Augmented Reality: Understanding Human Performance with Imperfect Systems by Using Virtual Simulations

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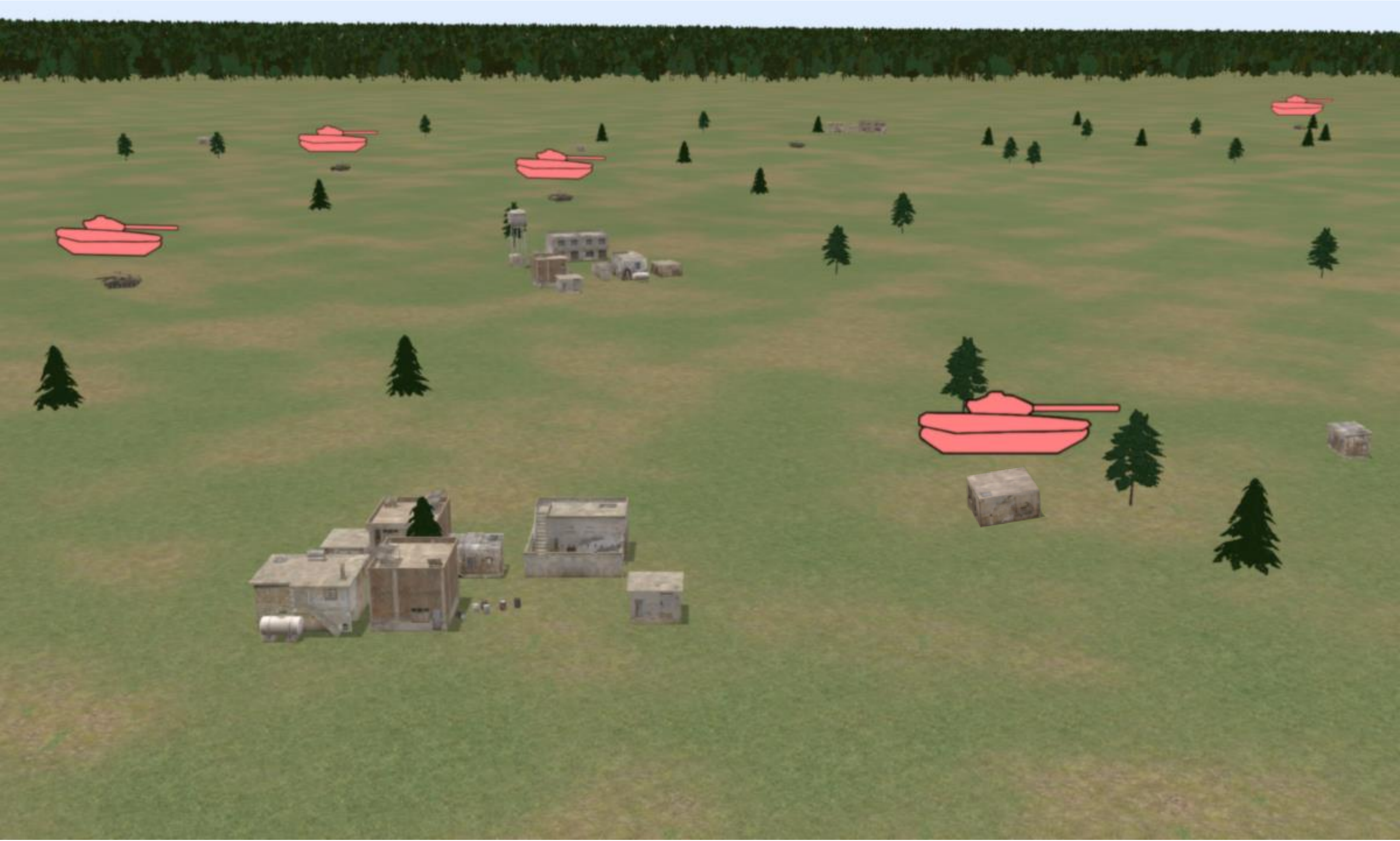
10/11/2018

AR SYSTEMS WILL INEVITABLY MAKE "MISTAKES"

