods compared view and assess SA in a very different manner.

Keywords

Situation Awareness, Command and Control, SA measurement

INTRODUCTION

SA refers to the awareness that an individual has of a situation, an operator's dynamic understanding of 'what is going on' (Endsley, 1995a). Endsley (1995a) formally defines SA as, "The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley 1995a).

Endsley's three-level model of SA describes the construct as an internally held product comprising three hierarchical levels that is separate to the processes (termed situation assessment) used to achieve it.

The first step, level 1 SA, involves perceiving the status, attributes and dynamics of task-related elements in the surrounding environment (Endsley, 1995a). Level 2 SA involves the interpretation of level 1 data in a way that allows an individual to comprehend or understand its relevance in relation to their task and goals. The highest level of SA (level 3) involves prognosticating the future states of the system and elements in the environment. Using a combination of level 1 and 2 SA-related knowledge and experience in the form of mental models, individuals forecast likely future states in the situation.

Various techniques exist for measuring the construct but there has been great debate over the utility of the approaches available. The most popular approach is the Situation Awareness Global Assessment Technique (Endsley, 1995b), however, many researchers have expressed doubts over the validity of this approach, particularly when used to assess team SA (e.g. Salmon, Stanton, Walker & Green, 2006).

The purpose of this research was to examine the measurement of SA in a command and control environment in order to identify the most suitable approaches for measuring individual, distributed and team SA during command and control activity. Of interest to us in this research was not only the ability of the different methods to accurately and validly measure SA, but also the ways in which the different methods used view and represent SA and the extent to which they were measuring SA and not some other construct.

MEASURING SITUATION AWARENESS

A review of human factors methods identified over twenty different approaches designed specifically for the measurement of SA. Salmon, Stanton, Walker & Green (2006) subsequently identified the following categories of SA assessment methods: freeze probe recall techniques, real-time probe techniques, post trial subjective rating techniques, observer rating techniques, process indices, performance measures and team measures.

Despite the plethora of approaches available, many researchers argue that further investigation into the measurement of SA in complex systems is required, particularly apropos to team SA (e.g. Artman, 2000; Gorman, Cooke & Winner, 2006, Patrick, James, Ahmed & Halliday, 2006; Salmon et al, 2006; Siemieniuch & Sinclair, 2006).

Validity of SA Measurement Approaches

One particularly pertinent issue is the validity of the approaches used to measure SA. Endsley (1995b) reports that it is necessary to establish that the technique: 1) measures SA and not some other construct; 2) possesses sufficient sensitivity to allow it to detect changes in SA; and 3) does not impact SA in any way during the measurement procedure. Despite its importance, the validation of human factors methods is often assumed rather than tested.

In terms of validation study evidence, the SAGAT approach does have the most encouraging associated with it. Jones & Kaber (2005), for example, report that numerous studies have been conducted in order to assess the validity of SAGAT. They suggest that the subsequent evidence derived from these studies suggests that the method is a valid metric of SA.

One interesting facet related to the many different approaches available is how they view SA. Much debate has taken place within the literature over how best to describe the construct. Some researchers view it as a cognitive component of information processing (e.g. Endsley, 1995a), some take an ecological stance, viewing it as an externally directed component of working memory (e.g. Smith and Hancock, 1995) and some take a systems perspective, viewing it as an emergent property of collaborative systems (e.g. Stanton et al, 2006). Ostensibly the various measurement approaches also view the construct in different manners and it is therefore important that researchers wishing to investigate SA select approaches that are congruent with the way in which they and their research views the construct.

Despite the number of different measurement approaches available, there has been only limited research undertaken in order to compare them. Endsley, Sollenberger & Stein (2000) compared the sensitivity and validity of SAGAT, a real-time probe approach and SART when used to assess air traffic controller SA. Participant SA was measured when using a traditional ATC display and an enhanced ATC display. In conclusion, Endsley, Sollenberger & Stein (2000) report that SART and the on-line probes approach did not show a significant difference in SA between conditions, whereas the SAGAT scores where sensitive to display changes. In addition, there was no correlation between total SAGAT scores and performance, however, significant relationships between the individual SAGAT queries and performance were identified. Moderate correlations between the different SA measures were also identified. Level 1 SAGAT scores were correlated with the overall SART rating, the supply dimension rating and the Level 1 real time probe. However, level 2 and 3 SAGAT scored correlated negatively with the SART understanding and supply ratings.

