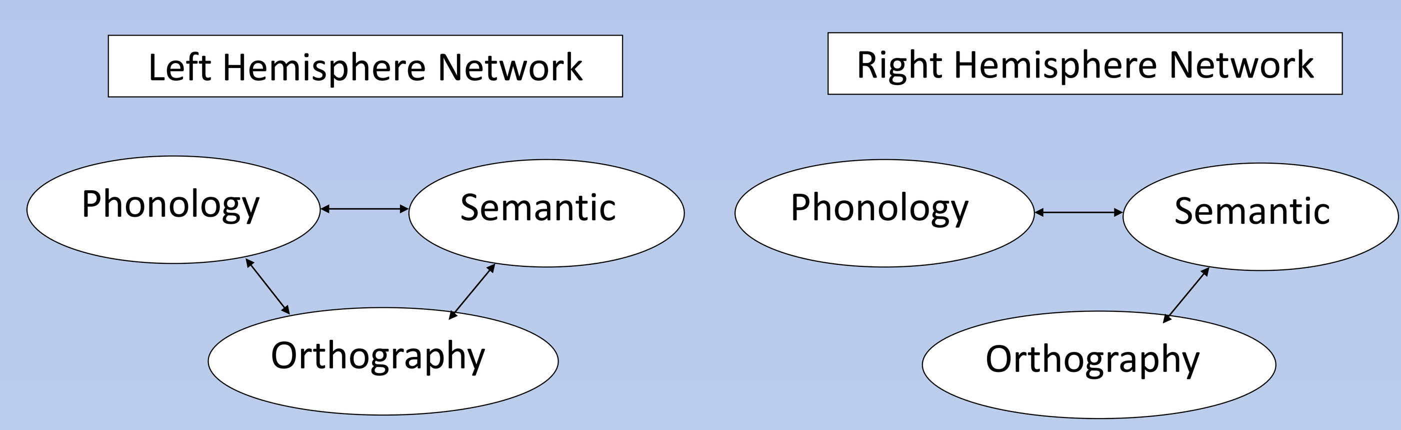
The effect of inter-hemispheric connectivity when resolving ambiguities in reading

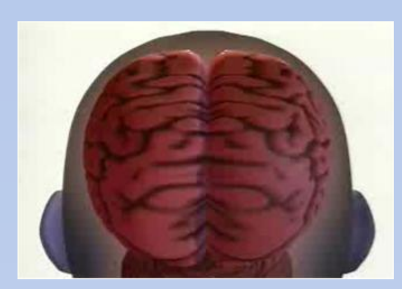
Rom Timor, Larry Manevitz, Hananel Hazan, Orna Peleg & Zohar Eviatar

Abstract

Computational model simulating left hemisphere (LH) and right hemisphere based on the proposed architecture in psychophysical theories of Eviatar and Peleg.
The two hemispheres are connected and interact both in training and testing in a reasonably "natural" way.
Experiments show that this integrated model reacts in a comparable way to human DVF experiments performed by Eviatar and Peleg on ambiguous homographs designed to tease out the differences in the two hemispheres.
The simultaion shows the importance of the transfer of information via the corpus collosum between the hemispheres and suggests further human experiments.

This work presents the computational advantage of having two networks that can exchange information: LH fully connected (Orthography, Phonology and Semantics) and RH lack of connection between Orthography and Phonology.





Our work focuses on the different possible connections between networks representing the two hemispheres and how these differences affect the results of processing homophones. The simulation examines the activation of meanings of ambiguous words with polarized meanings (where one meaning is much more frequent (dominant) in the language) and has shown that transfer of information from RH to a LH, when context biasing to the nondominant meaning is presented after the initial presentation of the word, is the most efficient mechanism for recovery from erroneous activation of the dominant meaning.

Computational Simulation

1. General

The simulation is based on Hazan's network, a two-hemisphere model based on Kawamoto's model. The model includes two separate networks. One network incorporates Kawamoto's version, and successfully simulates the time course of lexical disambiguation in the LH. In the other network based on the behavior of the disconnected RH of split brain patients (Zaidel & Peters, 1982), a change was made in Kawamoto's architecture, removing the direct connections between orthographic and phonological units.

