ISRCS 2012

A Dual-Process Cognitive Model for Testing Resilient Control Systems

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Deter Project

USC Information Sciences Institute

The DETER Project: science of cybersecurity

- A research program:
  - To advance capabilities for experimental cybersecurity research
- A testbed facility:
  - To serve as a publicly available national resource…
  - … supporting a broad base of users and experiments
  - … and act as a technology transfer and evangelization vehicle
- A community building activity:
  - To foster and support collaborative science…
  - …effective and efficient leverage and sharing of knowledge

DETER Research Goals

- Advance our understanding of of experimental cybersecurity *science and methodologies*
  - Enable new levels of rigor and repeatability
  - Transform low level results to high level understanding
  - Broaden the domains of applicability
- Advance the *technology of experimental infrastructure*
  - new levels of function, applicability, and scale
- Share knowledge, results, and operational capability

Human behavior and security

BBC Mobile

phish 1 of 1

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3 August 2011 Last updated at 08:45 ET

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Governments, IOC and UN hit by massive cyber attack

By Daniel Emery
Technology reporter, BBC News

IT security firm McAfee claims to have uncovered one of the largest ever series of cyber attacks.

It lists 72 different organisations that were targeted over five years, including the International Olympic Committee, the UN and security firms.

McAfee will not say who it thinks is responsible, but there is speculation that China may be behind the attacks.

The report says the cyber attacks had been going on since 2006

Related Stories

Most attacks rely on human action

[Crawford 06]

Inadvertent Insider Threat

Clumsy staff more dangerous than hackers: survey

Data breaches cost local business up to $1 million

Darren Pauli (Computerworld) — 23 October, 2008 12:41

Humans and system testing

- Human **error** may defeat otherwise resilient systems
- Humans are also **robust and flexible** to changes
- Human **behavior** affects environment model.

  e.g. **Task-oriented collaboration** impacts traffic patterns
- Human goals and **workflow** allow more focused measure of system resiliency

Approach: Multi-agent model of aspects of human behavior

- Test beds must model impact of human activity for experimentation
  - **But** real humans are expensive and non-repeatable
- Model human characteristics
  - Limited knowledge and attention
  - Flexibility to changing conditions
  - **Here: Decision biases based on architecture**
- Model goal-directed team activity
  - Measure impact of an attack on team goals
  - Model impact of organization structure
- Configurable tool for experimenters

Related work

- Human reliability analysis (HRA) e.g. Kelly et al. 11, human factors research
- Other models of bounded rationality e.g. Prospect theory
- Other cognitive architectures e.g. SOAR, ACT-R.

Desired properties for agents simulating humans

- Responsive to changes in the environment
- Effective behavior with limited knowledge
  - Mental models, analogy
- Model known heuristics and biases in judgment
  - E.g. confirmation bias, belief bias, anchoring, endowment, ..
- Model effects of limited attention
  - Distractions, fatigue

Our approach: DASH (Deter Agents Simulating Humans)

