Some Futures for Cognitive Modeling and Architectures: Approaches that You Can Too

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These include: (a) Interacting directly with the screen-as-world. It is now possible for models to interact with uninstrumented interfaces both on the machine that the model is running on as well as remote machines. Just one implication is that this will force models to have more knowledge about interaction, an area that has been little modeled, but essential for all tasks. (b) Providing a physiological substrate to implement behavioral moderators' effects on cognition. Cognitive architectures can now be more broad in the measurements they predict and correspond to. This approach provides a more complete and theoretically appropriate way to include stressor effects and emotions in models. (c) Fitting models to data using genetic algorithms. This can lead to model overfitting, but it can also be seen as a way to understand and predict how people are different in their underlying parameters using a multi-variable non-linear stochastic multiple-output regression (aka model fitting). It can also lead to a greater understanding of our models.

Supported by ONR, N00014-15-1-2275, N00014-03-1-0248 and N00014-06-1-0164
AFRL, DARPA, DERA, DMSO, DRA, DSTO, DTRA, NSF

Thanks to collaborators: ACS Lab, Robert St. Amant, Farnaz Tehranchi,
Chris Dancy, AOS (Lucas, Evertsz, Pedrotti), Bittner, Drew Pruett, Robert Hester
Sue Kase, Mike Schoelles, Jeanette Bennett, Laura Klein
Charles River Analytics (Weyhrauch, Lynn), Carley

Overview of Talk

(0) Brief **overview of architectures** 📖/📖/🎁

(a) **Model eyes and hands,** interacting directly with the screen-as-world. It is now possible for models to interact with uninstrumented interfaces both on the machine that the model is running on as well as remote machines. Just one implication is that this will force models to have more knowledge about interaction, an area that has been little modeled, but essential for all tasks.

(b) Providing a **physiological substrate** to implement behavioral moderators' effects on cognition. Cognitive architectures can now be more broad in the measurements they predict and correspond to. This approach provides a more complete and theoretically appropriate way to include stressor effects and emotions in models.

(c) **Fitting models using GAs.** This can lead to model overfitting, but it can also be seen as a way to understand and predict how people are different in their underlying parameters using a multi-variable non-linear stochastic multiple-output regression (aka model fitting). It can also lead to a greater understanding of our models.

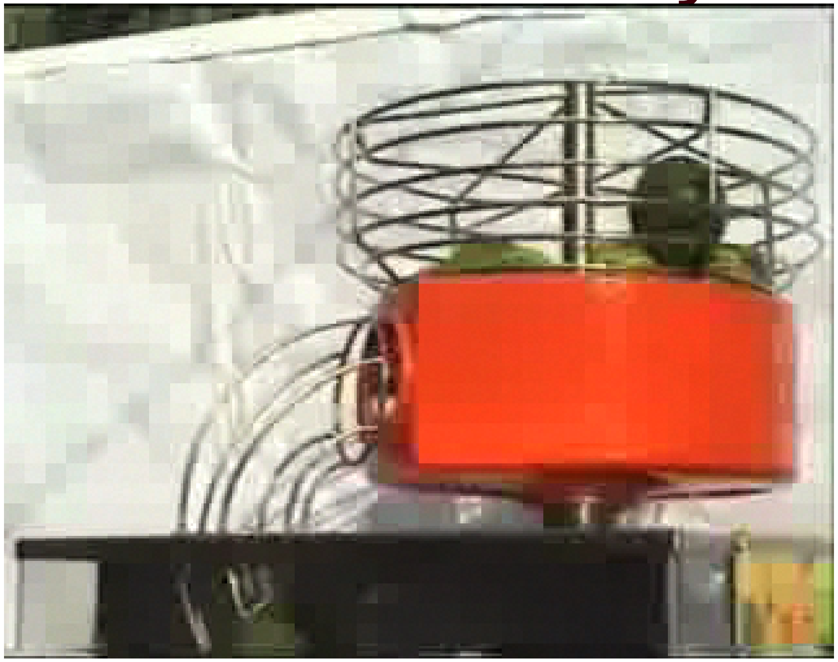
Intended to be helpful, slightly humorous, and I'll be as glad as you are when its over!

Or, how to be less happy because you take account of more behavior.

High level view with some low-level advice. 10Q for chance to reflect.

Cognitive Models and Architectures

- A program that models human behaviour by generating it using *fixed mechanisms*
  - Includes interaction
  - May include affect
  - Mechanisms are fixed

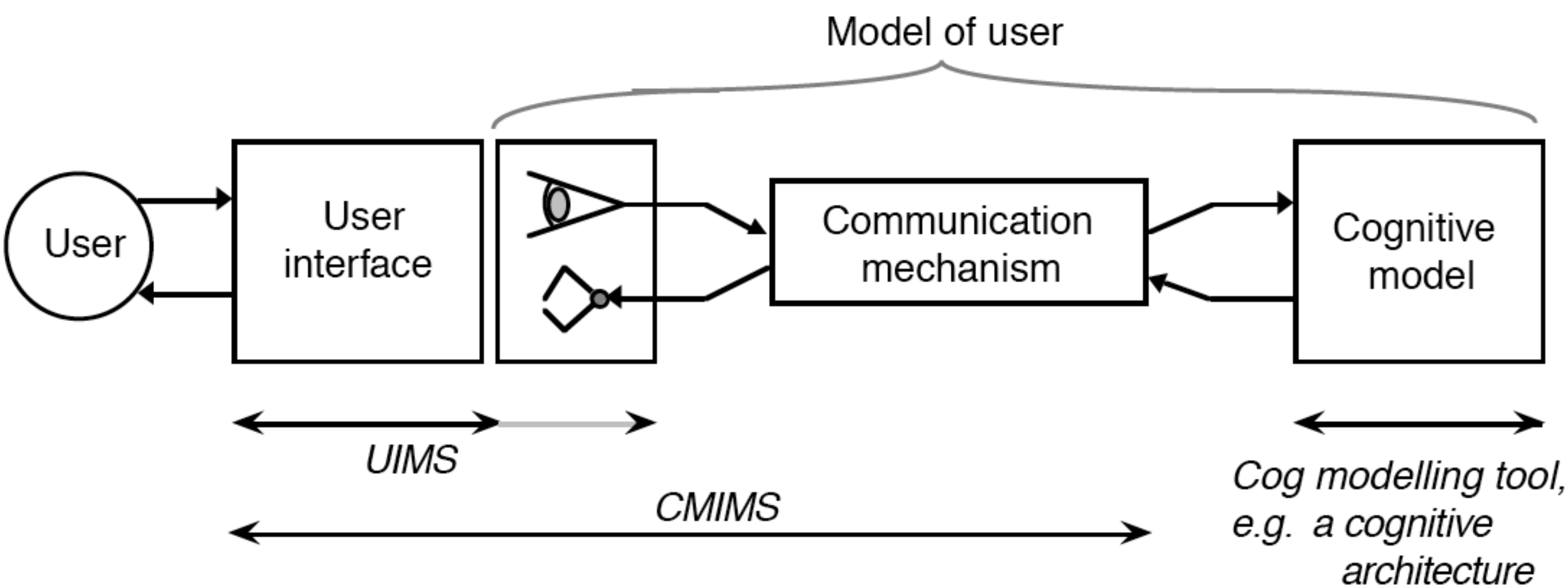


- Architecture + Task Knowledge = Behavior
- Projects on extending architecture

(Newell, 1990, *Unified Theories of Cognition*)
(Newell, 1992, Desires and Diversions, YouTube)

Future 1: Simulated Eyes and Hands

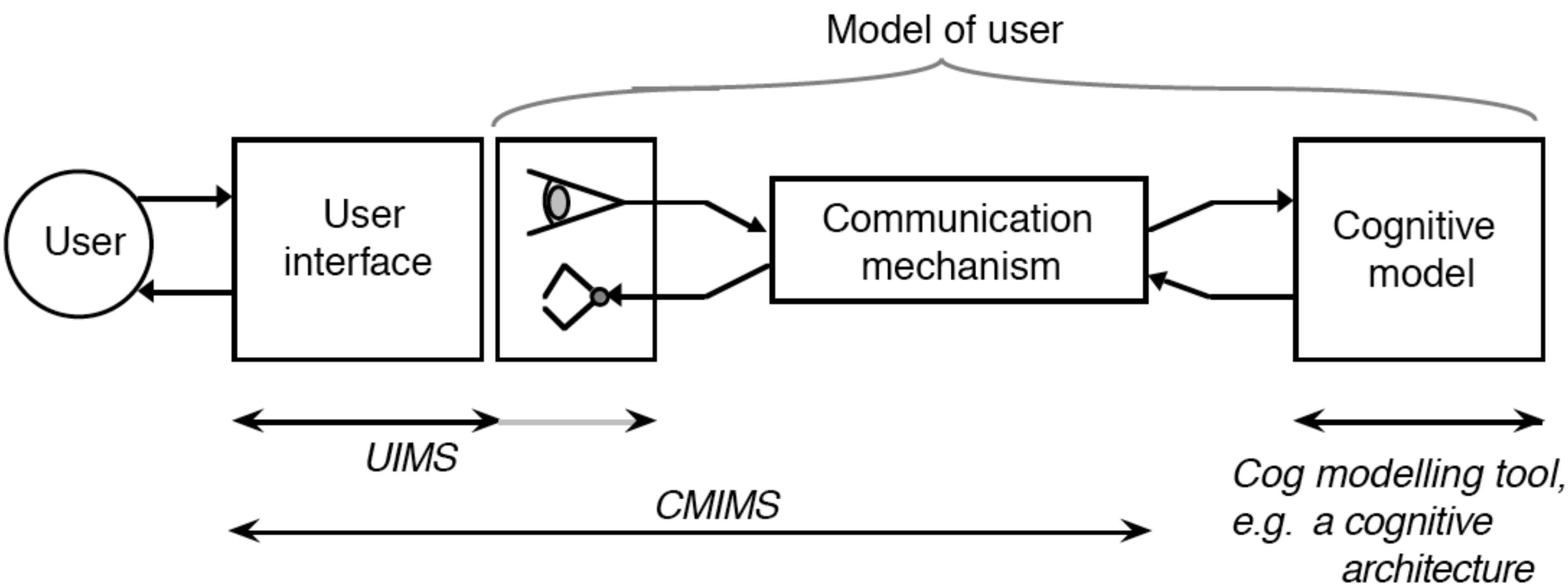
- Provide models/architectures ties to the world