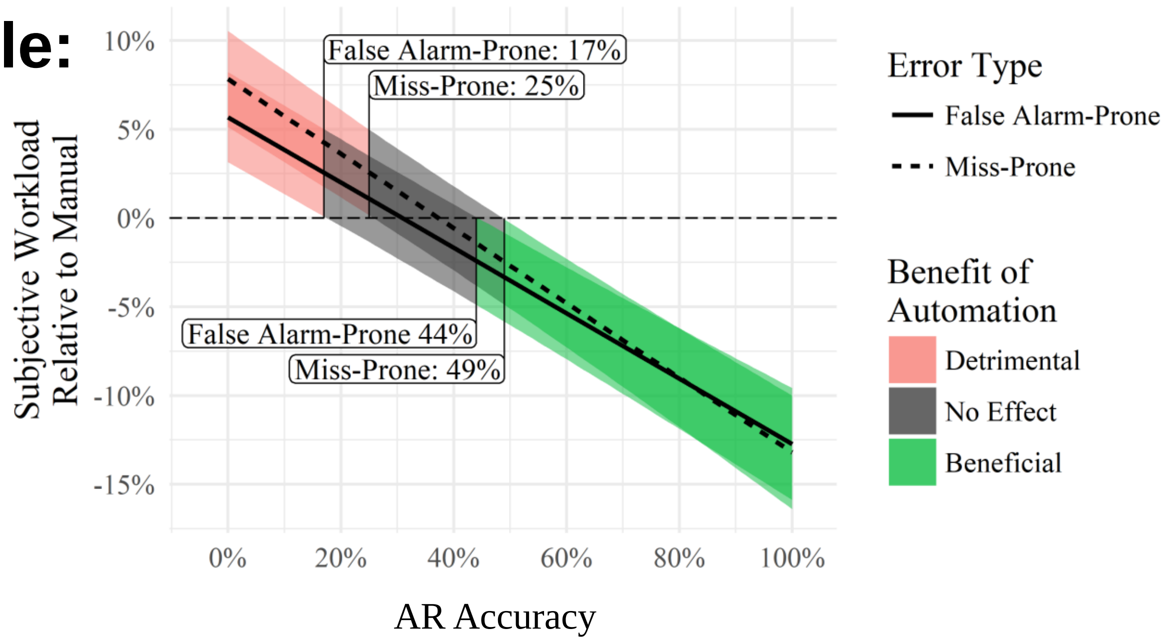


KEY QUESTIONS

- How "good" does AR information have to be to improve human performance? – *Empirical question*

- Poor performing AR will not provide benefits and may even impair human performance

Example:



AR RED TEAM RESEARCH OBJECTIVES

Our simulations currently focus on AR accuracy and human performance:

- How accurate does AR have to be in order to improve performance?
- What are the worst types of errors an AR system can make?

These are task-specific and potentially device-specific questions

Goals:

1) Contribute to general AR usage guidelines

2) Adapt our existing simulation capabilities to be able to define sensor- and task-specific AR Requirements

FIDELITY AND EXPERIMENTAL VALIDITY IN AN AR EXPERIMENTS

Fidelity: “the extent to which the virtual environment emulates the real world”[1]

Fidelity is a multidimensional construct: visualizations, operator movements and interface controls, scenario context, etc.

For our simulations, the cognitive dimension is critical: cognitive task must be realistic and participants must use the AR information the same way they would in reality

We reflect on informal feedback from the first participants on how to improve our simulations

1) Alexander, Brunyé, Sidman, & Weil, 2005

VEHICLE IDENTIFICATION WITH IR SENSORS

Research Objectives:

- Assess Soldier ability to identify military vehicles at various ranges when an AR system assists, but AR accuracy varies
- Compare time-constrained to time-unlimited performance

Methodology

- Use NVIG to generate synthetic images of vehicles
- 3 Ranges: “Close,” “Intermediate,” and “Distant”
- Assess 3 AR reliabilities: 100%, 75%, and 50%
- Control vehicle aspect to limit its impact on performance
- Control for the difficulty of each “AR mistake” by using a set ratio of near/far misses and multiple test permutations
- Measure baseline performance with no AR
- Present AR reliability/range combinations as “unique AR systems to be evaluated”
- Present images in cells; ask participants to rate AR performance and trust after each cell
- Measure task accuracy, response time, and subjective ratings of AR performance

Example imagery from the AR Vehicle Identification Task.

