Mental Health Function:

Neurocomputing Formulation

Here this approach is applied to

Psychosis Disorder: Schizophrenia

[Analysis is done by Natural Language Processing]

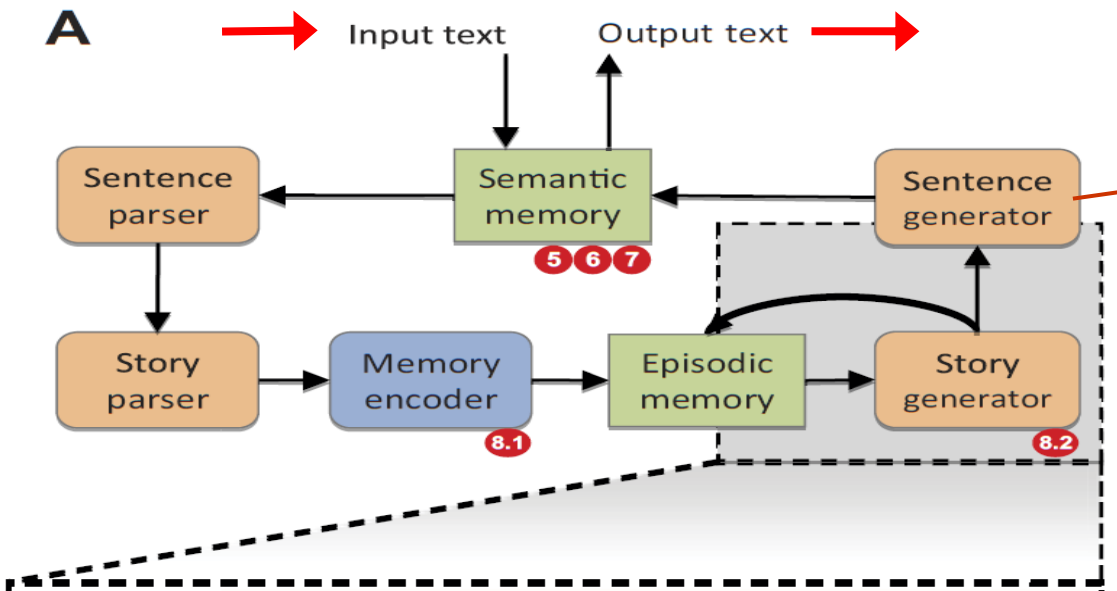
The DISCERN Model

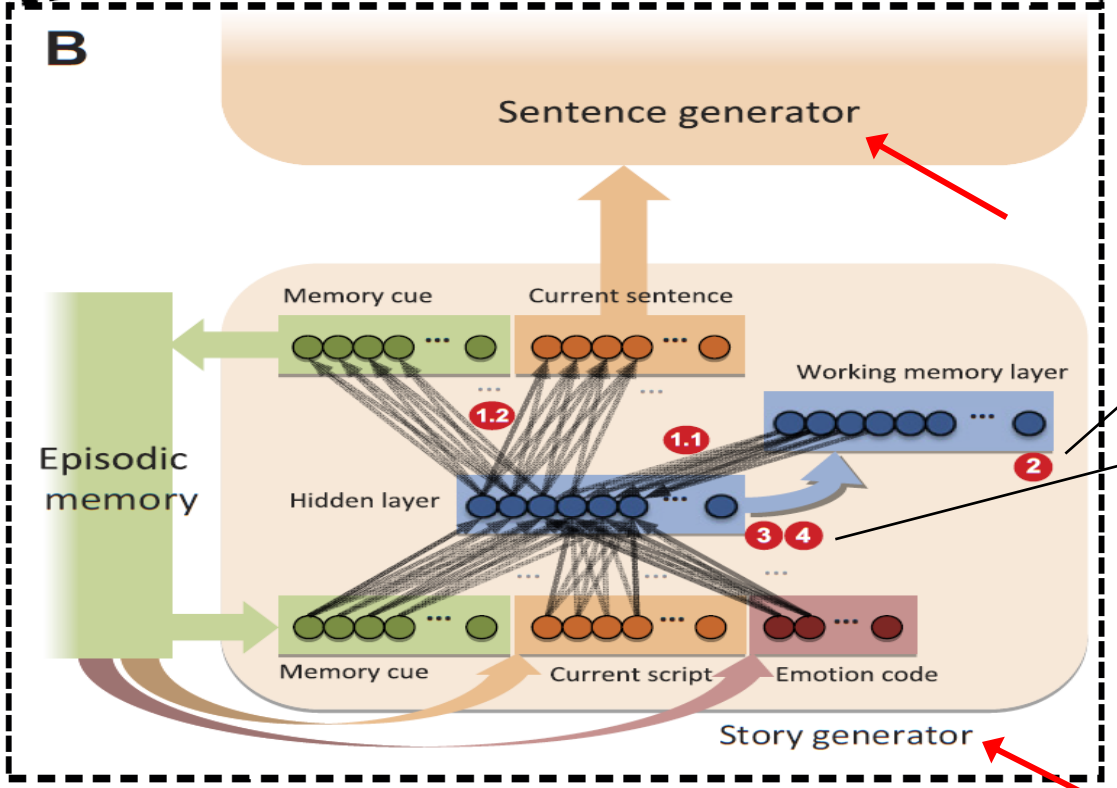
DISCERN = DIstributed Script-processing & Episodic-memoRy Network

