The Role of Psychology in Models and Decision Making: An Applied Cognitive Psychologist's View

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TRIMETIS
COGNITION + COMPLEXITY + COLLABORATION

Uncertainty is the norm, not the exception

"Because what I'm talking about is life. Because life is one of those things that most of us find very difficult to avoid. In the words of Plato, "Life is uncertain."

My life certainly has a certain uncertainty about it. And I'm certain yours does too. So with my uncertainty and your uncertainty there's certainly a certain degree of uncertainty about, of that we can be quite… sure."

Rowan Atkinson's – Sir Marcus Browning, M.P.

Collateral Damage Estimate – “Eye in the Sky” (2015)

MUSHTAQ: Adjusting the impact point to here... there is a forty-five to sixty-five percent possibility of fatality.

COLONEL POWELL: I need that calculation to be *below fifty percent*.

COLONEL POWELL: Perhaps there is an adjustment in the assessment on the impact here?

MUSHTAQ: That calculation is already at the lowest limit of what I believe is possible.

COLONEL POWELL: Or if you target the missile here?

MUSHTAQ: I would still have to make that a sixty-five per cent possibility on the upper limit.

COLONEL POWELL: I need you to make this work, Sergeant. Do you understand?

We are locked into this kill chain and a decision has to be made. There are many lives at stake.

MUSHTAQ: Ma'am... I think... I think that if the impact point is here then... then I could, I think, predict a forty-five per cent possibility of fatality. That might be possible.

COLONEL POWELL: Forty-five per cent?

MUSHTAQ: Possibly. Yes.

COLONEL POWELL: I will put that to Cobra.

MUSHTAQ: Ma'am, it's...

COLONEL POWELL: It is my understanding that, in these circumstances, your calculation *can only* be speculation. That puts you beyond any culpability.

