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Utility of Visual and Auditory Warning Alerting for Traffic Avoidance During UAS Operations

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This presentation covers the results of a human-in-the-loop simulation that examined the effect of caution versus warning-level alerting in the context of Unmanned Aircraft System (UAS) operations in civil airspace. Minimum Operational Performance Standards (MOPS) are currently being developed by RTCA Special Committee 228 for UAS Detect-and-Avoid (DAA) systems. Input from subject matter experts and multiple research studies have informed display requirements for DAA systems aimed at supporting timely and appropriate pilot responses to collision hazards. DAA alerting is designed to inform pilots of potential threats to DAA "well clear"; the two highest alert levels – caution and warning – indicate how soon pilot action is required and whether there is adequate time to coordinate with the air traffic controller (ATC). Additional empirical support is needed to clarify the extent to which warning-level alerting impacts DAA task performance. The present study explores the differential effects of the auditory and visual cues provided by the DAA Warning alert, and performance implications compared to caution-only alerting are discussed.

Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

Utility of Visual and Auditory Warning Alerting for Traffic Avoidance During UAS Operations

Presented to HFES 2018:

PP1 Visual Perception and Safety: Perception and Performance

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3 October, 2018

UAS INTEGRATION IN THE NAS

Background

- RTCA Special Committee 228 is developing the minimum operational performance standards (MOPS) for Unmanned Aircraft System (UAS) Detect and Avoid (DAA) systems operating in civil airspace

- Phase 1 of the UAS DAA MOPS prescribed minimum **alerting** and **guidance** requirements to aid pilots in avoiding a loss of DAA well clear (LoDWC)
  - CFR14 Part 91 requires pilots in civil airspace to proactively maintain 'well clear' so as to avoid potential collision hazards
  - A 'detect and avoid' can help compensate for pilots' removal from aircraft

- Both caution and warning-level DAA alerts were included as part of the MOPS alerting structure
  - Corrective DAA Alert: caution-level; immediate **awareness** is required
    - Pilot expected to coordinate response with ATC *then* maneuver
  - Warning DAA Alert: warning-level; immediate **maneuver** is required
    - Pilot expected to maneuver immediately and *then* contact ATC

***Consistent FAA Advisory Circular 25.1322-1**

Background

- SC228 members demonstrated frequent hesitation to included a warning-level alert within the DAA alerting structure
  - Theses members preferred to retain the warning alert for Collision Avoidance (as opposed to DAA)

- No studies directly assessed the utility of the warning-level DAA alert
  - It was shown to be effective in human-in-the-loop simulations where it was included but was not *systematically studied*

- Experiment Objective: specifically measure the impact of the DAA warning alert on pilots' performance
  - Evaluate whether the DAA Warning symbol and/or aural improves pilots' ability to remain well clear
    - Systematically vary the timing of the alert to see if *when* an intruder registers as an alert impacts effectiveness of alert type
  - Measure performance as response times and ability to maintain DAA well clear (DWC)

Experimental Design

- Independent Variable:
  - DAA Warning alert option (Between-Subjects)
    - D1: No DAA Warning Alert (Corrective/Caution Alerting Only)
    - D2: DAA Warning Aural Only (Retain Corrective DAA symbol)
    - D3: DAA Warning Alert (Aural + Symbol)

- Embedded Variable
  - Use Cases: varied by how close to a loss of DAA well clear (LoDWC) the intruder was when it first appeared
    - A: 15sec
    - B: 25sec

    Intruder appeared first as Warning-level alert

    Warning Alert Transition

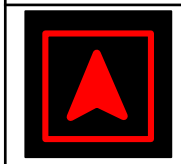
    - C: 35sec
    - D: 45sec
    - E: 55sec

    Intruder appeared first as Corrective/Caution-level alert

Alerting Logic

D1: Caution Only		
Symbol	Name	Aural Alert Verbiage
N/A	N/A	N/A
	Corrective DAA Caution Alert	“Traffic, Avoid”
	*Preventive DAA Alert	“Traffic, Monitor”
	Guidance Traffic	N/A
	None (Target)	N/A

D2: Warning Aural		
Symbol	Name	Aural Alert Verbiage
	DAA ‘Maneuver’ Alert	“Traffic, Maneuver Now” x2
	Corrective DAA Caution Alert	“Traffic, Avoid”
	*Preventive DAA Alert	“Traffic, Monitor”
	Guidance Traffic	N/A
	None (Target)	N/A