Endsley, Selcon, Hardiman & Croft (1998) compared SAGAT and SART when used to assess fighter pilot SA. In this case no correlation between the SAGAT and SART measures was found. In conclusion, Endsley et al (1998) reported that “the subjective assessment of SA derived via SART does not appear to be related to the objective measure of SA provided by SAGAT (Endsley et al, 1998).

Jones & Endsley (2000) compared a real time probe measure, SAGAT, SART and the NASA TLX workload measure during air sovereignty team’s performance of a low and a high workload task in the North American Aerospace Defence Regional Sector Air Operations Centre simulator. In conclusion, Jones & Endsley reported that all three SA measures demonstrated sensitivity to the differences in the two scenarios undertaken by the teams and that there was a significant correlation only between the real time probe measure and the SAGAT measure. A relationship between the NASA TLX and SART measures was also identified.

THE STUDY

The study was undertaken using the Brunel command wall experiment test bed system. The Brunel command system comprises the Brunel command wall interface (located at the command centre) and wearable units (worn by agents in the field). The Brunel command wall is presented in Figure 1.

Figure 1. Brunel Command Wall System

The left hand side screen provides a 2D view of the battlespace, whilst the right hand side screen provides a Google Earth based 3D view of the battlespace. The 2D display screen has an overlay drawing function which allows the commander to draw situational overlays and colour code different areas/objects within the battlespace (e.g. red = enemy). The commander interacts with the command wall interface through standard mouse controller and keyboard devices. The command wall is linked directly to agents in the field via a wireless network and wearable technology units. Agents in the field are dynamically represented on the 2D and 3D map display.

The Brunel University campus (presented in Figure 2) provides a realistic and, therefore, ecologically valid urban battlespace landscape. The campus covers an approximately rectangular area of 50 hectares (WiFi coverage is 20 hectares), with an elevation of 7.5 metres and no significant gradient. The campus is laid out with 20 definable structures (mainly concrete) ranging in height from approximately 3 metres to 20 metres (1 story to 8 stories respectively). The land adjacent to and between the structures is covered with hard paving and grass. The total battlespace is bounded by a perimeter road on all boundary faces, beyond which is chain link fencing on the South and North boundaries, a public road on the West boundary and a small river on the East boundary.

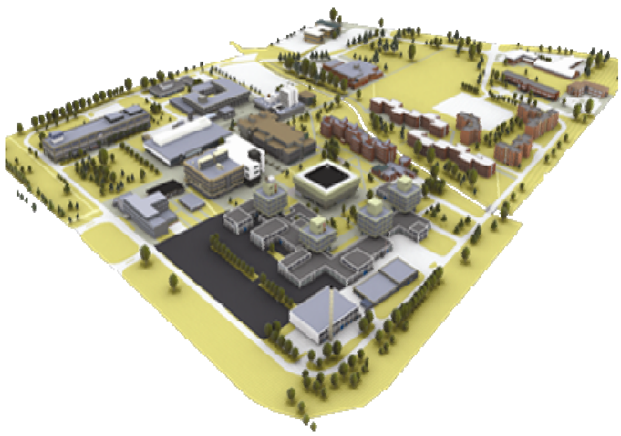

Figure 2. Brunel Campus Battlespace

THE COMBAT ESTIMATE

The experiment was based around question 1 of the Combat Estimate (CE) planning Technique. The CE is a military planning process that is currently used by the UK armed forces and employs the *Seven Questions* procedure, which offers a structured, step-by-step methodology designed to enable efficient and effective mission planning. This study focused only on question one of the CE, a brief description of which is given below.