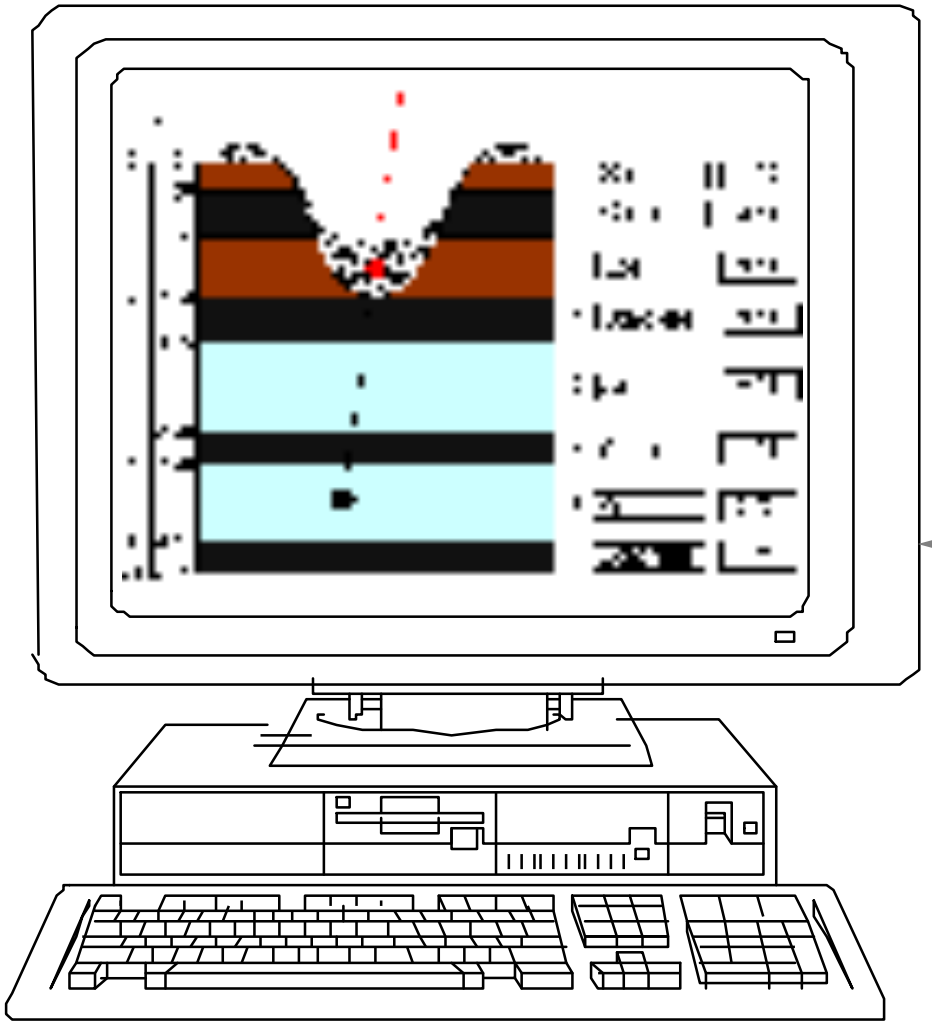
Sources of Uncertainty

- Is it the right people?
- Legality – Rules Of Engagement
- Amount of explosive material in the situation (bomb vests + UAV bomb)
- Extent of blast radius (through walls etc.)
- Strength of blast x radius – relative damage over distance
- Location of Target Impact Point to minimise collateral damage but maximise mission success
- Situational uncertainty – situation changes as people move into/out of estimated blast radius
- Outcome uncertainty
  - Number of dead/injured
  - Reputational damage
    - If we do
    - If we don't
- "Opportunity cost" uncertainty
  - If we do – collateral damage estimate, VS.
  - If we don't – future suicide bombing in a crowded area

Case Study of “Decision-Centred Design”

- Design: Munitions Effectiveness Assessment prototype development
- User: USAF 22 yr. old history graduate
- Goal: pull together an operational targeting folder including:
  - Delivery platform
  - Mission objectives
  - Delivery profile
  - Weapon/s
  - Target Impact Point
  - Expected damage assessment
- Cognitive Task Analysis to:
  - Uncover the requirements for supporting user’s cognitive work
  - Identify challenges of cognitive work
  - Develop tool to support user

Munitions Effectiveness Assessment Prototype (Pyle, Shaw, & Miller, 1993)



Task

Select weapon that will penetrate a buried target structure

Information Needs

Photographs
Cross-sections
Materials used
Damage desired

Existing Aids

Predictive code
Rules-of-thumb
Heuristics

Cognitive Processes

Analytic calculations
Feature matching
Identification of analogues (previous cases) for comparison

Potential Errors

No detailed information available
View task solely as hitting aim point
Over-confidence in analytic tools
Conversion errors (feet/meters)

HCI Solutions

Animate views of weapon penetration
Show different media (including thickness)
Tailor display to actual targets
Highlight difficult penetration factors
Show conversions

