Human factors, naturalistic behavior, and Virtual Reality: What we have learned from observing firefighters

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- A picture is worth a thousand words
- A movie is worth a thousand pictures
- A simulation is worth a thousand movies
- An interactive simulation is worth a thousand simulations
- A 3D interactive simulation is worth a thousand interactive simulations
- A full-scale, 3D, interactive simulation….Priceless

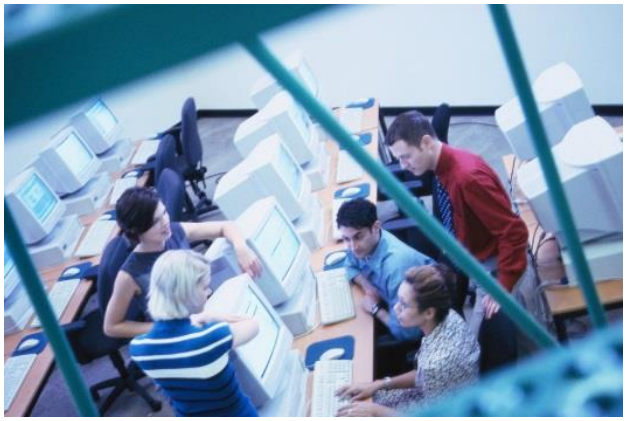
Agenda

- Human factors
- Schools of decision making research
- Attributes of simulators for naturalistic behavior
- C6
- VirtuTrace
- Experiments with firefighters
- Results
- Current efforts
- Transportation research in VR

Human factors

- Ergonomics
- Human centered design
- Naturalistic decision making

Schools of Decision Making Research



- **Two schools of thought**:
  - Heuristics and Biases
  - Naturalistic Decision Making

- **Heuristics and Biases**
  - Research conducted in well-controlled laboratory environment
  - How decisions *should* be made given unlimited resources and ideal conditions
  - Cynical approach toward the decision maker
  - Limited resemblance to actual decision environment – how generalizable are findings (e.g., in ill-structured, time critical functions, high stress environments)?

Schools of Decision Making Research

- **Naturalistic Decision Making (NDM)**
  - Research conducted in the decision environment (i.e., Real-life or real-life like environments)
  - How decisions *are* made in the "real world"
  - Positive approach toward the decision maker's efforts
  - Lack of controlled environment complicates understanding thought processes underlying the decision

Desired Attributes of Simulator for Naturalistic Decision Making Training

- **Literature suggests that, for training decision making…**
  - "…having subject matter experts (SME) verbally express to novices their reasons for rendering certain decision will be less than ideal." [1]
  - "SMEs through their experience and expertise know more than what they can tell novices." [1]
  - "That means that an approach to training intuitive reasoning needs to involve more than soliciting information from SMEs." [1]
  - Cognitive Transformation Theory:

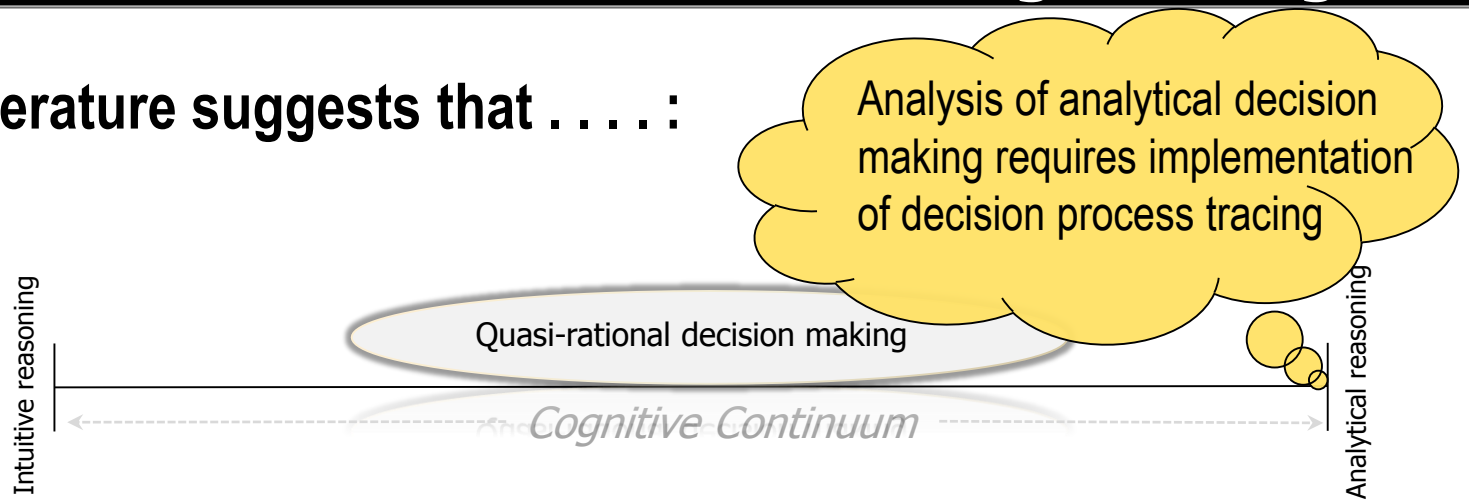
    Improving cognitive processes (e.g., decision making skills) requires unlearning mental models to allow new mental models to be established [2]

Sophisticated & flexible After-Action-Review to facilitate unlearning and re-creation of mental models

1. Patterson, R., Pierce, B., Bell, H. H., Andrews, D., & Winterbottom, M. (2009) Training robust decision making in immersive environments, *Journal of Cognitive Engineering and Decision Making,* 3(4), 331-361.
2. Klein, G. & Baxter, H. C. (2009). Cognitive Transformation Theory: Contrasting Cognitive and Behavioral Learning. In (Schmorrow, D., Cohn, J. and Nicholson, D.Eds), The PSI Handbook of Virtual Environments for Training and Education - Vol 1, Westport, CT.