Question One

Question one involves developing SA of the battlespace area and the enemy and threat. Question one comprises two initial phases, the *Battlefield Area Evaluation* (BAE) and the *threat evaluation* followed by a *threat integration* phase. The process involves defining the battlespace, describing the battlespace effects, evaluating the enemy and describing the enemy's course of action. The BAE phase involves an assessment of the battlespace on both friendly and enemy operations. The aim of the BAE is to analyse the terrain so that Mobility Corridors (MCs), Avenues of Approach (AAs) and Manoeuvre Areas (MAs), key terrain, choke points and restricted and severely restricted areas can be identified. The threat evaluation phase is used to identify the enemy's doctrinal norms. Once the BAE and threat evaluation phases are complete, threat integration is used to identify how the enemy are likely to operate during the battle.

The study involved participants, acting in the role of commander, conducting question one of the CE using the Brunel Command Wall system. Participant SA during the experiment was measured using three different approaches: SAGAT, SART and the Critical Decision Method (CDM; Klein & Armstrong, 2005) approach.

METHODOLOGY

Design

A between subjects design was used. The dependent variables were time taken to complete the task, participant SA, mental workload, and situational overlay accuracy.

Participants

A total of twenty participants (13 female and 7 male) were used during this study. The mean age of the participants was 30 years old. Participants were recruited via poster and email advertisement and comprised undergraduate students currently attending Brunel University.

Materials

The following materials were used during the study: The Brunel command wall system, including the experimental environment, three screen wall display containing 2D and 3D representations of the experimental environment, and a standard keyboard and mouse. A laptop containing a PowerPoint presentation was used to administer the SAGAT probes. SART, NASA TLX and CDM questionnaires were also administered post trial. Two stop watches were used, the first one to time the duration of the experiment and the second one to time the duration of responses to the SAGAT probes and other questionnaires. Pen and paper were provided to participants to make notes and also to complete the consent form. A demographic questionnaire was administered to participants, along with experimental instructions.

Procedure

After a short briefing, participants were given an instructions booklet and were taken through the experimental procedure in order to clarify what was required of them during the experiment. Participants then undertook a short trial which involved constructing a situational overlay using the command wall system and also answering a series of SAGAT probes. Next participants were asked to undertake the experiment for real. This involved them using the command wall system to construct a situational overlay based on the incoming intelligence provided by simulated field agents. SAGAT probes were administered at random points during the experiment. This involved the task being frozen, the command walls screens being blanked and the administration (via laptop computer) of SAGAT probes. The time taken to complete the entire experiment and respond to each SAGAT probe was recorded by the experimenter. Upon completion of the experimental trial, participants were asked to complete a NASA TLX workload questionnaire, a SART SA questionnaire and a CDM interview.

SA MEASURES

Three SA measures were compared during this study. SAGAT is a freeze probe technique that was developed to assess pilot SA based on the three levels of SA proposed in Endsley's (1995a) three-level model. Typically, a simulation of the task under analysis is randomly frozen and SA queries regarding the current situation at the time of the freeze are administered. During these 'freezes' all operator displays and windows are typically blanked. An SA score is then derived by comparing the query responses to the actual state of the situation at the time of the query.

SART is a subjective rating technique that was originally developed for the assessment of pilot SA. SART uses the following ten dimensions to measure operator SA: familiarity of the situation, focussing of attention, information quantity, information quality, instability of the situation, concentration of attention, complexity of the situation, variability of the situation, arousal, and spare mental capacity. SART is administered post-trial and involves the participant rating each dimension on a seven point rating scale (1 = Low, 7 = High) based on their performance of the task under analysis. The ratings are then combined in order to calculate a measure of participant SA.

The CDM interview technique uses a series of cognitive probes to elicit information about an individual's decision making during task performance. In order to represent SA, CDM interview data is used to construct propositional networks, which depict the knowledge elements related to task performance. Using a simple content analysis procedure, CDM data is analysed in order to identify the knowledge elements related to task performance. The knowledge elements are subsequently linked based on causal links that emerged during the task under analysis (e.g. enemy 'has' location, commander 'knows' plan etc) which results in a network of knowledge elements related to task performance. Thus, the knowledge comprising SA during task performance can be defined.

RESULTS

Situational Overlay Accuracy

The accuracy of participants situational overlay construction was calculated by comparing their completed situational overlay against a pre-defined 'expert' overlay for the same scenario, which reflected exactly the battle field area situation that was presented to the commander. In total there were 25 markers contained in the expert situational overlay. The percentage of correct markers added to the situational overlays by each participant is presented in Figure 3. The mean percentage score was 85.4% (SD = 0.09).