(Ritter, Baxter, Jones, & Young, 2000)

F1: Simulated Eyes and Hands

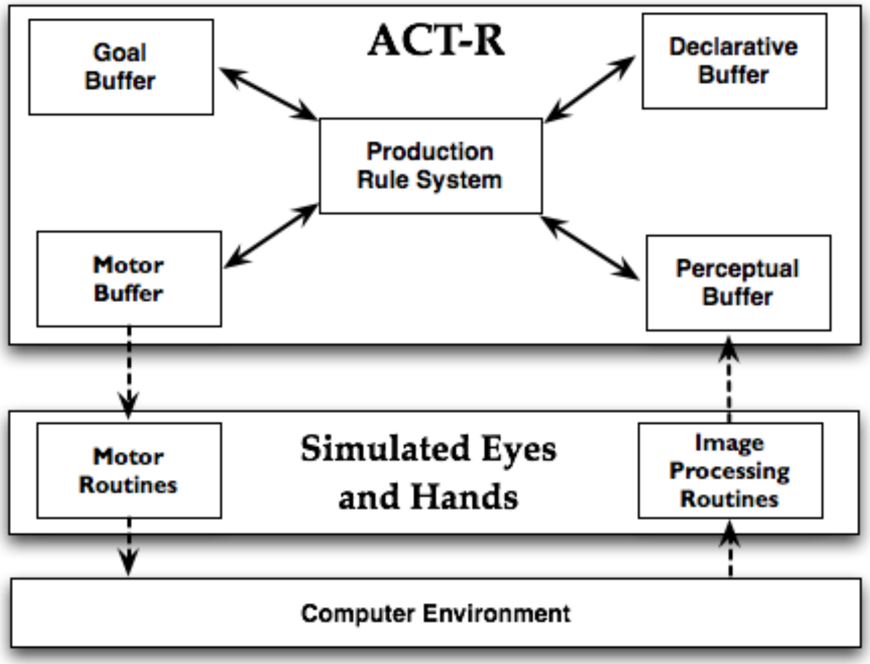
- You can instrument (a) the task, (b) the graphics library, (c) the operating system, or (d) build a whole new task



(Ritter, Baxter, Jones, & Young, 2000, *ToCHI*)

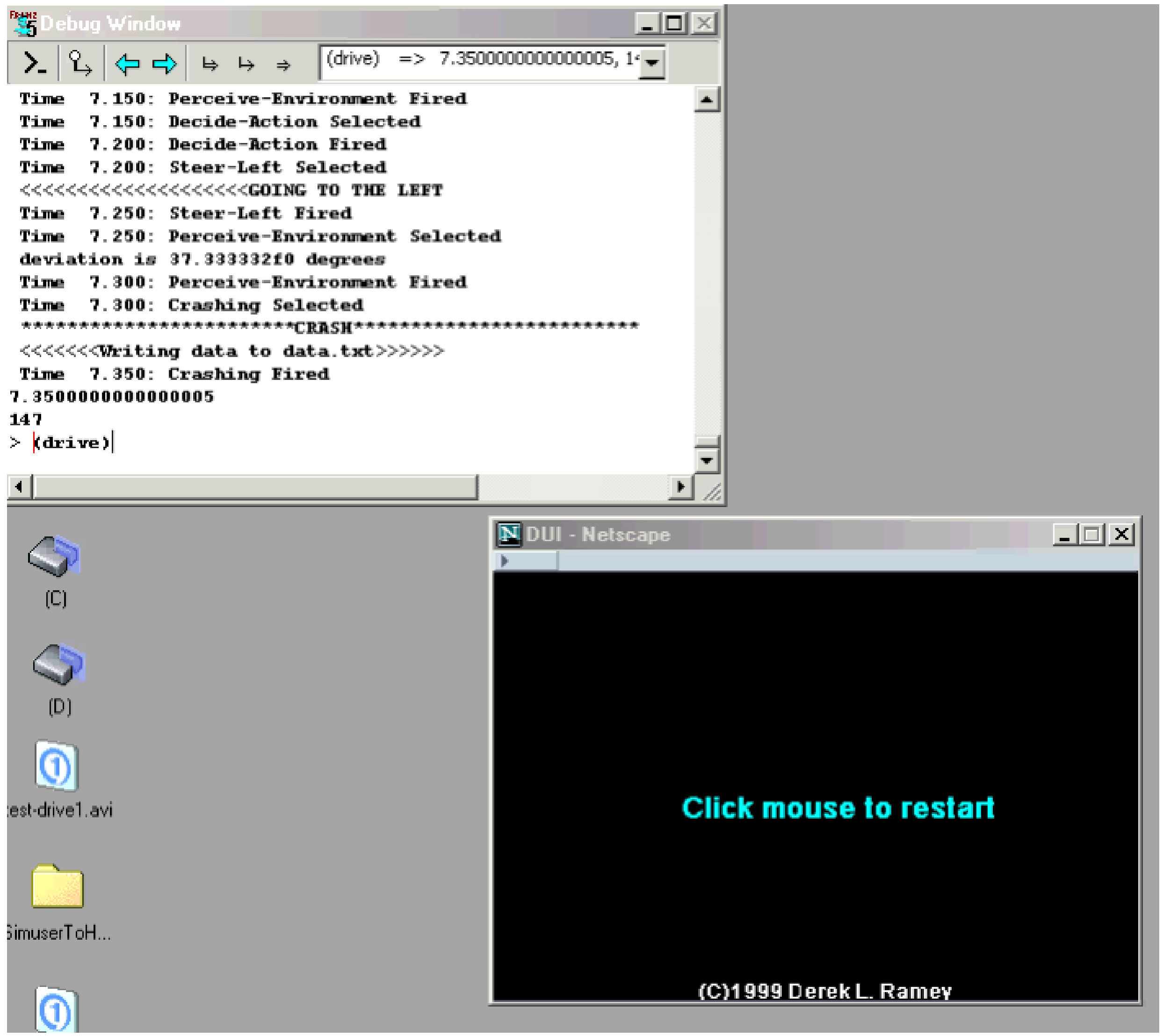
F1: Simulated Eyes and Hands

- We have worked with ACT-R in particular
- Need simulated eyes and simulated hands
- Within interfaces, the world is restricted
  (St. Amant, 2000)



F1: Simulated Eyes and Hands

- Previous examples Java driving game



(Ritter, Van Rooy, St. Amant, & Simpson, 2016)

