

**Simulated Task Environments:
The Role of High-Fidelity Simulations, Scaled
Worlds, Synthetic Environments, and Laboratory
Tasks in Basic and Applied Cognitive Research**

Gray, W. D. (2002). *Cognitive Science Quarterly*, 2(2), 205-227.



Topic

- Simulations of the Task Environment
- How do various Task Environment Simulations differ?
- What inferences do different types of Task Environment Simulations permit us to draw?

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Outline

- The Problem
- Distinctions, Dimensions, Definitions
- Examples
- Scaled Worlds

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The Problem

In field research there is too much [complexity] to allow for any more *definite* conclusions; whereas, in laboratory research there is usually too little complexity to allow for any *interesting* conclusions.

Brehmer, B. & Dörner, D. (1993). Experiments with computer-simulated microworlds: Escaping both the narrow straits of the laboratory and the deep blue sea of the field study. *Computers in Human Behavior*, 9(2-3), 171-184.

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Varieties of Simulated Task Environments

- Hi-Fidelity Simulations of Complex Systems
 - ◆ Mainly military and transportation
- Hi-Fidelity Simulations of Simple Systems
- Scaled Worlds
- Synthetic Environments & Microworlds
- Laboratory Task Environments

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Hi-Fidelity Simulations of Complex Systems

- Attempt to mimic the complexity of the real world but in a fail-safe environment
 - ◆ Examples: commercial flight simulators, nuclear power plant simulators, and many simulators used by the military
- Often used to train teams
 - ◆ Examples: flight crew, battalion of soldiers (approx. 900 people)

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Hi-Fidelity Simulations of Simple Systems

- Hi-fidelity simulations are not necessarily complex
 - ◆ One subsystem of a more complex system may be built as a stand-alone simulation; for example, Irving, Polson, and Irving used a simulation of the flight management computer used by commercial airline pilots to evaluate part-task training
 - ◆ The system itself may be relatively simple as, for example, a simulation of a VCR or global positioning system (GPS)

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Scaled Worlds

- Attempt to generalize to a particular task environment
 - ◆ A scaled world retains certain functional relationships, while paring away others
 - ◆ Can be multiple scaled worlds of the same complex, real-world task that differ on which functional relationships are retained and which are pared away
 - ◆ The nature of the research question determines what is retained and what is pared away

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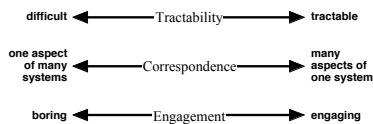
Synthetic Environments and Microworlds

- Theory is foremost, but be primarily applied or primarily basic
- Complex --> Less Complex
 - ◆ abstract functional relationships from one or more complex task environments and
 - ◆ to study these functional relationships in a less complex, make-believe world, or
- Simple --> Less Simple
 - ◆ Build synthetic environments to study how a simple research construct functions in a more complex environment

Simple Laboratory Environment

- No clear dichotomy between simulated task environment and traditional laboratory tasks
- What is considered a simple task depends on the research question of interest
 - ◆ Example: paradigm used to study role of effort on decision making

Three Dimensions of Simulated Task Environments



Dimensions are defined by differences in perspective between the researcher, the task, and the participant

The Researcher's Perspective: Tractability

- A thing is tractable if it is "(1) easily managed, taught, or controlled" or "(2) easily malleable" (Webster's New World Dictionary of the American Language, 1960)
- Key issue is whether the simulated task environment allows the researcher to productively pursue the research question of interest.

The Researcher's Perspective: Tractability

- Includes issues such as
 - ◆ Managed or controlled
 - The dynamic tension in all experimental research is between control and complexity. We wish to explain phenomena that occur in the world. Important parts of this explanation include
 - Analysis of complex phenomenon into simpler phenomena
 - Description of each of these simpler phenomena
 - Description of how one phenomenon is influenced by another
 - Different parts of this explanation may require that research be conducted in different task environments.
 - Example of Argus for serial attention

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The Researcher's Perspective: Tractability

- ◆ Training issues
 - Examples, 777 simulation, Ned, etc
- ◆ Easily worked, malleable
 - Data collection (the right data, at the right grain size, with the right timestamp)
 - Usability issues