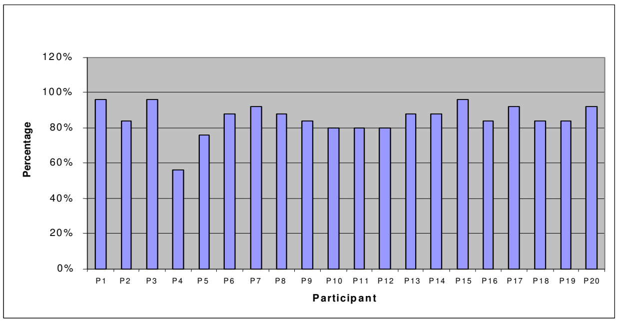

Figure 3. Participants correct response percentage for the situation overlay task.

SAGAT

Participant responses to the SAGAT probes were scored either as 1 (correct) or 0 (incorrect). Participant's total SAGAT scores were calculated by summing all correct responses which gave them a possible total score of 24. Participant total SAGAT scores are presented in Figure 4. The mean total SAGAT score was 11.35 (SD = 3.77).

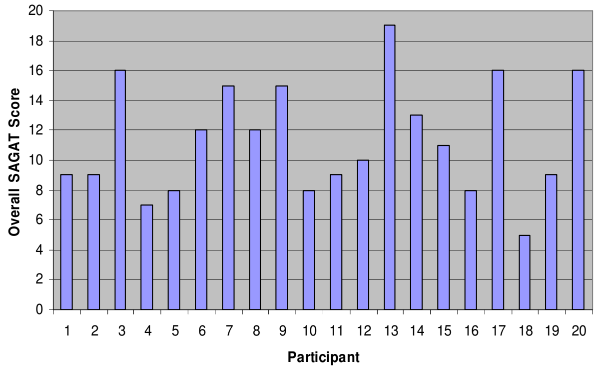

Figure 4. Participant total SAGAT scores

The SAGAT scores were also decomposed based on their corresponding SA level. The total SAGAT scores per SA level for each participant are presented in Figure 5.

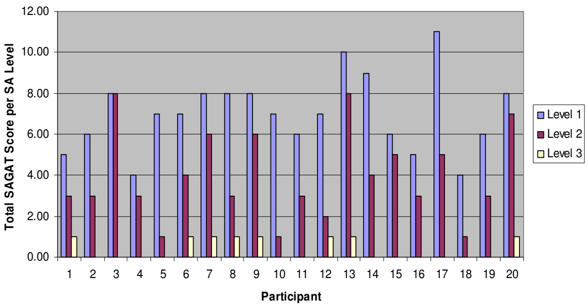

Figure 5. Total SAGAT scores per SA level

The mean overall participant SAGAT score for level 1 SA probes was 7 (SD = 1.87). The mean overall participant SAGAT score for level 2 SA probes was 3.95 (SD = 2.09). The mean overall participant SAGAT score for level 3 SA probes was 0.40 (SD = 0.49).

SART

An overall SART score was derived using the following formula: SA = U-(D-S), where:

U = summed understanding

D = summed demand

S = summed supply

The overall SART scores for each participant are presented in Figure 6. The mean overall SART score was 19.75 (SD = 5.7).

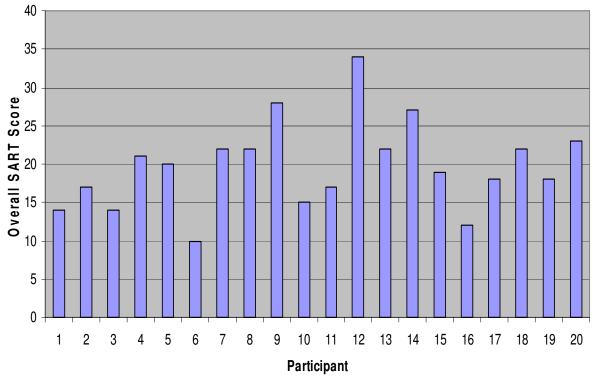

Figure 6. Overall SART scores

Participant scores for each SART dimension (Supply, Demand and Understanding) are presented in Figure 7. The mean score for Demand was 13.9 (SD = 3.95). The mean score for Supply was 20.15 (SD = 4.84) and the mean score for Understanding was 13.5 (SD = 3.03).