Desired Attributes of Simulator for Naturalistic Decision Making Training

- **Literature suggests that . . . . :**



- Intuitive reasoning and analytical reasoning exists on the two extremes of the cognitive continuum. [3]
- Effective decision making requires flexibility on the cognitive continuum. [1]
- Flexibility is the ease with which the decision maker slides along the continuum towards either the analytical or the intuitive edge to adjust to the situation. [1]

3. Hammond, K. R. (2007). Beyond rationality: The search for wisdom in a troubled time. New York: Oxford University Press

Psychophysiological Constraints

- **Cognition/individual decision making characteristics**
- **Physiological responses to situational constraints – Stress type**
- **E.g., In decision making:**
  - Challenge related stress
    - Elevated heart rate
    - Unchanged or reduced blood pressure
  - Threat related stress
    - Decrease in heart rate
    - Increased blood pressure
  - Heart Rate Variability for detecting Autonomic Nervous System activation (fight-or-flight)

Necessary elements for successful simulation

- Immersion
- Presence
- Situational awareness

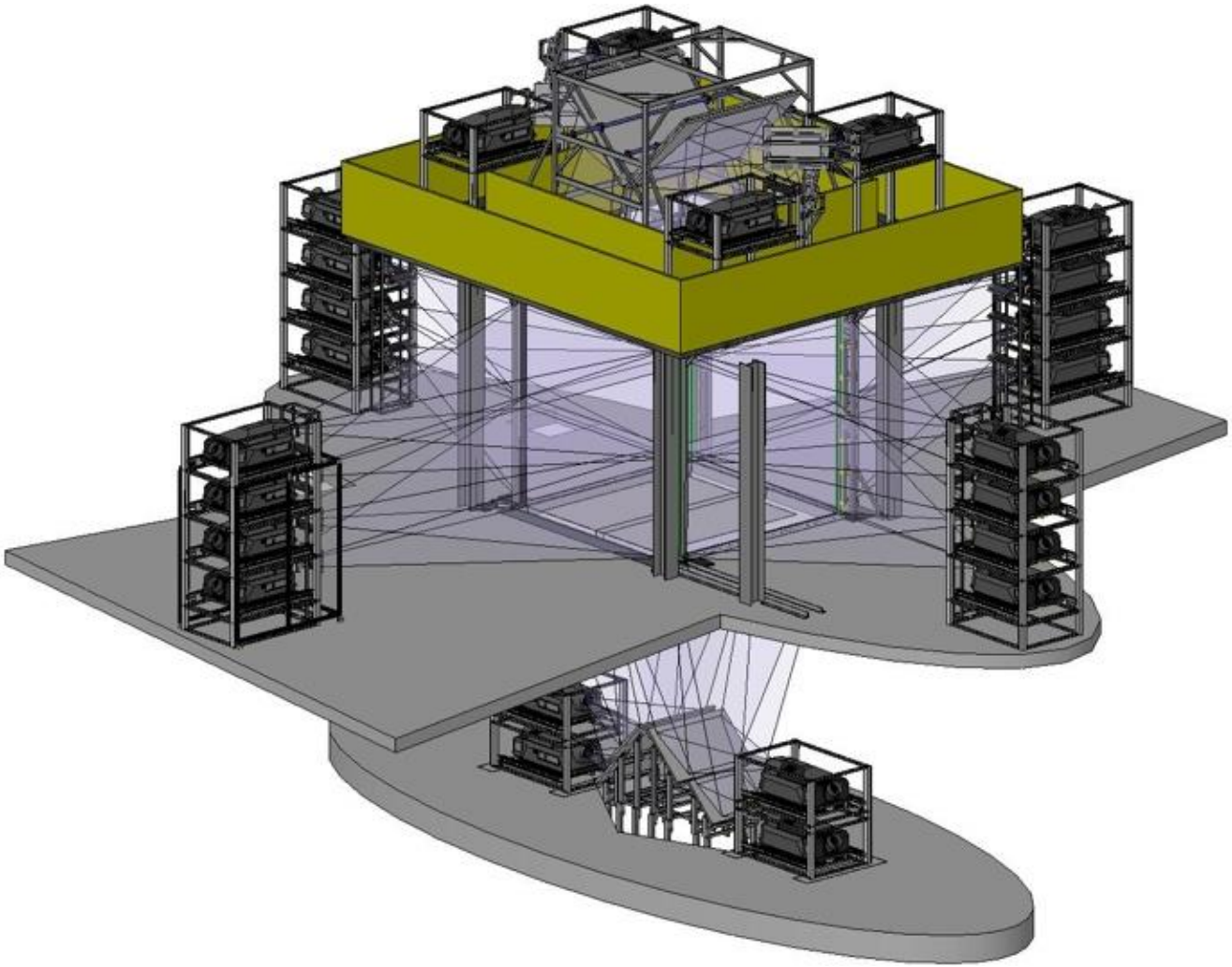
Desired Attributes of an Immersive Simulator

