Modeling the RAT as Retrievals from Semantic Memory

Soar Workshop 2021

Jule Schatz

Remote Associates Test (RAT)

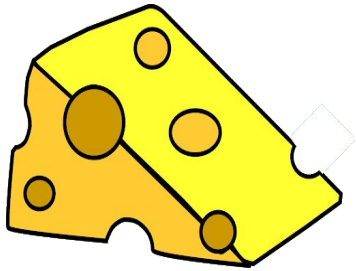
Remote Associates Test (RAT)

Remote Associates Test (RAT)

swiss | cake | cottage → cheese

Solution

swiss	cheese
cheese	cake
cottage	cheese



RAT is Theorized to Measure Creativity

https://www.the-possible.com/creativity-enigma-what-makes-us-more-creative-at-work/

Questions

- What aspects are important for modeling human performance on the RAT?
- Is there a “creativity” process that is missing from conventional cognitive architecture mechanisms found in Soar and ACT-R?

ACT-R

Agenda

1. **RAT Problems**
2. Overview
3. Model
4. Knowledge Base
5. Experiments, Variations, and Evaluation

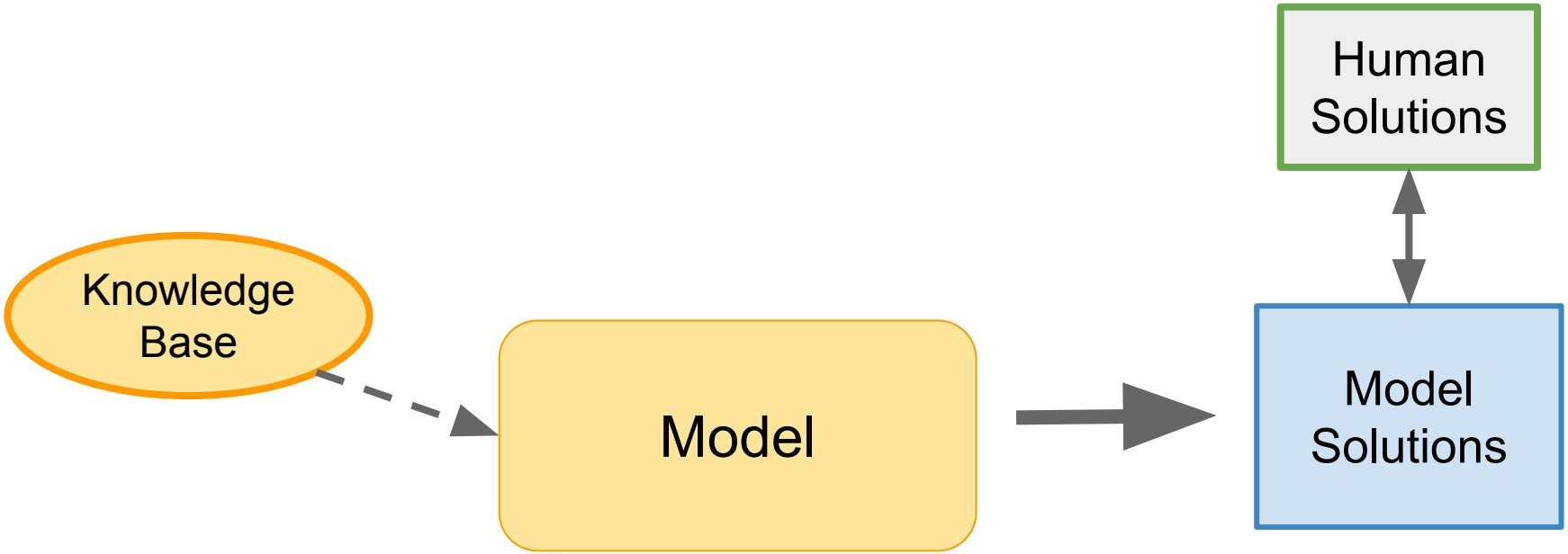
RAT Problems

- 144 RAT Problems
- Compound Word Associations
- 7 and 15 Second Human Data

Agenda

1. RAT Problems
2. **Overview**
3. Model
4. Knowledge Base
5. Experiments, Variations, and Evaluation

Overview



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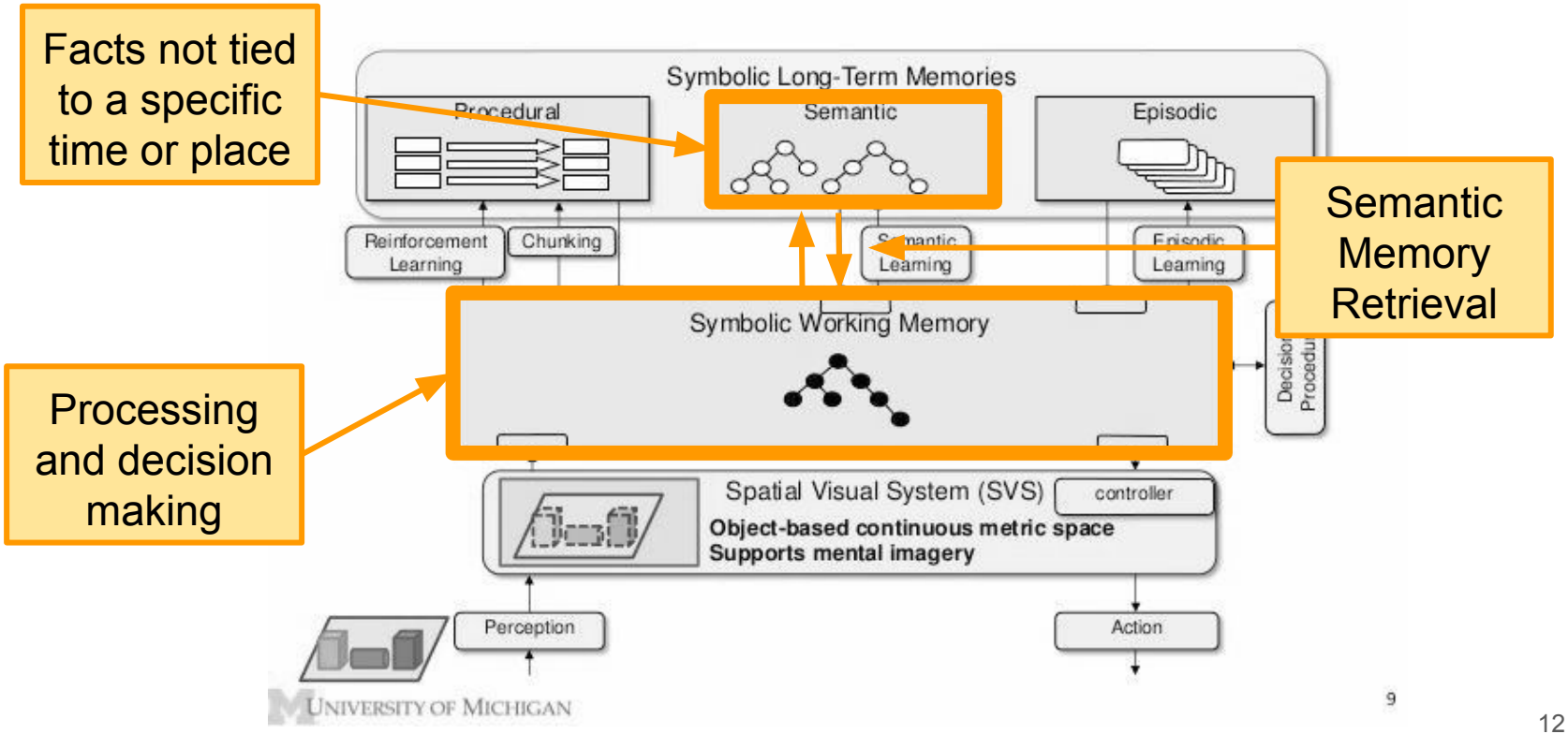
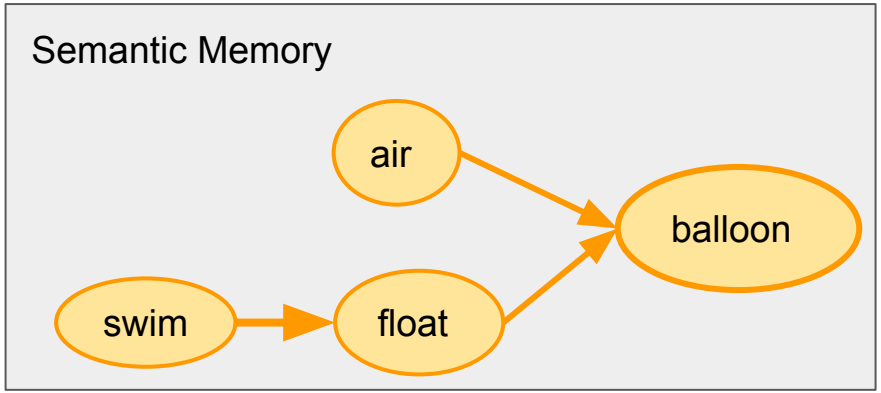
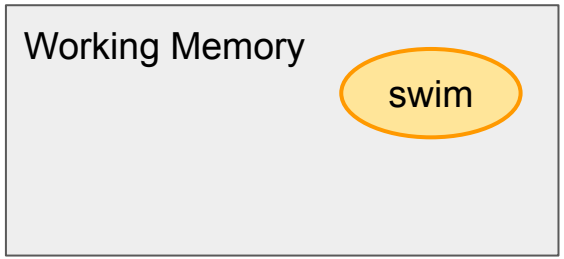
Soar Cognitive Architecture