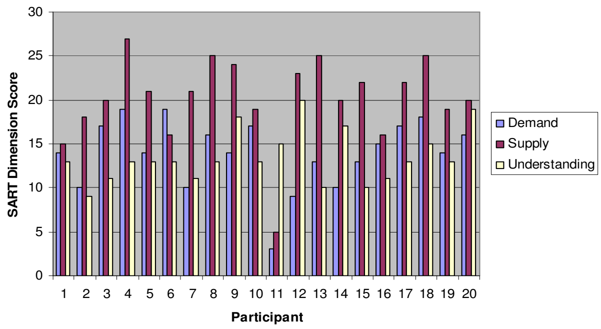

Figure 7. Participant SART dimension scores

Critical Decision Method

Participant responses to the CDM questionnaire were coded and used to construct propositional networks for each participant. These were then compared with an 'expert' propositional network for the scenario in order to assess their SA during the experiment. The signal detection paradigm was used to generate an SA score for each participant. The signal detection paradigm sorts the data into the following mutually exclusive categories:

1) Hit – A knowledge element reported by the participants in the post-trial questionnaire that was present in the expert propositional network.

2) Miss – The failure to report a knowledge element present in the expert propositional network in the post trial questionnaire.

3) False Alarm – A knowledge element reported by the participant that was not present within the expert propositional network.

4) Correct rejections – Correctly rejected knowledge element that was present in the total pool of false alarms made by the other participants.

These four categories were entered into the signal detection grid for each participant. The signal detection paradigm was then used to calculate a sensitivity index (SI) score for each participant. This returns a value of between 0 and 1, the closer that SI is to 1, the closer the participants SA responses to the expert propositional network were. The formula used to calculate SI is presented in Formula 1.

Formula 1. Sensitivity Index formula

$$Si = \left(\frac{\left(\frac{\text{Hit}}{\text{Hit + Miss}}\right) + 1 - \left(\frac{\text{False Alarm}}{\text{FA + Correct Rejection}}\right)}{2} \right)$$

Participant SI scores were converted into d'. Participant d' scores are presented in Figure 8.

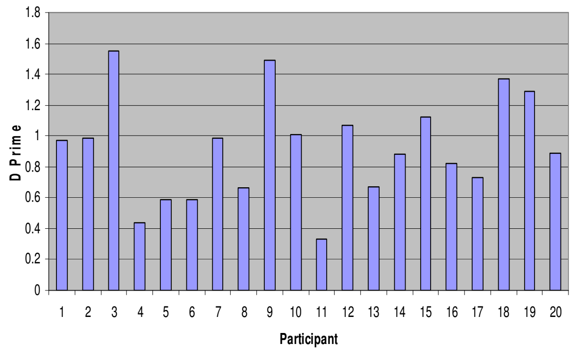

Figure 8. Participant d' Scores

Correlations

Spearmans Rho statistical tests were undertaken to identify significant correlations between the following variables:

1. Performance and SA (as measured by the three different approaches);
2. Performance and Workload (as measured by the NASA TLX);
3. Between the different SA measures (e.g. SAGAT versus SART, SAGAT versus Prop Nets and SART versus the Prop Nets) and between the different dimensions measured (e.g. SAGAT levels 1, 2 & 3 and SART understanding, SART demand and SART supply).

The statistical analysis findings are presented in Tables 1, 2, 3 and 4.

Performance and SA, Workload and Time

The correlation between participant overall SAGAT SA scores and performance was significant (.662, <0.01). There was also a significant correlation (.691, <0.01) between level 2 query SAGAT scores and performance. There were no significant correlations between the other SAGAT scores (levels 1 and 3), SART (Total, Understanding, Supply and Demand) and CDM d' scores and performance. There was a significant negative correlation between time and performance (-.474, <0.05) which suggests that the participants who took less time performed better in the overlay accuracy test. The correlation co-efficient and their corresponding significance levels are presented in Table 1.