- **This is inter-connecting ANN-Artificial Neural Network modules for Understanding & Recall.**

Key aspects:

- DISCERN learns to recognize words and the sentences and stories incorporating them using interconnected neural network modules dedicated to these different language processing levels.
- **Modules learn by updating their internal connection strengths to minimize prediction errors while processing sequential language.**
- After a group of stories is learned, DISCERN can recall any single story when prompted with an initial segment.





Architecture of Mental Processes: DISCERN Analysis:

(A) Remembering and reproducing a story in DISCERN is done by chain of modules. **Tan-colored modules are simple RNN-recurrent neural networks.**

(B) **The story generator simple recurrent network module shown in more detail. Hidden layer and recurrent layer interactions constitute a working memory (WM).** The modules in DISCERN communicate using distributed representations of word meanings, i.e., fixed-size patterns of neuron activations, stored in a central lexicon. **These representations are learned based on how the words are used in example stories, using a modified version of backpropagation.** The memory trace for each story was a compacted representation of a sequence of scripts and their slot fillers.

Alternative illness mechanisms simulated in DISCERN include:

1.1) Working Memory network disconnection;

1.2) disconnection incl. hidden output layer story generator connections;

2) Working Memory noise;

3) Working Memory gain reduction;

4) Lowered Working Memory neural bias simulating elevated arousal;

5) semantic network distortion;

6) excessive semantic network activation;

7) heightened semantic priming;

8.1) hyperlearning simulated as exaggerated prediction-error signal

8.2) hyperlearning extended to the story generator module

Experimental Task

- **The experimental task consisted of three stories presented binaurally on headphones.**

1. *"The Gift"*

"In one seat of the bus a wispy old man sat holding a bunch of fresh flowers. Across the aisle was a young girl whose eyes came back again and again to the man's flowers. The time came for the man to get off. He thrust the flowers into the girl's lap. "I can see you love flowers," he explained, "and I think my wife would like you to have them. I'll tell her I gave them to you." The girl accepted the flowers and watched the man get off the bus and walk through the gate of an old cemetery."

2. *"Hitchhiker"*

"I hitched into town. A wispy old man driving a pick-up truck with his frail wife gave me a ride. I sat in the back and watched the tires kick up dust. We stopped and waited for a traffic light. I turned around and peered into the rear window. I hadn't eaten all day and my eyes came back again and again to a bag of Fritos on the dashboard. The man got out of the truck and walked around to the back. "My wife noticed that you kept looking at the Fritos," he explained, "and she wanted you to have them."

- The third was the ***"Anna Thompson"*** story taken from the logical memory subtest of the Wechsler Memory Scale-III.

Comparing Human and DISCERN Story Recall

Table 1. Illustration of Method for Assessing Story Recall for First Two Sentences of "The Gift"

Proposition List[a]	Subject Recall: "I remember a whispering man that had flowers on a bus and he saw a girl and she wanted them . . ."[b]
(i) A (man) sat in a seat on the bus	1 ("man on a bus . . .")
1. a man rode or is on a bus	
.5. there was a man in some sort of vehicle	
(ii) man was a wispy/old	0
1. old man + indication of frailty	
.5. old man or frail man	
(iii) (man) was hold a bunch of flowers	1 ("[man] had flowers")
1. (man) possessed, holding or carrying flowers	
.5. (man) possessed something	
(iv) A young girl was/sat across the aisle from the man	.5 ("he saw a girl")
1. female sitting next to, near, or across from man	
.5. female riding in the same vehicle as man	
(v) The girl's eyes came back again and again to the man's flowers.	.5 ("[girl] wanted [the flowers]")
1. female paid special attention to the flowers	
.5 female noticed or wanted something	

[a] Propositional breakdown on the left with criteria for full and partial scores.