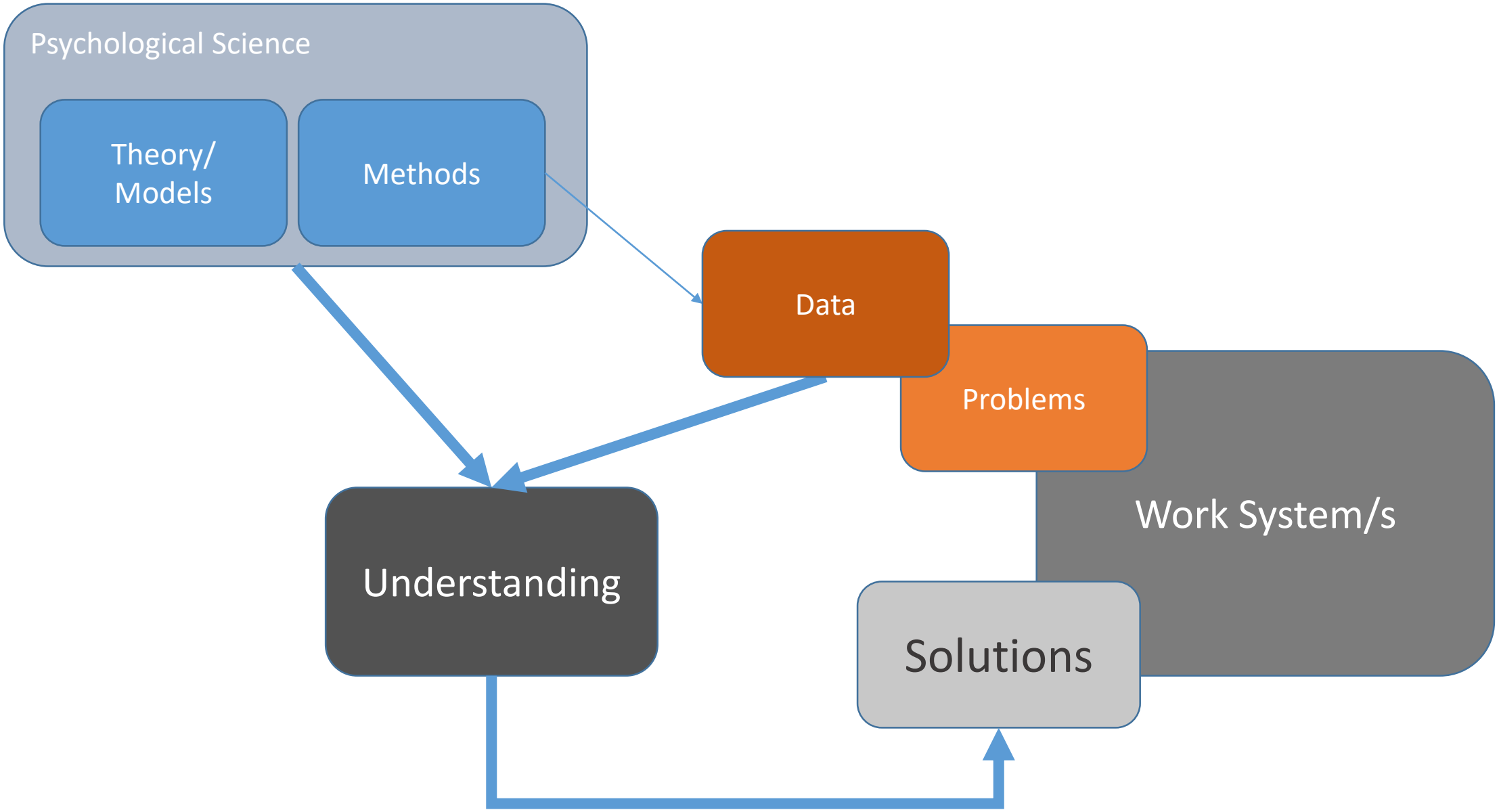
MEA Prototype

- Multiple-sources of subject matter expertise (SME)
  - Civil engineers
  - Pilots/”delivery” specialists
  - Munitions specialists
  - Weapons specialists
  - Intelligence/mission specialists
- Address cognitive requirements/challenges by:
  - Support integration of multiple SME heuristics/rules of thumb
  - Support simulation and visualisation of multiple options


Hätätie


OBSERVER

Applied psychological research; Human factors psychology; Cognitive systems engineering



Areas of Professional Interest

- Developing and applying:
  - Models (of behaviour/performance)
    - decision making, (re)planning, uncertainty management…
  - Methods
    - cognitive task analysis and cognitive systems engineering
  - Metrics
    - evaluating cognitive work performance

In support of designing:

- Technology (decision aiding/decision support systems; user interfaces)
- Training
- Doctrine
- Teams
- Ways of working/SOPs

Areas of Application

- Weather forecasters
- Air Traffic Controllers
- Electrical Power Grid control room operators
- Military planners (US & UK; from tactical to operational)
- Military operations (from small unit to operational headquarters/Operations centres; US & UK)
- Emergency services (e.g. fire fighters; incident commanders)
- Nurses (neonatal; midwives)
- Laparoscopic surgery
- Rugby decision making
- Intelligence analysts
- Aviation Safety Inspectors
- Aircraft maintainers (B-2 avionics and F-16 & C-141 ground crews)