Table 1. Correlation between Performance and SA, Workload and Time.

	SAGAT	SAGAT Level 1	SAGAT Level 2	SAGAT Level 3	SART	SART U	SART D	SART S	CDM	Workload	Time
Performance	.662 <0.01	.385 *Not Sig*	.691 <0.01	.297 *Not Sig*	-.120 *Not Sig*	-.120 *Not Sig*	-.120 *Not Sig*	-.120 *Not Sig*	.273 *Not Sig*	.330 *Not Sig*	-.474 <0.05

SA Measures

The analysis of the correlations between the different SA measures used is presented in Tables 2 (SAGAT and SART), 3 (SAGAT and CDM) and 4 (SART and CDM). There were no significant correlations between the participant SA scores provided by the three different SA measures.

Table 2. Correlations between SAGAT and SART measures

	SART	SART U	SART D	SART S
SAGAT	.274 *Not Sig*	-.044 *Not Sig*	-.152 *Not Sig*	.143 *Not Sig*
SAGAT Level 1	.375 *Not Sig*	-.230 *Not Sig*	-.124 *Not Sig*	.230 *Not Sig*
SAGAT Level 2	.123 *Not Sig*	-.230 *Not Sig*	-.052 *Not Sig*	.101 *Not Sig*
SAGAT Level 3	.356 *Not Sig*	.220 *Not Sig*	-.107 *Not Sig*	.160 *Not Sig*

Table 3. Correlations between SAGAT and CDM

	CDM
SAGAT	.095 *Not Sig*
SAGAT Level 1	-.023 *Not Sig*
SAGAT Level 2	.115 *Not Sig*
SAGAT Level 3	-.035 *Not Sig*

Table 4. Correlations between SART and CDM

	CDM
SART	.154 *Not Sig*
SART U	.009 *Not Sig*
SART D	-.045 *Not Sig*
SART S	.089 *Not Sig*

DISCUSSION

The purpose of this study was to compare three different approaches to measuring participant SA in a command and control environment. Of the three methods used, only the participant overall and level 2 SAGAT scores produced a significant correlation with performance. This indicates that the higher participant SAGAT overall and level 2 SAGAT scores were, the more accurate they were in the situation overlay construction task. It is concluded from this that the SAGAT approach was the most accurate at measuring participant SA during the study. Since the BAE task analysed involved constructing a situation overlay which represented the current situation on the battlefield, it was taken that levels of SA should correspond with levels of performance.

The study findings therefore offer encouraging support for the SAGAT tool when used to measure SA during a BAE task undertaken in a simulated environment. It is concluded that, when the task environment is relatively stable and the SA-related elements and associated states and properties can be accurately identified prior to task performance (as was the case with this study) it is appropriate to use a SAGAT type approach to measure participant SA.

There was no significant correlation between the participant SA scores provided by the three SA measures used. It is concluded from this that the different methods view the construct of SA differently and were essentially measuring different elements of the participant's awareness during the study. SAGAT, a probe recall approach, essentially measures the extent to which a participant is aware of a pre-defined element in the environment, their understanding of the properties of these elements in relation to the task they are performing, and also what the potential future states of these elements might be. SART provides a measure of how aware participant's perceived themselves to be during task performance (based on ratings of understanding, supply and demand) and makes no reference to the different elements within the environment. Finally, the CDM method presents a subjective description of goal-related decision making during task performance, from which knowledge elements are extracted. This presents a description of the participant's subjective view of the systems SA in terms of knowledge elements. Each method therefore takes a different view on what SA is and what it comprises and, as the lack of a correlation between the measures indicates, these findings suggest that the different methods are measuring different things when assessing participant SA.

The findings derived from this study can be compared to previous research that has compared SA measures. When using SAGAT and SART to assess fighter pilot SA, Endsley, Selcon, Hardiman & Croft (1998) found no correlation between SAGAT and SART scores (which was demonstrated in this study), whilst Endsley, Sollenberger & Stein (2000) reported that there was a significant correlation between Level 1 SAGAT scores and overall SART ratings. Endsley, Sollenberger & Stein also reported that there was no correlation between total SAGAT scores and performance, whereas in this study a significant correlation between overall and level 2 SAGAT scores and performance was identified. Further, Endsley, Sollenberger & Stein (2000) reported that there was a significant correlation between Level 1 SAGAT scores and overall SART ratings, the SART supply dimension ratings and the Level 1 real time probes. Jones & Endsley (2000) reported a significant correlation between SART and the NASA TLX workload ratings. This was not identified during this study.

