Designing for Self Organisation in Complex Sociotechnical Systems through Extensions of Cognitive Work Analysis

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Key Points

- Adaptation and self organisation in social systems
- Existing frameworks or paradigms
- Extensions to cognitive work analysis (CWA)
- Case study
Complex Sociotechnical Systems
Designing for Adaptation

- Fundamental design goal is to support adaptation (Rasmussen, 1986; Rasmussen, Pejtersen, & Goodstein, 1994; Vicente, 1999)

- Unanticipated events
  (e.g., Leveson, 1995; Perrow, 1984; Rasmussen, 1968, 1969; Reason, 1990; Vicente, 1999)
Nature of Adaptation

- Behavioural adaptation i.e., adjustment of tasks, plans, goals, actions, or priorities

- e.g., Emergency management (Bigley & Roberts, 2001)
Nature of Adaptation

- Structural adaptation i.e., multiple actors adjusting form or organisation

- e.g., Naval operations (Rochlin et al., 1987)
  - Shifts: between formal and informal structures
  - Flexible: no pre-specified plan
  - Emergent: no single informal organisation
Self Organisation in Social Systems

Structure

enacts or constructs

Behaviour

constrains or enables

(e.g., Fuchs, 2004)
Properties of Self Organising Systems

- **Distributed:**
  - Work demands distributed across multiple actors

- **Emergent:**
  - Not planned a priori

- **Nonspecific:**
  - External factors do not impose structural changes

(e.g., Haken, 1988)
Existing Frameworks

- Cognitive systems engineering
- Safety science
- Human factors
- Organisational psychology
- Management science
Descriptive Methods

- Safety science
- Human factors
- Organisational psychology
- Management science
Cognitive Work Analysis (CWA)

Formative

<table>
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<tr>
<th>CWA Dimensions</th>
<th>Constraints</th>
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Constraints
Value of CWA for Design

- Experimental studies on ecological interface design (Vicente, 2002)

- Industrial case studies e.g., team design, training-system design (Naikar, 2013)
Limitations of CWA for Design

Naikar and Elix (2015, 2016)
Analysis of Work Organisation

- Standard CWA (Rasmussen et al., 1994; Vicente, 1999)
- Descriptive, not formative:
  - Recurring situations
  - Common
  - Reasonable
- Does not account for the organisational structures that are possible regardless of the situation
Implications for Self Organising Systems

Structure

enacts or constructs

Behaviour

constrains or enables

Constraints
Designing for Self Organisation

- Interface design
  - Actor A: Work Demand 1, Work Demand 2, Work Demand 5
  - Actor B: Work Demand 2, Work Demand 3, Work Demand 4, Work Demand 5
  - Actor C: Work Demand 1, Work Demand 2, Work Demand 4, Work Demand 5

- Team design
  - Work Demand 1
  - Work Demand 2
  - Work Demand 5

- Training design

- Automation design
Analysis

Demarcate the set of possibilities for work organisation irrespective of the situation

Constraints on the possibilities i.e., limits placed on the distribution of work demands by the work organisation criteria
Work Organisation Criteria

- Compliance
- Safety and reliability
- Access to information/controls
- Coordination
- Competency
- Workload
Compliance

Arming of weapons
Safety and Reliability

Piloting
Access to information and controls

Sighting of targets
Access to information and controls

Detecting, tracking, and identifying targets
Coordination

Detecting, tracking, and identifying targets
Competencies and Workload

Detecting, tracking, and identifying targets
Diagram of Work Organisation Possibilities

Flight Deck Actors
- Aircraft safety
- Weapons authorisation
- Fly the aircraft
- Flight management
- Navigation
- ATC communications
- Observations
- Control power supply
- Environment control
- Self protection (EWSP)
- Weapons and stores release
- Stores management
- Fault management
- Data management
- Mission planning
- Detect, track, and identify targets
- Tactical communications

Observer Station Actors
- Observations
- Tactical communications
- Navigation
- Fault management
- Data management
- Mission planning

Workstation Actors
- Tactically employ the aircraft
- Weapons authorisation
- Weapons release
- Stores release
- Tactical communications
- Navigation
- Sensor management
- Detect, track, and identify targets
- Position the aircraft
- Navigation
- Stores management
- Fault management
- Data management
- Mission planning
Diagram of Work Organisation Possibilities

Actor A
- Work Demand 1
- Work Demand 2
- Work Demand 5

Actor B
- Work Demand 2
- Work Demand 3
- Work Demand 4
- Work Demand 5

Actor C
- Work Demand 1
- Work Demand 2
- Work Demand 4
- Work Demand 5
Can Be, not Will Be

Actor A
- Work Demand 1
- Work Demand 2
- Work Demand 5

Actor B
- Work Demand 2
- Work Demand 3
- Work Demand 4
- Work Demand 5

Actor C
- Work Demand 1
- Work Demand 2
- Work Demand 4
- Work Demand 5
Constraints versus Possibilities

