



The 30th Annual Conference of the Cognitive Science Society



Computational Modeling of Spoken Language Processing: A hands-on tutorial



Computational Modeling of Spoken Language Processing: A hands-on tutorial

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Plan

- Module 1: Introduction, About TRACE
- Module 2: Tour of jTRACE
- Module 3: Classic simulations
- Module 4: Scripting
- Module 5: Linking hypotheses
- Module 6: Lab time, Q&A, one-on-one



Module 2

- Motivation for jTRACE
- Tour of jTRACE



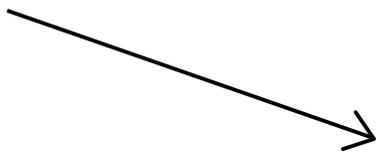
Why jTRACE?

- Original TRACE program was written in C. Requires computer savvy, time.
- We created jTRACE (with Java) to make TRACE simulation accessible to average PC users.
- Simulation, scripting and analysis can all be done within jTRACE. Data can be dumped for further processing in SPSS, MS Excel, Matlab, etc.
- The main advantage of jTRACE is its user-friendly interface.



cTRACE → jTRACE

```
Terminal — trace — 83x25
badi -17-18-18-16-14-12-14-13-12-11-10 -9 -7 -5 -4 -2 -2 -1 -1 -1 -1 -1
bust -17-18-18-17-16-15-15-13-12-11-10 -9 -7 -5 -4 -2 -2 -1 -1 -1 -1 -1
but -15-16-16-15-14-13-12-12-12-11-10 -9 -7 -5 -3 -2 -2 -1 -1 -1 -1 -1
bat^l -16-17-19-19-18-16-15-13-12-11-11 -9 -7 -6 -4 -2 -2 -1 -1 -1 -1 -1
baks -17-18-18-17-16-15-13-12-11-11-10 -9 -7 -5 -4 -2 -2 -1 -1 -1 -1 -1
brid -17-18-18-17-16-12 -8 -9-12-12-11 -9 -7 -5 -4 -2 -2 -1 -1 -1 -1 -1
brud -17-18-18-17-16-14-12-12-13-12-11 -9 -7 -5 -4 -2 -2 -1 -1 -1 -1 -1
br^s -17-18-18-17-16-13-10-10-12-12-11 -9 -7 -5 -4 -2 -2 -1 -1 -1 -1 -1
b^b^l -16-17-18-19-18-16-15-15-14-12-11 -9 -7 -6 -4 -2 -2 -1 -1 -1 -1 -1
b^k -15-16-16-15-14-13-12-12-12-12-10 -9 -7 -5 -3 -2 -2 -1 -1 -1 -1 -1
b^s -15-16-16-16-14-13-12-12-11-10-10 -9 -7 -5 -3 -2 -2 -1 -1 -1 -1 -1
b^t -15-16-16-15-14-13-12-12-12-12-10 -9 -7 -5 -3 -2 -2 -1 -1 -1 -1 -1
kar -15-16-16-15-12-11-12-11-11-10-10 -9 -7 -5 -3 -2 -2 -1 -1 -1 -1 -1
kard -17-18-18-17-15-14-14-13-12-11-10 -9 -7 -5 -4 -2 -2 -1 -1 -1 -1 -1
karp^t -16-17-19-19-17-16-16-14-12-11-11 -9 -7 -6 -4 -2 -2 -1 -1 -1 -1 -1
sis -15-16-16-16-14-13-13-10 -7 -6 -9 -8 -5 -3 -3 -2 -2 -1 -1 -1 -1 -1
klak -17-18-18-17-16-12 -8 -8-12-12-11 -9 -7 -5 -4 -2 -2 -1 -1 -1 -1 -1
kl^b -16-17-18-17-16-13-10-10-12-12-11 -9 -7 -5 -4 -2 -2 -1 -1 -1 -1 -1
klu -15-16-16-16-14-11 -7 -7-11-12-10 -9 -7 -5 -3 -2 -2 -1 -1 -1 -1 -1
kalig -18-19-19-16-12-10-14-14-12-11-11 -9 -7 -6 -4 -2 -2 -1 -1 -1 -1 -1
kul -15-16-16-14-10 -8-11-13-12-11-10 -9 -7 -5 -3 -2 -2 -1 -1 -1 -1 -1
kap -15-13 -9 -9-12-13-13-11-11-10-10 -9 -7 -5 -3 -2 -2 -1 -1 -1 -1 -1
kapi -17-15-13-10-12-13-14-13-12-11-10 -9 -7 -5 -4 -2 -2 -1 -1 -1 -1 -1
k^p^l -16-14-14-15-17-17-16-15-14-12-11 -9 -7 -6 -4 -2 -2 -1 -1 -1 -1 -1
krip -11-13-17-17-16-13 -9 -9-12-12-11 -9 -7 -5 -4 -2 -2 -1 -1 -1 -1 -1
```