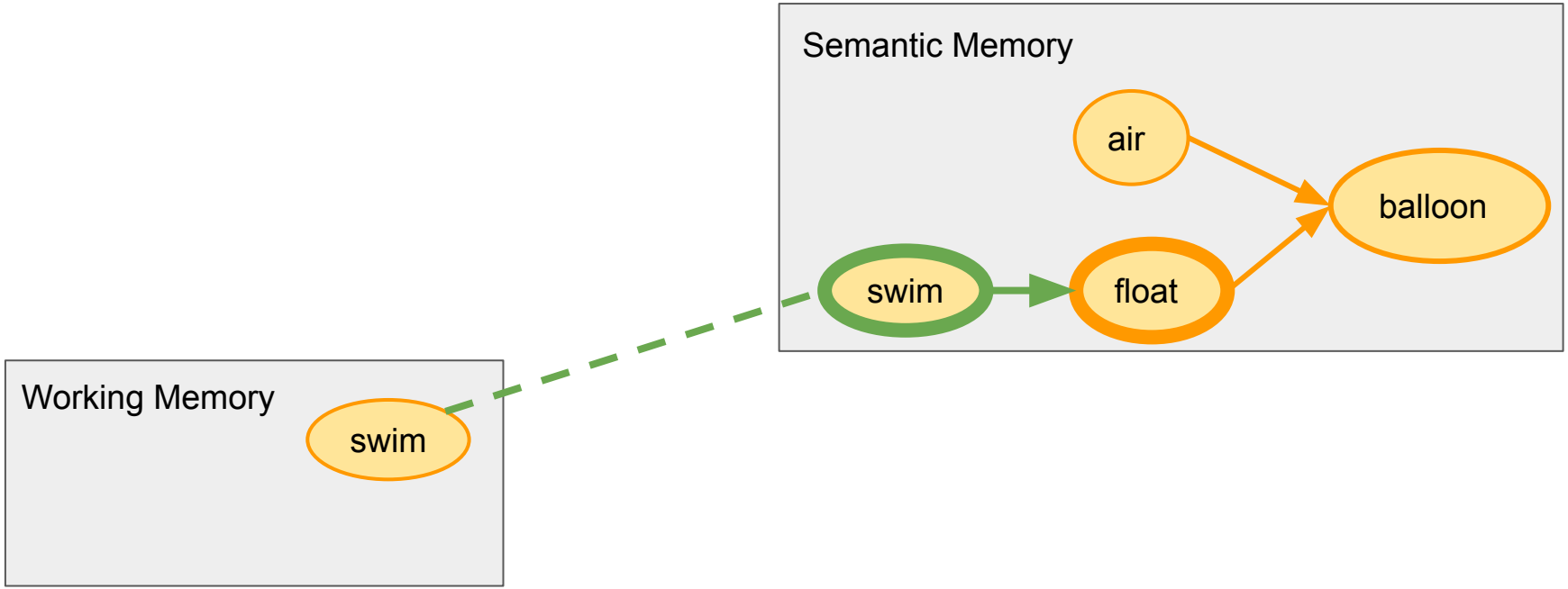
Retrieval From Semantic Memory





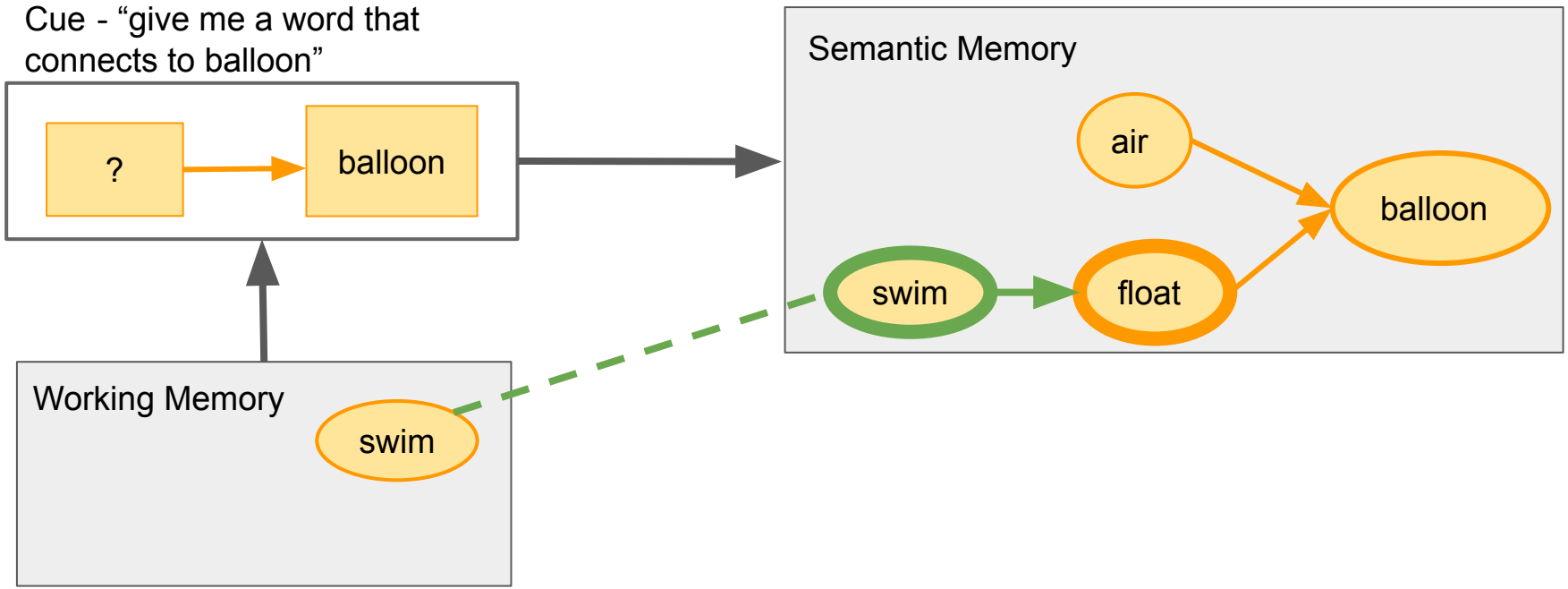
Spreading Activation - past retrievals of connected words

Retrieval From Semantic Memory



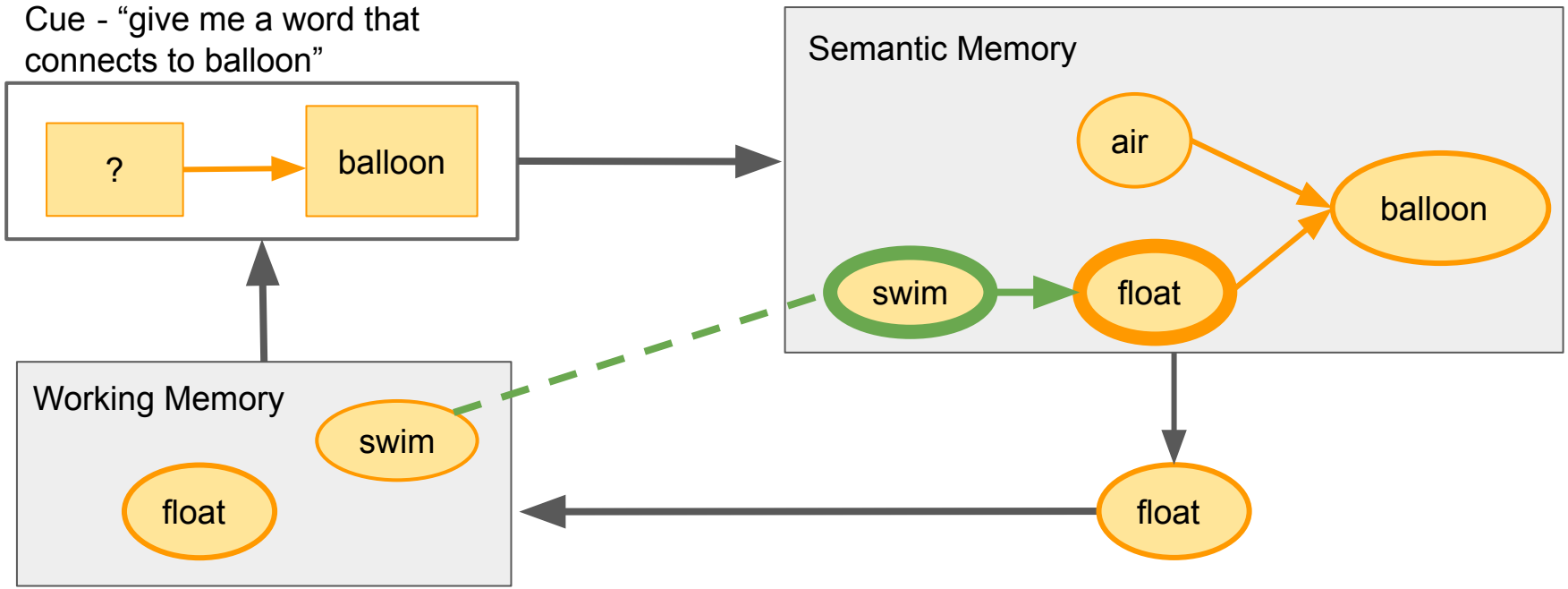
Spreading Activation - past retrievals of connected words