F1: Simulated Eyes and Hands

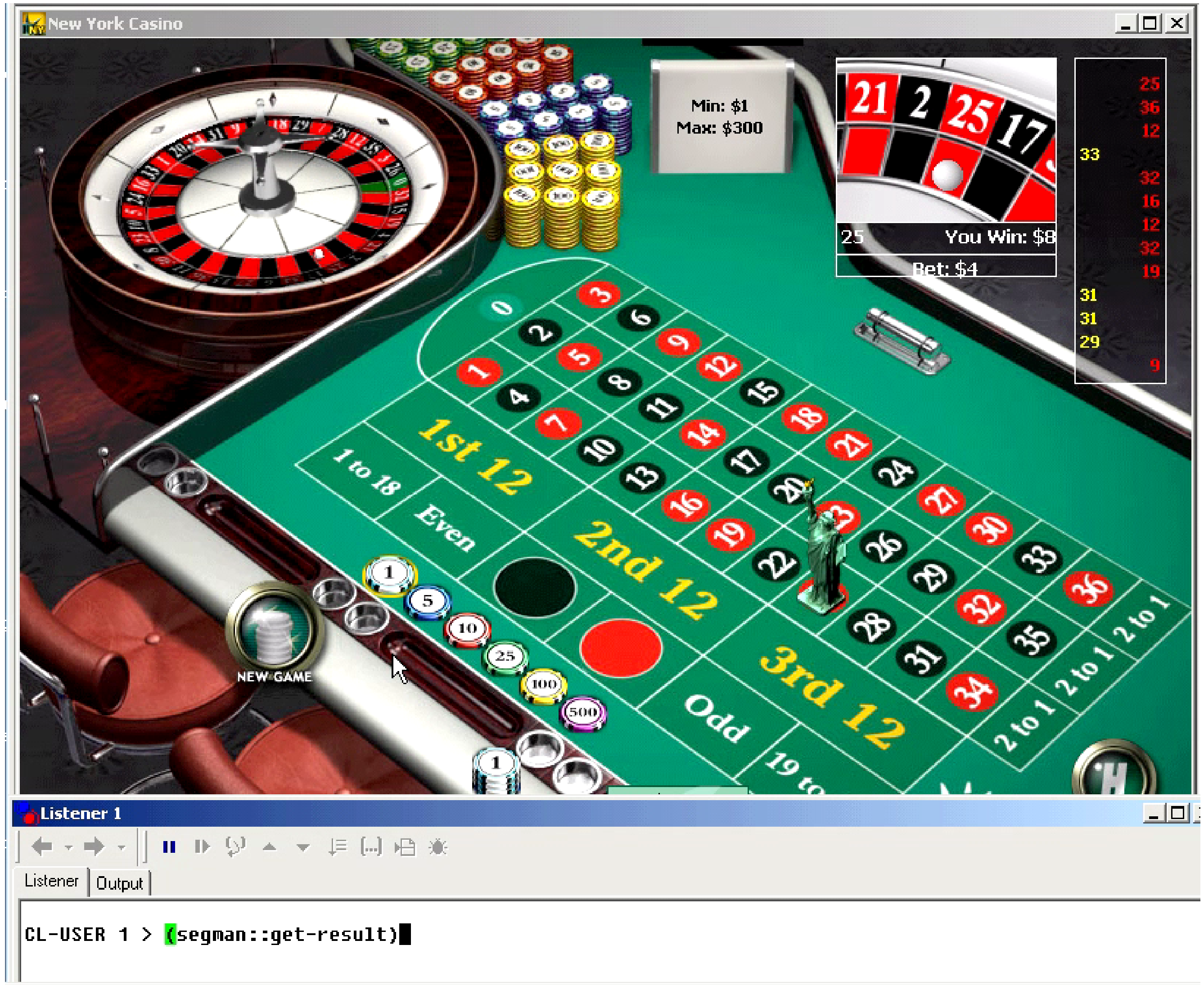
- On-board Robot driving

📖 (Ritter, Kukreja, & St. Amant, 2007)

F1: Simulated Eyes and Hands

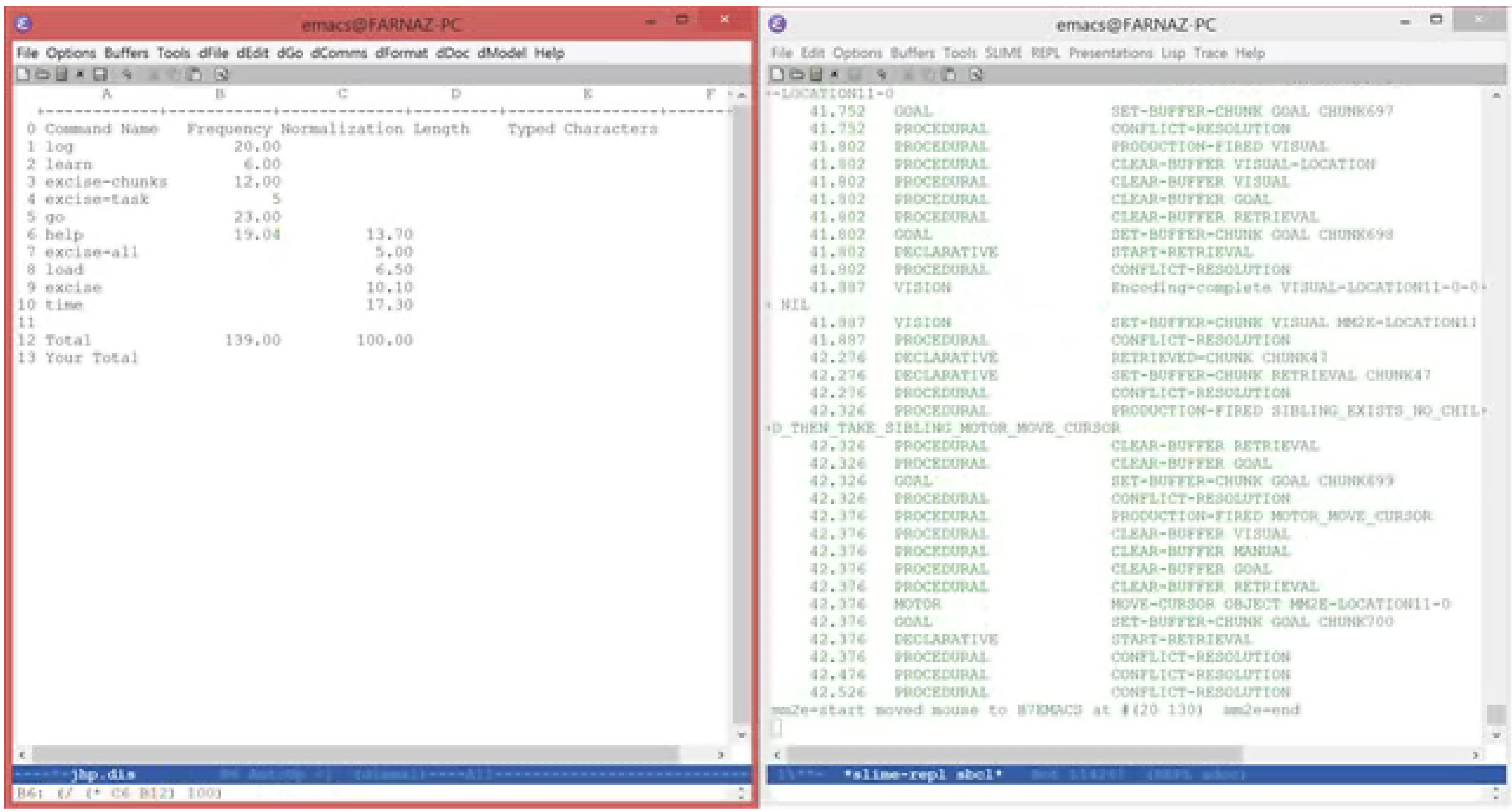
- Gambler's ruin on off-shore casino

(St. Amant, Reidel, Ritter, & Reifers, 2005)

