Constructible Assessment for Situation Awareness in a Distributed C2 Environment

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Outline

- Introduction
  - Background
  - Objectives of study
- Constraints of experiments in field exercises
- Constructible Assessment for SA (CASA)
  - Key features
  - Sample questions
  - Administration details
- Results and Discussion
- Future Work
Introduction

Background

- In 2003, an exercise was conducted by the Singapore Armed Forces to experiment with distributed but collaborative command and control processes
- Division-Level exercise with human participants in Brigade and Division-level command post; computer generated forces for fighting units
- One of the experimental conditions: Two command teams differed in physical proximity to HQ but otherwise have identical communication links and information systems
- Cognitive performance was among the variables being investigated
Introduction

Objectives of study

- To assess cognitive performance of command teams in the exercise
  - To attempt and evaluate various methodologies for cognitive assessment in the field
- To collect data on baseline cognitive performance of command teams

Cognitive performance assessment methods used

- Situation Awareness (SA)
  - Constructible Assessment For Situation Awareness (CASA)
  - Situation Awareness Rating Technique (SART)
- Workload
  - NASA-TLX
- Communication activity
  - Video/Audio recordings
Constraints of experiments in field exercises

- Intrusiveness of data collection to be minimized
- Exercise events take precedence over data collection
- Low degree of experimental control - possibility of unexpected event injects from Director of Exercise
- Logistics challenge
  - Large number of participants (56)
  - Long duration (24hrs)
  - Physical mobility of participants
Categories of SA Measurement

Performance measures
- Global performance measures
- Subtask performance
- Performance in response to introduced anomalies or events

Direct experimental techniques
- Retrospective measures (e.g. recollection)
- Concurrent measures (e.g. verbal protocols)
- Psycho-physiological measures
- Direct questioning / freeze technique

Subjective measures
- Direct self rating
- Comparative self rating
- Observer rating
Endsley’s SAGAT

- Direct (explicit) measure of SA that is well-validated and widely applied

- Based on three levels of SA (Endsley, 1991)
  - Level 1: Perception of elements in the environment
  - Level 2: Comprehension of the situation
  - Level 3: Projection of future status

- Randomised administration
  - Exercise or simulation will be frozen
  - Randomly-selected pre-determined questions based on SA requirements
  - Probes into knowledge of environment and events
  - SA is captured in real-time rather than post-hoc to reduce memory errors
Constraints of experiments in field exercises

- Intrusiveness of data collection to be minimized
  - Exercise freezes were not tolerated, administration times to be short (5 minutes)
  - Irrelevant questions from randomisation are a concern due to limited number of administrations over duration of exercise
- Exercise events take precedence over data collection
- Low degree of experimental control - possibility of unexpected event injects from Director of Exercise
- Logistics challenge
  - Large number of participants (56)
  - Nine key participants identified for objective SA assessment
  - Long duration (24hrs)
  - Physical mobility of participants
  - Paper-based administration
Workflow of CASA

Cognitive Task Analysis

Creation of question templates

Observation of Exercise

Selection of administration time

Selection/generation of relevant questions

Generation of questionnaires

Obtain answers from ground truth

Dissemination to subjects

Data collection and Analysis

Progressive buildup of database of CASA question templates
Examples of CASA questions

**Question Formats**

**Level 1 SA**
1. Mark the location of [red/blue] unit on map.
2. What is the current size force of [red/blue] unit? (e.g. “Coy+”)

**Level 2 SA**
1. What is the most critical additional asset that [blue] unit requires to carry out its mission?
2. Which hostile unit currently poses highest threat priority to this [blue] unit?

**Level 3 SA**
1. When is the earliest projected time for the securing of [location]?
2. Is [red] unit likely to be in contact with [blue] unit by [time]?

**Answer Formats**
- Only 1 correct answer per question
- Multiple choice questions
- Map-based
- Open-ended (constrained by context)
CASA Analysis

<table>
<thead>
<tr>
<th>Question</th>
<th>X’s answer</th>
<th>Y’s answer</th>
<th>Z’s answer</th>
<th>SA Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(a) ✓</td>
<td>(a) ✓</td>
<td>(c) ×</td>
<td>Individual X SA = 3 ÷ 5 = 60%</td>
</tr>
<tr>
<td>2</td>
<td>(b) ×</td>
<td>(b) ×</td>
<td>(c) ×</td>
<td>Group XY SA = 7 ÷ 10 = 70%</td>
</tr>
<tr>
<td>3</td>
<td>(a) ✓</td>
<td>(a) ✓</td>
<td>(a) ✓</td>
<td>Group XYZ SA = 9 ÷ 15 = 60%</td>
</tr>
<tr>
<td>4</td>
<td>(c) ×</td>
<td>(d) ✓</td>
<td>(d) ✓</td>
<td>Shared* XY SA = 4 ÷ 5 = 80%</td>
</tr>
<tr>
<td>5</td>
<td>(d) ✓</td>
<td>(d) ✓</td>
<td>(b) ×</td>
<td>Shared* YZ SA = 2 ÷ 5 = 40%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Shared* XYZ SA = 1 ÷ 5 = 20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Complementary SA of XYZ = 4 ÷ 5 = 80%</td>
</tr>
</tbody>
</table>