Retrieval From Semantic Memory



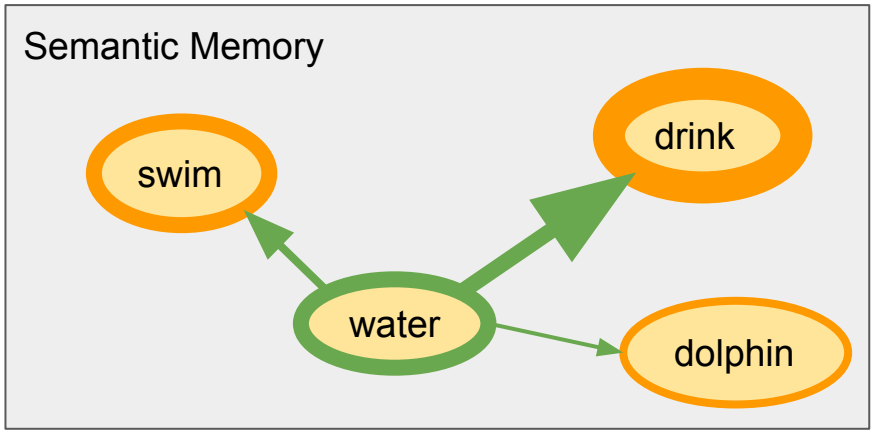
Spreading Activation - past retrievals of connected words

Retrieval From Semantic Memory



Spreading Activation - past retrievals of connected words

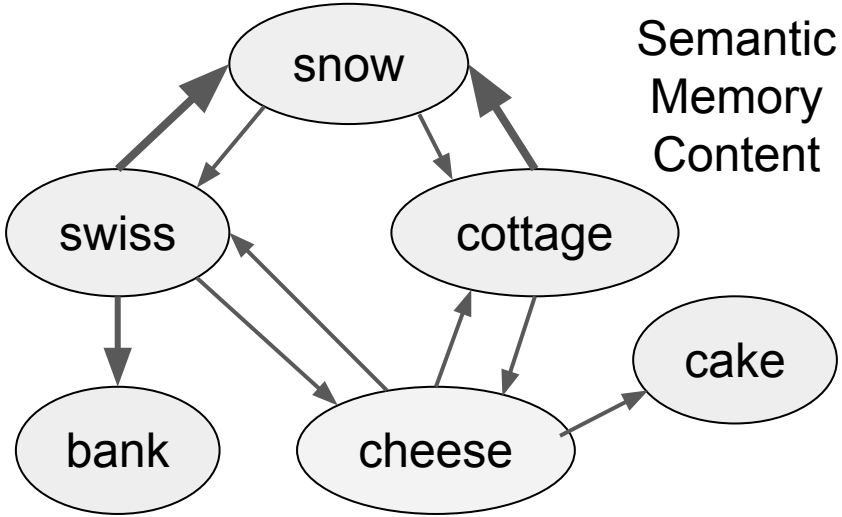
Spreading Activation



Association strength - Relative strength of the connections

Model Algorithm

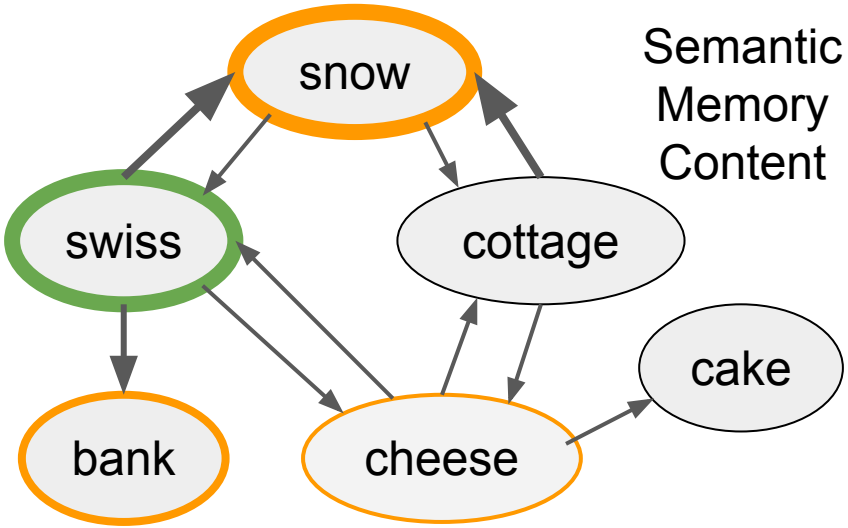
1. Receives RAT problem

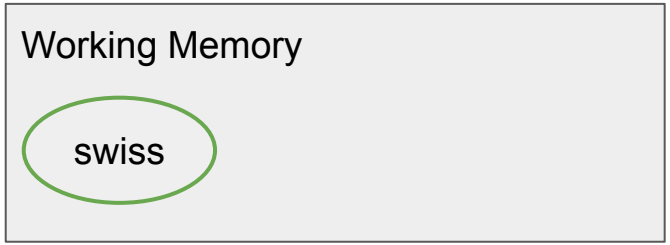


Working Memory

Model Algorithm

1. Receives RAT problem





Model Algorithm

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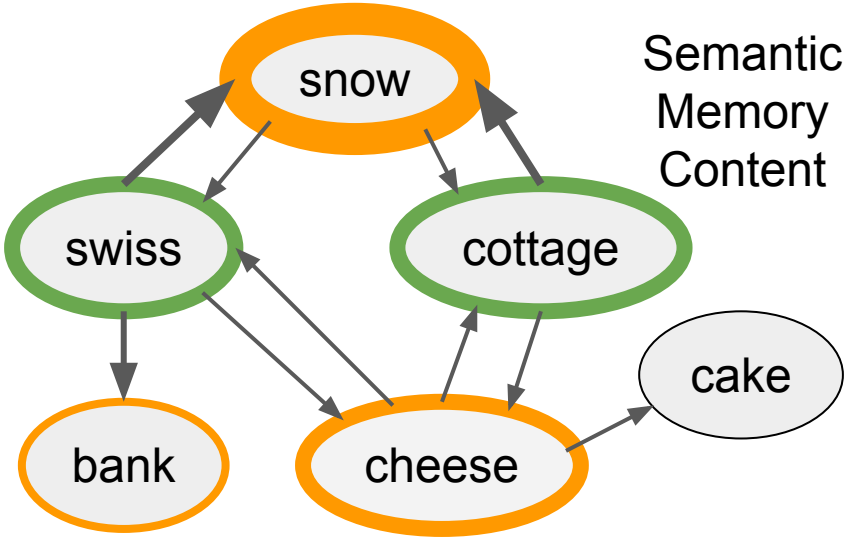

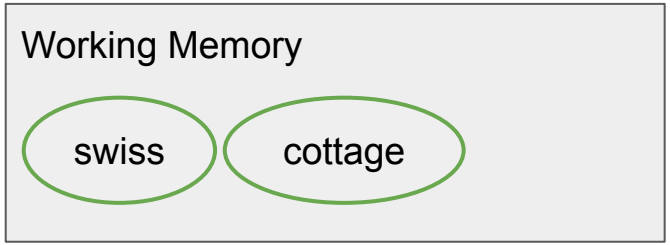

Model Algorithm

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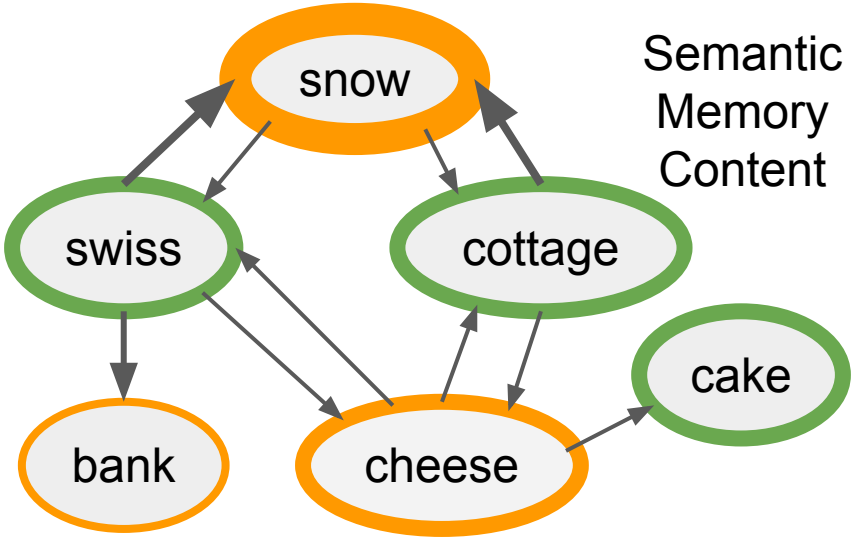
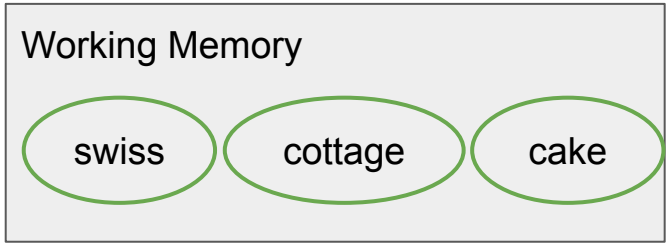
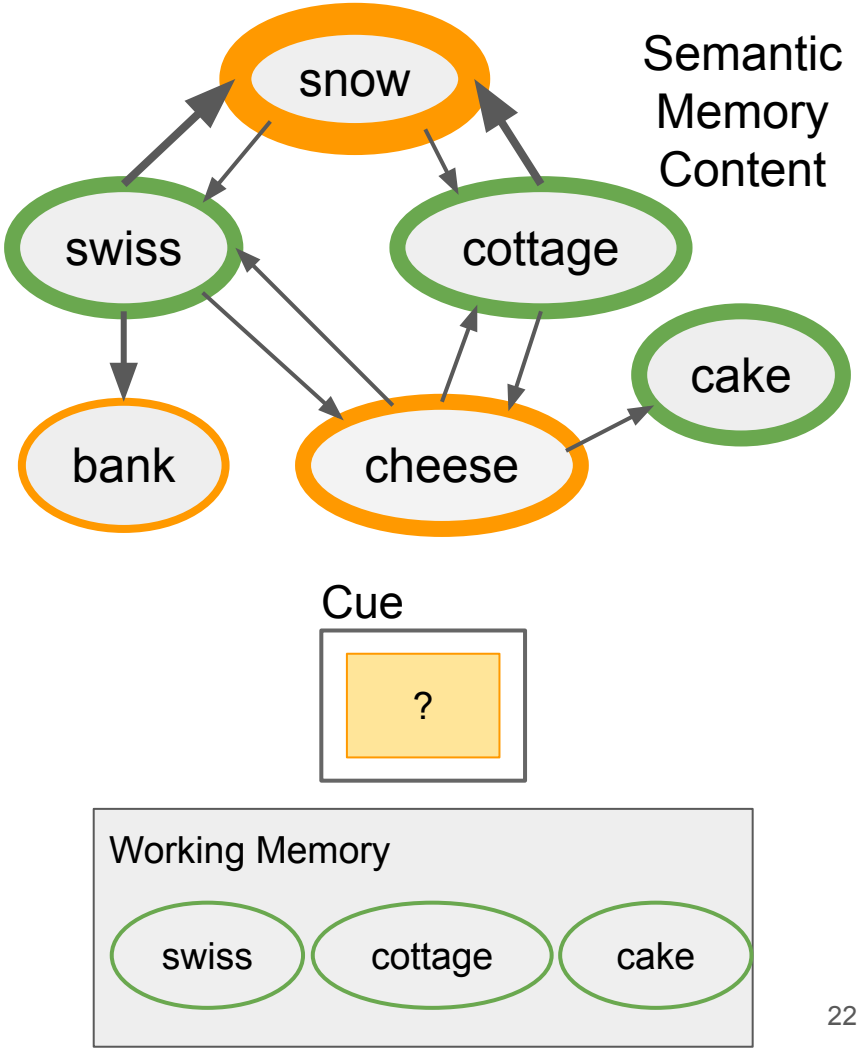