[b] Out of maximum score of 5, this segment assigned a score of 3.

Result: Comparison of Two Groups of Subjects for Individuals

Table 2. Comparison of Two Groups of Subjects for Individuals Completing Day 7 Delayed Recall of Stories

	Age[a]	Gender (M/F)	Parental Education (Grades)[a,b]	WAIS Scaled Vocabulary Score[a]
Healthy Control Subjects (n = 20)	36.6 (9.0)	(11/9)	13.7 (4.0)	12.2 (3.0)
Persons with Schizophrenia (n = 37)	41.5 (9.6)	(16/21)	15.1 (7.6)	9.9 (4.6)
Significance Test (two-tailed)	$t(55) = 1.51, p = .14$	$\chi^2 = .72, p = .40$	$t(53) = .77, p = .44$	$t(55) = 2.04, p = .046$

F, female; M, male; WAIS, Wechsler Adult Intelligence Scale.
[a]Mean (standard deviation).
[b]Data not available for two patients.

Result: Comparison of Two Subject Groups

Table 3. Comparison of Two Subject Groups on 7-Day Story Recall

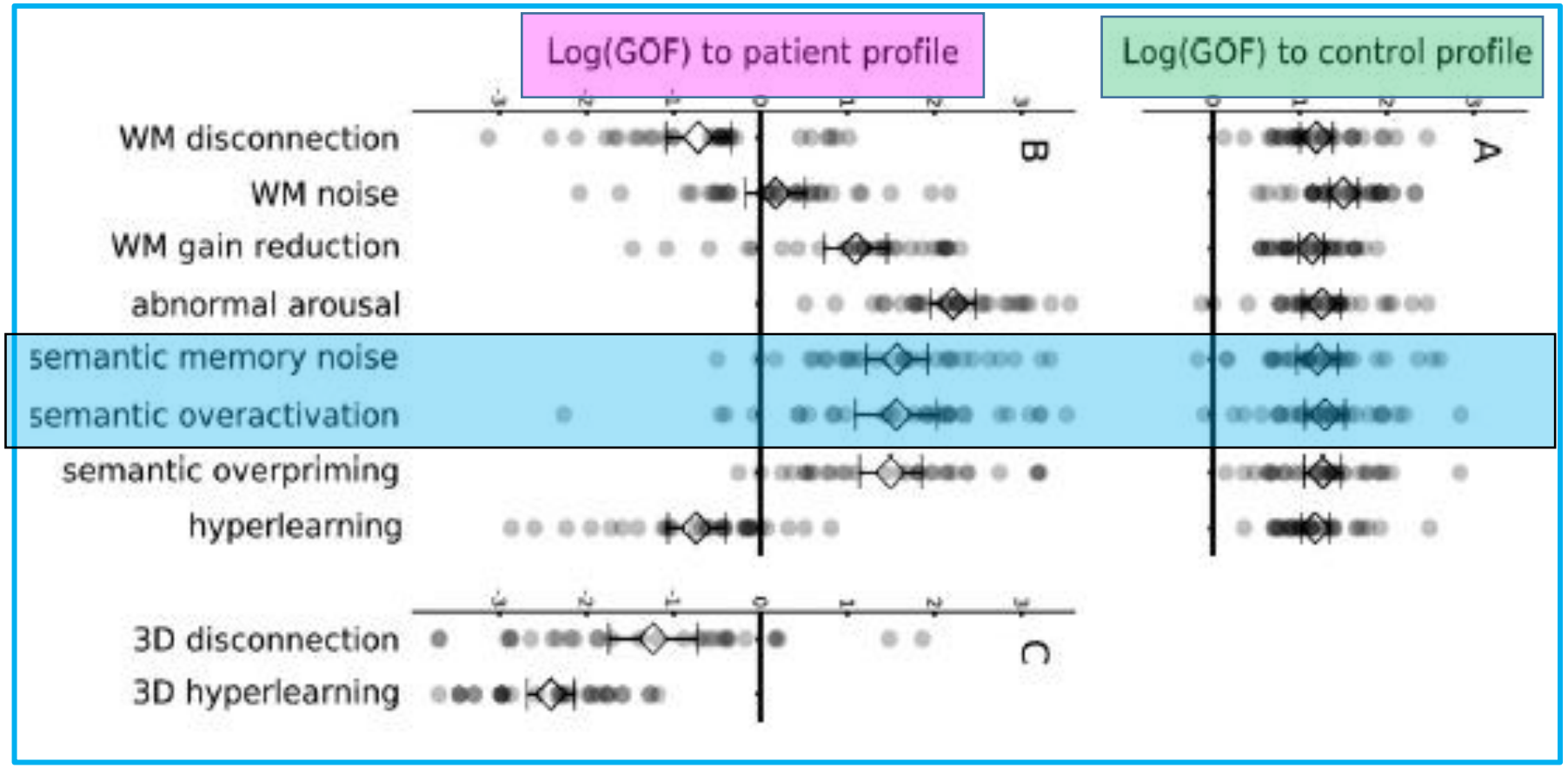
	Recall Success[a]	Agent Slotting Error Penetrance[a]	Lexical Misfire Penetrance[a]	Derailment Penetrance[a]
Healthy Control Subjects (n = 20)	.67 (.12)	.023 (.033)	.051 (.064)	.011 (.040)
Persons with Schizophrenia (n = 37)	.41 (.23)	.086 (.121)	.065 (.085)	.122 (.226)
Significance Test (two-tailed, uncorrected)	$t(55) = 4.9, p = .00001$	$t(44.8) = 3.0, p = .004$[b]	$t(49.3) = .70, p = .49$[b]	$t(50.7) = 3.8, p = .0004$[b,c]