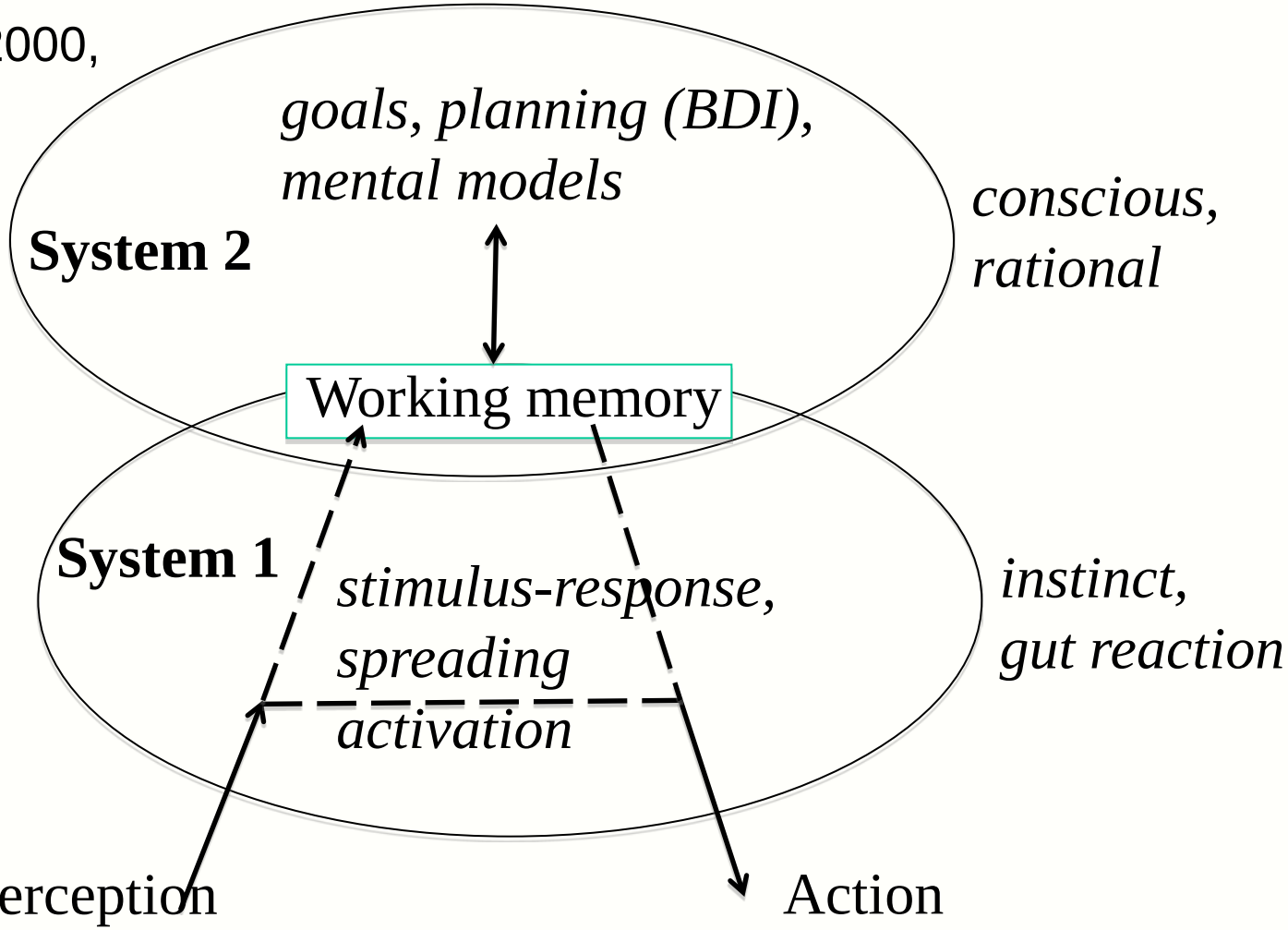
- Responsive to changes in the environment
  - BDI architectures [Bratman 87; Blythe et al. 2011]
- Effective behavior with limited knowledge
  - Mental models, analogy
  - Implementing mental models [Gentner & Stevens 83; Blythe 2012]
- Model known heuristics and biases in judgment
  - E.g. confirmation bias, belief bias, anchoring, endowment, ..
- Model effects of limited attention
  - Distractions, fatigue

Dual-process model

Dual-process cognitive models

Stanovich & West 2000,
Kahneman 2012

(Examples include
SOAR and ACT-R)