The simulation includes the "Corpus Callosum" (CC) that was implemented as a connection from LH units to RH units in a various ways including "One to One", "One to Many", within regions and between regions.

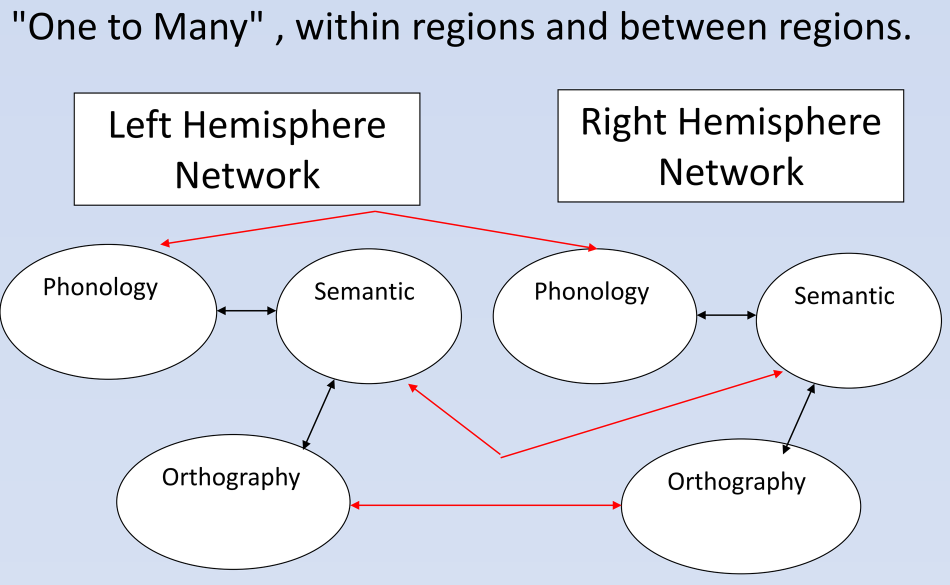


Illustration of network, The network include CC connections between LH and RH (Same region).
In each simulation, 12 identical networks were used to simulate 12 subjects .

2. The Learning stage

The network was trained with a simple error correction algorithm taking into consideration a learning constant and the magnitude of the error determining a bipolar activity of a single unit. This activity is determined by the input from the environment, the units connected to it (within the hemisphere and from the CC) and a decay in its current level of activity .
In a learning trial an entry was selected randomly from the lexicon. Dominant and subordinate meanings were selected with a ratio of 5 to 3 roughly based on linguistic considerations.
We performed different experiments that include different learning stages. First, the learning stage was done while the LH and RH are disconnected. Second, the learning stage was done when the LH and RH are connected via the CC: free learning (no restriction on the CC weights) and restricted learning (weights limited to 0.1 - 0.3).

3. Testing the model

We tested by presenting just the orthographic part of the entry as the input (to simulate neutral context) or by presenting part of the semantic (subordinate meaning) sub-vector after presenting the orthography (to simulate contextual bias). The number of iterations for full vector saturation was measured. A response was considered an error if the pattern of activity did not correspond with the input; non convergent if all the units did not saturate after 50 iterations.