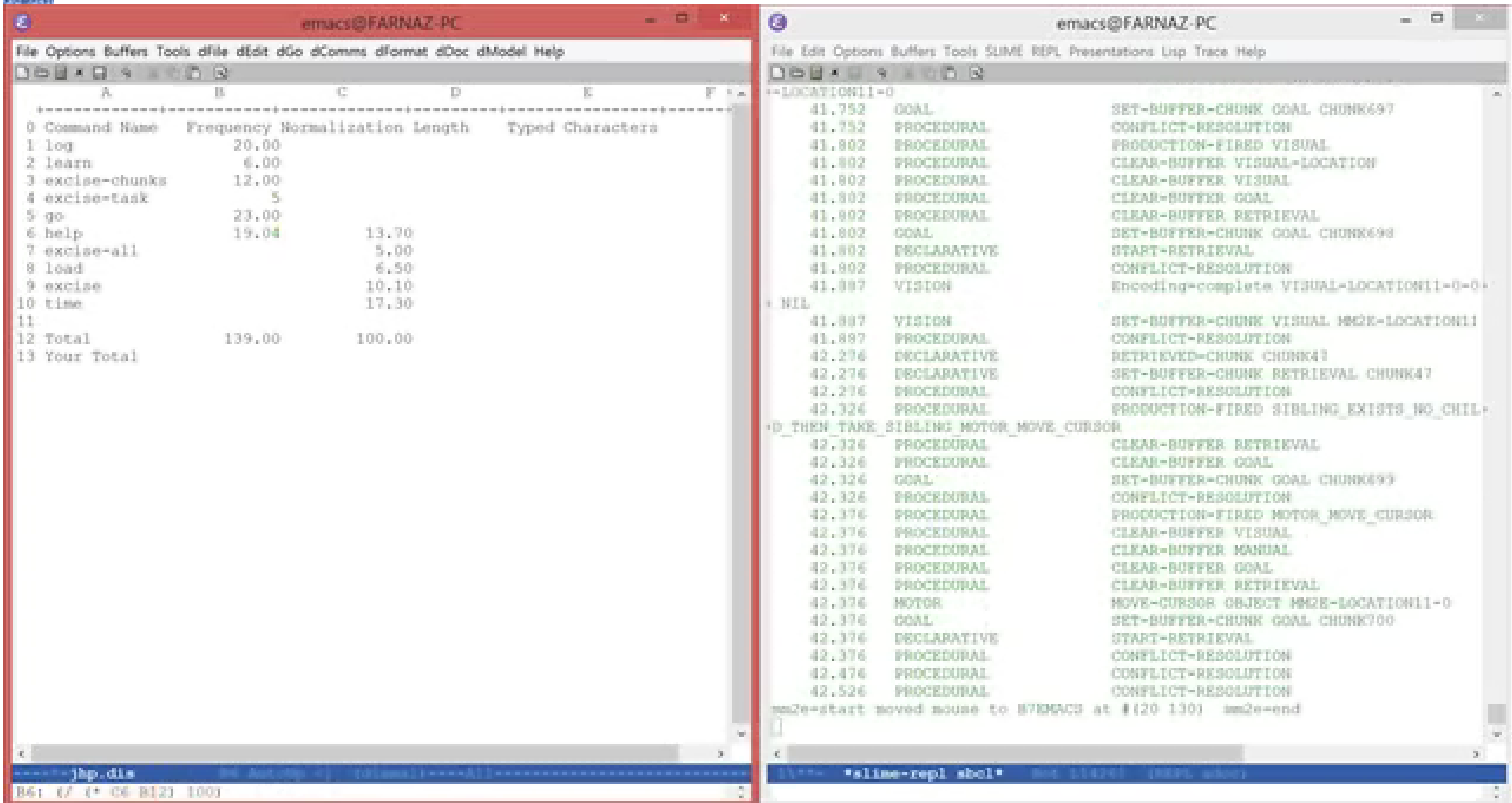


F1: Latest Version, JSegMan

- Revision of SegMan from C to Java, using Robot and Sikuli libraries



📖 Tehranchi & Ritter, 2018a, 2018b



📖 Tehranchi & Ritter, 2018a, 2018b

F1: JSegMan Applied to a Large Model

- Does the task, like, it *actually* does it
- Large, like 20 min. non-iterated, 500x10 rules (Paik et al., 2015) (Tehranchi & Ritter, 2018a, 2018b)
- Found mistakes in model b/c we could see
- Closer fit:

Day	Human	Original Model	JSegMan Hands+Eyes
1	1366 (60.8)	1326 (12.1)	1339 (11.7)
2	894 (26.6)	891 (6.1)	894 (6.5)
3	727 (25.5)	693 (4.5)	704 (5.0)
4	659 (22.7)	594 (5.8)	614 (4.4)
R2		.997	.9984
MSE		1745	820

F1: Conclusions: Interaction

- You can just not do it: "It only takes 25% of every project" -- anonymous colleague
  - If recreated each time, not fixed, not architectural
- You can instrument (a) the task, (b) the graphics library, (c) the operating system
  - *We* are instrumenting the operating system
- We (Farnaz) will have to/get to:
  - Better fit, better applications
  - Model interaction, errors, error correction,
  - Vision, visual search, visual recognition, finding the mouse,
  - A whole new world for models

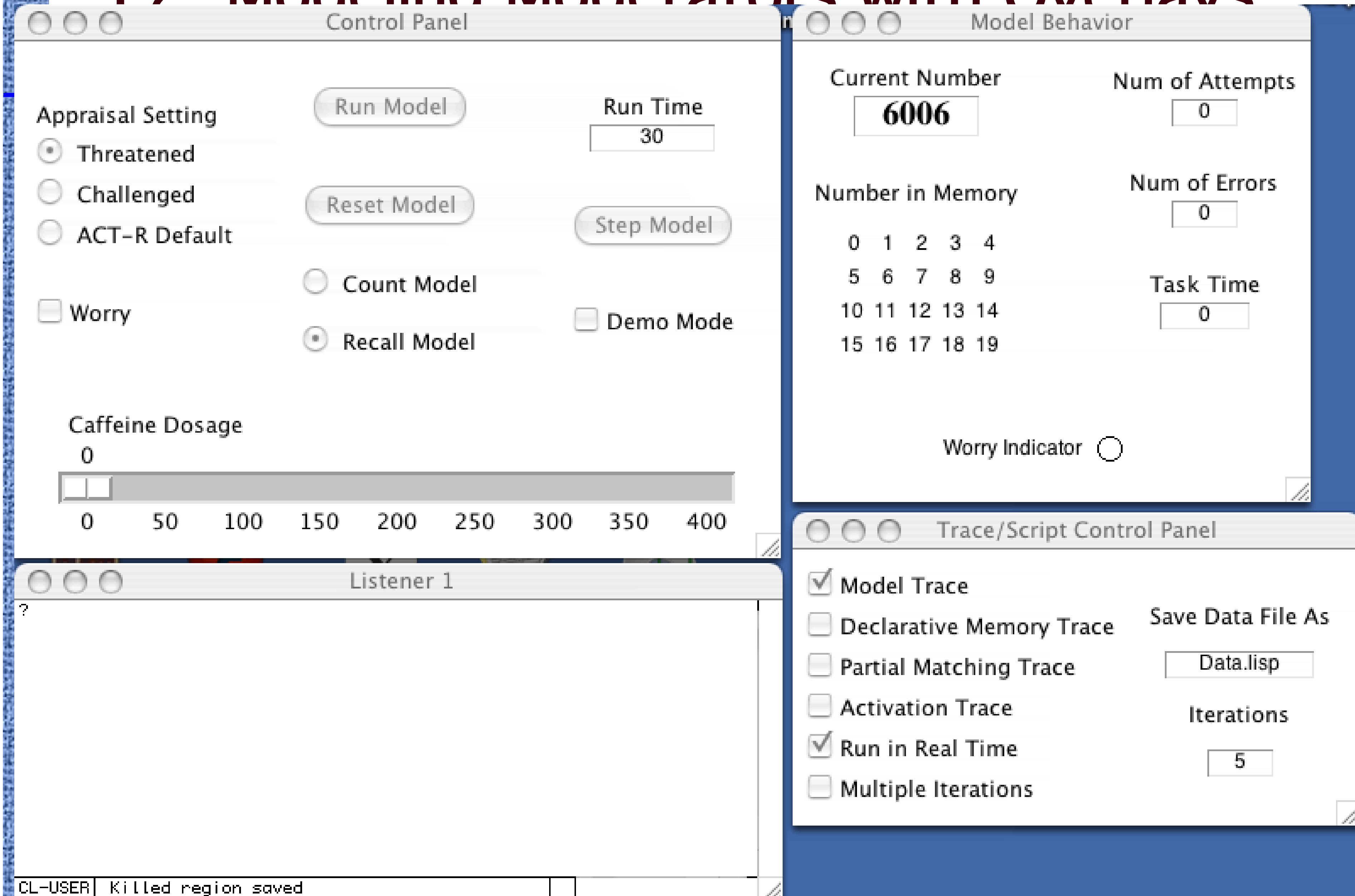
Future 2: Modeling Moderators

- How to include moderators into an architecture?
- Ritter (1993) for Sloman’s workshop
  - Knowledge about ‘emotions’, Reasoning about emotions
  - Thoughts that affect physiology
  - Physiology that affects cognition

F2: Modeling Moderators with Overlays

- First pass: overlays to architecture
- Caffeine influences cognition: faster central processing
- Stress influences cognition: slower decl. memory
- To add: load sequentially
- But, can clash

F2: Modeling Moderators with Overlays



F2: Modeling Moderators with Overlays: CoJACK

- Cognitive Java Agent Construction Kit
- Caffeine influences cognition, faster
- Created fear

