## 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.

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# **Overview of Talk**

(0) Brief overview of architectures 2/2/

- (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

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- 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)



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



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

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Previous examples Java driving game

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



## On-board Robot driving

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

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## Gambler's ruin on off-shore casino

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



## F1: Latest Version, JSegMan

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

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🛄 Tehranchi & Ritter, 2018a, 2018b



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# 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)
- Found mistakes in model b/c we could see

Closer fit:

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Day	Human	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)		
<b>R2</b>		.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  $\blacksquare$
- 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

EPENNSTATE F2. Modeling Moderator Control Panel	TS with Overlavs Model Behavior
Appraisal Setting Run Model Run Time   Threatened 30   Challenged Reset Model   ACT-R Default Step Model   Worry Count Model   Worry Demo Mode	Current Number       Num of Attempts         6006       0         Number in Memory       Num of Errors         0       1       2       3       4         5       6       7       8       9       Task Time         10       11       12       13       14       0         15       16       17       18       19
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## F2: Modeling Moderators with Overlays: CoJACK

Cognitive Java Agent Construction Kit Caffeine influences cognition, faster

Created fear

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

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



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## F2: Modeling Moderators with Overlays: CoJACK

## Overlays of caffeine and fear

Created fear, caffeine





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## F2: Modeling Moderators with Overlays: Grossman

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

$$p_{a} = \frac{1}{1 + \left(\frac{1}{t_{d}} * e^{\frac{g_{\text{composition}} * \left(\left(d_{\text{friend}} * \sqrt{g_{\text{size}}}\right) + \frac{d_{\text{leader}}}{t_{a} + k}\right)}{g_{\text{size}} * d_{\text{observer}} * (c + k)}}\right)}$$

Definitely influenced behavior:

# F2: Effect of Grossman's Formula

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## F2: Modeling Moderators with Physiology

But, overlays can clash

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- 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)

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

Table 2Some of HumMod's major systems

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#### ( 24 )

## F2: ACT-R/ $\Phi$

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



## F2: ACT-R/ $\Phi$

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# 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/ $\Phi$

## Future 3: Using GAs to Optimize Model Fit

Model fitting is a multivariable non-linear multi-value optimization

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- 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

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

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# F3: Optimized the Fit of a Serial Subtraction Model

## Shown earlier as threatened model

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000	Control Panel		n 🔿 🔿 🔿 Model Behavio	or
Appraisal Setting <ul> <li>Threatened</li> </ul>	Run Model	Run Time 30	Current Number	Num of Attempts
<ul> <li>Challenged</li> <li>ACT-R Default</li> </ul>	Reset Model	Step Model	Number in Memory 0 1 2 3 4	Num of Errors
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CL-USER Killed region sa	ved			

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## F3: Optimized the Fit of a Serial Subtraction Model

## 200 genotypes x 100 gen.

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			Human performance	Avg. model prediction	Avg. fitness value	ACT-R parameters ANS, BLC, SYL (N)
NCSA Linux Cluster	НРС	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)
	Parallel	ТН	40.4/77.9%	40.3/77.4%	0.36	0.71, 2.53, 0.55 (5)
Génétic	Processing	LoCAF (200 mg caffeine)				
Algorithm		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)
Lisp ACT-R		TH	37.5/74.8%	37.2/74.9%	0.58	0.71, 2.48, 0.61 (6)
Cognitive	Lisp Image	HiCAF (400 mg caffeine)				
Model	-	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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