D3: Warning Aural + Symbol		
Symbol	Name	Aural Alert Verbiage
	DAA Warning Alert	“Traffic, Maneuver Now” x2
	Corrective DAA Caution Alert	“Traffic, Avoid”
	*Preventive DAA Alert	“Traffic, Monitor”
	Guidance Traffic	N/A
	None (Target)	N/A

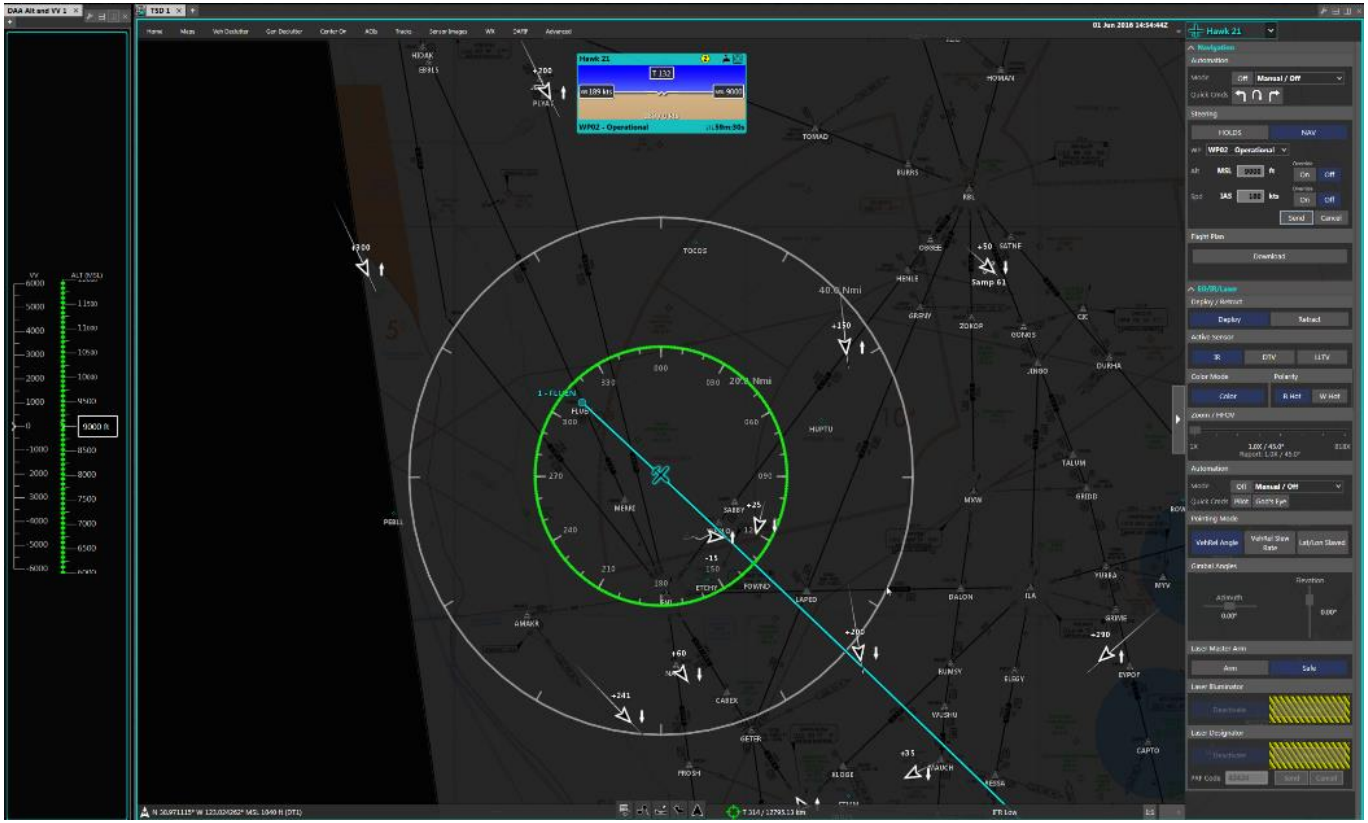
**Applied to cooperative intruders only*