Constraints

Actor A
- Work Demand 1
- Work Demand 2
- Work Demand 5

Actor B
- Work Demand 2
- Work Demand 3
- Work Demand 4
- Work Demand 5

Actor C
- Work Demand 1
- Work Demand 2
- Work Demand 4
- Work Demand 5

Possibilities

Actor A
Actor C
Actors A and C
Computable, but Unnecessary

Constraints

Actor A
- Work Demand 1
- Work Demand 2
- Work Demand 5

Actor B
- Work Demand 2
- Work Demand 3
- Work Demand 4
- Work Demand 5

Actor C
- Work Demand 1
- Work Demand 2
- Work Demand 4
- Work Demand 5

Possibilities

Actor A
Actor B
Actors A and B
Design

Design of each element should support the set of work organisation possibilities
Case Study (Elix & Naikar, 2016)

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UAS
Analysis: Work Organisation Possibilities for UAS

**Observers**
- Tactical Communications
- Navigation
- Fault Management
- Data Management
- Mission Planning

**Flight Crew**
- Position the Manned Aircraft
- UAV Release
- Detect and Localise Targets
- Tactical Communications
- Navigation
- Stores Management
- Fault Management
- Data Management
- Mission Planning

**Senior Tactical Commander**
- Tactically Employ the Manned Aircraft
- UAV Release
- Operate the UAV
- Detect and Localise Targets
- Tactical Communications
- Navigation
- Stores Management
- Fault Management
- Data Management
- Mission Planning

**Junior Tactical Commander**
- Position the Manned Aircraft
- UAV Release
- Detect and Localise Targets
- Tactical Communications
- Navigation
- Fault Management
- Data Management
- Mission Planning

**Dry Sensor Operators**
- Operate the UAV
- Detect and Localise Targets
- Tactical Communications
- Navigation
- Fault Management
- Data Management
- Mission Planning

**Wet Sensor Operators**
- UAV Release
- Operate the UAV
- Detect and Localise Targets
- Tactical Communications
- Navigation
- Fault Management
- Data Management
- Mission Planning

**Flight Crew**
- Tactical Communications
- Navigation
- Stores Management
- Fault Management
- Data Management
- Mission Planning

**Observers**
- Tactical Communications
- Navigation
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**Junior Tactical Commander**
- Tactical Communications
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**Observers**
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**Junior Tactical Commander**
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Design: Work Organisation Possibilities for UAS

Interface design

Team design

Automation design

Training design

Work Demands
Example of Design Solution

**Observers**
- Tactical Communications
- Navigation
- Fault Management
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- Mission Planning

**Flight Crew**
- Position the Manned Aircraft
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Example of Design Solution

**Observers**
- Tactical Communications
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**Dry Sensor Operators**
- Operate the UAV
- Detect and Localise Targets
- Tactical Communications
- Navigation
- Fault Management
- Data Management
- Mission Planning

**Wet Sensor Operators**
- Operational Readiness
- Set up Resolution
- Deploy Resolution
- Detect and Localise Targets
- Tactical Communications
- Navigation
- Fault Management
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- Mission Planning

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Example of Design Solution

- Observers
  - Tactical Communications
  - Navigation
  - Fault Management
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  - Mission Planning

- Flight Crew
  - Position the Manned Aircraft
  - UAV Release
  - Detect and Localise Targets

- Senior Tactical Commander
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**Flight Crew**
- Position the Manned Aircraft
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<th>Phases</th>
<th>Senior Tactical Commander</th>
<th>Junior Tactical Commander</th>
<th>Wet Sensor Operators</th>
<th>Dry Sensor Operators</th>
</tr>
</thead>
</table>
| Launch | • Competent and authorised to release the UTAS  
• Best suited to formulate the release point  
• High workload | • Competent to release the UTAS and can be given the authorisation to do so | • Before MAD has detected the target, the risk of the track being lost on acoustics is unacceptable | • Would need to coordinate with the TACCO or COTAC to release a store |
| Control | • Must have a big picture perspective of the mission  
• High workload | • Coordination may be minimised if the same crew member is responsible for launch and control | • The reliance on acoustics tracking the target may reduce when MAD is also tracking the target  
• Tracking the target with acoustics and MAD are interrelated  
• The risk of the track being lost (on acoustics) may still be unacceptable | • Competent to operate sensors and best placed to achieve collision avoidance |
| Recovery | • If the UTAS is not being replaced, coordination may be minimised if the same crew member is responsible for launch, control, and recovery  
• If the UTAS is being replaced, workload could be reduced if the same crew member is not responsible for launch and recovery. | | • Best placed to achieve collision avoidance |
Value of Approach

- **Impact:**
  - Design solution accepted by Royal Australian Air Force

- **Uniqueness:**
  - Design solution promotes greater capacity for self organisation compared with likely design solutions obtained with other techniques

- **Feasibility:**
  - Design solution achieved within time, staff, and financial constraints
Conclusion

- Extensions:
  - Of CWA to promote self organisation
  - Of design approaches to accommodate organisational constraints

- Future work:
  - Design processes for respecting organisational constraints
  - Empirical validation
Resources

Website:

Key Paper:

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