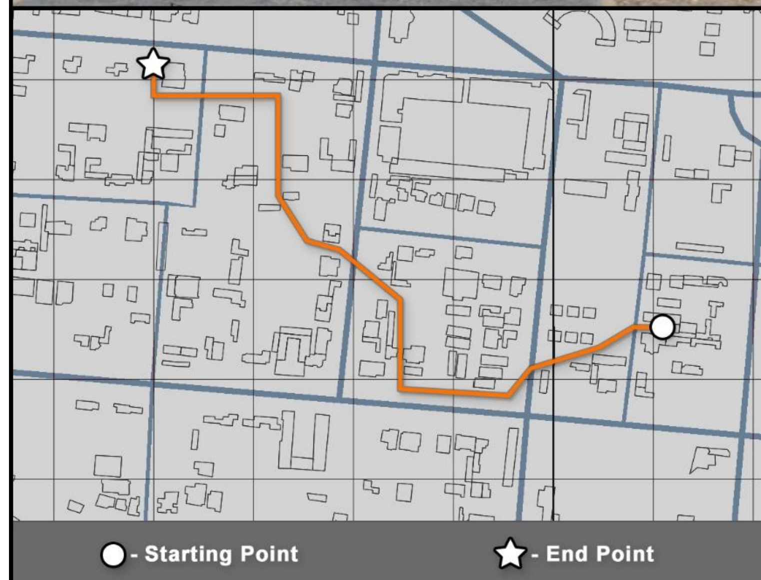
NAVIGATION

Research Objectives:

- Assess ability to navigate a designated route using AR waypoints when AR errors are present
- Determine whether minor or severe errors are most harmful

Methodology

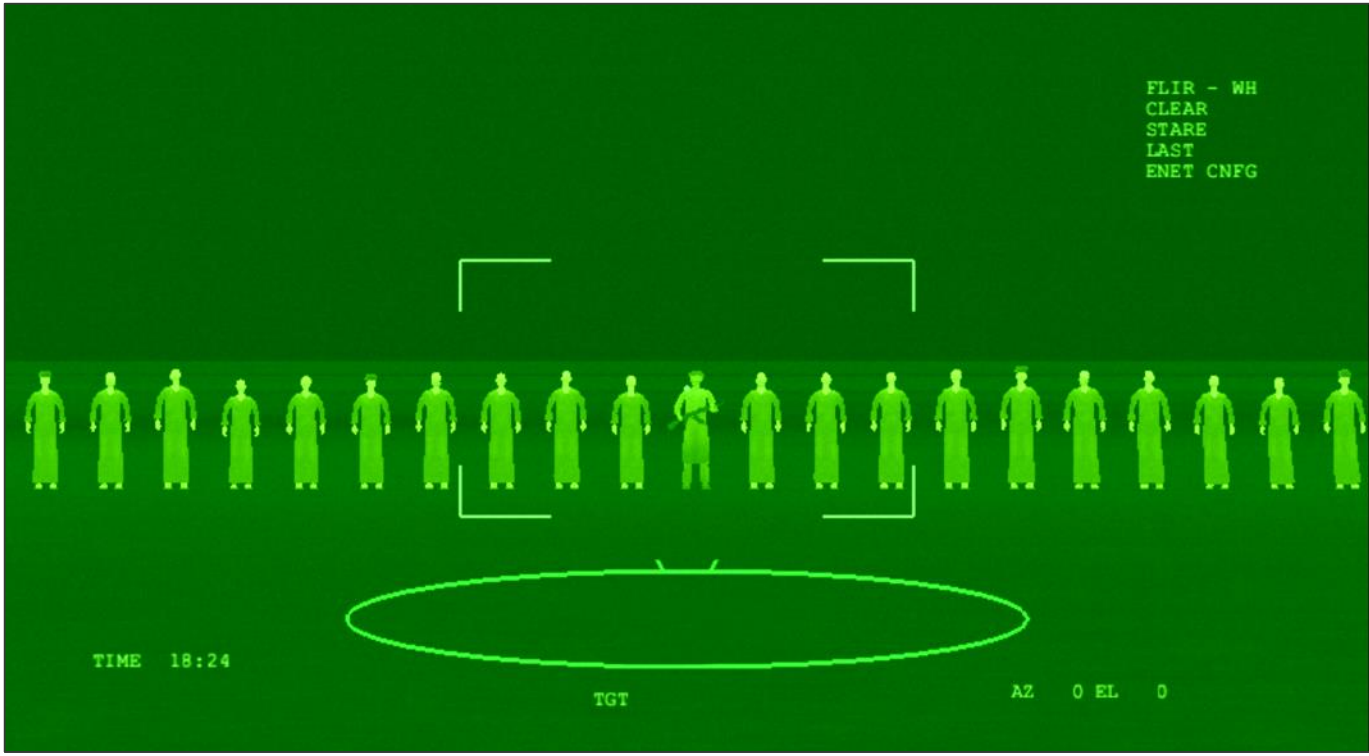
- Use NVIG to generate navigation scenarios (location: Kandahar)
- Present operators with a map of a safe route
- Instruct operators to navigate to the location as quickly as possible, without deviating from the safe route
- Assess 4 AR conditions: No AR (baseline), perfect AR, subtle AR mistakes, and severe AR mistakes
- Control for navigation scenario difficulty by creating multiple permutations of the test
- Measure time to reach destination, path efficiency, incorrect turns, and time spent outside of the safe path