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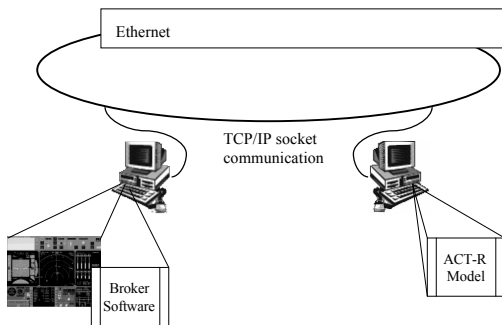
The Researcher's Perspective: Tractability

- ◆ Models as Users
 - More common alternative is to simulate the simulated task environment in the modeling environment
 - A tractable to solution to problem of getting two independent computer programs to communicate
 - But, easy to leave out an important feature of the simulated task environment
 - May be possible to communicate with commercial software as did Wolfgang Schoppek with ACT-FLY

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Communication between ACT-R Model and the Flight Simulator



The Researcher's Perspective: Tractability

■ For Models as Users -- cont'

- ◆ But, often run into limits due to how the software is written
- ◆ Best solution is to write the software yourself!

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The Task's Perspective: Correspondence

1. "The act, fact, or state of agreeing or conforming. 2. Similarity or analogy." (The American Heritage Dictionary of the English Language, 2000)

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The Task's Perspective: Correspondence

- High correspondence simulated task environments simulate many aspects of one system
- Low correspondence simulated task environments simulate one aspect of many systems

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The Participant's Perspective: Engagement

- “1. To involve oneself or become occupied; participate: ‘engage in conversation’ 2. To assume an obligation; agree.” (The American Heritage Dictionary of the English Language, 2000)

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Definitions: Engagement

- The simulated task environment is engaging to the degree to which it involves and affects the participants; that is, the degree to which they take it seriously

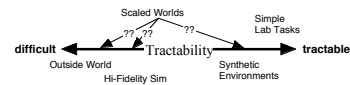
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Simulated Task Environments

- Where do the various types of simulated task environments fall on the three dimensions?

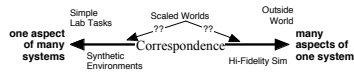
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Dimension: Tractability

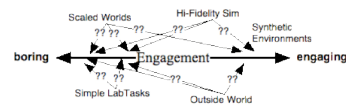


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Dimension: Correspondence



Dimension: Engagement



How Simulated Task Environments vary on Tractability, Correspondence and Engagement

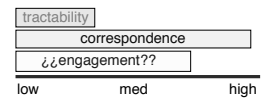
■ Four examples

- ◆ Flight Simulator
- ◆ VCR
- ◆ Argus
- ◆ Ned

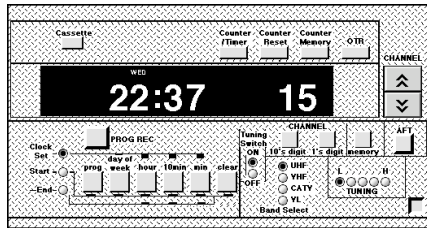
■ Each is followed by a discussion of whether it is or is not a scaled world

Example: Flight Simulator

- As High Fidelity as \$\$\$ and current technology can provide
- Is it a scaled world? NO

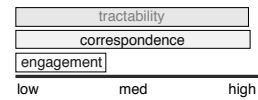


Example: VCR -- A High Fidelity Simulation of a Very Simple Task



Is the VCR a Scaled World?

- No -- more like a high fidelity simulation of a low complexity task



The Transmutation of the VCR Simulated Task Environment

- From Hi-Fidelity simulation of a simple task environment to synthetic environment
- VCR 1.0 was designed to establish our error basic taxonomy and approach to studying errors of procedural skill; it was important that the simulation be based on a widely used, commercially designed product

Changes to the VCR

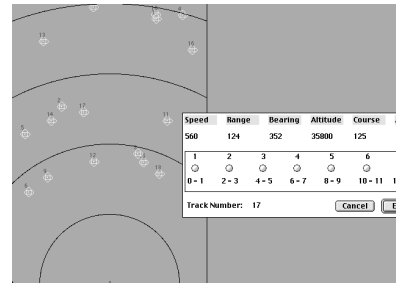
- Now used as a tool to study tradeoff between perceptual-motor and cognitive effort
- A hi-fidelity simulation of a VCR was not required
- Could use any simulated task environment that
 - ◆ Provided clear separation between using the task interface versus accessing information for the task.
 - ◆ Would not force users to keep or manipulate information in-the-head
 - ◆ Enabled us to manipulate the perceptual-motor effort involved in accessing information.