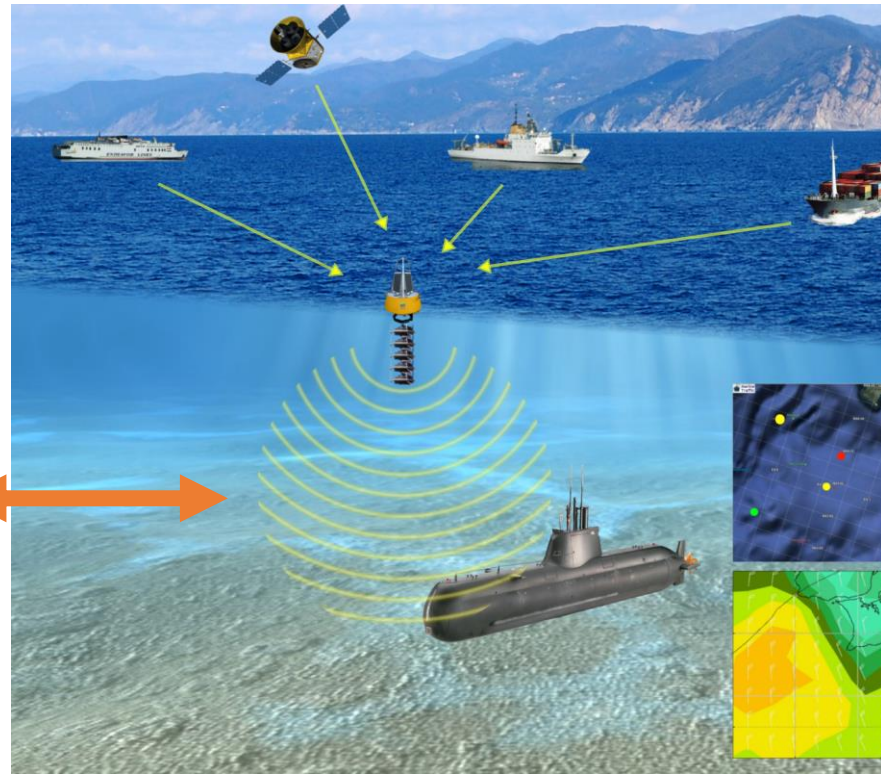
Joint Cognitive Systems View

- Dynamics of people, tools, environment, tasks interactions
  - E.g. Decision cycles vs. choice points
- How to identify and support those interactions
- How to anticipate the inevitable emergent properties
- How to support “muddling through” wicked/emergent challenges

Team:
Authorities
Roles
Responsibilities
Knowledge
“Intelligent agents”

Task:

- Goals
- Values
- Constraints
- Resources



Individual:
Experience
Knowledge
Mental models

Technology:

- Sensor feeds
- Representations
- Decision aids
- Models
- Processing
- “Intelligence”

Operating Context:

Constraints?
Adversaries?
Dynamic?
Unpredictable?

Models, models, everywhere…

- People
  - User models/inference modelling
  - Behaviour (e.g. crowd modelling)
- Characterising Operating Contexts (in tools/aids)
  - Blast effects
  - Fire behaviour
  - Dynamics of movement (different vehicles over terrain)
  - Dynamics of resource consumption
  - Etc. etc.
- Supporting
  - Inference/reasoning
  - Prediction