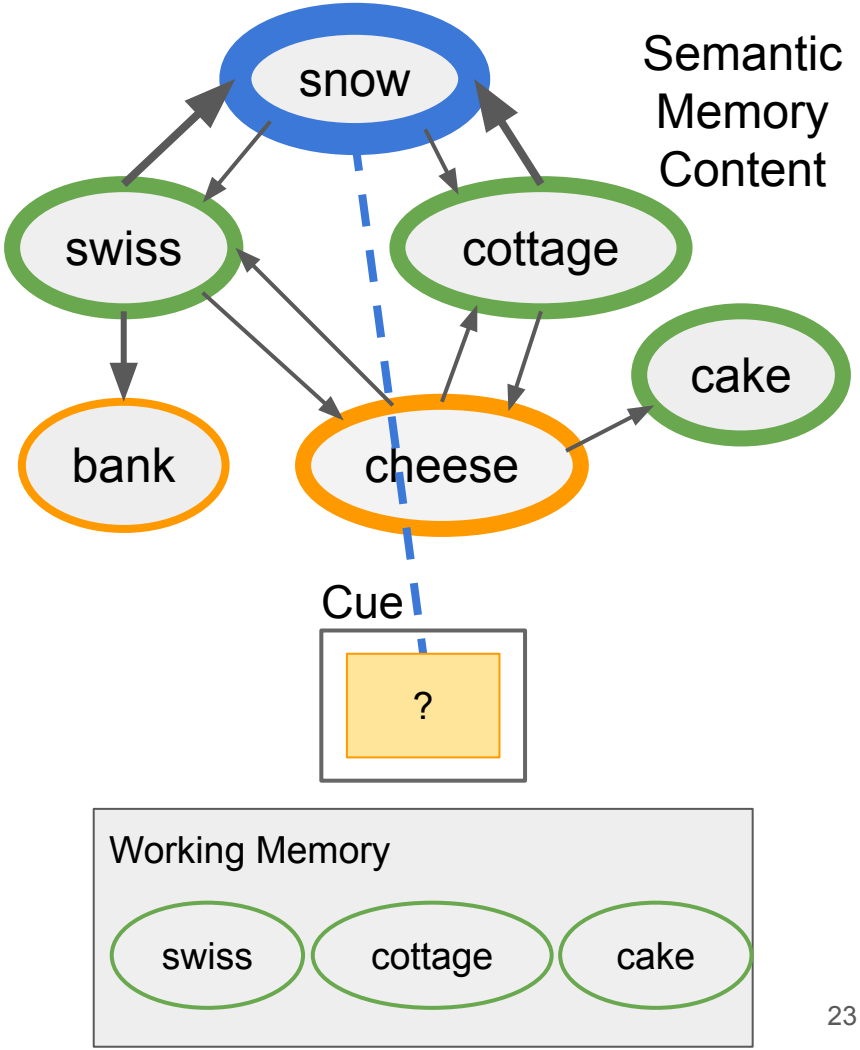
Model Algorithm

1. Receives RAT problem
2. Retrieves possible solution



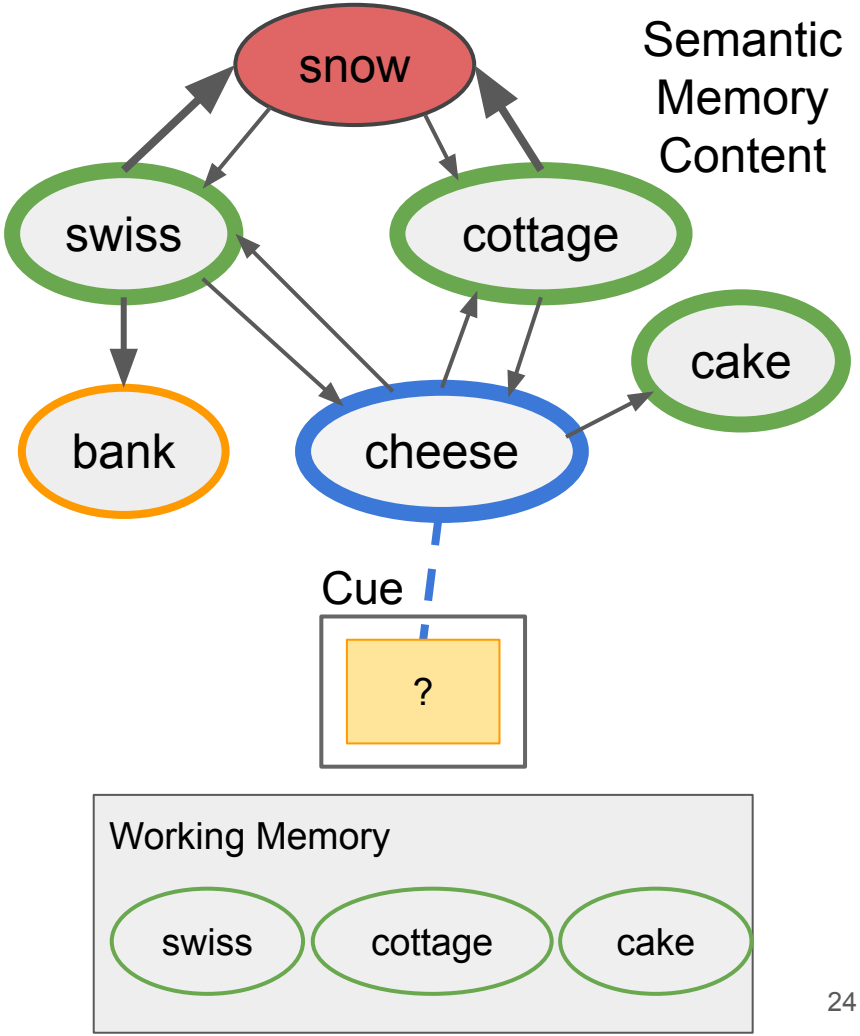
Model Algorithm

1. Receives RAT problem
2. Retrieves possible solution
3. Evaluates possible solution



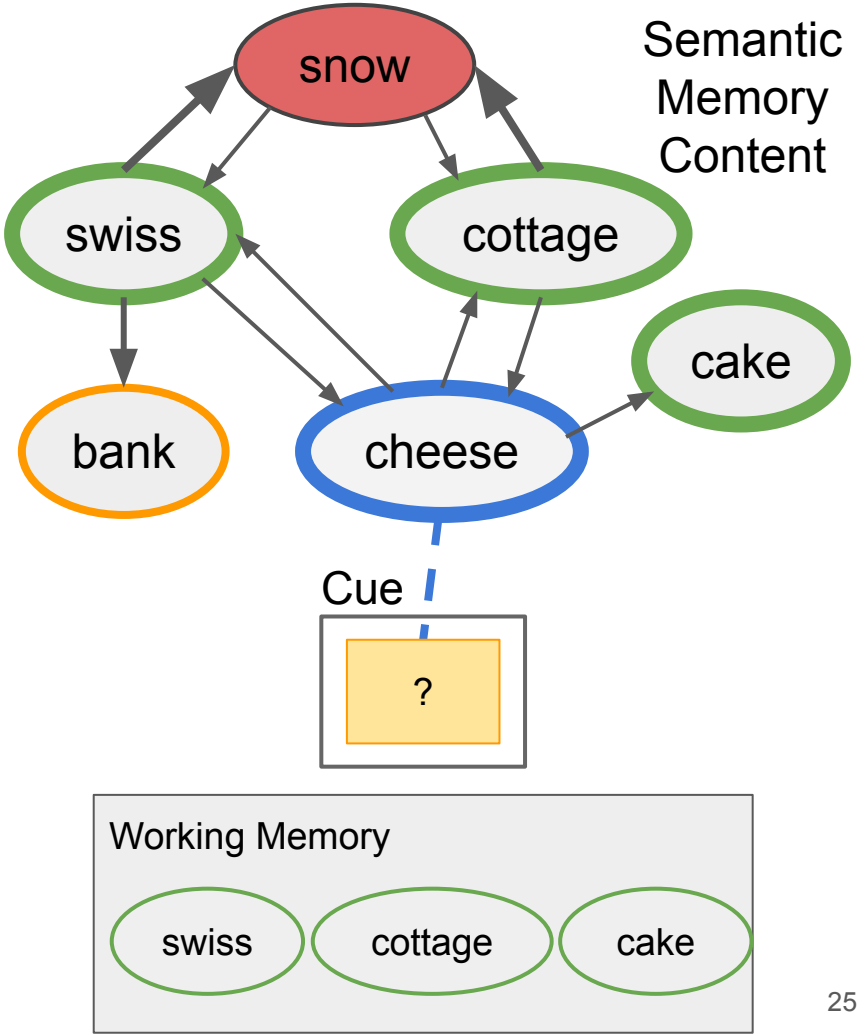
Model Algorithm

1. Receives RAT problem
2. Retrieves possible solution
3. Evaluates possible solution
4. Repeats steps 2-3



Model Algorithm

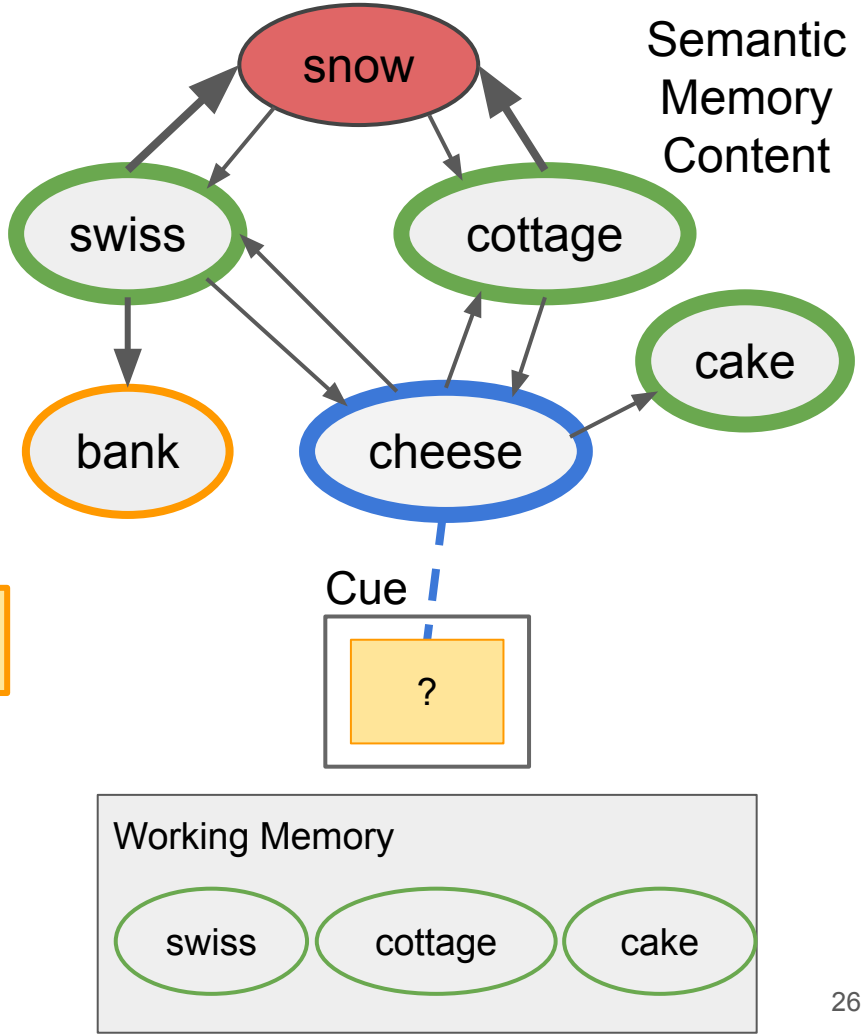
1. Receives RAT problem
2. Retrieves possible solution
3. Evaluates possible solution