[a]Mean (standard deviation).
[b]Equal variance not assumed.
[c]After square root transformation to normalize data.

Goodness-of-Fit (FOF) Analysis

- A four-variable story-recall profile was averaged for human control subjects, and for patients.
- For each of the 30 DISCERN exemplars and 8 illness mechanisms, parameters were adjusted to best reproduce these two story-recall group profiles.
- This yielded 30 GOF measures for each mechanism and group profile.
- Each illness mechanism was studied initially by adjusting two parameters: the mechanism parameter itself (level of noise, pruning, etc.) and the filter threshold.
- Goodness-of-fit used a mean square deviation metric.
- A mixed model was used with GOF as the dependent variable, the 30 DISCERN exemplars as independent subjects, and type of mechanism (8 levels) and human group (healthy control subjects vs. schizophrenia patients) as factors.

Simulation Result of Disease Mechanisms



- Scatter plots of 30 independently generated simulations showing each of the eight mechanisms mapped using a mean square deviation metric of **goodness-of-fit (GOF)** to the language profile of control subjects **(A)** and patients **(B).**
- Goodness-of-fit was ***log*** converted to normalize distributions; smaller values represent a better fit.
- Adding another mechanism parameter to these disconnection & hyperlearning models improved **GOF** to patient performance for both

Pairwise Comparisons of Optimized Goodness-Of-Fit (GOF) of the model developed

Table 4. Pairwise Comparisons of Optimized GOF for Two-Dimensional Hyperlearning and WM Disconnection Relative to the Other Six Two-Dimensional Models Based on Mixed Model Analysis[a,b,c]

	2-D Hyperlearning		2-D WM Disconnection	
	t Test	*p* Value	*t* Test	*p* Value
WM Noise (2)	3.9	<.0001	3.6	.0004
WM Gain Reduction (3)	7.8	<.0001	7.2	<.0001
Altered WM Bias (4)	14.7	<.0001	13.3	<.0001
Semantic Network Distortion (5)	9.9	<.0001	9.2	<.0001
Excessive Semantic Network Activation (6)	8.2	<.0001	7.7	<.0001
Semantic Blurring/Overpriming (7)	9.5	<.0001	8.8	<.0001

2-D, two-dimensional; GOF, goodness-of-fit; WM, working memory.

[a]WM working memory in story generator.
[b]df 203, all pairwise comparisons favored 2-D hyperlearning and disconnection over other models; numbers in parentheses correspond to mechanism code.
[c]Comparison of 2-D hyperlearning versus 2-D WM disconnection in terms of optimized GOF with patient narrative breakdown profile was nonsignificant (*t* .09).