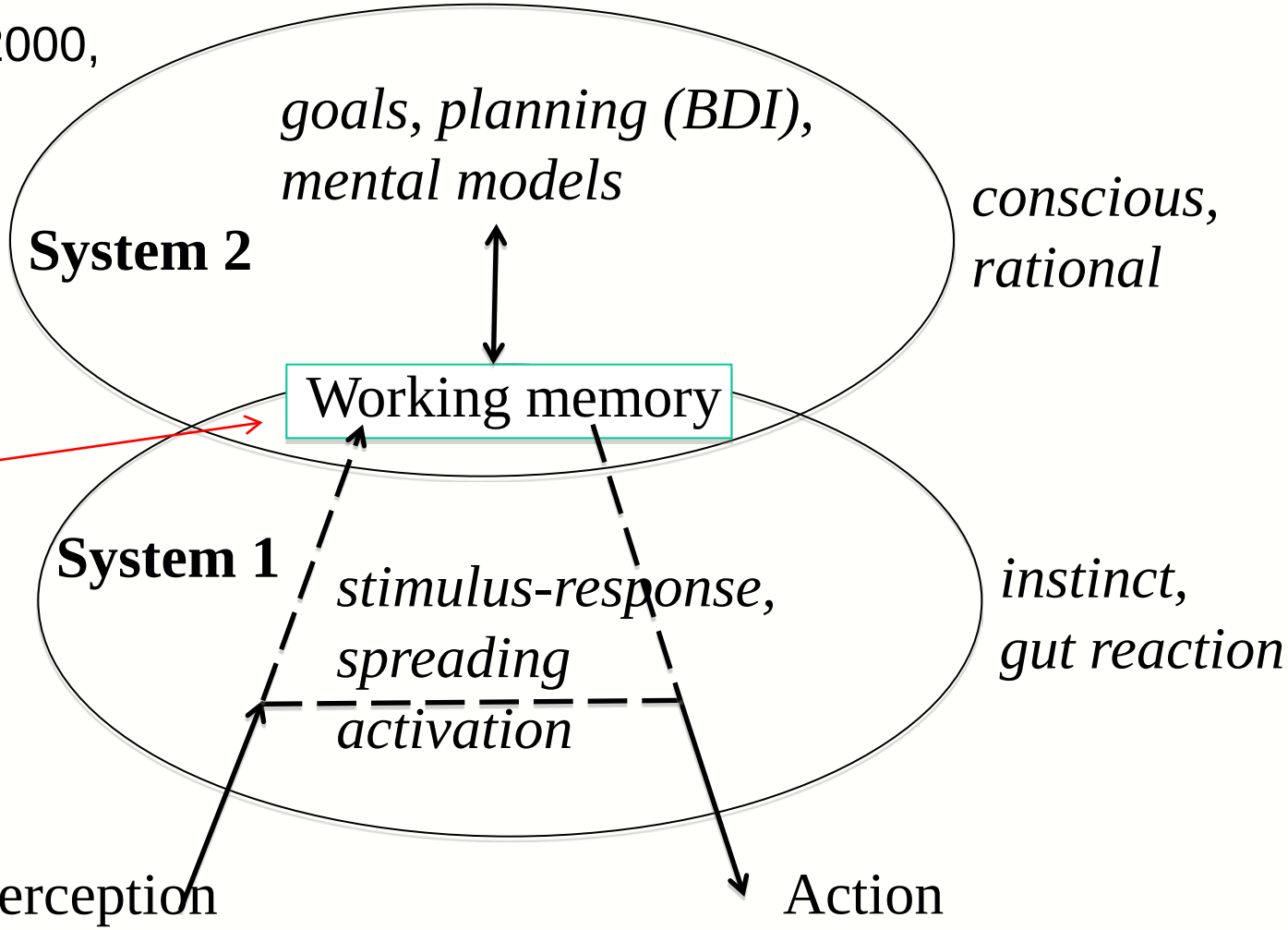


Dual-process cognitive models

Stanovich & West 2000, Kahneman 2012

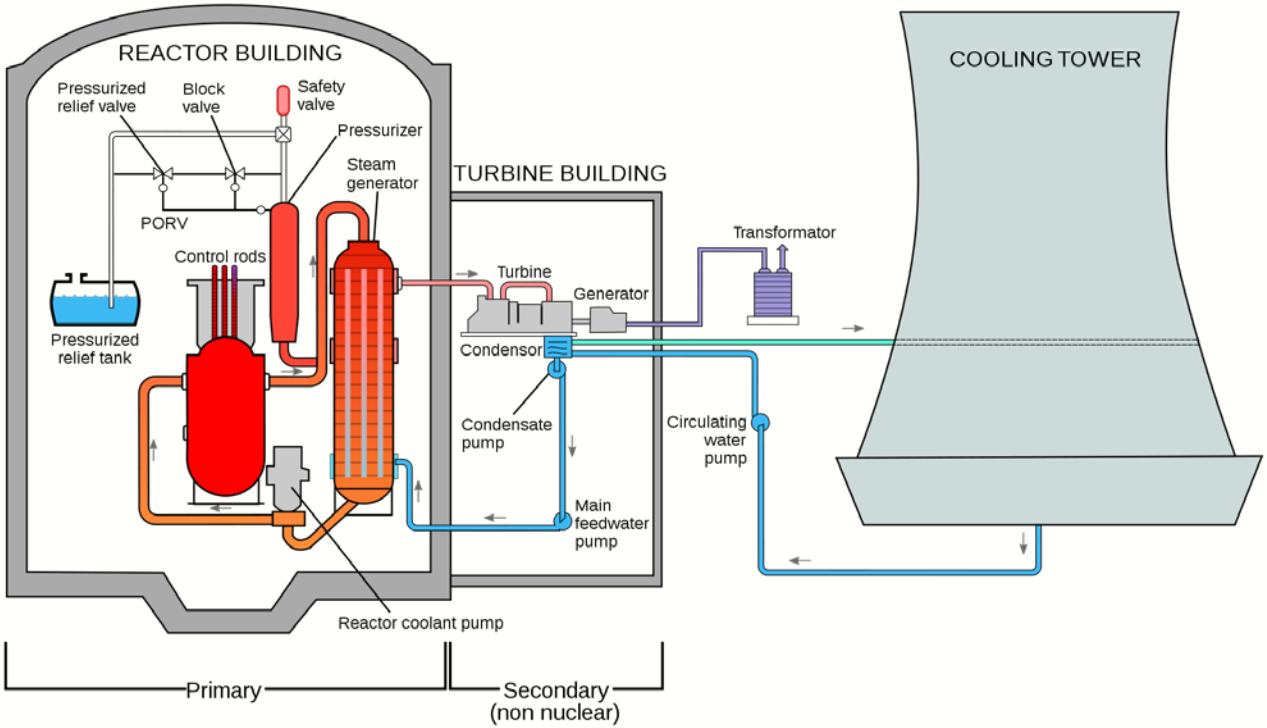
(Examples include SOAR and ACT-R)