4. Repeats steps 2-3
5. Returns best possible solution



Model Algorithm

1. Receives RAT problem
2. Retrieves possible solution
3. Evaluates possible solution
4. Repeats steps 2-3
5. Returns best possible solution

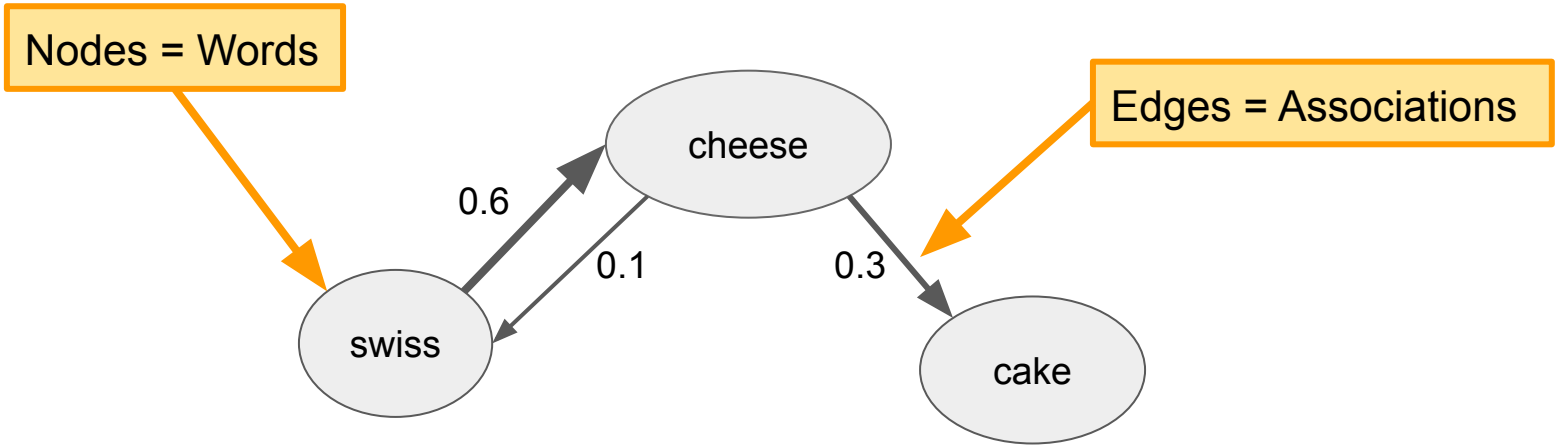
Attempts



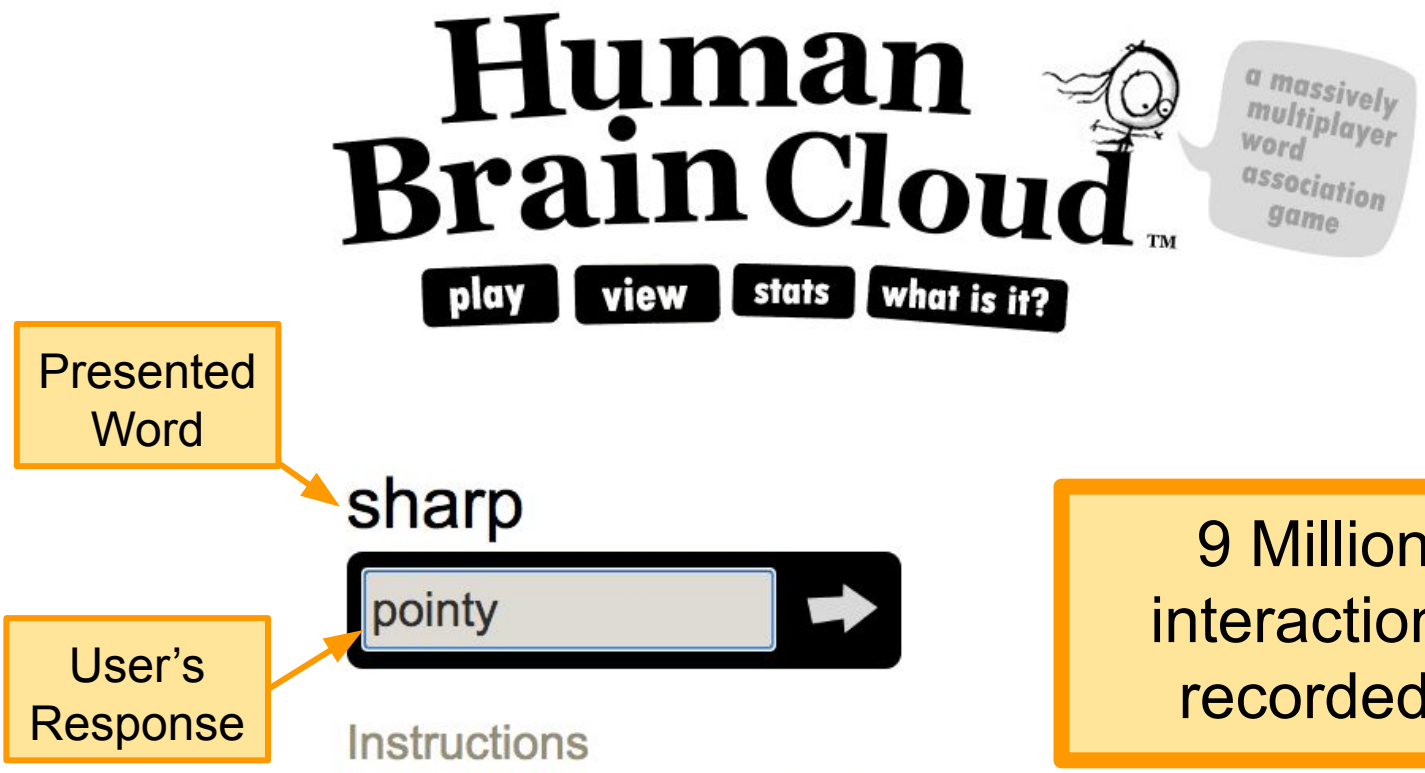
Agenda

1. RAT Problems
2. Overview
3. Model
4. **Knowledge Base**
5. Experiments, Variations, and Evaluation

Word Association Knowledge Bases




Human
Brain Cloud
TM
a massively multiplayer word association game
play
view
stats
what is it?