Attributes	Features of Synthetic Simulated Frameworks
Ecologically valid environment	Immersive synthetic environment (preferably 3-D): • Real-life like experience • Naturalistic operational functions (e.g., use controls that are as true as possible to the decision environment by avoiding use of game pads)
Capture of cognitive-rich process data	Implementation of decision process tracing – preferably mid-simulation (e.g., avoid memory distortion and memory loss due to information that was not encoded into long term memory)
Development of pattern recognition skills to enhance intuitive responses	Repeated exposure in naturalistic environment, yet maintaining a controlled setting
Identification of psychophysiological constraints	Assess psychophysiological responses in real-time: • Collect physiological responses • Implement post-experiment data analysis • Present decision portraits that can be contrasted with physiological constraints for psychophysiological mapping
Facilitation of transformative cognitive learning	After-Action-Review protocol(s)

The C6

- The C6 is a six-sided immersive system in which a subject is fully enclosed with 10’ x 10’ screens.
- Each screen has a resolution of 4,000 x 4,000 pixels
- The C6 is the highest-resolution VR system in the world, more than double that of any other similar system.
- The large size of the screens, along with the 3-D effect created by shutter glasses and stereo sound, increases the level of presence and situation awareness.
- The use of 46 computers with 92 graphic cards to change the display of 100,000,000 pixels at 120 Hz further enhances the realistic effect

C6

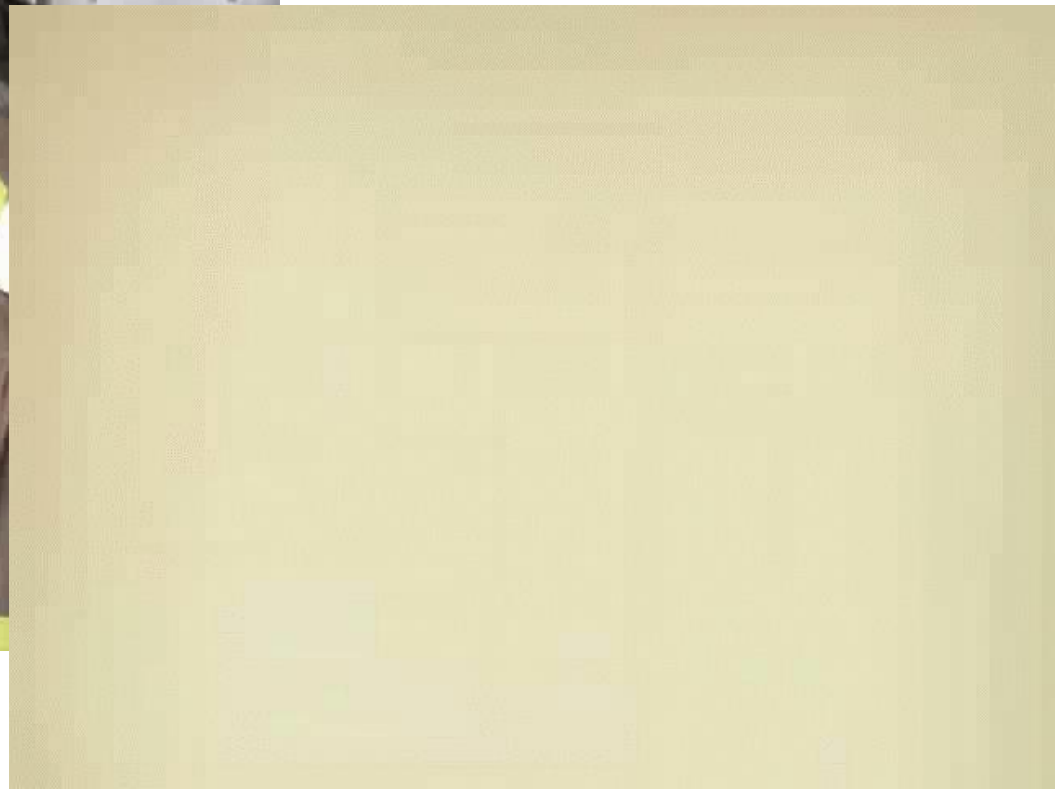


VirtuTrace:
Simulator for Decision Making under Stress

C6: Fully Immersive VR Room

Tracking System

Decision Process Tracing



The Role of After-Action-Review Protocols

- **Traditionally**:
  - *An After-Action-Review (AAR) is a professional discussion of an event, focused on performance standards, that enables soldiers to discover for themselves what happened, why it happened, and how to sustain strengths and improve on weaknesses…*

The *Leader's Guide to After-Action-Review* standard of the Headquarters Department of Army (1993) defines After-Action-Review (AAR)