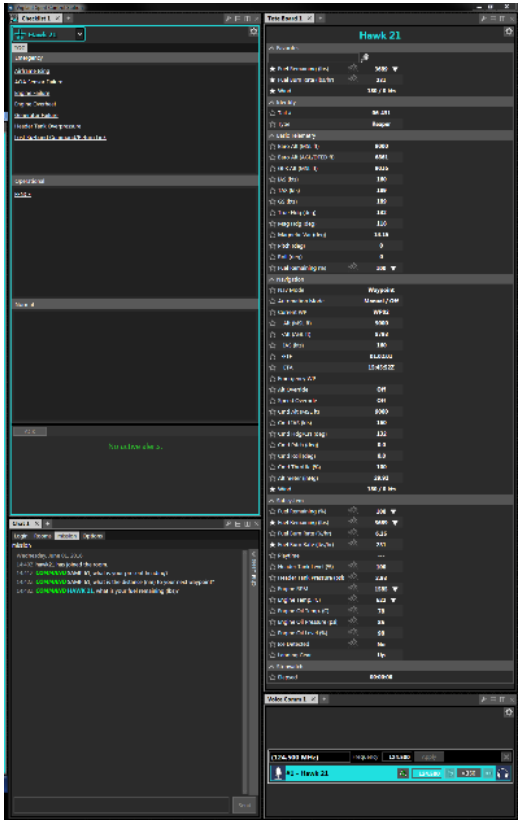
Test Setup

- 15 participants
  - 5 per alerting condition
  - Background = ‘manned’ aviation pilots

- DAA Pilot Task
  - Fly simulated MQ-9 Reaper along mission route (ZOA 40/41)
    - Remain Well Clear from intruder aircraft
      - Minimal deviation from mission route/altitude
    - Coordinate with ATC (when necessary)
      - Prioritize maneuver over contacting ATC after the onset of a DAA Warning alert
      - Researcher acting as surrogate ATC from sim manager room
  - Attend to secondary tasks
    - Chat messages requesting status information

AFRL's Vigilant Spirit Control Station (VSCS)





Tactical Situation Display

- Traffic Alerting & Guidance
- Range Rings
- Mission Route
- Navigation information and controls

Side Panel

- Electronic Checklist
- Status panel
- Chat client

Hypotheses

- Research Question
  - What are the differential effects of the DAA Warning symbology and aural on pilot performance?

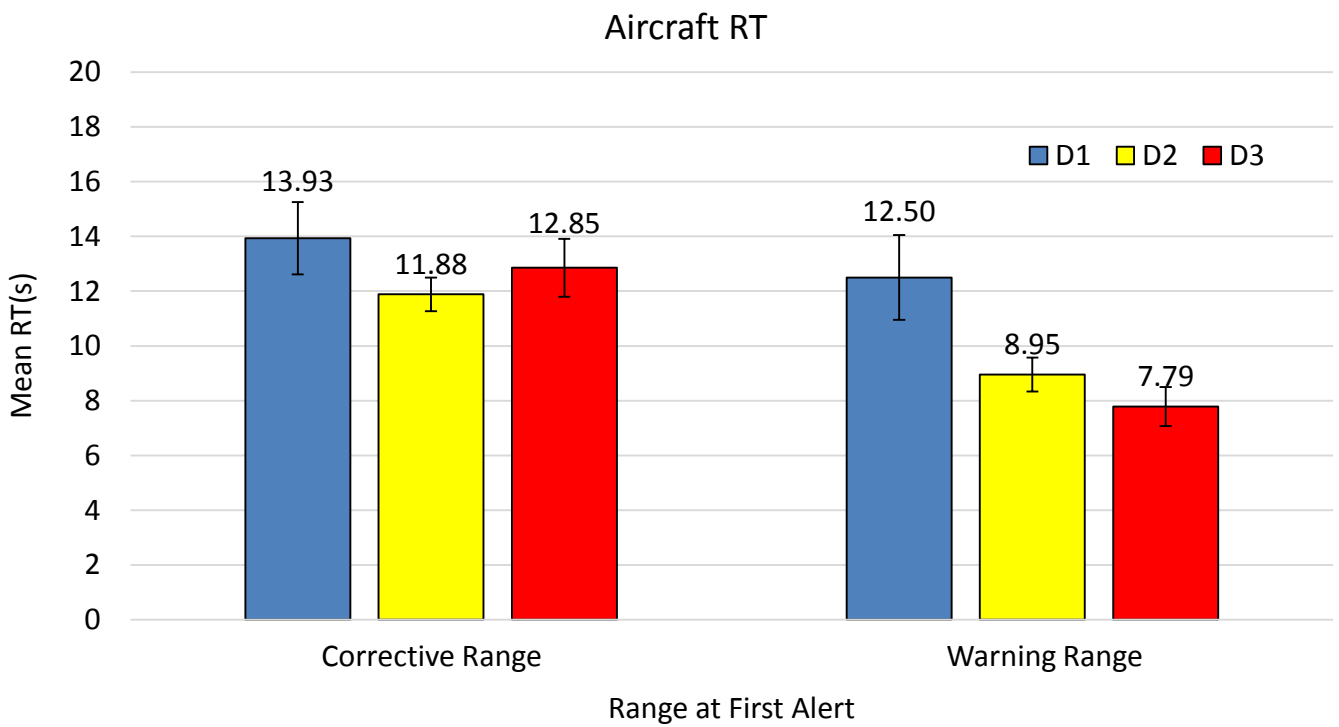
- Expected Outcome
  - Faster response times and better task performance in conditions with DAA Warning alert compared to no DAA Warning
    - Performance improves with more warning-level information
      - D3 > D2 > D1
    - Benefit of warning-level information most pronounced for encounters alerting near well clear threshold (≤ 25sec to LoDWC)