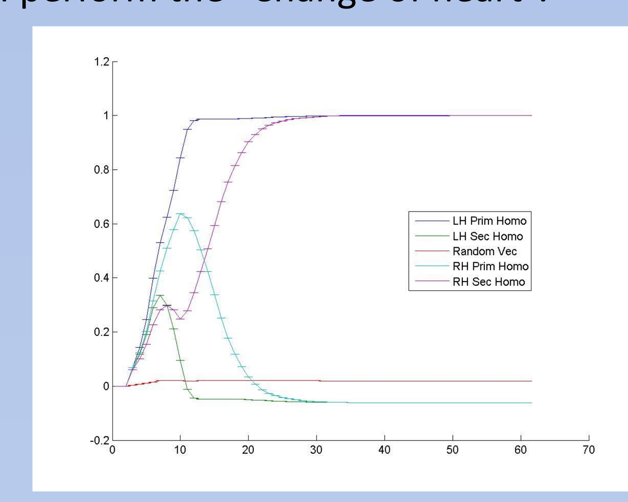
Summary

A model of both the RH and LH, with architectural differences between the hemispheres as proposed by the theories of Peleg and Eviatar. The hemispheres are linked together in a natural fashion, both during learning and functioning. The results of the simulations show that the connections between the hemispheres allow additional functionality for the LH as observed in humans ("change of heart"); and the hemispheres also perform at comparative speeds that also qualitatively match human DVF experiments. Further, our work predicts connectivity strength between the two hemispheres in architectural regions; and thus suggests new human experiments.

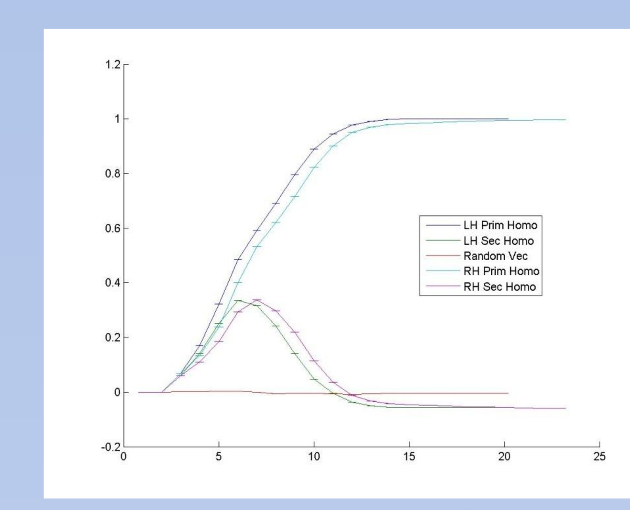
Results

Hazan's previous results indicated that without transfer of data between LH and RH the LH cannot recover to the subordinate meaning after receiving semantic clues and thus selects the dominant meaning. The RH was able to perform this recovery and select the subordinate meaning. This phenomenon was called the "Change of heart".
Our initial results indicated that when setting the weights of CC from RH to LH to 0.25 in a "One to One" connection the transfer of data from RH to LH can help the LH perform the "Change of heart".

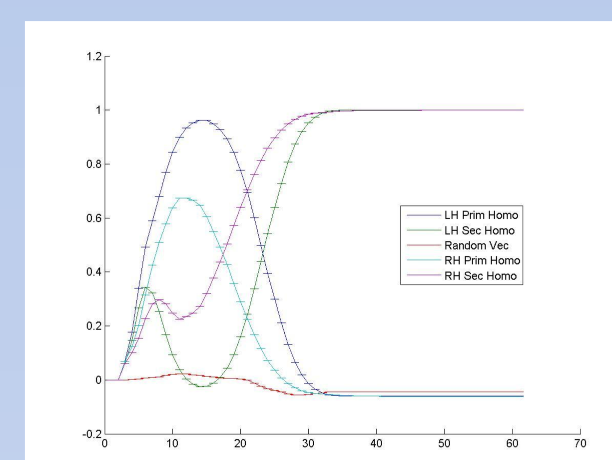
Connected learning yield the following results:
A. Free learning of CC weights caused the LH and RH to lose their special properties. LH became slower while selecting the dominant meaning and the RH lost its ability to perform the "Change of heart" when presented with clues to the subordinate meaning .
B. Restricted learning was able us to cause the LH and RH to not lose their special properties. Both RH and LH performed the "Change of heart" but LH recovery is partial.