The screenshot shows the jTRACE software interface with several panels:

- Graphing Panel (Untitled #3):** A line graph showing 'Activations' vs 'Cycle' (0-100). It features four curves in blue, green, yellow, and red, representing different phoneme or word activations over time.
- Word Activations Panel (Untitled #2):** A plot showing 'Activation Magnitude' vs 'Temporal Alignment' (0-32). It displays a sequence of word activations: 'p', 'a', 'r', 't', 'i', 'g', 'r', 'i', 'd', 'b', 'r', 'p', 't'.
- Phoneme Activations Panel:** A plot showing 'Activation Magnitude' vs 'Temporal Alignment' (0-32). It displays individual phoneme activations: 'b', 'a', 'r', 't', 'i', 'p', 't', 'a', 't'.
- Feature Continua Panel:** A plot showing 'Feature Continua' vs 'Time' (0-96).
- Controls:** Includes buttons for 'Display enabled', 'Export data...', 'Set Input', 'Validation...', 'Graph activation info.', and 'TRACE Controls' with play/pause buttons and a '100' value.



cTRACE = jTRACE ??

- We validated jTRACE against TRACE by running the same simulations in both models and comparing the outputs.
- In the *worst* case, the two versions of TRACE differed by 0.007%.



jTRACE basics

- A simulation is treated like a document.
- Each simulation has a parameter set, a lexicon, an input string, a simulation display panel, a graph panel, and analysis settings.
- **Parameters panel** - set parameters, lexicon, input, ambiguous phonemes, etc.
- **Simulation panel** - run the simulation and watch progress as an animation.
- **Graphing panel** - graph activations and response probabilities of individual word/phoneme units.
- **Input panel** - setup and visualize the model's input
- **Phoneme panel** - edit, create phoneme set



Parameters panel

Phonemes Input Parameters Simulation Graphing

Lexicon

Lexical Item	Frequency	Priming	Label	# Cohorts[1]	# Cohorts[2]
A	23,248	0	12 (^)	0 (^)	
^br^pt	37	0	12 (^)	1 (^b)	
^dapt	71	0	12 (^)	2 (^d)	
^dAlt	50	0	12 (^)	2 (^d)	
^gri	264	0	12 (^)	2 (^g)	
^lat	50	0	12 (^)	1 (^l)	
^part	57	0	12 (^)	3 (^p)	
^pil	108	0	12 (^)	3 (^p)	
ark	50	0	5 (a)	4 (ar)	
ar	4,406	0	5 (a)	4 (ar)	
art	274	0	5 (a)	4 (ar)	
art^st	112	0	5 (a)	4 (ar)	

Model Input

Input string: -AbrApt-

Enable continuum

from - to -

steps: 3

Use 0 to (steps-1) in the input for interpolated phonemes

Parameters

Parameter	Value	Function	Default	Notes
Comment	-	-	-	-
User	-	-	-	-
Date	-	-	-	-
aLPHA[if]	1	-	-	1 Input-Feature weights
aLPHA[fp]	0.02	-	-	0.02 Feature-Phoneme weights
aLPHA[pw]	0.05	-	-	0.05 Phoneme-Word weights
aLPHA[pf]	0	-	-	0 Phoneme-Feature weight...
aLPHA[wp]	0.03	-	-	0.03 Word-Phoneme weights
GAMMA[f]	0.04	-	-	0.04 Feature-layer inhibition
GAMMA[p]	0.04	-	-	0.04 Phoneme-layer inhibition
GAMMA[w]	0.03	-	-	0.03 Word-layer inhibition
DECAY[f]	0.01	-	-	0.01 Feature decay
DECAY[p]	0.03	-	-	0.03 Phoneme decay
DECAY[w]	0.05	-	-	0.05 Word decay
REST.F	-0.1	-	-	-0.1 Feature resting activation
REST.P	0.1	-	-	0.1 Phoneme resting activation