* In this illustration, wrong answers contribute to Shared SA if respondents answered similarly

Legend

1-(a) represents Question 1 being answered correctly with option (a)
2-(b) represents Question 2 being answered incorrectly with option (b)

Shared SA = Intersection
Complementary SA = Union
Applying CASA

Pre-exercise preparation

- Nine subjects identified
  - (Commander, Operations, Intelligence) x 3 teams
- Generation of CASA question templates
  - Interviews with 2 military Subject Matter Experts (SMEs)
  - Identified information requirements of Commanders, Operations and Intelligence officers to complete their tasks
  - Categorised requirements into three levels of SA
  - Translated information requirements into questions
Applying CASA

During the exercise

- Questionnaires were constructed 1-2 hours from the time it was decided to have an administration; jointly by DSO researchers and SMEs
- Disseminated to subjects within 5 minutes of time of administration
- Subjects completed questionnaires (10 or less questions) within 5 minutes
- Answers to queries (ground truth) were recorded at the appropriate times
- Questionnaires were graded against the answers
Breakdown of CASA questions administered

- Level 1 SA: 36%
- Level 2 SA: 9%
- Level 3 SA: 9%
- Decision Making type questions: 11%

Breakdown of questions:
- Location of [blue] unit (map): 36%
- Current mission / status of [blue] unit: 9%
- Location of [red] units: 8%
- Current size force of [red] unit: 4%
- Others (_LVL 1): 9%
- Others (_LVL 2): 2%
- Relationship between [red/civ] unit to [blue] unit: 11%
- Impact of [blue] mission on [blue] unit: 9%
- Projected time for [event] to happen: 2%
- Projected location of [blue] unit (map): 2%
- Erroneous questions: 4%
- Others (_LVL 3): 4%
Results

SA level of each individual, averaged across 5 assessments
Results

Possible explanation: Level 1 SA information elements are currently better represented or conveyed compared to Levels 2/3 SA information elements.

Need to enhance Level 2/3 SA representation and conveyance (e.g. visualization, symbology, decision support, etc)
Results

1. Intelligence SA > Operations SA
2. Level 1 SA > Level 2/3 SA

- Result consistent with the roles of intelligence and operations officers
- It has been suggested that Commanders’ Level 2/3 SA > Level 1 SA as they focus on the big picture. However this is not supported by the results
Results

Group SA by team

SA level of Team A > Team B, except for Administration 3.
Results

**Shared SA** measures how much information each member has in common with others.

**Complementary SA** is a measure of team SA assuming all members readily share information – may be a more appropriate measure in the military C2 context with assigned roles.

- Suggests that information was not shared as freely as may be desirable.
- Need to enhance both (co-located) physical communication and (distributed) electronic tools to support communication.
Issues

- Possible introduction of bias on the part of SMEs
  - With regards to:
    - (i) Selection of questions
    - (ii) Selection of administration times
  - Mitigated with multiple SMEs or third-party researchers

- Labour-intensive method
  - Constant monitoring of events
  - Generating and administering questionnaires in a short time frame
  - Electronic means (e.g. wireless devices) to replace paper administration

- Diagnostic capability – allows experimenters to select or generate SA questions to probe participants on specific issues
Reliability and Validity of CASA

- Reliability of CASA
  - Careful phrasing of question templates
  - Generation of actual questions from the question templates

- Validity of CASA
  - CASA results (objective measure) were compared with SART results (subjective measure) but they did not correspond
  - Possible Reason – Overestimation of own-self’s performance

- Possible Reason – Objective measures of SA measures a slice of an individual’s SA over time, whereas subjective measures of SA may be more inclusive base on an individual’s overall experience.
Future Work

- Develop new measures of SA comprising both objective and subjective components

- Correlate SA with measures of effectiveness (MOE) e.g. time taken to formulate plans or quality of decisions made

- Correlate SA with workload in command teams

- Further validation of CASA in other experiments and settings
Questions?