- **To pursue the 'transformative cognitive learning':**
  - AAR should allow for the participant's session (including all interactions) in the virtual scene to be played forward and backward in a user-selected variable speed
  - Facilitator(s) can use bookmarks during the training/experiment session and, during AAR, to 'teleport' to these bookmarks at any time

The Role of After-Action-Review Protocols

Experiments with Firefighters

- **Annually** [4]**:**
  - Firefighters fatalities: 100
  - Firefighters injuries: 30,000
  - Civilian fatalities due to fires: 3,000

Suboptimal decision-making, exacerbated by job-related stress, is potentially a major contributor to the losses

4. Cote, A. E. (2004) Fundamental of Fire Protection, National Fore Protection Association

Experiments with Firefighters

Results: Decision Process Tracing

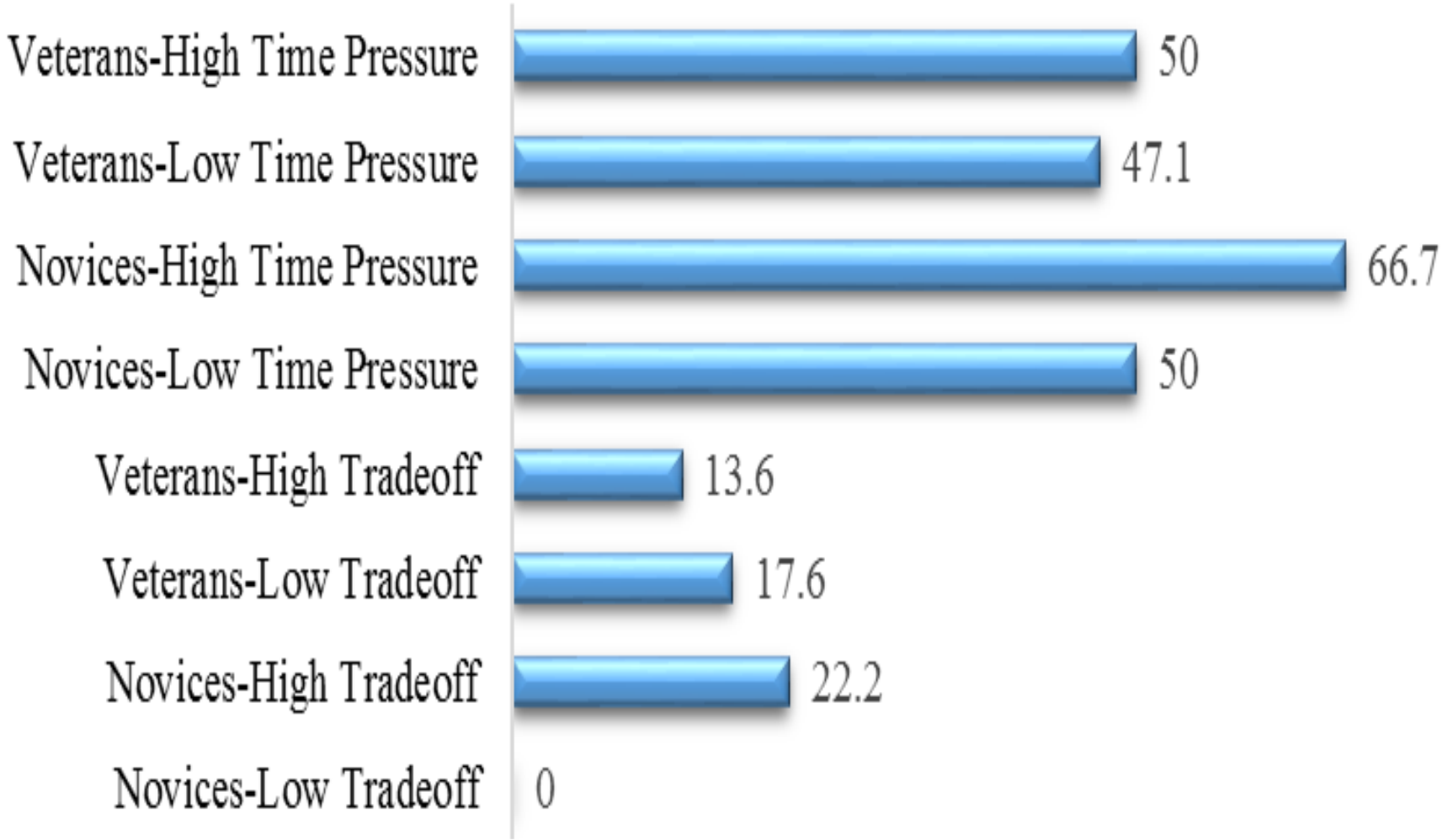
	Attack through main door	Horizont. ventilate through a window	Ventilate through the roof	Ventilate from ladder truck
Risk/ Benefits	1 (565.9)	2 (595.7)	3 (607.8)	4 (615.3)
Size-up factors				
Type of structure				
Avail. resources	1 (701			

	Attack through main door	Horizont. ventilate through a window	Ventilate through the roof	Ventilate from ladder truck
Risk/ Benefits				
Size-up factors				
Type of structure	1 (500.7)			
Avail. resources				