VCR Changes

- This line of work shifted from requiring a hi-fidelity simulation of a simple system to requiring a synthetic environment
- The current generation STE for this work is a Cognitive Interface Tool that allows us to directly manipulate the three cognitive engineering principles described by Gray (2000)

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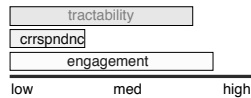
Example: Argus



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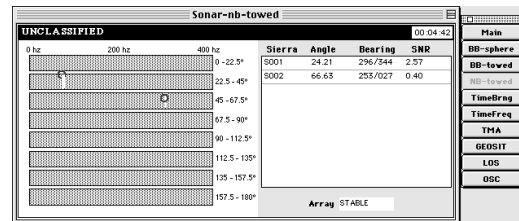
Is Argus a Scaled World?

- No -- Lacks the relation to a complex, real-world task that defines a scaled world
- It is a Synthetic Environment
 - ◆ Focus is on the study of interactive behavior under conditions of high workload



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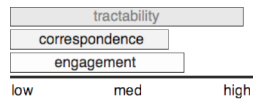
Example: Ned



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Is Ned a Scaled World?

■ Yes



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Design Goals for Ned

- Has been carefully designed to retain certain functional relationships of a complex, real-world task
- The functional relationships retained were defined by the goals of the study
- Most other functional relationships have been pared away
- Specifications for Ned arose from
 - ◆ Studying and listening to submarine Approach Officers

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Research Goals for Ned (1)

- Functional Relationships
 - ◆ Project goals entail the description and simulation of the cognitive processes and memory structures used by Approach Officers in locating enemy submarines
- Impact on Cognitive Theory
 - ◆ To be able to say something new and different about the expertise required for performing a complex, event-driven task

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Research Goals for Ned (2)

- Generalizability
 - ◆ Our goal is to be able to generalize the data and models of Ned to a new, unknown submarine, with reduced manning, and new instrumentation
- Caveat: "generalizability may be hindered by excessive attention to mundane realism" (DiFonzo, Hantula, and Bordia 1998)

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Ned on the Tractability Dimension

- Ten displays with no overlapping information
- Each object clicked is time stamped to nearest tick (60hz) and saved to a log file
- Researchers can “play back” Approach Officer scenarios
- Computational cognitive models written in ACT-R can use Ned in same manner that our Approach Officers do.

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Ned on the Correspondence Dimension

- We decreased correspondence
 - ◆ by paring away the functional relationships provided by the Approach Officer’s interactions with his crew and boat
- But, we maintained an information environment in which the functional relationships essential to our goals were preserved
- Used scenarios that represented situations familiar to the Approach Officer

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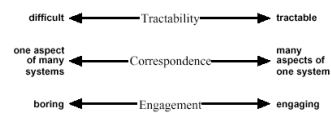
Ned on the Engagement Dimension

- Ned maintains a reasonable level of engagement
 - ◆ but only for those with much prior submarine experience -- i.e., not suitable for this audience!!
- The engagement arose from presenting Approach Officers with scenarios, information types, and displays that were recognizable as similar to those encountered in real missions

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Dimensions Revisited



Summary: Tractability

■ Tractability

- ◆ Simple Lab Environments \geq Synthetic Environments \geq Scaled World $>$ High Fidelity Simulation
- ◆ Tractability is defined by the needs of the research question

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Summary: Correspondence

■ Correspondence

- ◆ Hi-Fi simulation $>$ Scaled World $>$ Synthetic Environments $>$ Simple Lab Environment
- High correspondence simulated task environments simulate many aspects of one system
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Summary: Engagement

- The simulated task environment is engaging to the degree to which it involves and affects the participants; that is, the degree to which they take it seriously

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The End

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