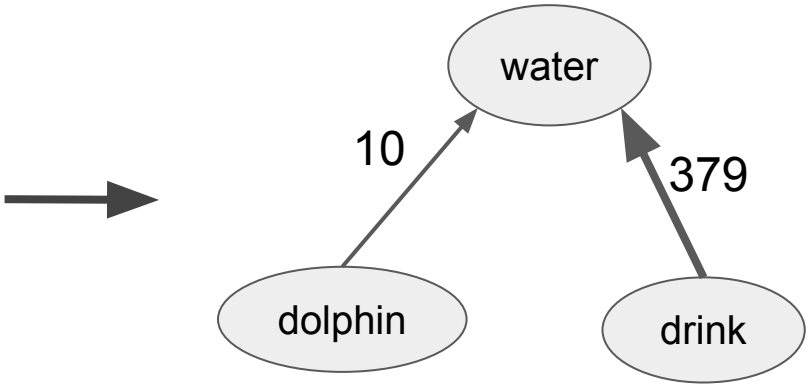
9 Million interactions recorded!

Human Brain Cloud (HBC)

- 231,851 unique words
- 2,403,203 associations between words

Data from HBC

Presented word	Response word	Count
drink	water	379
dolphin	water	10



Gabler, K. (2013). Human brain cloud. Retrieved from https://humanbraincloud.com/

Agenda

1. RAT Problems
2. Overview
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4. Knowledge Bases
5. **Experiments, Variations, and Evaluation**

Human Data on the RAT

- 289 participants
- Given 2, 7, 15, or 30 seconds for each of the 144 RAT problems
- Only comprehensive results are reported for 7 and 15 second data

RAT Item	Solution	% of Participants who solved the RAT problem in 7 seconds
swiss/cake/cottage	cheese	84% (low difficulty)
dew/comb/bee	honey	66%
man/glue/star	super	9% (high difficulty)

Evaluating Problem Difficulty

Human Data

RAT item ID	% of Participants who solved the RAT item in 7 seconds
1	84%
2	76%
...	...
144	1%

How to compare?

Sample Model Data

RAT item ID	Average model performance
1	1
2	1
...	...
144	0

Binning Based on Human Data

RAT item ID	% of Participants who solved the RAT item in 7 seconds
1	84
2	76
...	...
144	1

Easiest 12 questions for humans

Hardest 12 questions for humans

Bin Number	Average number of RAT items expected for the humans out of 12	Average number of RAT items expected for the model out of 12
Bin 1	8.24	7
Bin 2	5.59	5
...	...	
Bin 12	0.14	0

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Bin Number	Average number of RAT items expected for the humans out of 12	Average number of RAT items expected for the model out of 12
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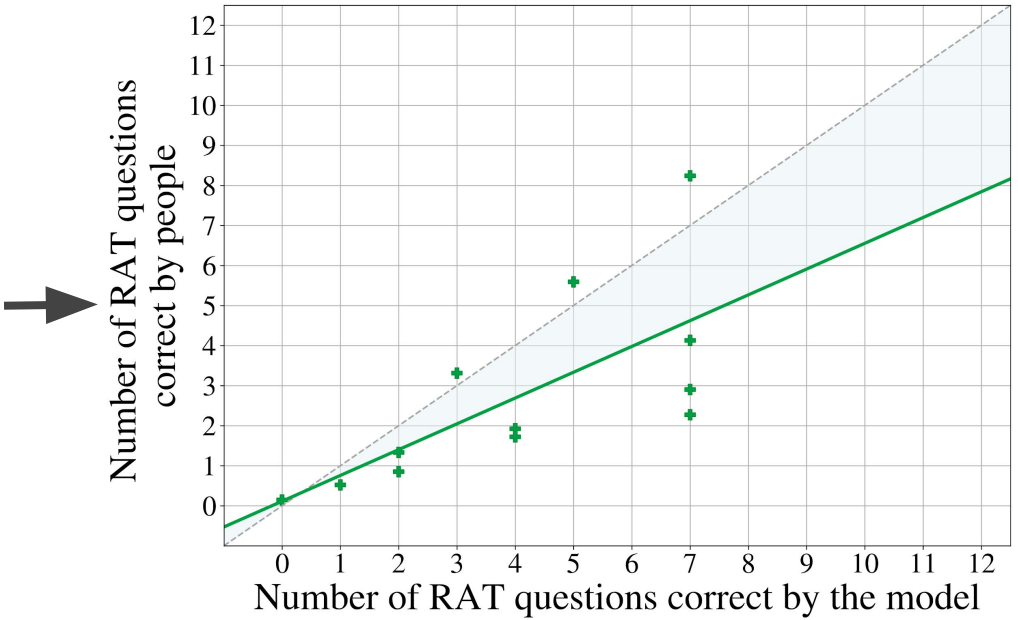
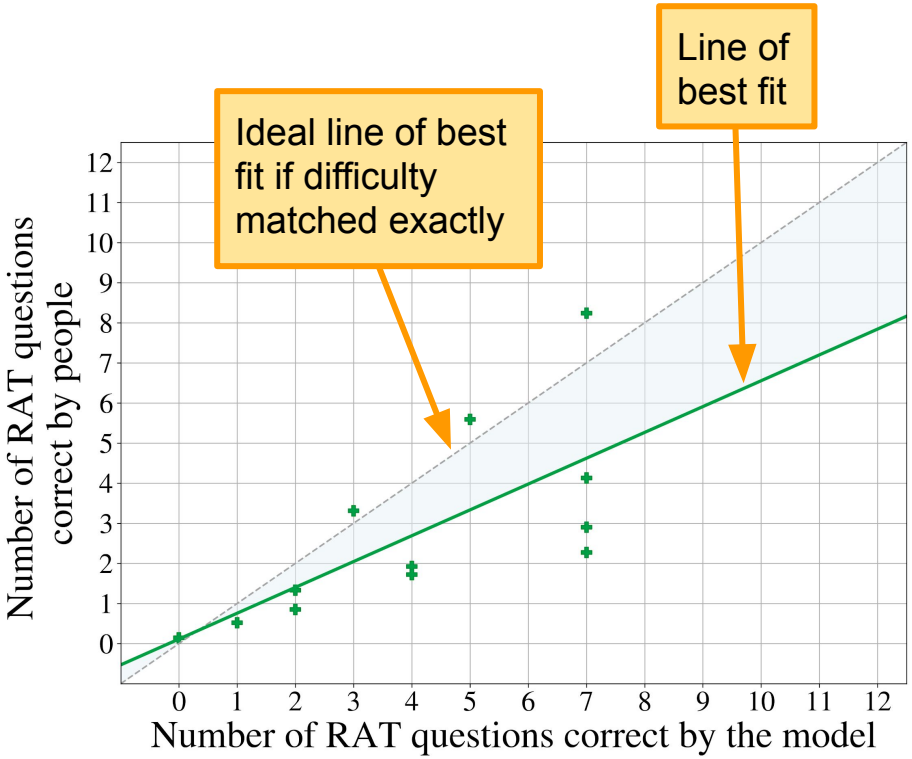