Results: Decision Strategy

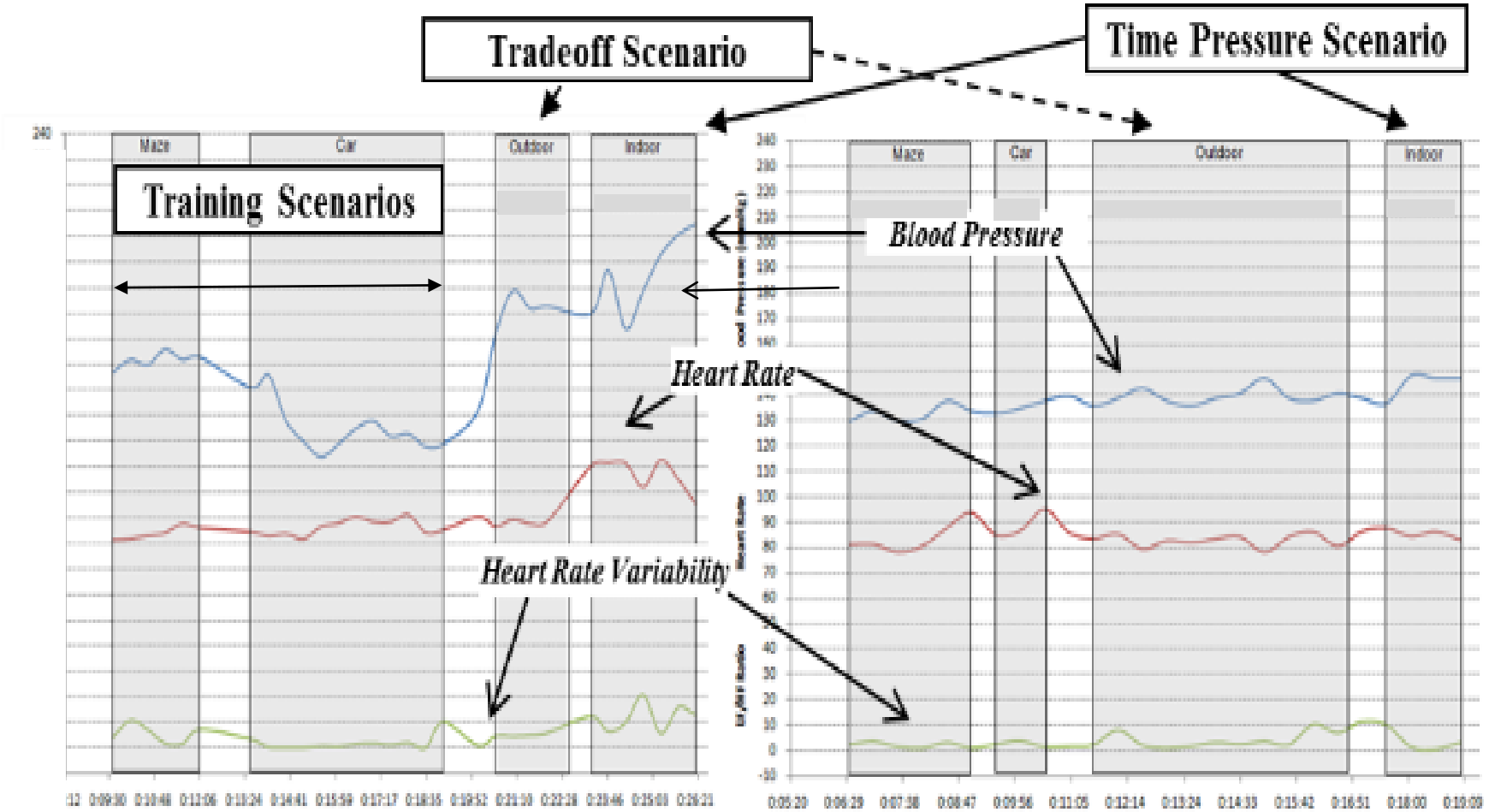
- Variation 1 of RPD was not frequent in Tradeoff scenario; it was used considerably more in the Time Pressure.
- Our data do not support the finding that RPD is prevalent in ~ 88% of the cases that were examined (Klein, 2010).
- The visibility of other lines of action may promote consideration of different strategies that otherwise would not have been consciously considered.
- Klein's findings are largely based on both retrospective and field interviews. Our results are based on mid-simulation assessments.

Results: Decision Strategy



Experience was not a major factor in distribution of usage of RPD Variation 1.