Reset

input string

ambiguous phonemes

parameters table

lexicon table



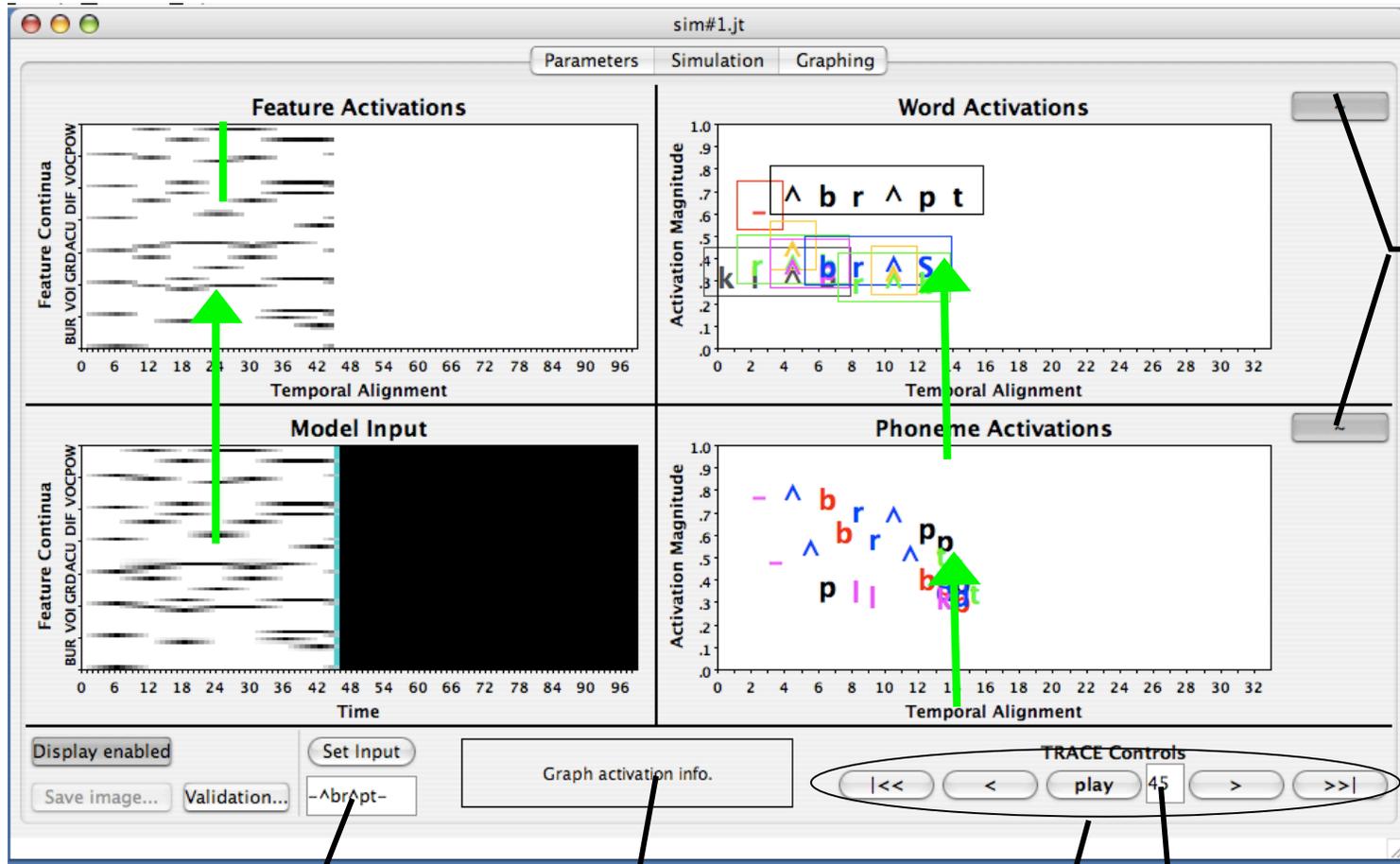
Lexicon notes

- Composition of the lexicon is key to word competition and attendant processes.
 - Trade-off between complex and simple lexicons.
- Default lexicon has 213 words. A larger lexicon of 901 words is included, plus some others.
- Lexicons can be edited in the table or written by hand in a file using a simple XML markup.

```
<lexeme><phonology>^br^pt</phonology><frequency>37</frequency></lexeme>
```
- Phoneme roster includes 14+1 phonemes: a ^ i u p b t d k g s S r l; and – is the *silence* phoneme.
 - It is possible to add/edit phonemes.