METHODOLOGY: TARGET ACQUISITION

Scene Generation in NVIG:

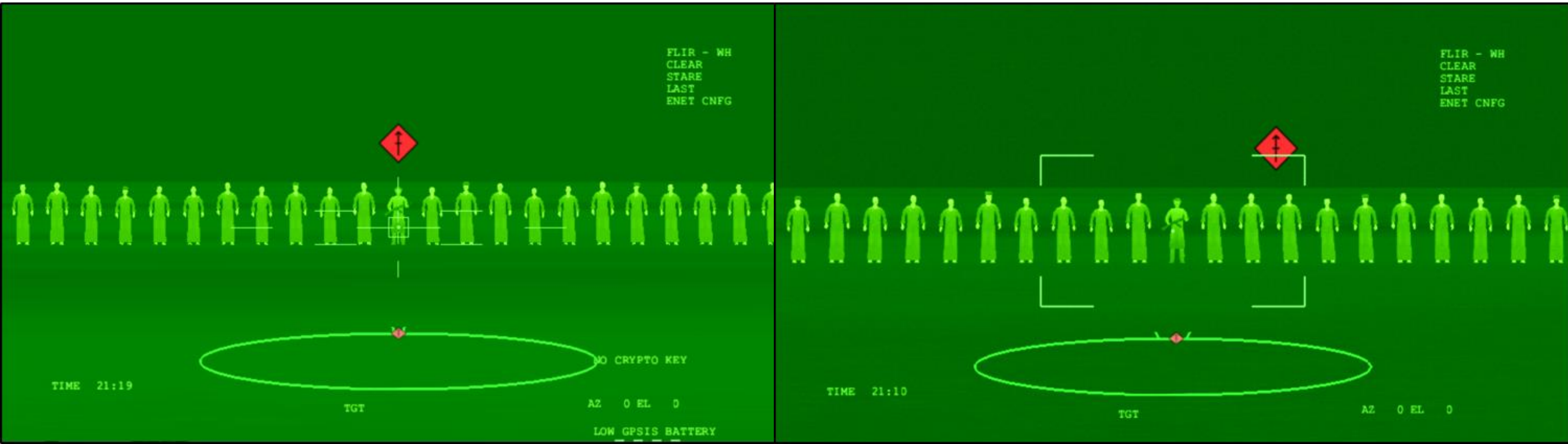
- Virtual humans arranged in a 30˚ arc around the sensor, placed closely together (1m apart)
- A single target held an AK-47