Results: Variability in Physiological Responses

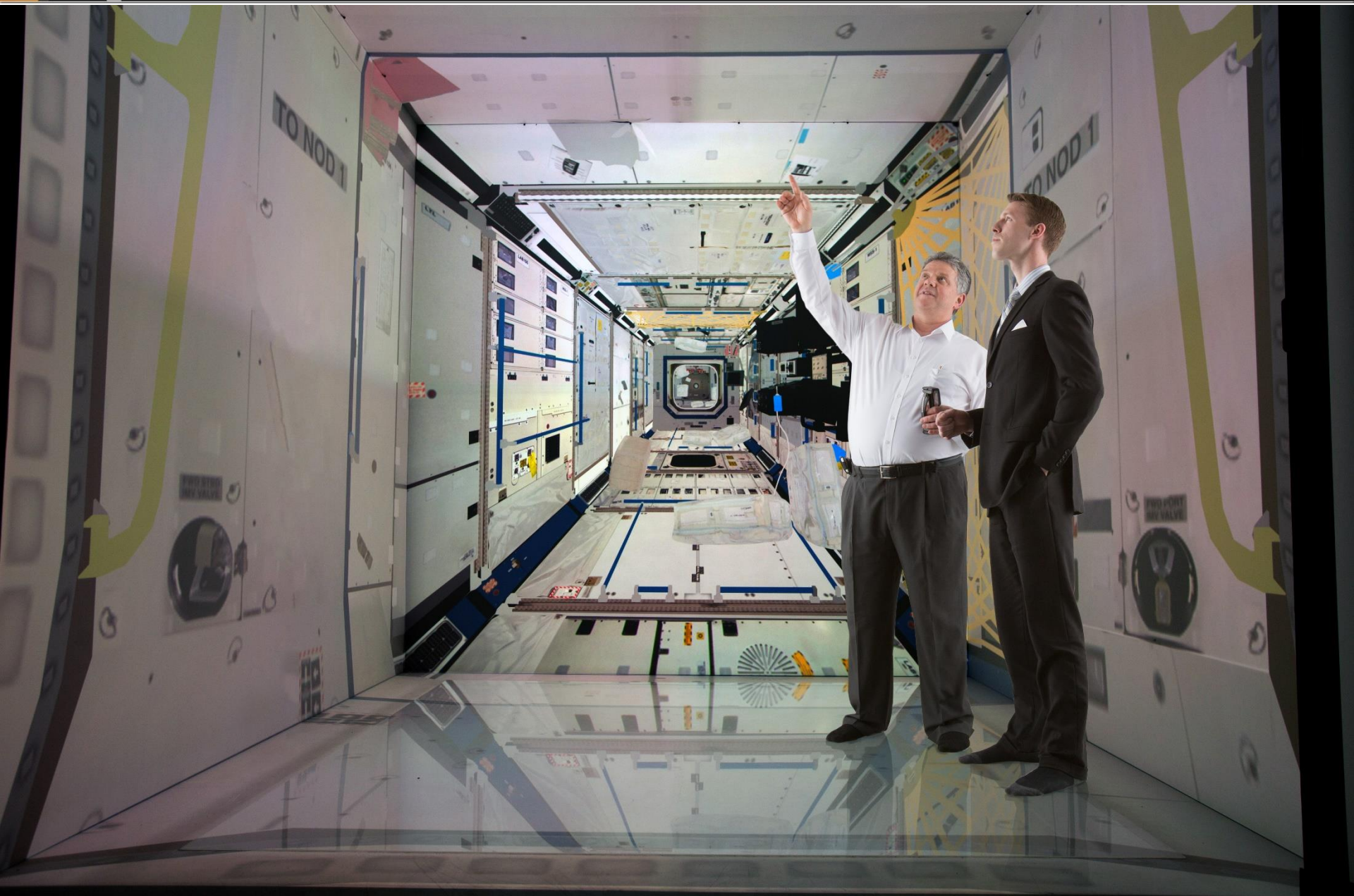


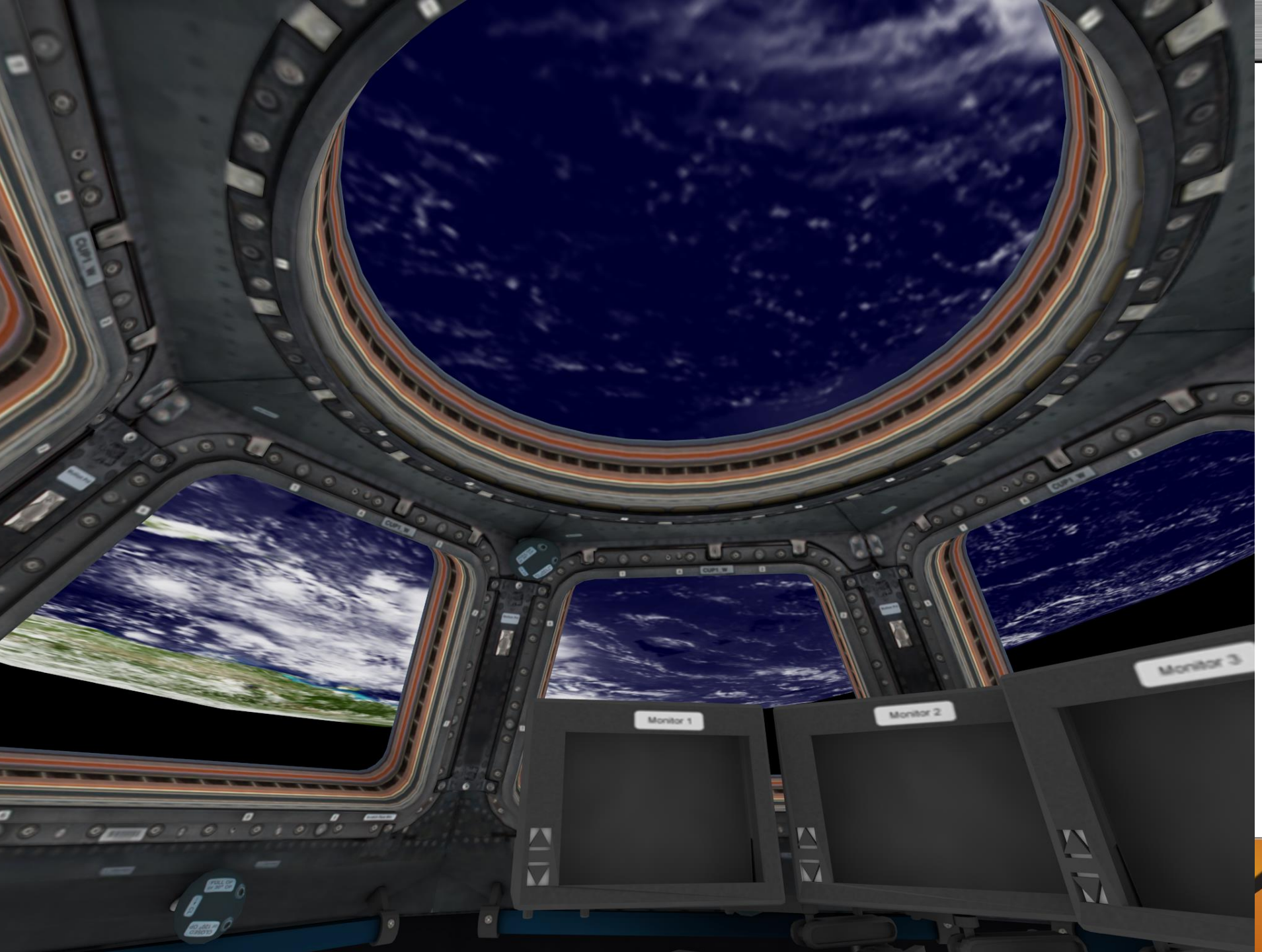
Other Results

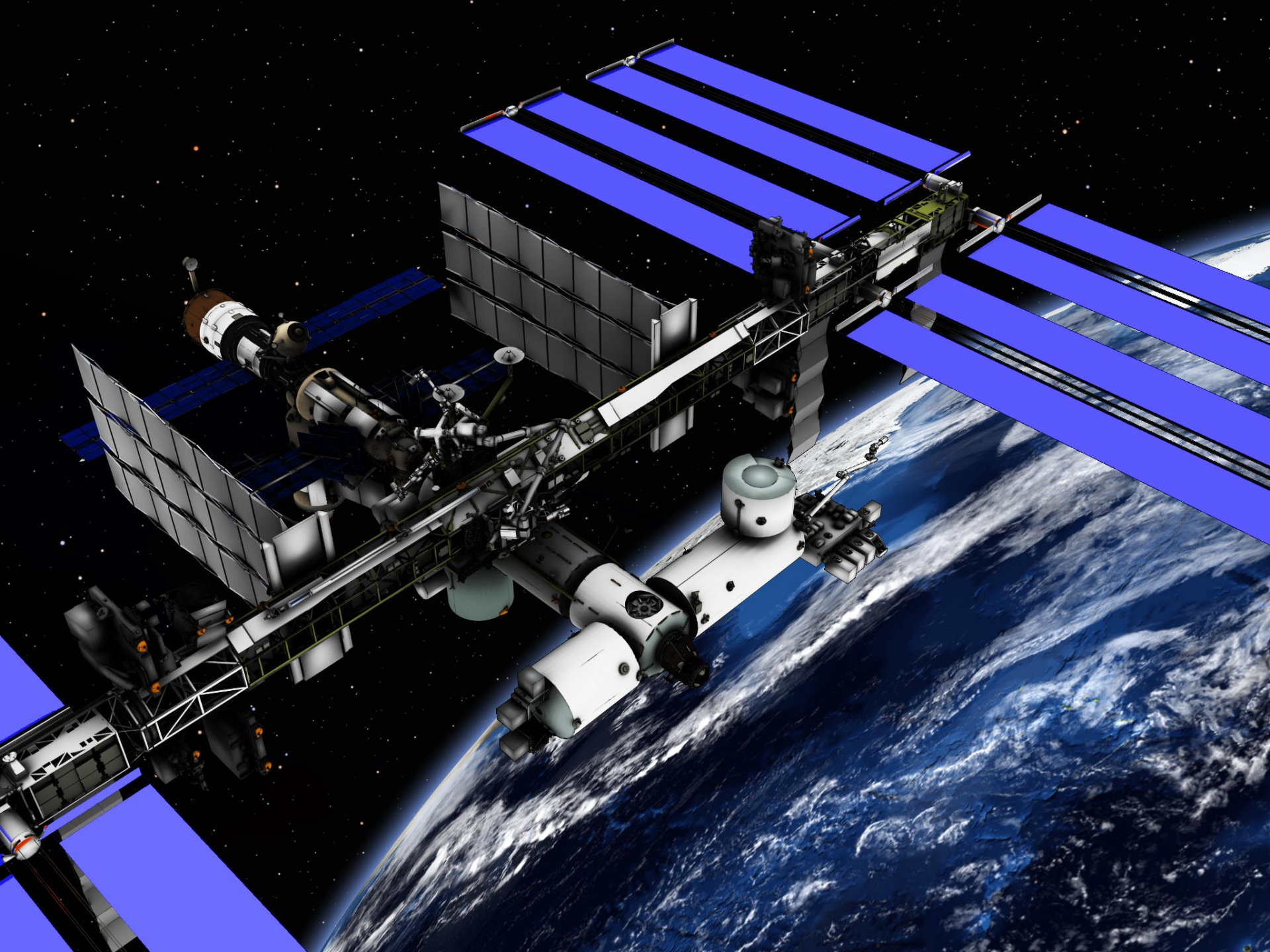
- Two new decision patterns were detected
- Decision making dogma suggests that time pressure is the major stressor during command and control situations.
- However, results from the simulations suggest that difficult tradeoffs, rather than high time pressure, evoke significantly greater stress responses in veteran firefighters than in less experienced firefighters.