Simulation panel



toggle view

change input

query cell

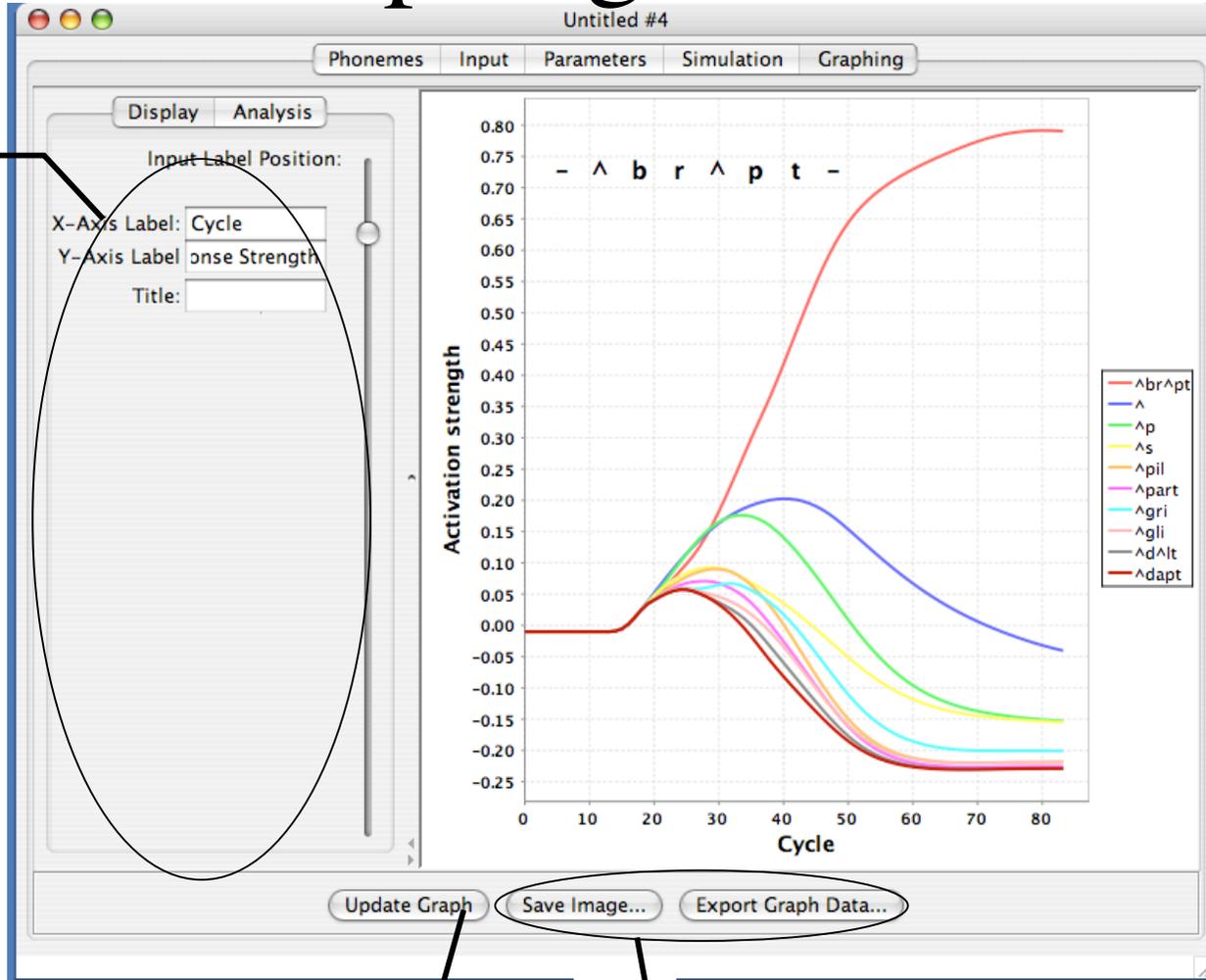
simulation controls

cycle #



Graphing Panel

analysis & display settings



update button

export data



Input Panel = training wheels

letter-by-letter spec

setup the highlighted phoneme using simple menus (normal, ambiguous, spliced)

model parameters re: input

input visualizer



Phoneme panel (experimental)

- Edit phoneme specs; custom phonologies.