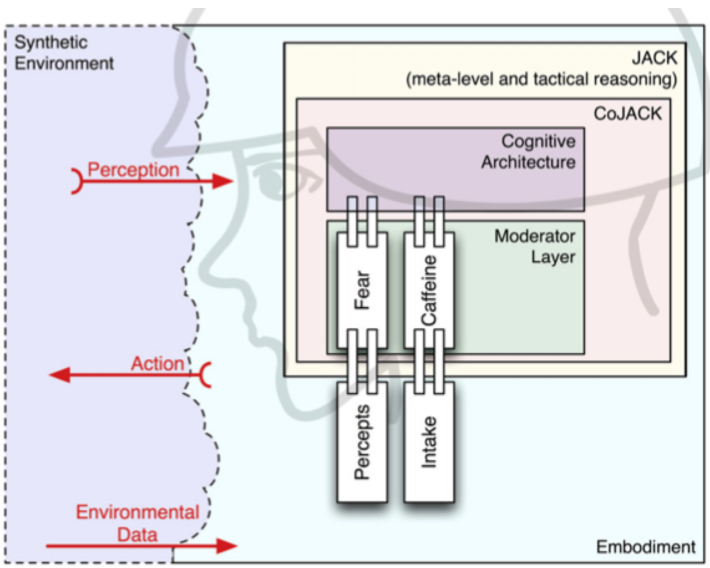
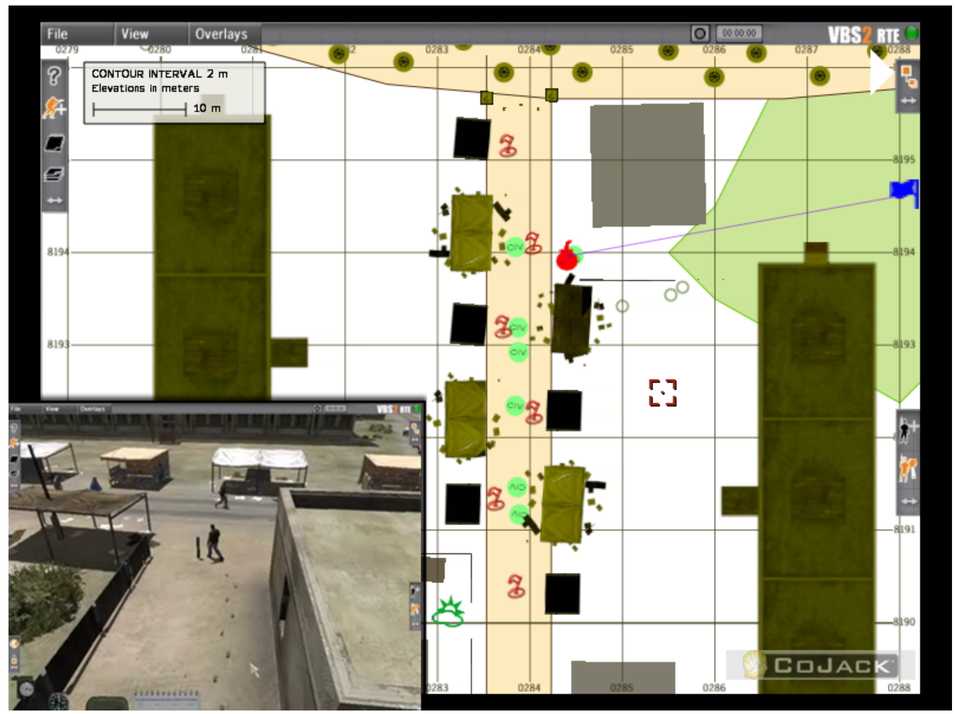
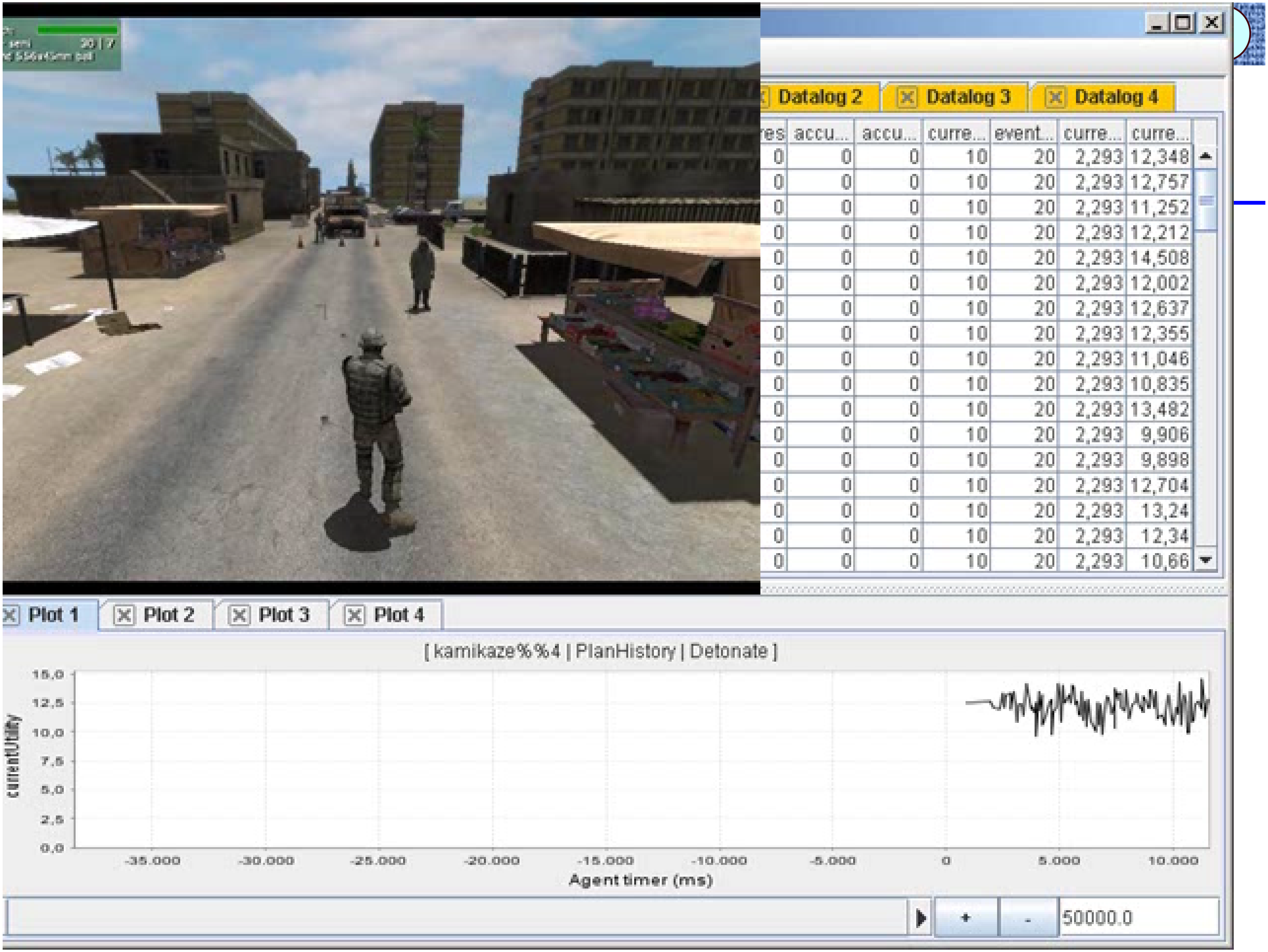


Fig. 2 CoJACK's components and their relationship to JACK.



📖 Evertsz, Ritter, Russell, & Shephardson (2007). Best Paper award, at the 16th BRIMS


Datalog 2
Datalog 3
Datalog 4
res accu... accu... curre... event... curre... curre...
0 0 0 10 20 2,293 12,348
0 0 0 10 20 2,293 12,757
0 0 0 10 20 2,293 11,252
0 0 0 10 20 2,293 12,212
0 0 0 10 20 2,293 14,508
0 0 0 10 20 2,293 12,002
0 0 0 10 20 2,293 12,637
0 0 0 10 20 2,293 12,355
0 0 0 10 20 2,293 11,046
0 0 0 10 20 2,293 10,835
0 0 0 10 20 2,293 13,482
0 0 0 10 20 2,293 9,906
0 0 0 10 20 2,293 9,898
0 0 0 10 20 2,293 12,704
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0 0 0 10 20 2,293 12,34
0 0 0 10 20 2,293 10,66
Plot 1
Plot 2
Plot 3
Plot 4
[kamikaze%%4 | PlanHistory | Detonate]
currentUtility
15,0
12,5
10,0
7,5
5,0
2,5
0,0
-35.000
-30.000
-25.000
-20.000
-15.000
-10.000
-5.000
0
5.000
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Agent timer (ms)
+
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F2: Modeling Moderators with Overlays: CoJACK

- Overlays of caffeine and fear
- Created fear, caffeine

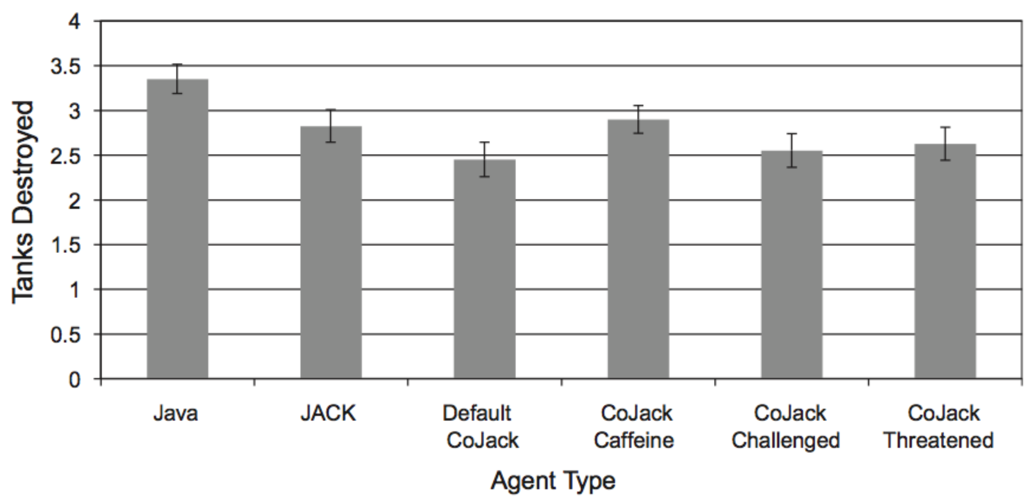


Fig. 5 Basic comparison between agents (*N* = 40). (Error bars show SEM).

