Evaluating Impacts of System Integration on Joint Fires Operations

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Coalition Attack Guidance Experiment (CAGE)

- CAGE: series of multinational joint warfare human-in-the-loop experiments
- Develop new concepts of operations for joint fires
  - Explore new tools & processes to assist coalition joint operations at brigade & divisional HQ levels
- CAGE3A was Australia led:
  - Between 28 Oct – 8 Nov 2013
  - In situ military participation from Australia, Canada & UK
- AUS focused on improving:
  1. Tactical Air Picture
  2. Joint C2 Fires Messaging
  3. Digital Targeting
- Hypothesis testing mandated
  - 1 experiment to test 9 hypotheses
- CAGE3A, Canada & UK had own experimental objectives
- CAGE experiment run annually
  - CAGE2 in 2012: AUS, CAN & USA
A Complex System of Systems in CAGE3A

Australia

- **ASC:** All Source Cell ~ 10 pers
- **SACC:** Supporting Arms Coordination Centre ~ 20 persons
- **JFECC:** Joint Fires Effect Coordination Centre ~ 20 persons
- **Gallipoli Barracks, Enoggera**

Canada

- **TOC:** Tactical Ops Centre
- **ASIC:** All Source Intel Cell

UK

- **UAS:** Unmanned Aerial System

**Australia**

- 3
Benefits from CAGE

Return for the Military:

- Understand benefits & constraints of CSS
- Opportunity to influence future TTPs & systems
- Experience in new roles
  - In SACC, JFECC & ASC
- Interact with Coalition
  - Canada, UK (US in CAGE2)
  - Activities: request for CFF, UAV & logistics support

Reward for DSTO:

- Extensive client engagement
- Running human-in-the-loop experiments
  - Live, constructive, virtual
- Collect firsthand data
- Invaluable learn experience
- Engage coalition analysts
  - Technical experts in CSS
  - Human factors scientists
- Develop expertise to design & run experiments
CAGE3A Experimental Design

- Single group (mostly) repeated measures design
  - Same group employed *As-Is* and *To-Be* C2 sociotechnical system
  - Same scenario was run in both weeks to trigger participant activity

- A sequential experimental design
  - A counterbalanced design or week reversal was discarded due to perceived system complexity

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- Potential problems with CAGE3A experimental design
  - Can’t discount possibility that order effects cause performance improvements in 2\textsuperscript{nd} week (from learning or memory effects)
Objective 1: Improving Tactical Air Picture (TAP)

- **Hypothesis**: A digital TAP comprising of UAV and army aviation positional information improves ability to manage and control airspace.

- **As-Is**: limited UAV positional info was augmented into TAP for coordinating and controlling battlefield airspace.

- **To-Be**: UAV positional info was supplied via 2 separate systems due to system constraints, resulting in a partial air picture being presented on each.
Objective 1: Improving Tactical Air Picture (TAP)

- Seek to understand whether additional UAV positional info in TAP improves ability to manage and control airspace.
- **Qualitative measures**: evaluations from targeted participants and SMEs in both SACC & JFECC.
- **Quantitative measure**: time taken for ‘clear air calls’.
Objective 1: Did Ability to Manage and Control the Airspace Improve?

- Qualitative results revealed statistical significance between As-Is and To-Be weeks.
- There was little agreements
  - Between SMEs
  - Between SMEs and participants
Objective 1: SME Evaluation of Tactical Air Picture Usefulness

Usefulness of the TAP in Managing & Controlling Airspace

- SACC SME
- JFECC SME

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As-Is

To-Be
Objective 1: Improving Tactical Air Picture

- **Hypothesis:** A digital TAP comprising of UAV and army aviation positional information improves ability to manage and control airspace.

- **Outcome**
  - Not possible to attribute various improvements in SA, task performance or decision quality to improvement in TAP.
  - Supported by quantitative analysis of average times to clear air (no statistically significant improvement in SACC or JFECC).
  - Unable to reject null hypothesis.
Objective 2: Improving Joint C2 Fires Messaging

- Seek to understand whether C2 processes improve as a result of additional recognised land picture (RLP) information.