#	BUR	VOI	GRD	ACU	DIF	VOC	POW
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	1.0	1.0	1.0	1.0	1.0	1.0	1.0

#	BUR	VOI	GRD	ACU	DIF	VOC	POW
Len	1	1	1	1	1	1	1

Feature vectors

duration scalar

"allophonic" relation

Phoneme selector

Language selector



First jTRACE simulation

- File > new model
- Parameters tab > choose a word from the lexicon
> type it into the input string field
- Simulation tab > play > the “~” button changes
visualization > stop at cycle 70
- Graphing tab > save image... > file-name.png
- File menu > save as... > file-name.jt



How to *read* a simulation

- Open a new simulation, enter “-tik^p-” as input string
- Simulation panel, run for 80 cycles
- Graphing panel: Top N Items=5, Alignment=Max (post-hoc)
- Press update graph button
- What do we see?
 - Recognition of words in sequence
 - Lexical competition amongst cohort of k^p
 - Monotonic activation, peak, plateau, decay
 - Other observations?



Graph analysis options

- Analyze
 - words / phonemes
- Content
 - Activations
- Items
 - top N / specific items
- Alignment
 - avg / **max...** / **specified** / Frauenfelder
- Luce Choice Rule (LCR)
 - choice: normal / forced
 - k value

The screenshot shows a dialog box with two tabs: "Display" and "Analysis". The "Analysis" tab is active. The dialog is organized into several sections:

- Analyze:** Radio buttons for "Words" (selected) and "Phonemes".
- Content:** A dropdown menu set to "Activations".
- Items:** Radio buttons for "Top N Items:" (selected, with a value of 10) and "Specified Items". Below this is a list of items: ^, ^br^pt, ^dapt, ^d^lt, ^nri. There are navigation buttons (->, <-) and a "Re..." button.
- Alignment:** Radio buttons for "Average", "Max (Ad-Hoc)", "Max (Ad-Hoc-2)", "Max (Post-Hoc)", "Specified:" (selected, with a value of 4), and "Fraunfelder (x, x+1)".
- Luce Choice:** Radio buttons for "All Items" (selected, with a "k Value:" of 4) and "Forced Choice".
- Global Competition Index:** A dropdown menu set to "2nd Derivative" and a "Sampling width:" of 4.