Participants:
10 U.S. Soldiers

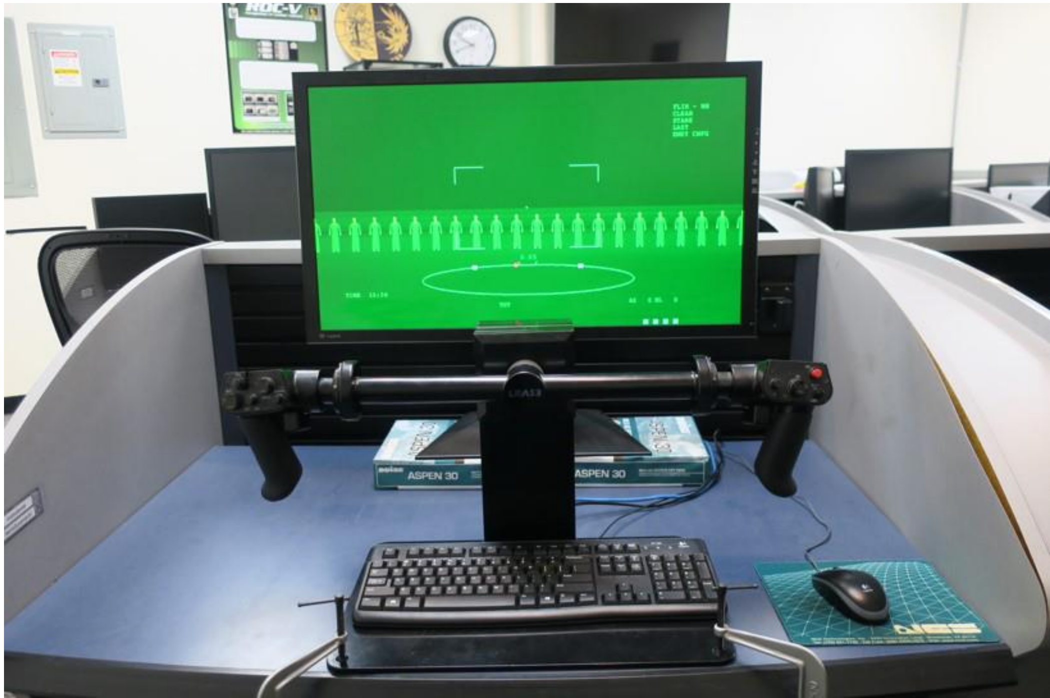
EXPERIMENTAL DESIGN

- AR Conditions: No AR, Perfect AR, 1°, 2°, 3°, and 4° of angular error
- 3 Ranges: “Close,” “Intermediate,” and “Distant”
- Targets placed at 3°, 4.5°, 6°, and 7.5° across all Range by AR condition trial combinations
- 144 trials, divided in 8 blocks (rest between blocks)
- Counterbalanced blocks by AR condition across range



LRAS3 CONTROLS

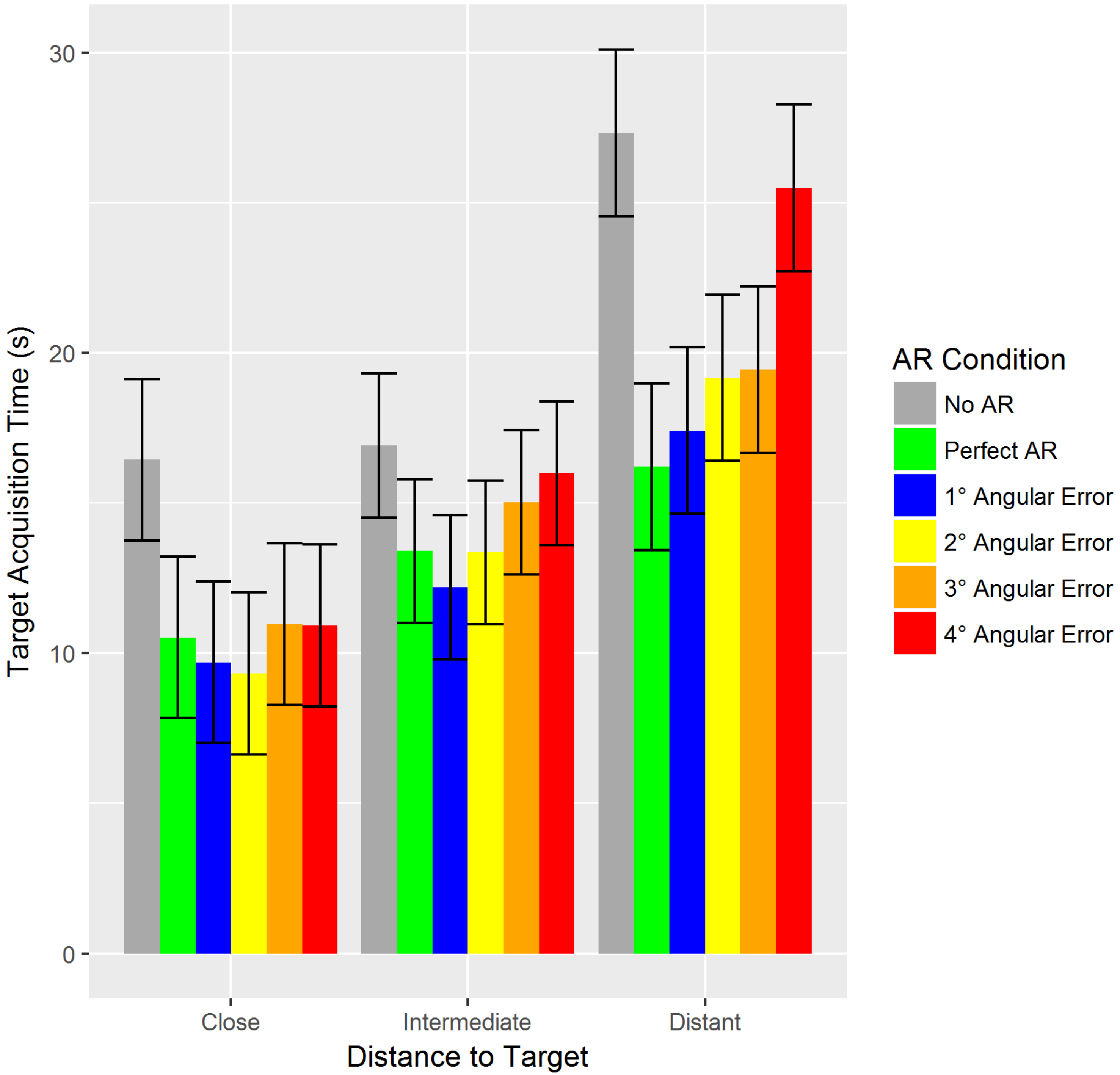
- Highly realistic LRAS3 sensor grips used as experiment interface
- Controls simplified: used optical zoom, LRF for target designation, and “Menu” button to “Confirm” targets; other buttons disabled
- Push sensor grips to rotate sensor view proportionally to the strength of a push
- Added a dot at the center of the targeting reticle for ease of alignment