System 2's world is filtered by System 1 to allow focus



How can dual-process models capture biases?

Example scenario: Three-mile island and confirmation bias



Confirmation bias

- One (oversimplified) explanation of human operator behavior: **confirmation bias**
  - Given belief of over-pressurization, confirmatory evidence (pressure sensor, PORV relay reading) used over disconfirmatory (core temperature)

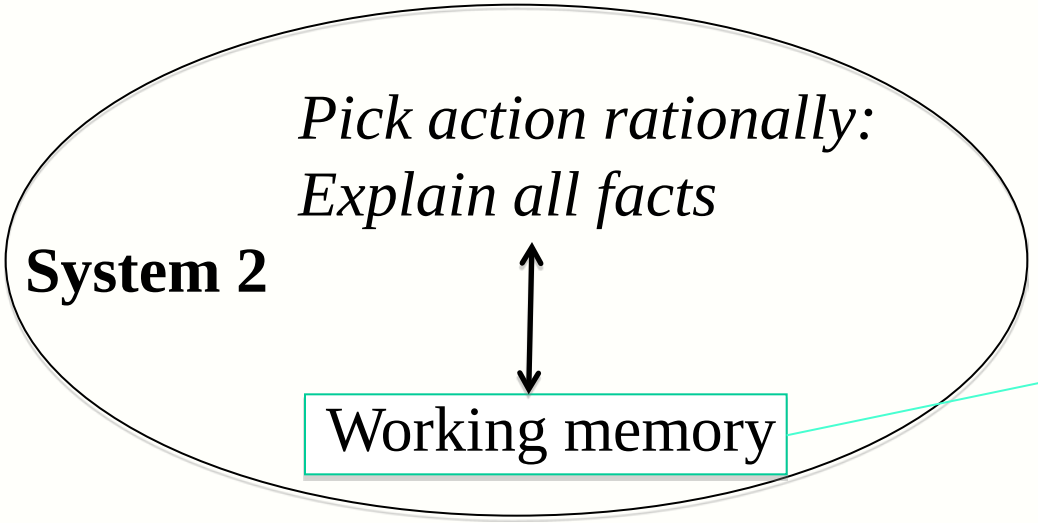
- In dual-process architecture, system 1 forms belief quickly based on stimulus rules.
- The Belief increases activation of aligned facts and decreases for disconfirmatory.
- Given an activation threshold, System 2 is never made aware of disconfirmatory facts.

- Operators should have deliberately sought disconfirmatory data, but fatigue and signal overload led to System 1 overriding System 2.