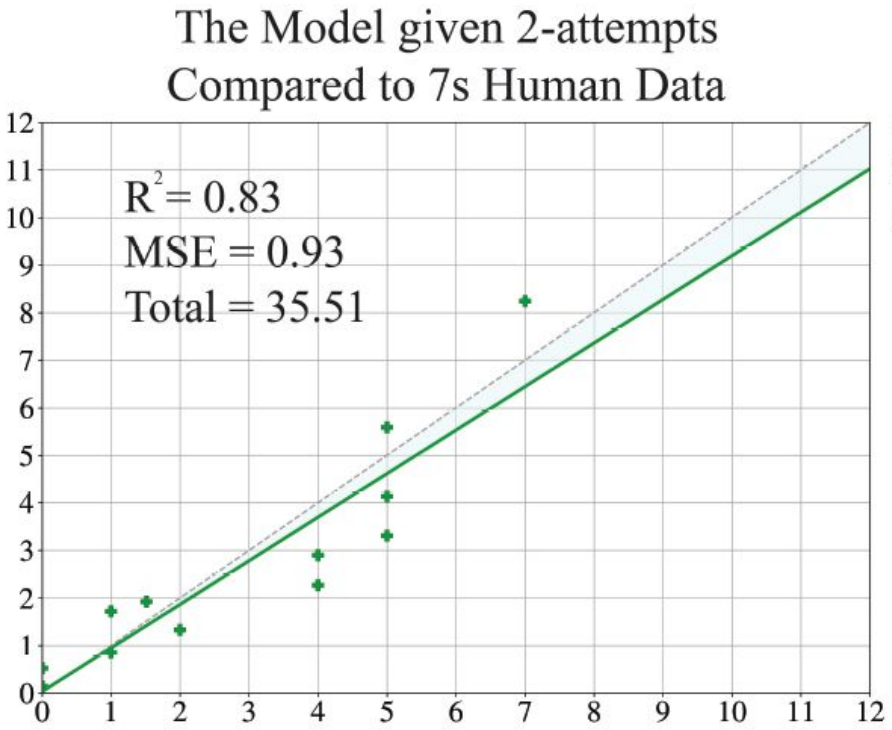
Comparison Metrics

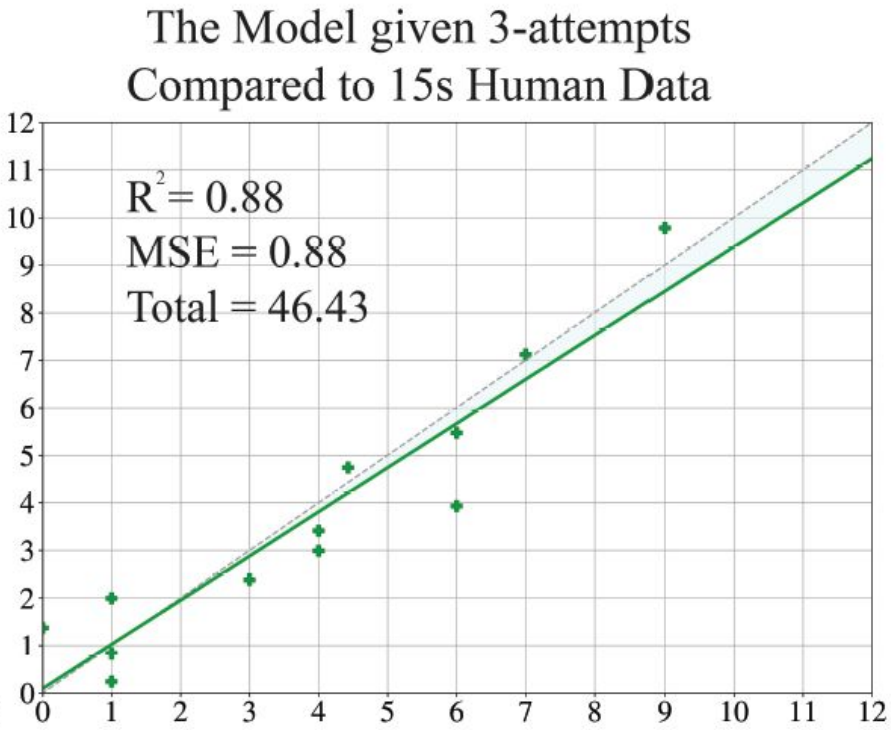


R^2 - measuring how well the variance in the model data can be explained by the variance in the human data.

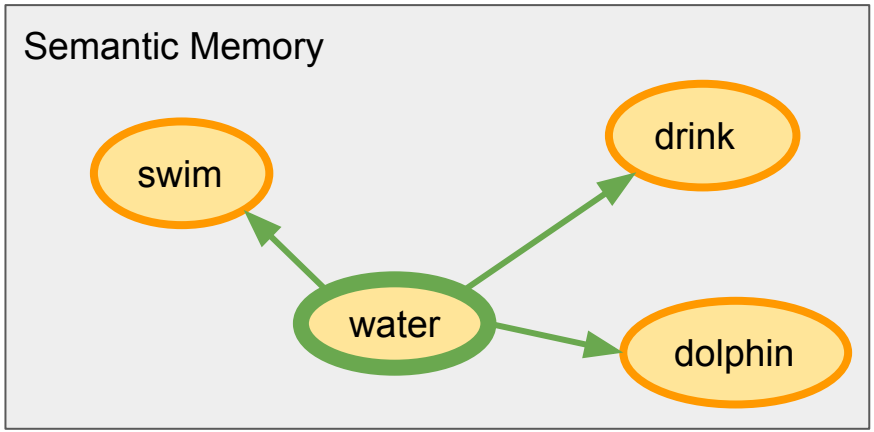
MSE - Measuring the difference between the model data and the human data.