PROCEDURE

- Participants stayed for 5 days (vehicle identification training, other experiments)
- Group presentation on experiment and controls
- 27 training trials (3 trials each of No AR, Perfect AR, and 4° angular error at all 3 ranges)
- Experiment: breaks as desired between blocks of trials, 10 minutes at halfway point
- Length: ~90 minutes total

RESULTS



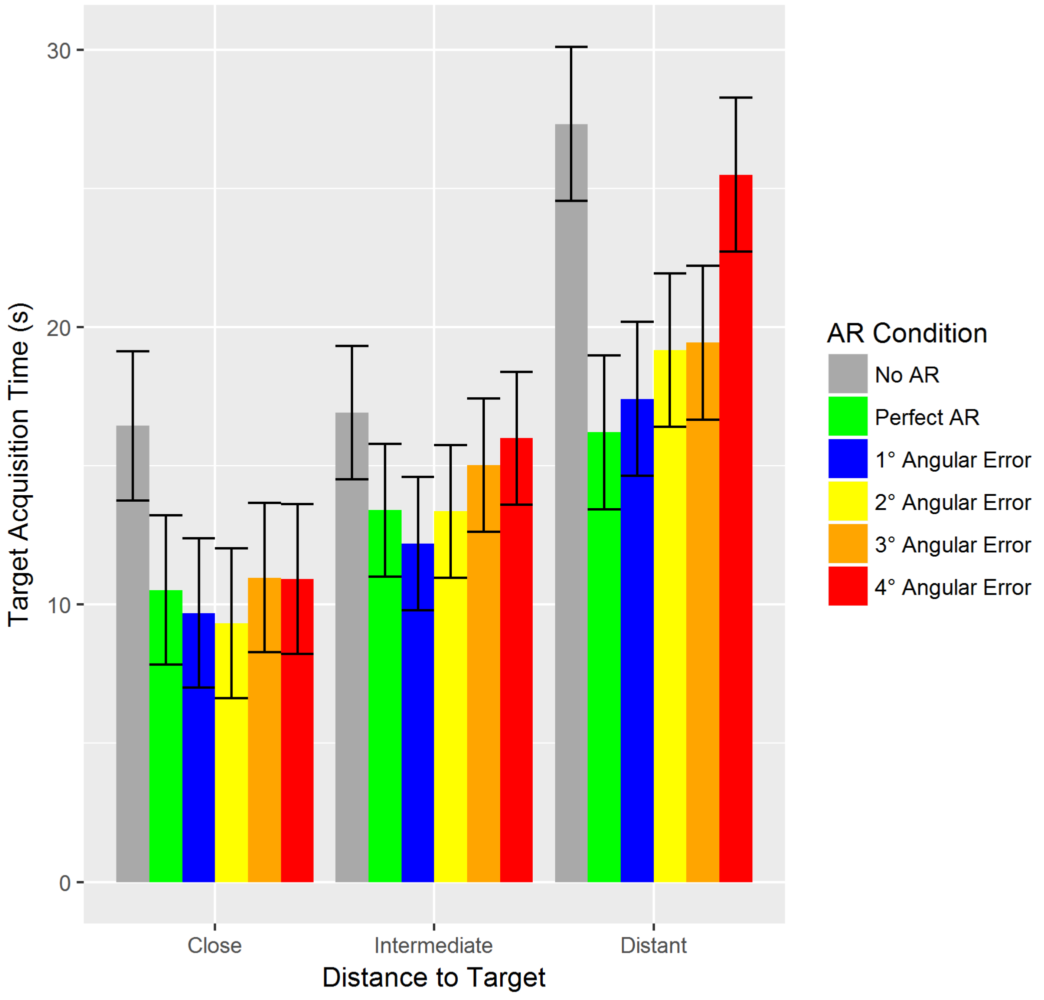
Target Acquisition Time (s)
30
20
10
0
Close
Intermediate
Distant
Distance to Target
AR Condition
No AR
Perfect AR
1° Angular Error
2° Angular Error
3° Angular Error
4° Angular Error