RESULTS

Response Time

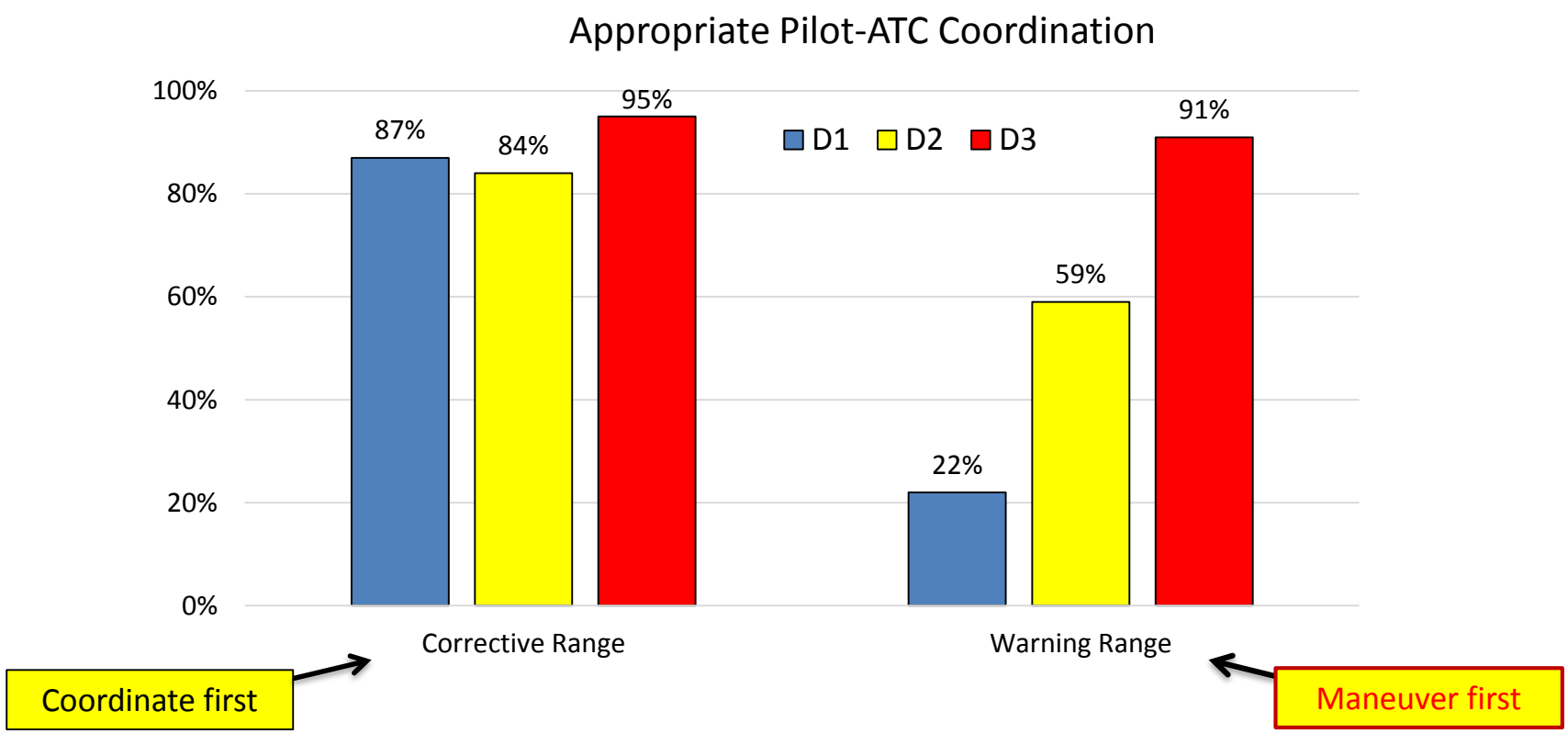
- Aircraft Response Time (AC RT) = time elapsed from the onset of the DAA alert and the first upload sent to the vehicle in response