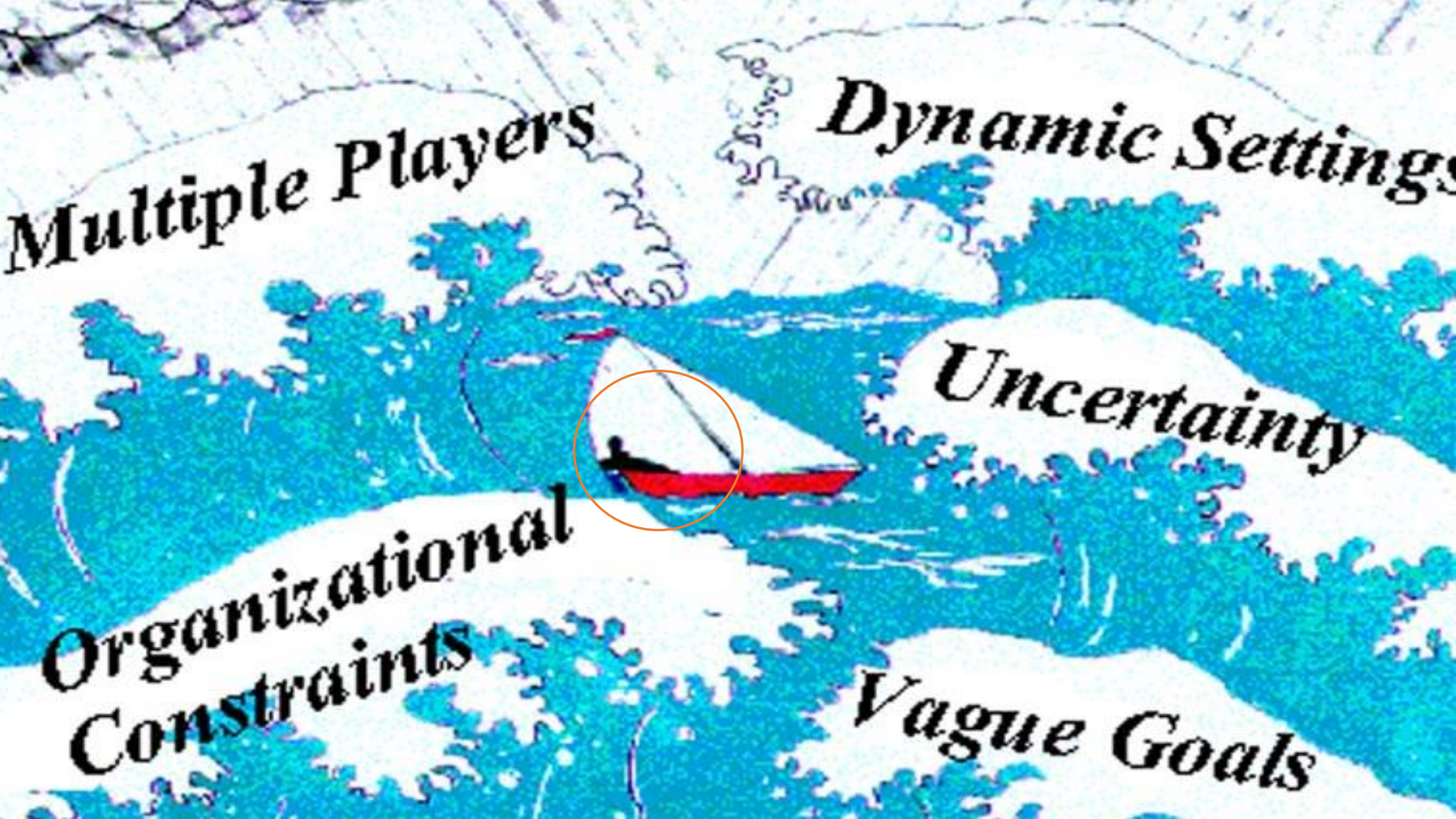
Joint Cognitive Systems – Cognition in a work Context

- Distributed cognition – not just “in the head”
  - “Intelligent” artefacts/systems
  - Intelligent agents
  - Other people
- Situated cognition – not just “in the head”
  - Perception-action cycle (Hutchins, 1995; related to Gibson’s ecological psychology)
  - Affordances (active psychophysics)
- Expertise – making the most of experience
  - Sophisticated mental models
  - Heuristics
  - Situation-action patterns
  - Seeing the invisible
  - Seeing “the differences that make a difference”
- Macrocognitive models – professionals making decisions at work/purposeful

How we might use models…

Models to support…

What we might use models for…


Multiple Players
Dynamic Settings
Uncertainty
Organizational Constraints
Vague Goals

Cognitive Systems Engineering (CSE)

- Understanding the work that needs to be supported
  - Cognitive task/work analysis
  - Macrocognition: decision making; sensemaking; planning; coordinating
    - Under uncertainty
- Design requirements (system and user)
  - Inc. application of HF design principles/guidance
  - Inc. application of “intelligent systems” (inc. models and modelling of “work”)
- Evaluation
  - Identify measures of performance
  - Manage human-system performance variability

Human Performance Perspective

- “a sense of doubt that blocks action” (Lipshitz & Strauss, 1997)
- Uncertainty is an emergent property of:
  - People (experience, individual differences)
  - Tasks (relevance of information)
  - Environment (physical vs. intentional; structured vs. ill-structured)
  - Technology (sensors and interfaces)
- Uncertainty is not on objective property if data

Uncertainty's Many Guises

- **Situation**
  - Is X there? (detection)
  - What is X? (identification)
  - Is there a problem/threat? (problem)
  - What is going on? (sensemaking)
  - What will happen next? (projection, forecasting)
  - What just happened? (explanation, postmortem)
  - Are we achieving our goals? (goal monitoring, control)
- **Goal**
  - What are we trying to do?
  - Is there a conflict in goals? How do we resolve it?
  - Are the current goals still applicable/appropriate?
- **Resource**
  - What are our capabilities?
  - What are our resources?
- **Method**
  - What should we do?
  - What are we going to do?
  - Which is the better option?
- **Outcome**
  - How will this turn out?
- **Team/Own**
  - How are we doing?
  - Do we share goals?
  - Do we share understanding of the situation?