**Hypotheses**

- **Coalition**: Using To-Be system improves coalition C2 fires messaging in a Joint environment
- **Australian Only**: Using To-Be system improves Australian C2 fires messaging in a Joint environment

**As-Is**: Operators are required to request for clear ground from responsible C2 node through Chat or VOIP.

**To-Be**: 

- JF ECC has visibility of coalition RLP.
- JF ECC has visibility of RLP showing SACC controlled ground units.
- SACC has visibility of RLP showing JF ECC controlled ground units.
Objective 2: Did Procedures Change for C2 Fires Messaging?

- Participants made no changes to existing TTPs despite given additional SA over other AOs through RLP.

- Strong evidence to support null hypothesis for Objective 2.

- Valid reasons to commit to existing doctrine include:
  - Lack of blue force tracker across all units in coalition
  - Positional info reported on CSSs may be inaccurate
  - Coalition forces might use different ROEs
  - Responsibility for engagement into another AO belongs to C2 node in charge
Objective 2: Were There Improvements in To-Be Week?

- Evidence suggests that more SA from RLP did not improve C2 fires messaging.
- Possible improvements due to learning or memory effects resulting from identical scenarios (single group experimental design).
Objective 2: Improving Joint C2 Fires Messaging

- Qualitative Assessment
  - Measures: SA Rating, RLP Usefulness, RLP Timeliness, RLP Intuitiveness, Decision Confidence
  - Multivariate analysis of session-based survey results
    - JFECC participants show significant difference across weeks ($p = 0.042$)
    - SACC participants show no significant difference across weeks ($p > 0.05$)

- Quantitative Assessment
  - Timing for clearing ground for each mission
    - Avg times appeared similar across weeks
    - Greater delay in To-Be week after zero duration removed
    - Adversely influenced by unreliable CSSs and loss of trust
Objective 3: Digital Targeting

- Involve using digital C2 systems, roles and processes associated with identification, development and prosecution of targets.

- Targets could be prosecuted
  - within seconds or minutes, or
  - require complex development, gathering of information and careful prosecution over hours or days
Objective 3: Digital Targeting

- **Hypothesis**: An integrated set of digital tools will lead to improved situation awareness and understanding for target development and prosecution

- Participants’ feedback
  - Unreliable technical systems as most serious problem
Objective 3: Assessment of Situation Awareness

- Self-rating responses from participants
- 3-D version of SA Rating Technique (SART)
  - Quick and easy self-rating assessment
  - Three dimensions on a 7-point rating scale (1 = Low, 7 = High)
    - Demand on attentional resources
    - Supply of attentional resources
    - Understanding of the situation
Objective 3: Mean Dimensions of SA for Each Type of Architecture
Objective 3: Summary of p-values from MANOVA results

- No significant difference over architectures on SACC, JFECC, or JFECC JOR.
- Significant effects of architectures on SACC JOR

![Table of p-values for situation awareness metrics](image-url)

* Indicates a statistically reliable effect at a significance level of $p < .05$

** Indicates a statistically reliable effect at a significance level of $p < .01$

Green & red cells: statistically significant improvement & degradation, respectively
Conclusion

- CAGE3A provides useful coalition joint fire experience
  - Users gained exposure to new systems and processes
  - Validate whether doctrine is an accurate representation of practice

- CAGE3A is an excellent opportunity for scientists
  - Collect invaluable data from warfighters and SMEs
  - Understand operators’ needs
  - Specify technical requirements to support warfighters
  - Examine C2 issues and TTPs not available in traditional exercises
Lessons Learnt from CAGE3A

- Mitigate confounding factors
  - Order effects, system failures, controlled variables

- More than system integration
  - Consider human element and processes to ensure effective socio-technical system

- Develop meaningful hypotheses
  - Identify real and important problems faced by operators

- Employ modelling and simulation
  - Identify suitable problems to investigate as a precursor to controlled experiments

- Test systems rigorously before an experiment
  - System unreliability and failure is a serious threat to experimental integrity