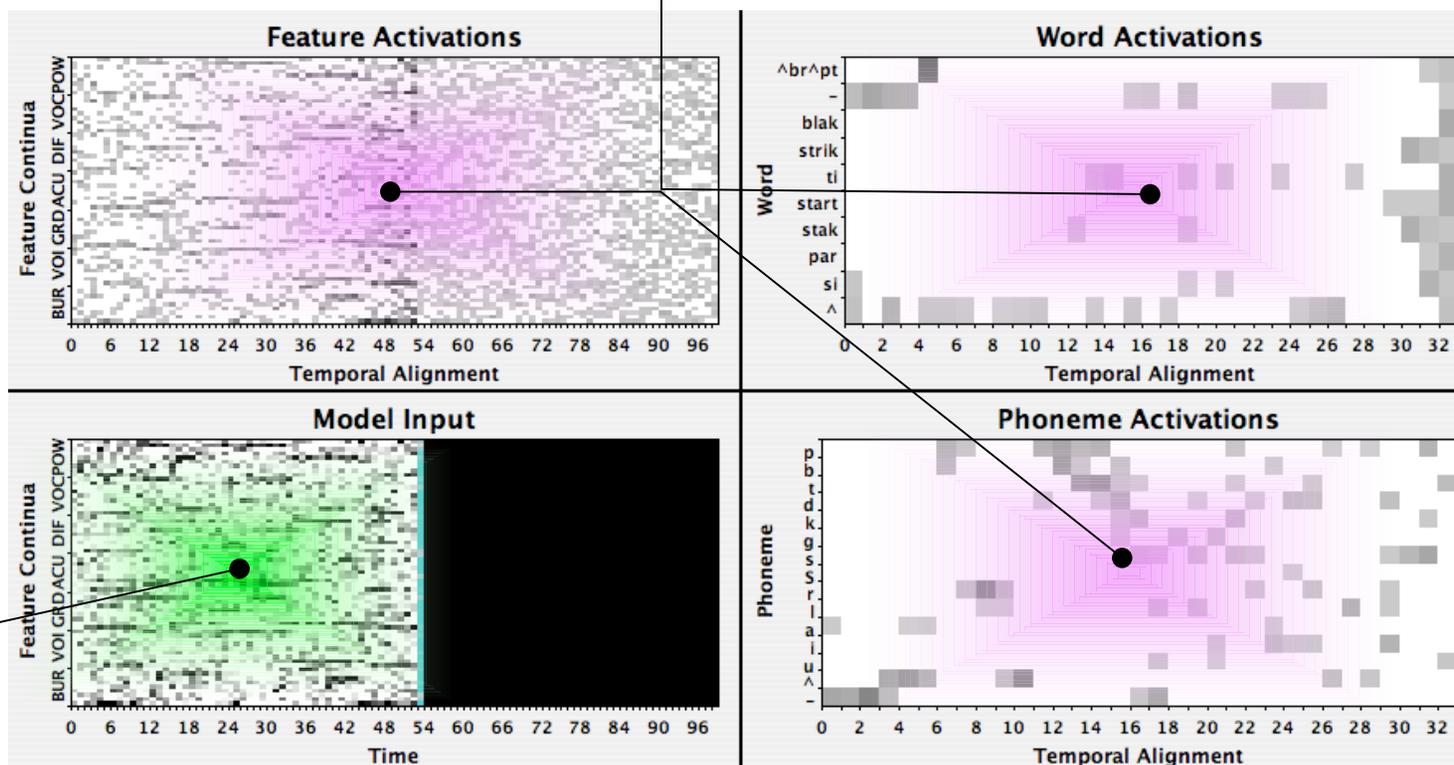
Some useful parameters

- Main TRACE parameters
 - Alpha (excitation, feedforward & feedback)
 - Gamma (within-layer inhibition)
 - Rest (resting level activation)
 - Decay (rate of unit decay)
- Extensions of the model
 - Input noise, stochasticity
 - Frequency effects
 - Priming effects
 - Attention - gain, bias



Using noise & stochasticity

Stochasticity
(applied every cycle)



Input noise (applied once)



Using frequency

1. The TRACE lexicon must contain frequency values.
2. Activate desired frequency implementation in the parameters table.

Lexical Items	Frequency
^	23,248
^br^pt	37
^dapt	71
^d^lt	50
^gri	264
^lat	50
^part	57
^pil	108
ark	50
ar	4,406
art	274
art^st	112

Parameter	Value	Default	Notes
spreadScale	1	1	1 Scales FETSPREADs
min	-0.3	-0.3	Minimum activation
max	1	1	Maximum activation
frq resting levels	0	0	Dahan et al.: 0.06
frq p->w wts	0.13	0	Dahan et al.: 0.13
frq post-act	0	0	Dahan et al.: c=15
FETSPREAD.pow	6	6	Power feature spread
FETSPREAD.voc	6	6	Vocalic feature spre...
FETSPREAD.dif	6	6	Diffuse feature sore...



Priming

- Exactly the same as using frequency;
see previous slide.

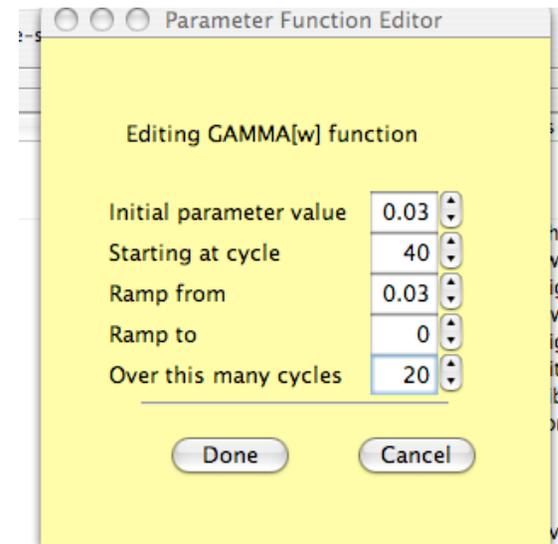


Attention

- Lexical bias - negative input to all words
- Lexical gain - responsiveness of lexical units to their input.