Models & Decision Making: A Double Edged Sword?

- Models can help us reduce uncertainty
  - Supporting mental models
  - Tools with models that support mental processes underpinning decision making:
    - filling in gaps in understanding
    - (mental) simulation of a situation or of a course of action

- Provided they don’t add to the uncertainty
  - Opacity
    - Rationale
    - Trust
    - Values
  - Complex
  - Inaccurate
  - Overly precise (e.g. Satnav route options: A vs. B?)
  - Etc.

A final thought… managing uncertainty…

Blackadder: Baldrick, what are you doing out there?

Baldrick: I'm carving something on this bullet sir.

Blackadder: What are you carving?

Baldrick: I'm carving "Baldrick", sir.

Blackadder: Why?

Baldrick: It's a cunning plan actually.

Blackadder: Of course it is.

Baldrick: You see, you know they say that somewhere there's a bullet with your name on it?

Blackadder: Yes?

Baldrick: Well, I thought if I owned the bullet with my name on it, I'd never get hit by it, 'cos I won't ever shoot myself.

Blackadder: Oh, shame.

That's All Folks!!

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Supporting Uncertainty Management through Interface Design

- Goal: to support uncertainty management through interface design
- Issues:
  - Nature of uncertainty
  - Uncertainty management (UCM) in complex, dynamic domains
  - Implications for interface supports
- Three phases
  - Analytic based lit review and discussion
  - Empirical based on verbal transcript analysis
  - Dissertation research based on hypotheses from models

Perspectives: Old & New

- Normative Decision Theory
  - Bayesian
  - Subjective Expected Utility
- Heuristics and Biases
- Cognitive Science
  - Problem solving (HPS; Non-linear PS)
  - Computer Science
- Naturalistic Decision Making
- Ecological Psychology
  - Control theory metaphor
  - Adaptive behavior (reciprocity of behavior and environment)

Uncertainty as Objective Property of Data

- Uncertainty is often treated as an objective property of the data
  - Accuracy
  - Reliability
  - Confidence/certainty value
  - Measurement error
- Uncertainty can therefore be represented as a property of individual datum using
  - Error bars
  - Confidence intervals
  - Fuzzy boundaries

Typical Focus: Sensor Uncertainty

- Technology provides mediated representation of the environment.
- What is the sensor coverage (where do we not have sensors)?
- What can those sensors pick up?
  - Reliability
  - Sensitivity limitations (uni-dimensional)
  - Resolution (how fine are the discriminations?)
- How current is the data?
- Hypothetical data points (generated for planning?)
  - Based on what assumptions, extrapolations, etc.?

Typical Focus: “Decision” Uncertainty

- Typically, decision making under uncertainty has reflected **uncertainty about outcomes and/or methods (courses of action)**:
  - What is the likelihood of a favorable outcome (e.g. gambling)?
  - Which method will provide the best utility (choice tasks, e.g. which house to buy)?
- Uncertainty management in each case boils down to:
  - Reasoning about probabilities (Bayesian)
  - Calculating utility (subjective expected utility; multi-attribute utility analysis)
- Typically, the relevant tasks are well-specified
  - Goals or choices are provided
  - Task is static
  - Outcomes are probabilistic (providing a normative standard of performance)

Technology Making Us Stupid…

- Klein (2003), technology can handicap operator skill, knowledge and expertise by:
  - Disconnecting us from data
  - Limiting how we search for data
  - Weakening mental models
  - Hiding rationale for solutions
  - Making us less adaptive/more rigid
  - Making us passive
- Norman (1990, 1991): The problem of feedback
  - American Eagle Flight 4184 – icing problem
  - The automation failed at the most critical moment, presenting the operator with an extreme challenge

Eye in the Sky – film clips

- https://www.youtube.com/watch?v=grBtXQYZZUU
- CDE - https://www.youtube.com/watch?v=kksqu10Wq-8