- Effect of alert condition (D1 - 3) most pronounced when the intruder appeared inside the Warning threshold (i.e., within 25sec to loss of DAA well clear)
  - D2 and D3 resulted in significantly faster response times against threats within warning threshold



ATC Coordination

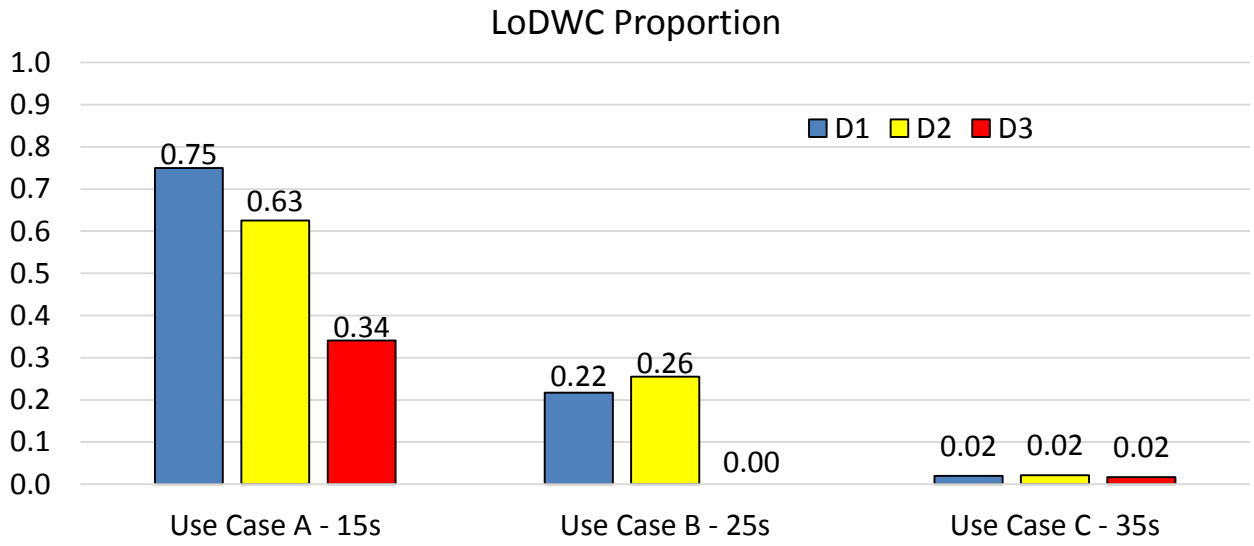
- Pilots presented with warning-level alerting were more likely to respond ***appropriately*** to severe threats within 25*s*-to-LoDWC
  - Pilots acted appropriately against alerts in the Corrective range
  - Pilots acted most appropriately against alerts in the Warning range in the D3 condition
    - Without warning-level information, pilots were much more likely to contact ATC when they should have been prioritizing maneuvering



Loss of DAA Well Clear

- LoDWC Proportion
  - D1 = 15%
  - D2 = 9%
  - D3 = 2%
- 91% of total LoDWC occurred in Use Cases A & B
  - None outside of 35*s* in any condition
  - Inappropriate ATC coordination was the most common cause

- Pilots were nearly twice as likely to remain DWC against the most severe threats with the DAA Warning Alert compared to Caution-only
  - Auditory Maneuver alert (D2) provided minimal benefit on its own



Conclusions

- Warning-level information improves pilot performance against *severe* threats (i.e., those that appear within 25 seconds to LoDWC)
  - Faster response times
    - Prioritized actions appropriately with indication of increased severity
  - Performance remains stable at farther ranges

- Warning alerting is most conducive to DWC maintenance when auditory cue is coupled with a change in symbology
  - Least pilot-responsible LoDWCs with Phase 1 MOPS DAA Warning alert
  - 'Maneuver Now' aural alone did not improve separation performance compared to Caution-Only
    - Potential to miss the aural change while already coordinating with ATC
      - Most likely when intruder alerts at ~35*s* to LoDWC
    - "*Aurals start with the same word; not as attention-grabbing without distinct changes in symbology*"
    - "*Harder to distinguish between Preventive and Corrective without no Warning symbol; trained that Red means severe*"

Questions?

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