Implementation in DETER agent model

System 1 hypothesizes over-pressurization partly because of training

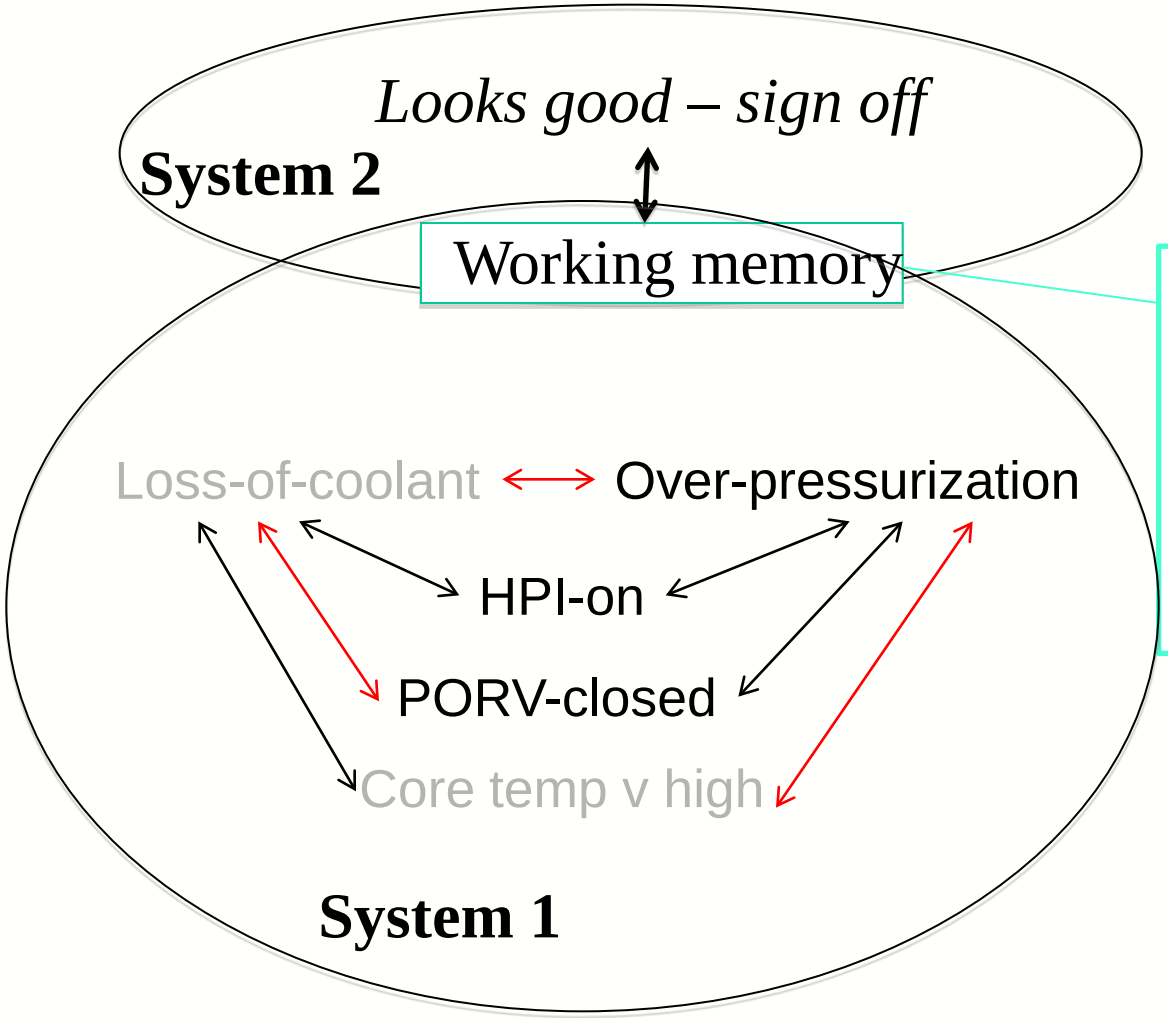
If System 2 gets all relevant signals, their incoherence causes it to override and "step back"



From System 1:

Over-pressurization:
HPI is on
PORV is closed
Core temp. very high
Turn HPI off

Spreading activation biases working memory



From System 1:

Over-pressurization:
HPI is on
PORV is closed
~~Core temp. very high~~
Turn HPI off

Summary

- Modeling some human behaviors can improve fidelity in test systems
  - What-if modeling for interface design
  - More accurate testing for automatic defense mechanisms
- Dual-process approach can model several human biases in one architecture
  - confirmation bias, anchoring, belief bias
- Implemented in DASH. Available for testing this fall.
- Works in concert with models of responsive planning and limited knowledge

Current work

- Computational emotion models work well with dual-process models, under development [Lin et al 11]
- Used to duplicate results from phishing studies that indicated attention/distraction effects [Dhamija 06; ..]
- Designing experiments to test and calibrate model.
- Looking for DASH beta users in the fall

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