📖 (Ritter, Bittner et al., 2007)
Lead paper in BICA journal

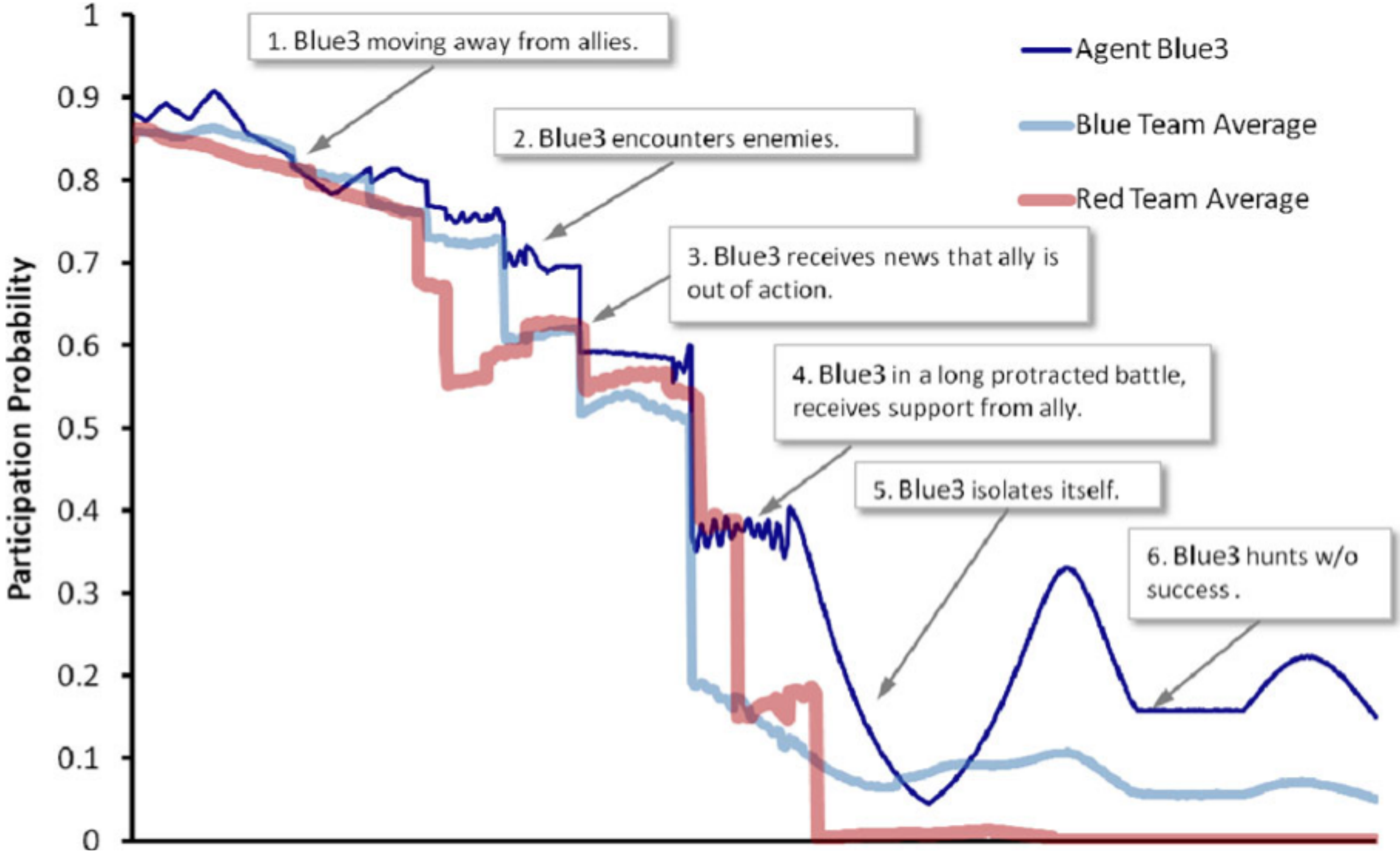
F2: Modeling Moderators with Overlays: Grossman

- Implemented Grossman's (1996) formula for participation
(BRIMS, Morgan et al., 2009; 2010)
- Participation ∝ (demands of authority) x (group absolution) x (target attractiveness) x (tendencies) x distance to target

$$p_a = \frac{1}{1 + (\frac{1}{t_d} * e^{\frac{g_{\text{composition}} * ((d_{\text{friend}} * \sqrt{g_{\text{size}}}) + \frac{d_{\text{leader}}}{t_a + k})}{g_{\text{size}} * d_{\text{observer}} * (c+k)}})}$$

- Definitely influenced behavior:

F2: Effect of Grossman's Formula



F2: Modeling Moderators with Physiology

- But, overlays can clash
- Simple formulas are not architectural
  - Was stuck for a while
  - Worked with CaffeineZone, iPhone app
- Took up physiology model

  (BRIMS best student paper: 🕮Dancy et al. 2012; Dancy et al. 2015)

  (Middleton et al., submitted)

F2: HumMod

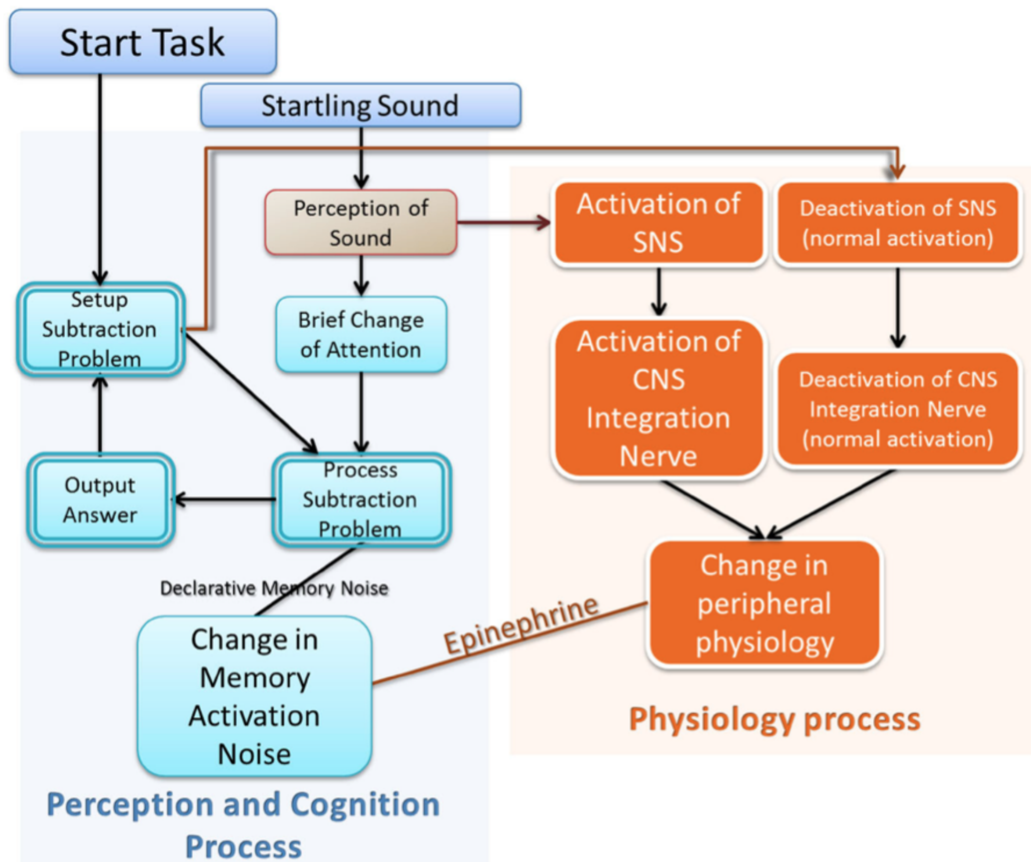
- Model of human physiology based on Guyton and Hall (2012) textbook, arising from cardio model
- Hester et al. (2011), manual in prep.
- Realised as >1.5k equations, runs faster than real time, adjustable, extendable (e.g., Salt model)