Other project

International Space Station




Monitor 1
Monitor 2
Monitor 3



Analytic tools

Traffic data

Road data

Vehicle data

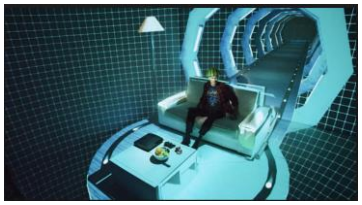
Driver data

Road data

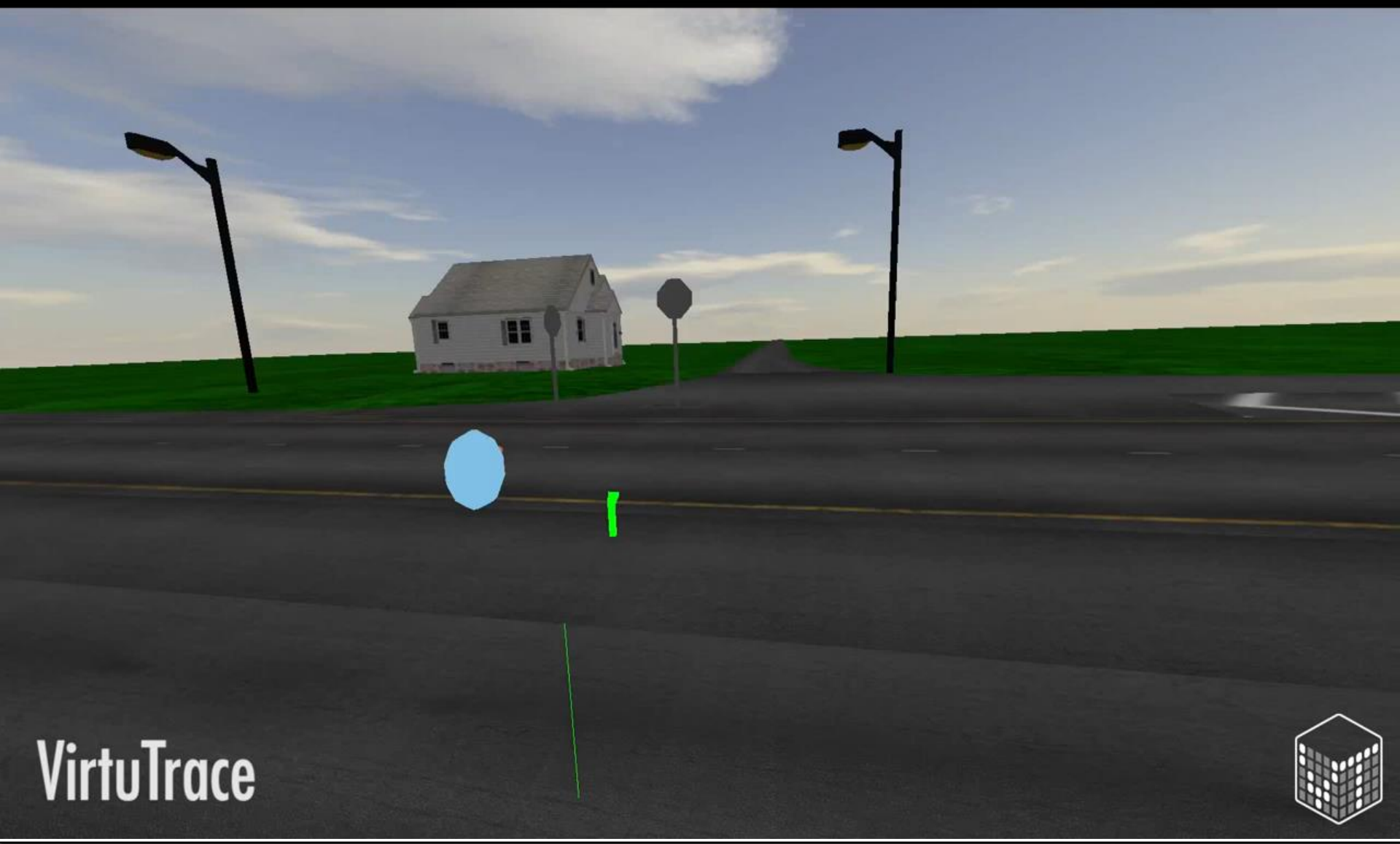
Weather data

Real-time data integration and distribution manager

VirtuTrace



MTC: Proof of Concept



Q&A