Model Results

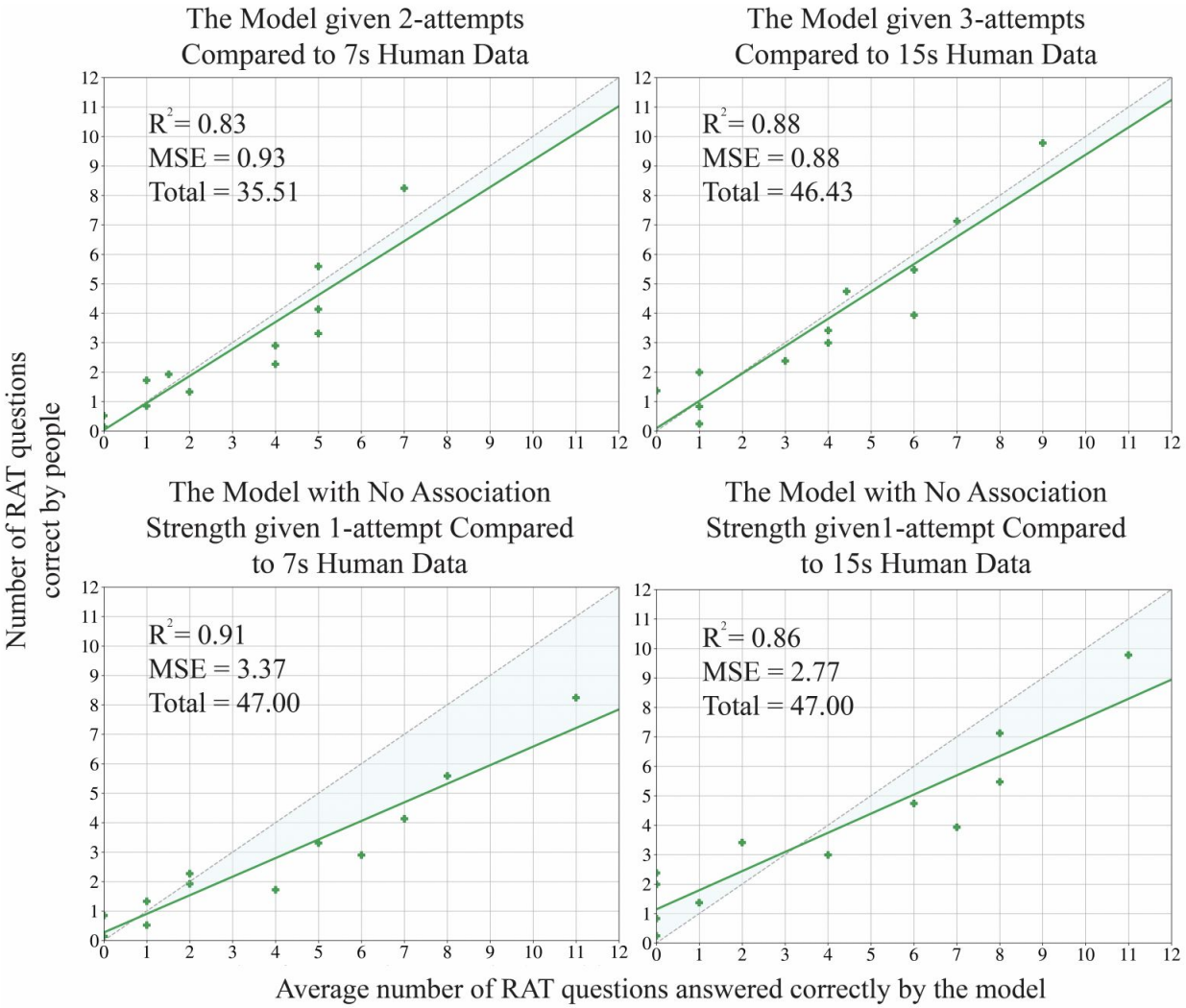


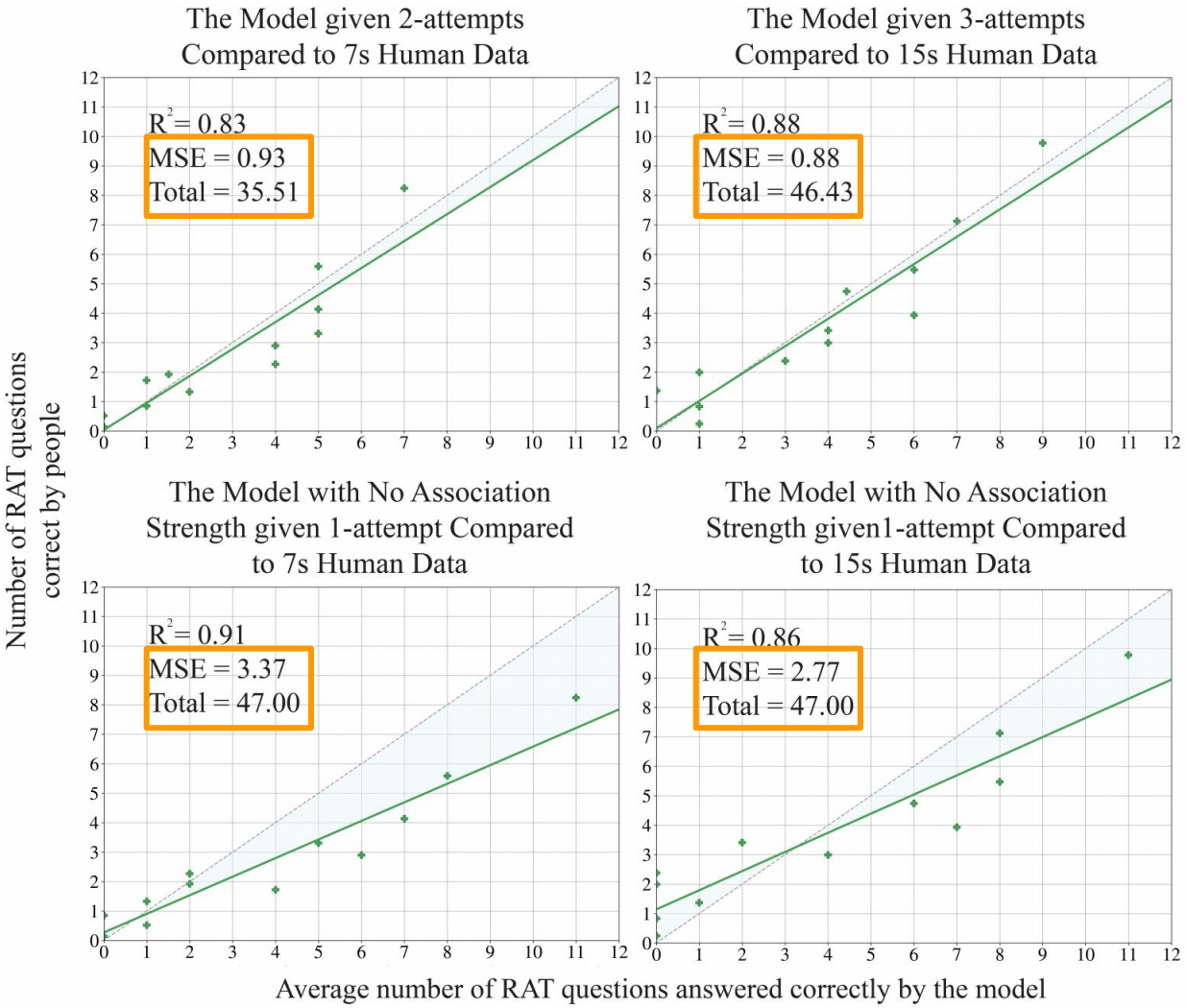


No Association Strength



Association strength - Relative strength of the connections


The Model given 2-attempts Compared to 7s Human Data
R² = 0.83
MSE = 0.93
Total = 35.51
The Model given 3-attempts Compared to 15s Human Data
R² = 0.88
MSE = 0.88
Total = 46.43
The Model with No Association Strength given 1-attempt Compared to 7s Human Data
R² = 0.91
MSE = 3.37
Total = 47.00
The Model with No Association Strength given1-attempt Compared to 15s Human Data
R² = 0.86
MSE = 2.77
Total = 47.00
Number of RAT questions correct by people
Average number of RAT questions answered correctly by the model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Number of RAT questions correct by people
Average number of RAT questions answered correctly by the model

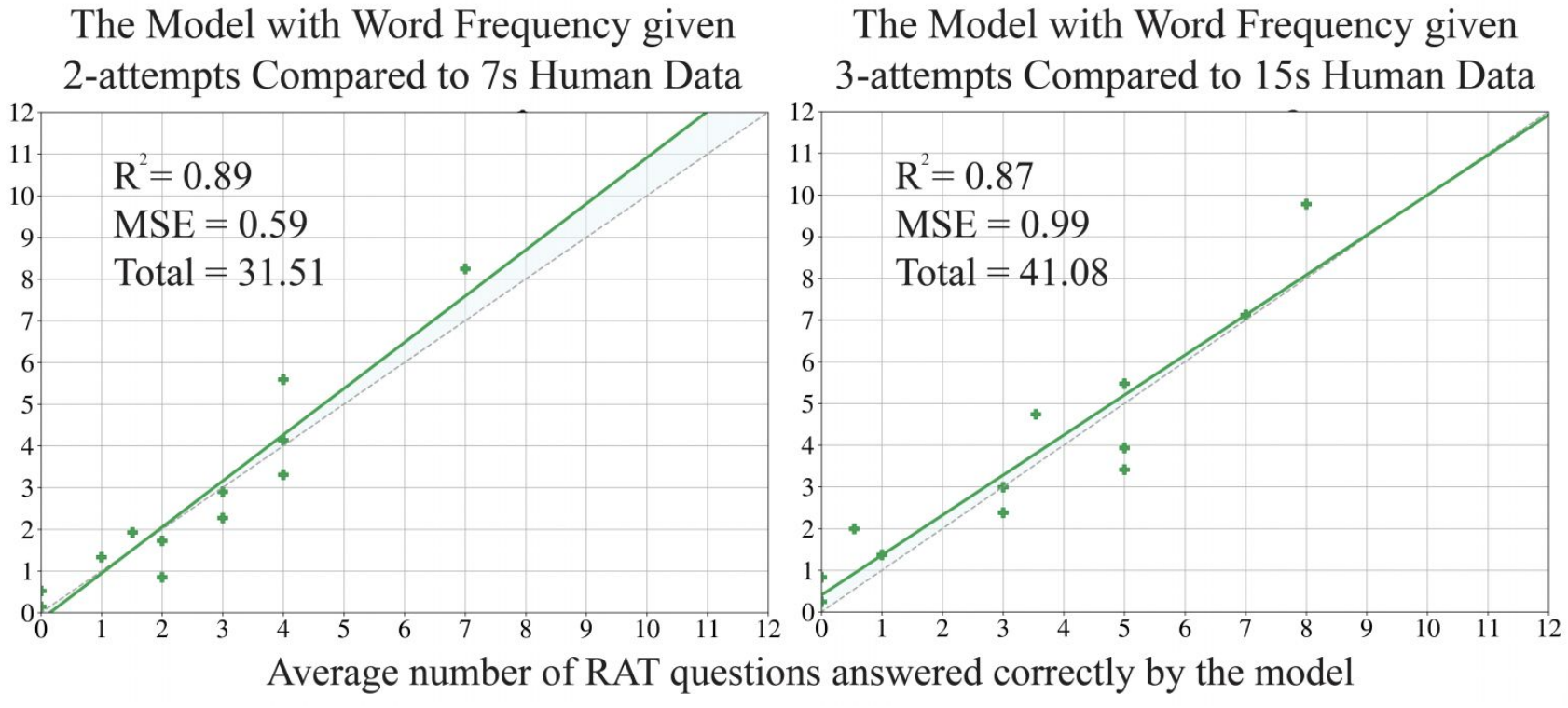
Activation in the Model

$$Activation = SpreadingActivation$$

Activation in the Model

$$Activation = BaseLevelActivation + SpreadingActivation + Noise$$

Base-Level Activation



Noise

	7s				15s			
	Attempts	# Correct	R^2	MSE	Attempts	# Correct	R^2	MSE
Human	–	32.92	–	–	–	44.25	–	–
0.0 Noise	2	35.51	0.83	0.93	3	46.43	0.88	0.88
0.5 Noise	2	31.32	0.94	0.37	3	42.40	0.94	0.49
1.0 Noise	3	34.59	0.92	0.44	4	42.43	0.94	0.43
1.5 Noise	4	33.01	0.93	0.49	6	44.10	0.93	0.50

Noise

	7s				15s			
	Attempts	# Correct	R^2	MSE	Attempts	# Correct	R^2	MSE
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Noise

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	7s				15s			
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1.5 Noise	4	33.01	0.93	0.49	6	44.10	0.93	0.50

Nuggets

- No creativity mechanism needed!
- A single model of human behavior on the Remote Associates Test (RAT)
- Important aspects are the knowledge base and a spreading activation mechanism that uses association strengths

Coal

- Only looks at aggregate human data on the RAT

Iterative Retrievals given “dew,” “comb,” and “bee”

	Attempt 1	Attempt 2	Attempt 3	Attempt 4	Attempt 5
	mountain	hair	brush	sting	honey
dew	0.37	0.00	0.00	0.00	0.01
comb	0.00	0.35	0.29	0.00	0.03
bee	0.00	0.00	0.00	0.15	0.10

Spreading Activation

$$S_j = \log\left[\sum_i \left(\frac{a_{ij}}{fan_i}\right)\right] + offset$$

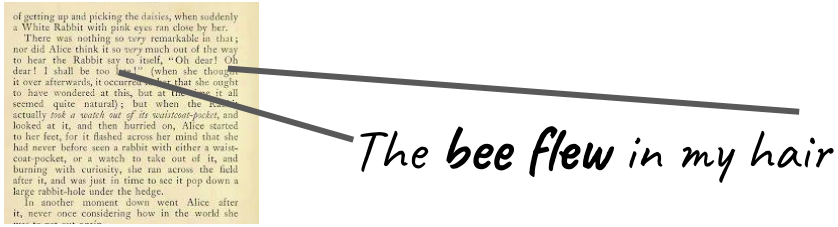
a_{ij} - Association strength from node i to node j

fan_i - Number of outgoing links from node i

S_j - Total spread node j receives

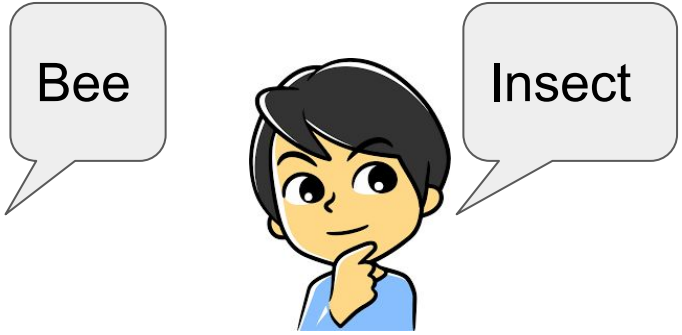
Two Ways of Collecting Word Associations

1. Word-Word Frequency



Word 1	Word2
Bee	Flew

2. Reported Associations



Word 1	Word2
Bee	Insect

Five Potential Knowledge Bases

COCA-TG - Olteteanu, and Falomir (2014)

Google Books - Kajic et al. (2016, 2017)

USF Norms - Kajic et al. (2016, 2017)

SWOWEN - Valba et al. (2021)

HBC - No one yet!

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