RESULTS: TARGET ACQUISITION TIME

Significant Main Effects:
Range, AR Condition

<u>Compared to No AR:</u>

- All AR information significantly improved target acquisition times
- Perfect AR reduced increases in reaction time w/increased range, but imperfect AR did not
- At “Close” range, all AR conditions were an improvement; 4° was not an improvement at “Distant” or “Intermediate”, and 3° was not at “Intermediate”



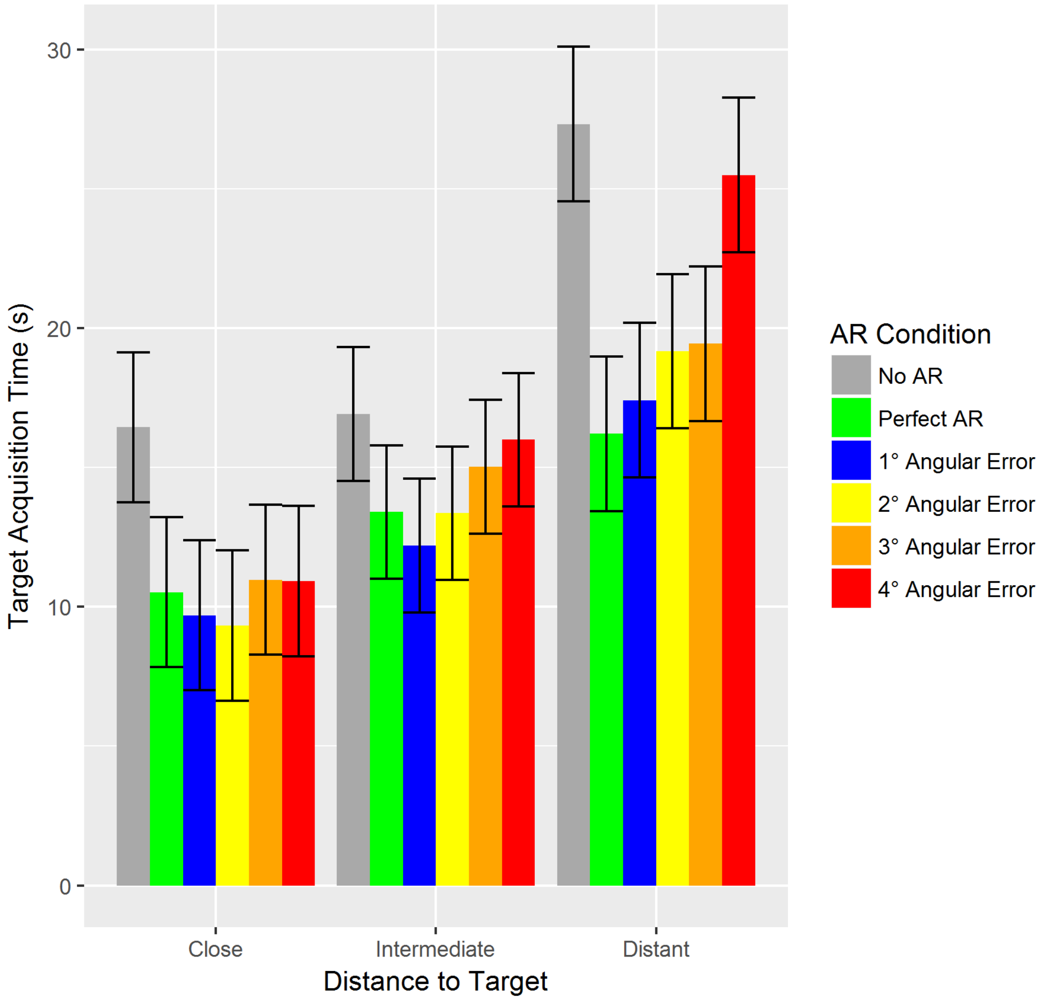
RESULTS: TARGET ACQUISITION TIME

Compared to Perfect AR:

- 3° and 4° of error significantly impaired overall acquisition times

- With 4° of error, *increases* in acquisition time *across range* were worse than perfect AR

- 4° was significantly worse at the “Distant” range



RESULTS: TARGET ACQUISITION ACCURACY

- Accuracy: extremely high when participants designated a target within 60 seconds (>99.5%)
- Thus, accuracy represents ability to find the target in 60 seconds
- Significant Main Effects: Range, AR Condition
- Compared to No AR at the "Distant" range, accuracy significantly improved in all imperfect and (by extension perfect) AR conditions

AR Error Condition	Mean (%)	Standard Deviation
Perfect AR	100.0	0.0
1° Angular Error	98.8	4.0
2° Angular Error	96.3	6.0
3° Angular Error	95.0	12.1
4° Angular Error	93.8	8.8
No AR	86.1	15.3

