Comparison of Situation Awareness (SA) in Hierarchical and All-connected Network Structures

www.hfidtc.com

Human Factors Integration Defence Technology Centre
Content

- Theoretical Background
- Method
- Findings
- Conclusion
Theoretical background
Two opposing theories

Shared SA
- SA Definition: ‘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’
- Team SA is presented as Shared SA where individual team members share the same SA requirements
- Psychological tradition

Distributed SA
- SA Definition: ‘activated knowledge for a specific task, at a specific time within a system’
- The system ergonomics school consider SA as an emergent property arising from people’s interaction with the world
- Team SA is seen as distributed and view the system as a whole: ‘by considering the information held by the artefacts and people and the way in which they interact’
- Systems Ergonomics tradition
## Comparison of the two theories

<table>
<thead>
<tr>
<th>Comparison of two theoretical approaches to SA</th>
<th>Psychological tradition</th>
<th>Systems ergonomics tradition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanation of SA</td>
<td>Resides in the mind</td>
<td>Emerges from the interaction between individuals and the world</td>
</tr>
<tr>
<td>How is team SA explained?</td>
<td>Shared SA requirements</td>
<td>Compatible, distributed SA</td>
</tr>
<tr>
<td>How is individual SA explained?</td>
<td>Only individual is of interest</td>
<td>Ind. interesting as part of a system</td>
</tr>
<tr>
<td>What is the unit of analysis?</td>
<td>The individual, in terms of their cognitive abilities</td>
<td>The interaction between parts of the system and the activation of knowledge within it</td>
</tr>
<tr>
<td>How is SA assessed?</td>
<td>The individual; SAGAT and SART</td>
<td>The System; SNA and Propositional Networks</td>
</tr>
</tbody>
</table>
Method
Aims of study

The present work sought to highlight the differences of the two theoretical approaches by comparing SA whilst exploring organisational structure and performance of two different teams in an intelligence analysis task.

• explore which theory of SA, Shared or Distributed SA, which reveal the functioning of the networks in terms of SA.
• explore which measures reveal most SA in the two conditions
Sample of 34 postgraduate students;
  - 17 in Hierarchical
  - 17 in All-connected
Hypotheses

• Hypothesis 1: The measures derived from the psychological tradition of SA, SAGAT and SART will reveal differences between the two network structures.

• Hypothesis 2: The measures derived from the systems ergonomics tradition of SA, SNA and Propositional Networks will reveal differences between the two network structures.

• The independent variable is organisation type; Hierarchy and All-connected, while the dependent variable is SA.
Organisational structures

• Comparison of two network structures; traditional Hierarchy and All-connected (peer-to-peer).

Constraints on information

<table>
<thead>
<tr>
<th>Condition</th>
<th>Availability of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-connected</td>
<td>Who &amp; What &amp; When &amp; Where</td>
</tr>
<tr>
<td>Hierarchical</td>
<td>Who or What or When or Where</td>
</tr>
</tbody>
</table>
Distributed SA:
- Social Network Analysis tests of network diameter, density, centrality and sociometric status were performed
- Propositional Networks were created

Shared SA:
- Situation Awareness Global Assessment Technique (SAGAT), Situation Assessment Rating Technique (SART)
- SAGAT and SART were compared for difference in medians, Mann-Whitney U test of SAGAT and SART overall scores, test of Spearman’s correlation for SAGAT and SART.
- SAGAT: Spearman’s correlation coefficients calculated for level 1 – level 2, level 2 – level 3, and level 1 – level 3; Mann-Whitney U rank-sum test.

Distributed SA:
- Performance measures; correct identify, time to complete and sharing behaviours.
Findings
There was no statistically significant differences between Hierarchy and All-connected on the overall SAGAT scale (U = 0.559, P = N.S.).

- Participants in both conditions therefore reported the same level of objective SA.