Implications for SA measurement

The findings from this study (and from previous research) raise doubts over the validity of SART and CDM as measures of SA. Since SAGAT was correlated with performance, but SART and CDM was not correlated with either SAGAT or performance, questions are raised over the construct validity of SART and CDM. Further, the findings indicate that the three SA measures SAGAT, SART and CDM view the construct from differing perspectives and so measure the construct in different ways. It is therefore important that experimenters select SA measures that are congruent with the way in which they view the construct and also that their selection is driven by the characteristics of the task under analysis and the nature of the research question.

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REFERENCES

Artman, H., 2000, Team situation assessment and information distribution. Ergonomics, Vol 43, pp 1076 – 1095.

Endsley, M.R., 1995a, Towards a theory of situation awareness in dynamic systems, Human Factors, Vol. 37, pp. 32-64.

Endsley, M.R., 1995b, Measurement of situation awareness in dynamic systems, Human Factors, Vol. 37, pp. 65-84.

Endsley, M. R., Sollenberger, R., & Stein, E., 2000. Situation Awareness: A comparison of measures. In Proceedings of the Human Performance, Situation Awareness and Automation: User-Centred Design for the New Millenium. Savannah, GA.

Endsley, M.R., Selcon, S.J., Hardiman, T.D., & Croft, D.G., (1998). A comparative evaluation of SAGAT and SART for evaluations of situation awareness. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (pp 82-86). Santa Monica,CA: Human Factors and Ergonomics Society.

Gorman, J. C., Cooke, N., & Winner, J. L., 2006. Measuring team situation awareness in decentralised command and control environments. Ergonomics, Vol 49, pp 1312 – 1326.

Jones, D. G., & Endsley, M. R., 2000. Can real-time probes provide a valid measure of situation awareness? In Proceedings of the Human Performance, Situation Awareness and Automation: User-Centred Design for the New Millenium. Savannah, GA.

Jones, D.G., and Kaber, D.B., 2004. In N. Stanton, Hedge, Hendrick, K. Brookhuis, E. Salas (Eds.) Handbook of Human Factors and Ergonomics Methods. Boca Raton, USA, CRC Press.

Klein, G. & Armstrong, A. A., 2005. Critical decision method. In N. A. Stanton, A. Hedge, E. Salas, H. Hendrick, & K. Brookhaus, (Eds.), Handbook of Human Factors and Ergonomics Methods. Boca Raton, Florida, CRC Press, (pp. 35.1-35.8).

Patrick, J., James, N., Ahmed, A., and Halliday, P., 2006. Observational assessment of situation awareness, team differences and training implications. Ergonomics, Vol 49, pp 393 – 417.

Salmon, P., Stanton, N., Walker, G., & Green, D., 2006. Situation awareness measurement: A review of applicability for C4i environments. Journal of Applied Ergonomics, 37, 2, pp. 225-238.

Siemieniuch, C. E., & Sinclair, M. A., 2006. Systems Integration. Journal of Applied Ergonomics, 37, pp. 91-110.

Smith, K., & Hancock, P.A., 1995, Situation awareness is adaptive, externally directed consciousness, Human Factors, 37, pp. 137-148.

Stanton, N. A., Stewart, R., Harris, D., Houghton, R. J., Baber, C., McMaster, R., Salmon, P. M., Hoyle, G., Walker, G. H., Young, M. S., Linsell, M., Dymott, R., & Green, D., 2006, Distributed situation awareness in dynamic systems: theoretical development and application of an ergonomics methodology. Ergonomics, Vol 49, pp 1288 – 1311.

Taylor, R.M., 1990, Situational Awareness Rating Technique (SART): The development of a tool for aircrew systems design. In Situational Awareness in Aerospace Operations (AGARD-CP-478) pp3/1 –3/17, Neuilly Sur Seine, France: NATO-AGARD.