DISCUSSION

An early exploration into simulating the effects of AR error on target acquisition during a visual search task

Our work provides an experimental template for studying AR error in other contexts (prior to possessing hardware prototypes)

A significant step toward our goal of defining sensor- and task-specific AR requirements

- Linked existing simulation capabilities to target acquisition
- Developed infrastructure to easily change sensor properties and targets/scenery in NVIG

DISCUSSION

Results Highlights:

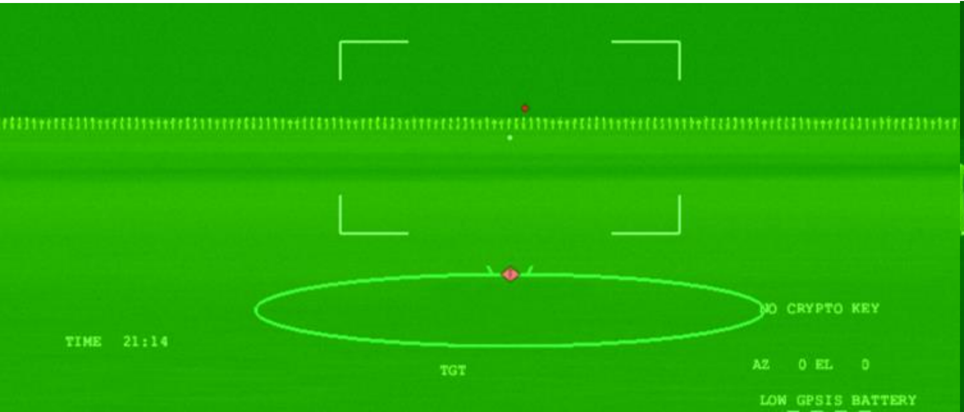
- Simulation generated logical results (ex. increased acquisition time with increased range)
- Incremental degradations in AR accuracy produced incremental degradations in target acquisition performance
- Greater AR accuracy is needed at greater ranges: 4° error was an improvement over No AR at close ranges but lost benefits at the “Distant” range

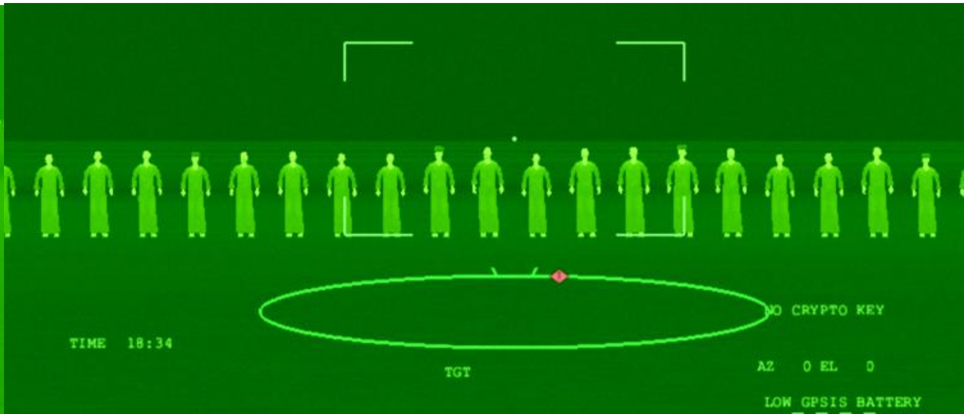
We can achieve greater statistical precision with additional participants

IMPROVEMENTS BASED ON PARTICIPANT FEEDBACK

1) Sensor rotation speed was "too slow" at the "Close" range
  - Speed was constant, but perceived differently
  - No true reference (sensor is physically rotated)
  - Settings facilitated target acquisition of "Distant" targets

- For future simulations: we increased speed & made it proportional to field of view
  - Also added a speed "boost" button
  - This better simulates orienting quickly to a target, then struggling to compensate for AR errors





IMPROVEMENTS BASED ON PARTICIPANT FEEDBACK

2) Disliked removal of sensor azimuth heading, caused disorientation
   - We placed targets at fixed locations to control for rotation time across AR conditions, so azimuth heading was removed
   - Mistake: changed the way they experienced the search task
   - Restored azimuth heading for future simulations and randomly placed targets within counterbalanced arc sections

CONCLUSION

- The impact of AR information distorted by angular error on target acquisition depends on both the amount of error and the range

- Simulation is a critical asset capable of exploring human performance with AR

- NVESD will continue to invest in AR technologies and research simulating human performance with AR applications for electro-optical and infrared sensors (head-mounted displays, etc.)

QUESTIONS?