Hierarchical SAGAT mean score = 12.12 (median = 12)
All-connected SAGAT mean score = 12.59 (median = 13)
AT – 3 level (absolute scores)

Level 1: The All-connected condition achieved a slightly higher score (7) than Hierarchy (6.5).
Level 2: The Hierarchy condition achieved a higher score than All-connected on level 2 SA (4.5 and 4 respectively).
Level 3: Both conditions achieved the same score.
GAT - three levels of SA

SAGAT by the three SA levels, Hierarchical condition

SAGAT by the three SA levels, All-connected condition
SART scores
  – Hierarchical median = 4
  – All-connected median = 5

No statistically significant differences was found on the Mann-Whitney rank sum test for the overall SART scale \((U = 0.786, P = \text{N.S.})\).
  – Participants therefore report the same level of subjective SA in both conditions.
Spread of SART scores

Network Structure
- Hierarchical
- All-Connected
The two measures were compared using the Mann–Whitney two-sample rank-sum test. There was no statistically significant differences between the overall SAGAT (U = 120, P = N.S.) and SART (U = 129, P = N.S.) scores.

- Hence no difference was found between the two measures for either condition.

SAGAT’s three SA levels and SART’s three dimensions was subjected to Spearman’s test of correlation.

- No statistically significant correlation was found between any of the three SAGAT levels and the SART dimensions (P = N.S.).
Propositional Networks

The Propositional Network represents a systems level depiction of SA contained within the network structure.

– Therefore reflects Distributed SA
Hierarchical condition
connected condition
Both Propositional Networks contain many of the same conceptual elements, however, there are a number of concepts that are exclusive to one network structure.

For instance, “receive” exists only in the Hierarchical condition’s network structure, while “process” is unique to the All-connected network.

– This tells us that the way in which the two networks operated/collaborated to perform the task was different (Hierarchical team waited to receive information while All-connected team focused on the process of gathering information).

The relationship between the concepts in any of the Propositional Networks are also qualitatively different

– the information available to a system, and the way in which it is utilised within the team, differ for the two conditions.
Applying SNA to the pattern of communication enables a quantitative probe of the qualitative findings. The All-connected network is denser than the Hierarchical network.

- also reflected in the larger number of edges found in the All-connected network despite the smaller number of nodes found in this network compared to the Hierarchy network.

In both conditions ‘Information’ is the node with highest sociometric status

- the higher mean for Sociometric status for the All-connected indicates that ‘Information’ has greater connectivity in this condition.

<table>
<thead>
<tr>
<th>SNA statistics for Hierarchy Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
</tr>
<tr>
<td>Number of nodes</td>
</tr>
<tr>
<td>Number of edges</td>
</tr>
<tr>
<td>Density</td>
</tr>
<tr>
<td>Centrality (mean)</td>
</tr>
<tr>
<td>Sociometric status (mean)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SNA statistics for All-connected Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
</tr>
<tr>
<td>Number of nodes</td>
</tr>
<tr>
<td>Number of edges</td>
</tr>
<tr>
<td>Density</td>
</tr>
<tr>
<td>Centrality (mean)</td>
</tr>
<tr>
<td>Sociometric status (mean)</td>
</tr>
</tbody>
</table>
Performance measures

Correct identify

- Commander in the Hierarchy network structure identified the task solution correctly, while three individual team members identified correctly in the All-connected network structure.
- Both network structures therefore successfully completes their task.

Time

The All-connected condition achieved task completion 2 min 28 sec faster than the Hierarchy condition; contrary to expectations.
Sharing behaviours
Share: There were greater instances of sharing in the Hierarchy condition (326) than in the All-connected condition (119).
Posts: There was greater number of posts in the Hierarchy condition (154) than in the All-connected condition (131).
Pull: There were greater instances of pull, i.e. extracting information, in the All-connected condition (747) than in the Hierarchy condition (167).

The difference in pull may be due to greater clarity in allocation of decision rights in the Hierarchy network than in the All-connected network.
The significantly higher instances of pull in the All-connected condition may be due to each individual having to take responsibility for solving the problem and as efforts are duplicated.
The findings from SAGAT and SART did not reveal any statistically significant differences between the Hierarchical and All-connected conditions. No support was therefore found for hypothesis 1. The findings from the SNA and Propositional Networks lend support to Hypothesis 2:

- SNA and Propositional Networks were found to reveal differences between the two network structures.

The performance measures support the DSA findings, highlighting that there is indeed a difference between the two conditions.

- The network structures enforce a difference in the way in which information is gathered, distributed and utilised within the structures.
This study sought to contribute to the ongoing debate about appropriate measures to assess team SA.

– By contrasting two approaches to SA the discrepancy between them has been highlighted and;

– in applying quantitative and qualitative measures which have been developed within these approaches this incongruity is further emphasised.
Thank you.