Parameter functions

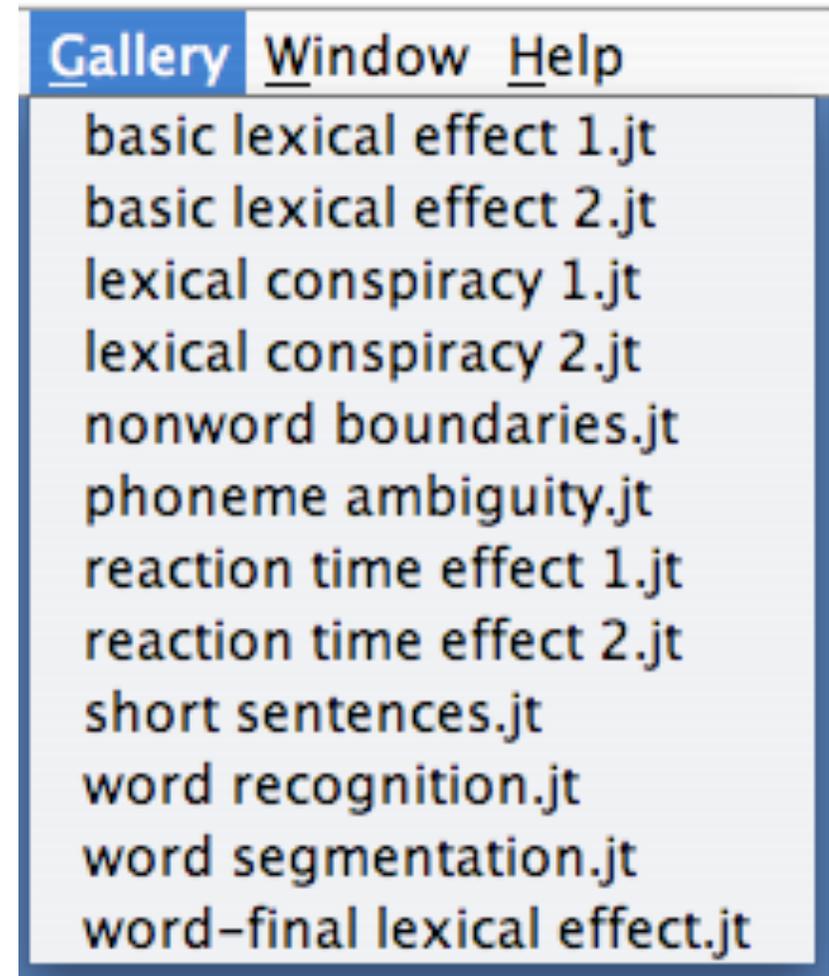
- Use a linear function to ramp a function on or off during a simulation.





Gallery menu

- Simulations described in the original TRACE paper are implemented and can be executed by simply selecting from this list.
- Simulations and analyses are performed automatically.
- Add to the gallery by saving your simulations to the `jtrace/gallery/` folder.





jTRACE Menus

File

Gallery

Window

Help

<u>F</u> ile	<u>G</u> allery	<u>W</u> indow	<u>H</u> elp
<u>N</u> ew Model	basic lexical effect 1.jt	<u>S</u> cripting	<u>H</u> elp...
<u>C</u> lone	basic lexical effect 2.jt	<u>C</u> ascade	<u>A</u> bout...
<u>L</u> oad...	lexical conspiracy 1.jt	<u>T</u> ile	
<u>S</u> ave	lexical conspiracy 2.jt	<u>U</u> ntitled #2	
<u>S</u> ave As...	nonword boundaries.jt		
<u>C</u> lose All	phoneme ambiguity.jt		
<u>E</u> xit	reaction time effect 1.jt		
	reaction time effect 2.jt		
	short sentences.jt		
	word recognition.jt		
	word segmentation.jt		
	word-final lexical effect.jt		



Your turn

- Try some simulations and explore the interface. Think about what the simulation pertains to perceptual processing.

Example simulations:

1. “-artbist-” : another example of segmentation, note how competitors become inhibited.
2. “-^grit-” : failed segmentation, since *^gri* and *grit* are both in lexicon. How is recognition resolved?
3. “-parti-” : segmentation and competition effects.



Next: Module 3

- 3 classic psycholinguistic experiments, and how their results are modeled by TRACE.
 1. Time course of lexical activation and competition
 2. Lexical consequences of acoustic deviations
 3. Lexical effects on identification of ambiguous phonemes