Table 2 Some of HumMod's major systems

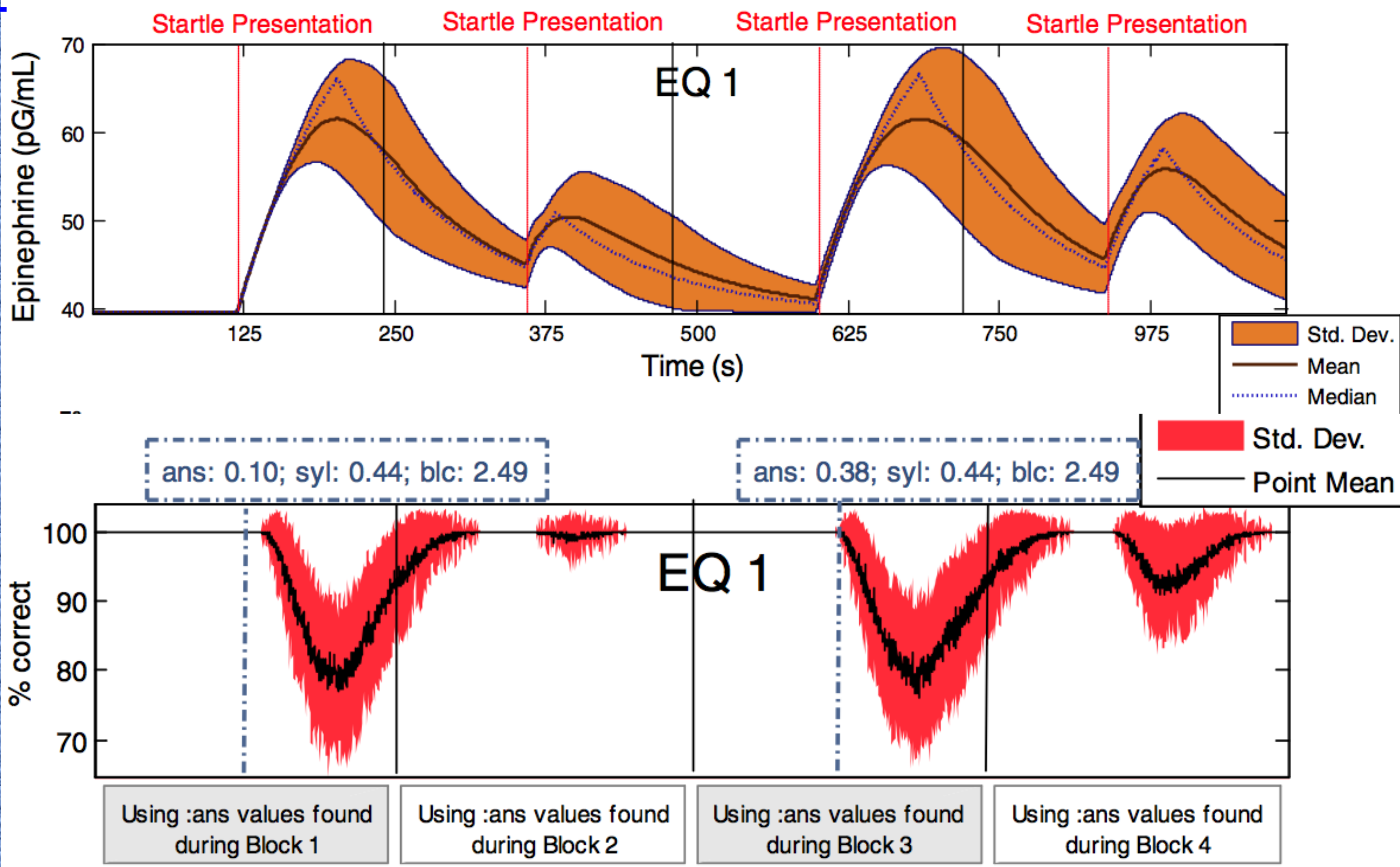
HumMod system	Number of variables	Example variables
Body Fluids	214	Blood plasma volume
Circulation	426	Sinoatrial (SA) node rate
Electrolytes	140	Sodium Ion (NA+) pool mass
Hormones	534	Adrenocorticotropic hormone secretion
Metabolism	321	Energy stored (calories)
Nervous system	187	Norepinephrine (NE) pool mass
Organs	2,349	Bladder volume
Respiration	326	Breathing tidal volume
Other systems (lifestyle, heat, etc.)	2,026	Skin temperature

F2: ACT-R/Φ

- ACT-R + HumMod physiology simulator
- For serial subtraction



F2: ACT-R/Φ



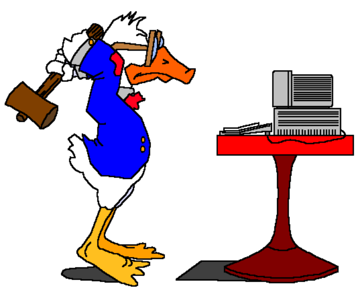
Startle Presentation
Startle Presentation
Startle Presentation
Startle Presentation
EQ 1
Epinephrine (pG/mL)
70
60
50
40
125
250
375
500
625
750
975
Time (s)
Std. Dev.
Mean
Median
ans: 0.10; syl: 0.44; blc: 2.49
ans: 0.38; syl: 0.44; blc: 2.49
Std. Dev.
Point Mean
EQ 1
% correct
100
90
80
70
Using :ans values found during Block 1
Using :ans values found during Block 2
Using :ans values found during Block 3
Using :ans values found during Block 4

F2: Conclusions: Modeling Moderators

- Several ways to simulate and explore moderators
  - Simple formulas
  - Overlays
  - *We* will be using a physiology and appraisal substrate
- Will need lots of data, and new types
- Will need to expand HumMod and ACT-R/Φ

Future 3: Using GAs to Optimize Model Fit

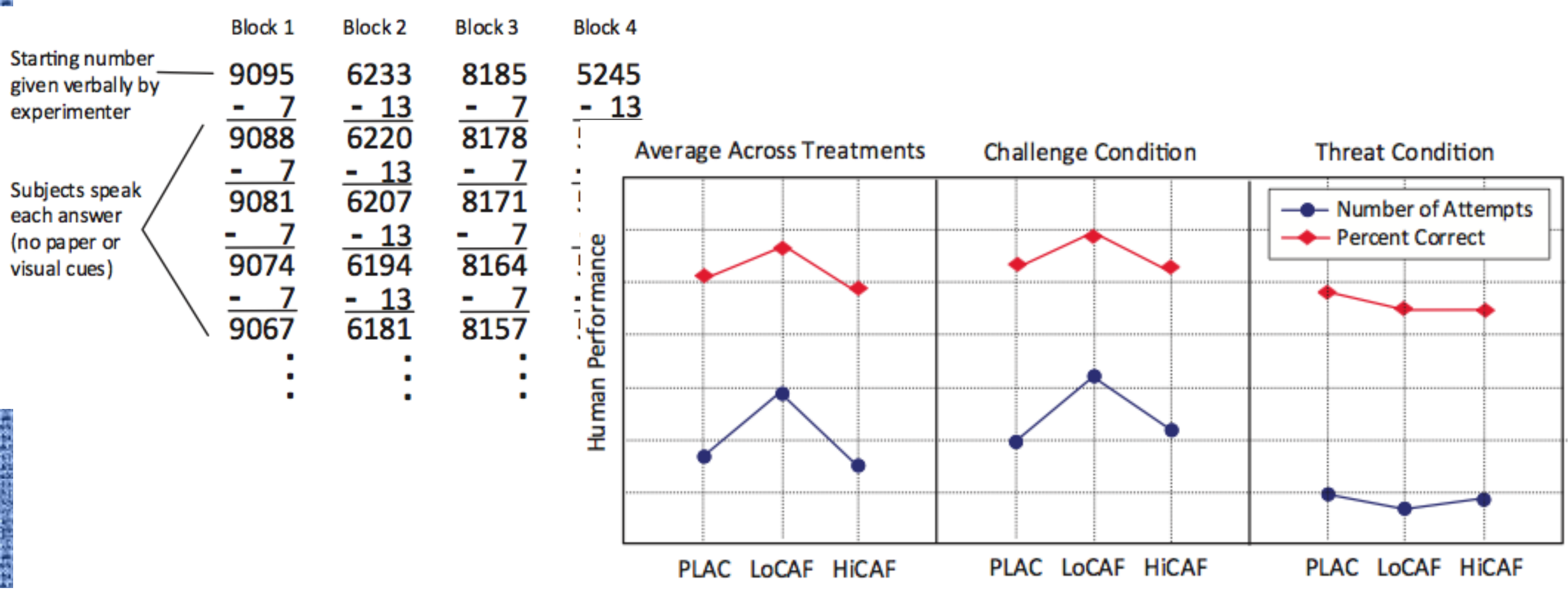
- Model fitting is a multivariable
  non-linear multi-value optimization
- We had a complex task
  of a complex model
  with complex data:
  the Trier Social Stressor Task, with caffeine
  (Klein et al., 2008)
- Genetic algorithms provide a way
  to optimize nearly anything



Kase, S. E., Ritter, F. E., Bennett, J. M., Klein, L. C., & Schoelles, M. (2017). Fitting a model to behavior reveals what changes cognitively when under stress and with caffeine. *Biologically Inspired Cognitive Architectures, 22*(October), 1-9.