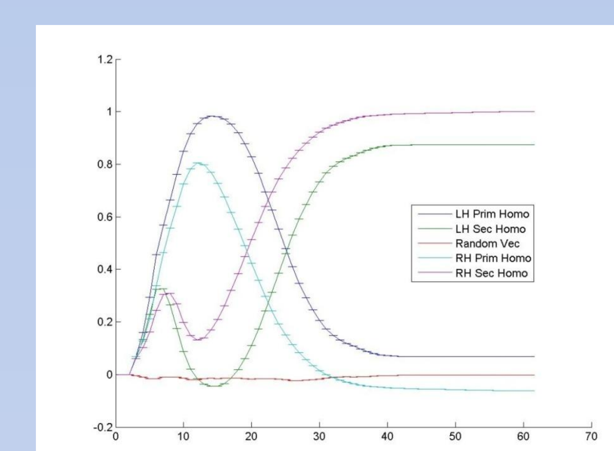
Network performance without CC.
Only RH can perform the "Change of heart"



Network performance with CC (Free learning).RH & LH cannot perform the "Change of heart"



Network performance with CC.
RH & LH can perform the "Change of heart"



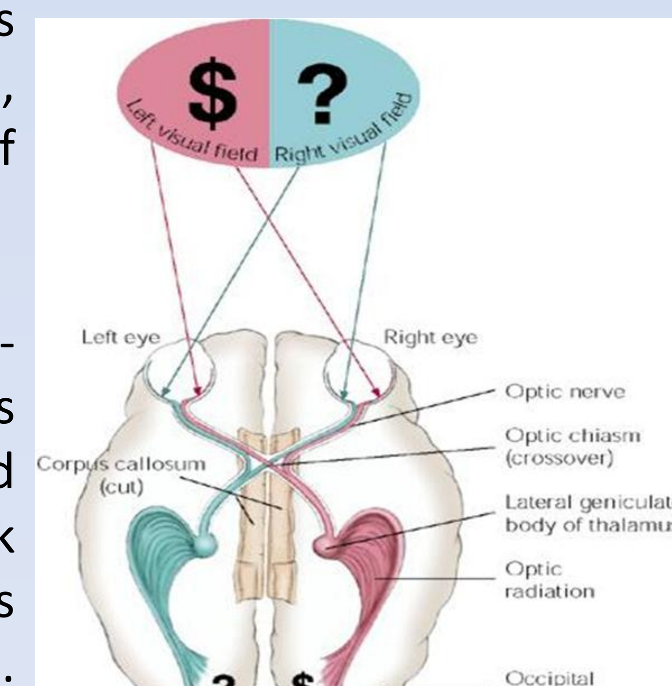
Network performance with CC (CC weights are fixed at 0.25). RH & LH can perform the "Change of heart". Note LH recovery is partial

#	Network architecture	LH	RH	Recovery
1	Without CC	14.73	19.58	RH Only
2	With CC: Weights fixed at 0.25 (RH to LH)	13.42	19.58	Both
3	With CC: Weights fixed at 0.25 (LH phonology to RH phonology, RH semantics to LH semantics).	17.74	18.54	Both (Partial)
4	With CC: Weights fixed at 0.25 RH to LH and 0.10 LH to RH.	15.78	18.12	Both (Partial)
5	With CC: Weights fixed at 0.25 (All, Both ways)	19.23	20.15	None

1. Connecting the LH and RH in a more natural way draws the same conclusions as Hazan's previous work.
2. Data transfer is more beneficial when done from RH to LH.
3. Connection between the hemispheres via the CC is "weakly coupled" as compared to the inner hemisphere connections.
4. Free learning of the CC weights causes the network to lose the "weakly coupled" proportions and therefore the LH and RH lose their special properties.

Consequences for Human Experiments

Behavioral studies have been performed by Peleg and Eviatar designed to test certain intra-hemispheric connectivity assumptions that they put forward. These studies combined divided visual field (DVF) techniques with a semantic priming paradigm. These studies, succeed in implying different patterns of activation of both meanings in the two hemispheres.



Our simulations, built to correspond to their intra-hemispheric connectivity assumptions produce results that fit well with those human experiments and thereby further support their theories. Our work suggests a refinement of these experiments to check as well the connectivity strength between hemispheres. One possible method to do this, would be to use Dynamic Causal Modeling to test the effective connectivity between hemispheres during fMRI studies.