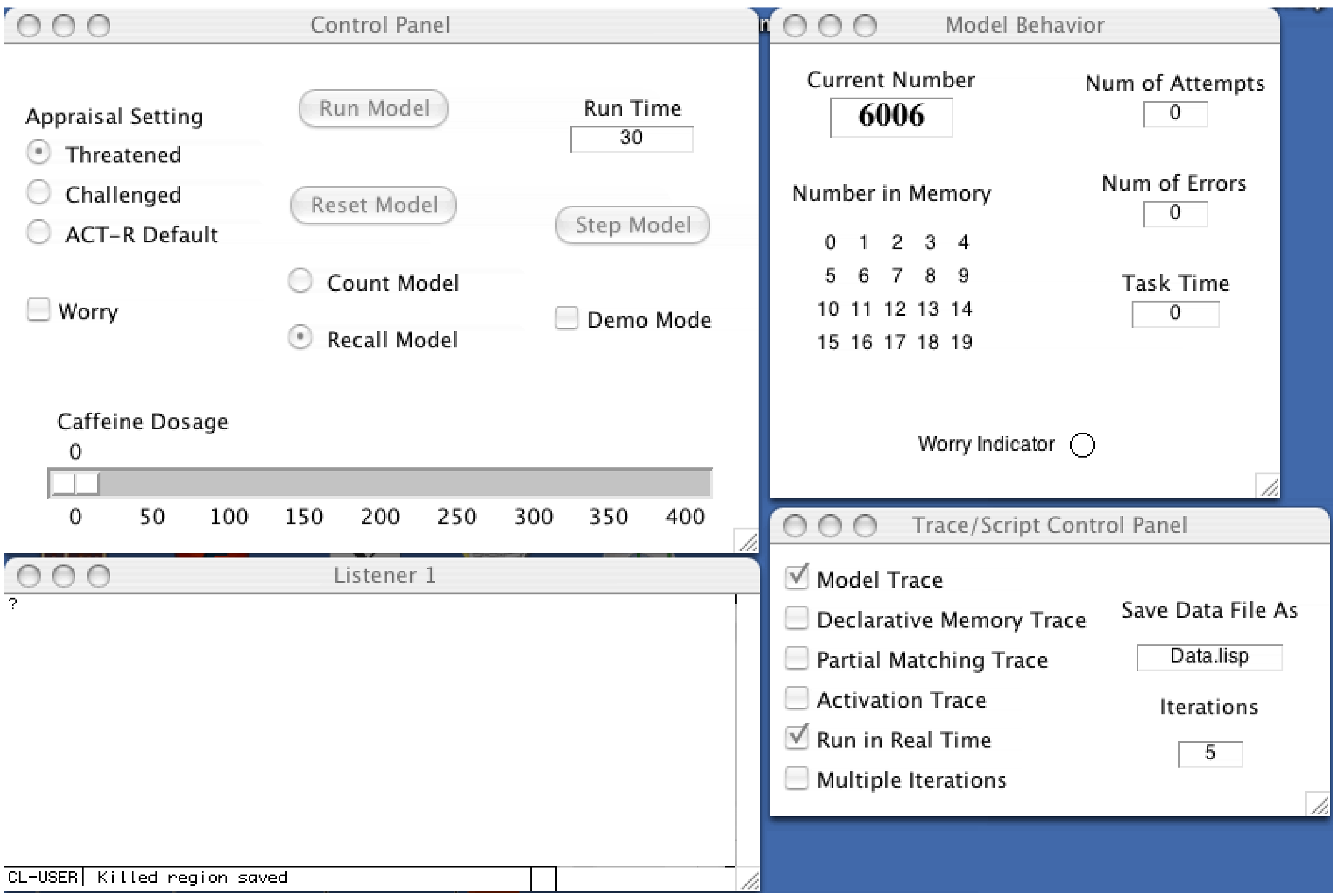
F3: Optimized the Fit of a Serial Subtraction Model

- Trier Social Stressor task
- 4 blocks of subtraction, 3 levels of caffeine



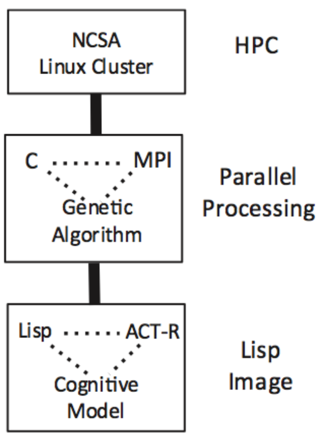
F3: Optimized the Fit of a Serial Subtraction Model

- Shown earlier as threatened model



F3: Optimized the Fit of a Serial Subtraction Model

- 200 genotypes x 100 gen.

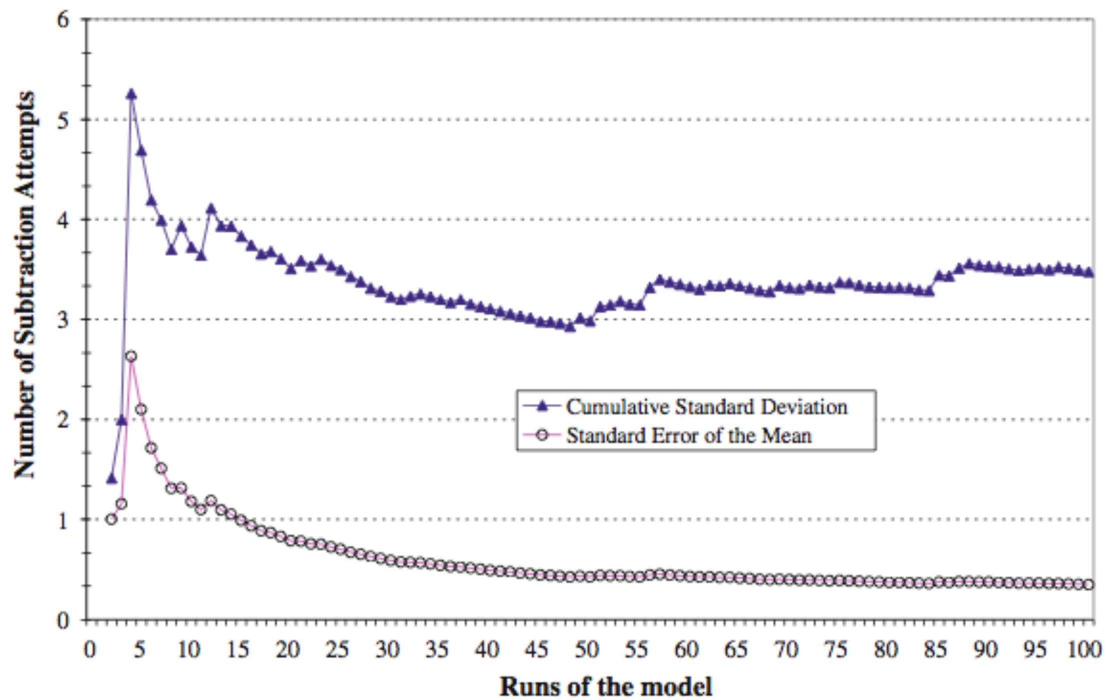


	Human performance	Avg. model prediction	Avg. fitness value	ACT-R parameters ANS, BLC, SYL (N)
PLAC (no caffeine)				
ALL	47.3/81.5%	48.1/81.4%	0.83	0.70, 2.49, 0.44 (3)
CH	50.7/83.3%	50.4/83.0%	0.47	0.68, 2.48, 0.41 (6)
TH	40.4/77.9%	40.3/77.4%	0.36	0.71, 2.53, 0.55 (5)
LoCAF (200 mg caffeine)				
ALL	59.1/86.5%	59.1/86.7%	0.12	0.72, 2.64, 0.33 (4)
CH	62.4/88.3%	62.7/88.4%	0.42	0.69, 2.65, 0.31 (3)
TH	37.5/74.8%	37.2/74.9%	0.58	0.71, 2.48, 0.61 (6)
HiCAF (400 mg caffeine)				
ALL	45.7/79.2%	44.7/80.4%	0.50	0.78, 2.65, 0.47 (4)
CH	51.6/82.8%	46.1/87.7%	0.53	0.75, 2.69, 0.40 (3)
TH	38.9/75.1%	50.4/92.3	0.58	0.67, 2.35, 0.57 (4)

- Fits very close
- Caffeine -> fluency,
  more decl. memory noise when threatened

F3: Run Your Model until You Have Stable Predictions

- How many times to run a model to get stable performance? (Ritter et al., 2013) and to report results?
- GAs don't really care, but multiple runs can help

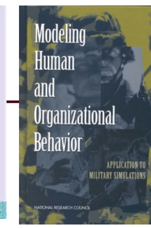


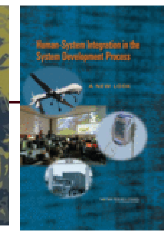
F3: Conclusions: Using GAs

- Use machine learning (GAs) to optimize architecture's algorithms and fit model
- Caffeine seems to affect speaking speed and decl. memory noise
- Run your models enough to understand them

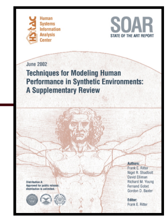
Conclusions

- Plenty of places to learn more
  - Pew and Mavor (Elkind et al., 1989; 1999, 2007)

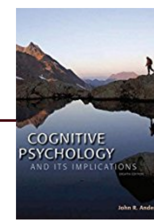


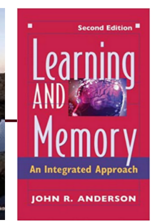


  - Ritter et al. (2003)

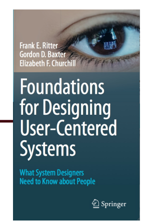


  - Anderson (2014; 2000)

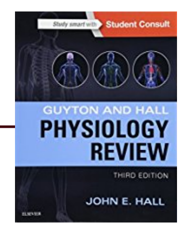




  - Ritter et al. (2014)



  - Guyton and Hall (2015)



Conclusions

- Document your systems, code, graphs, movies
- Helpful to reuse data, models, tools, b/c so darn hard to create them
- Don’t build for others, build for yourself and use
- These design patterns of interaction, physiology underlying cognition, and optimized fits were recreated, you can too!

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