Reading

National Brain Research Centre

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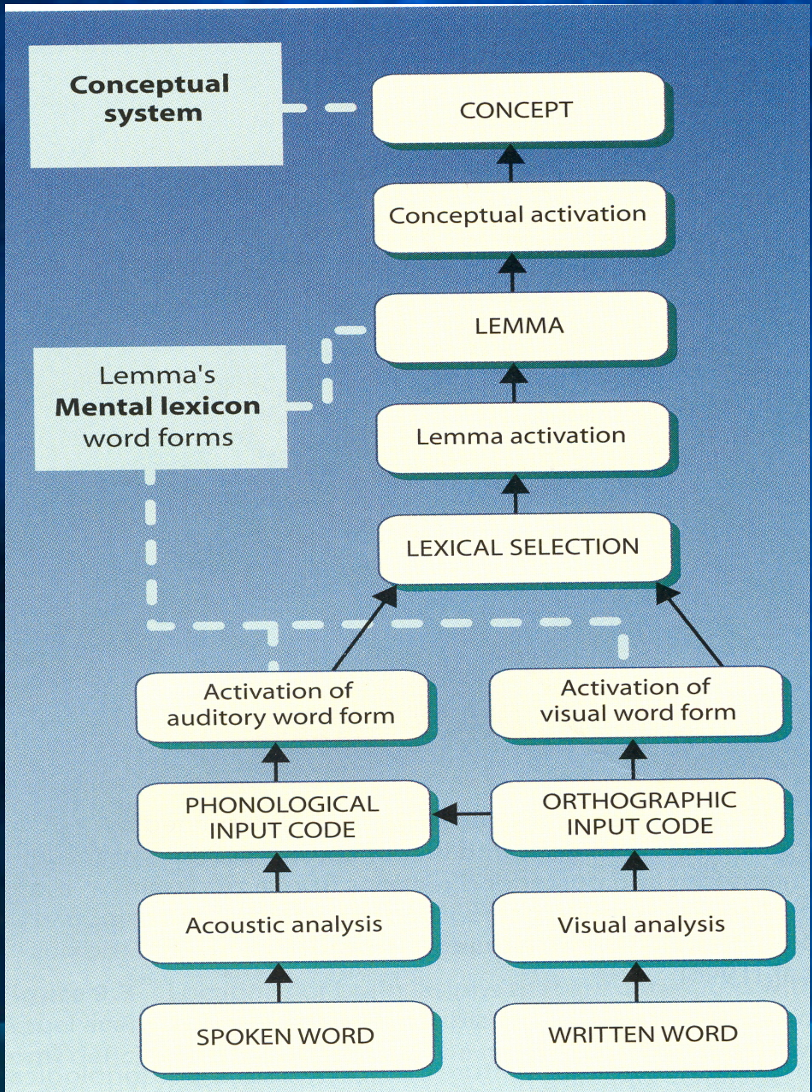
- Reading – an extraordinary ability, particularly human, and yet distinctly unnatural, acquired in childhood, forms an intrinsic part of our existence as human beings and is taken for granted by most of us. (Shaywitz, 2003)

Differences between speech and reading

- Unlike speech which can be acquired by exposure to language reading is learnt and is only acquired by formal instruction.
- No specific module in the brain for reading.

Perceptual analysis of linguistic input



Schematic representation of the components involved in spoken and written language

Written input

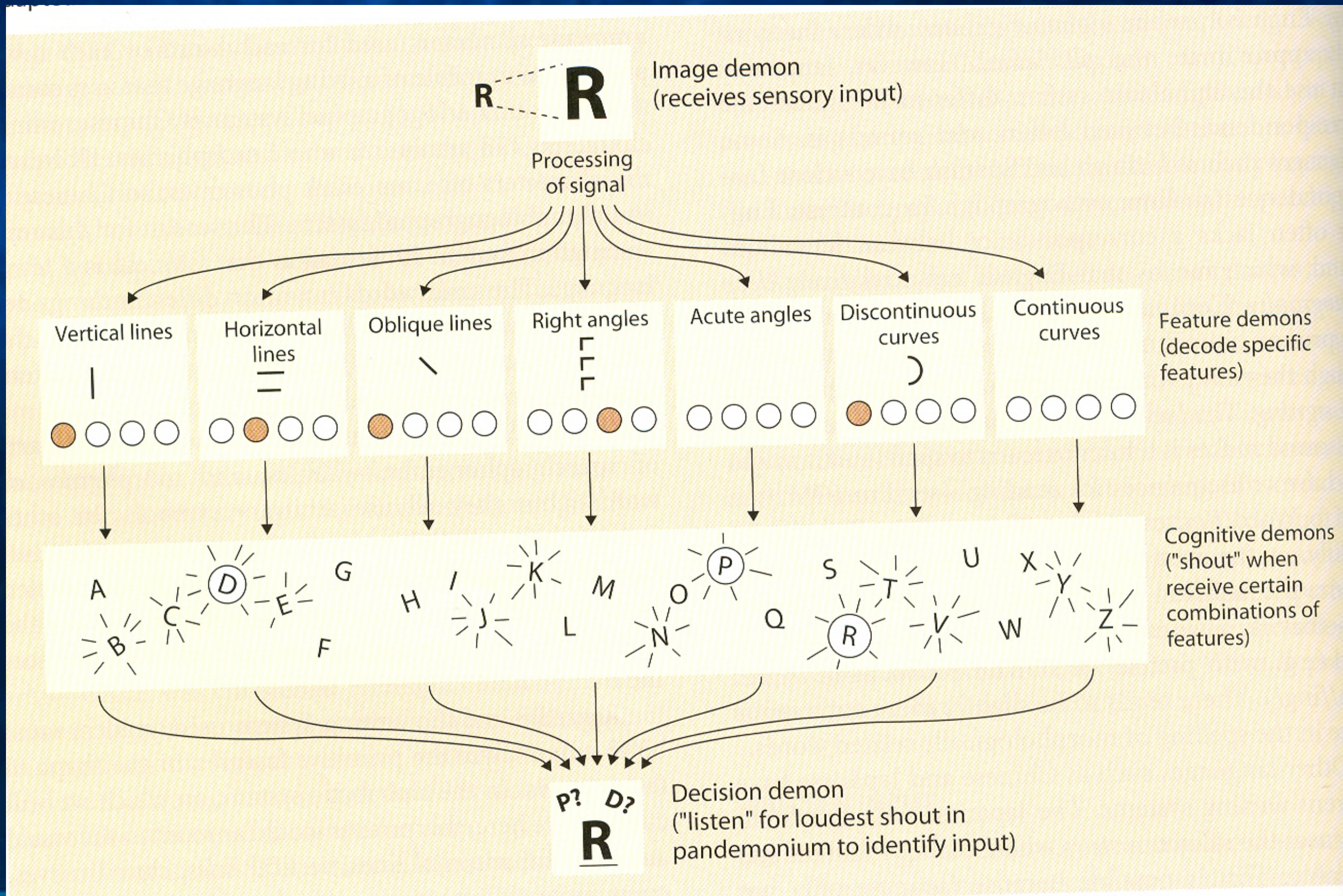
- Recognise visual patterns
- Vary across writing systems

- English – Alphabetic (symbols approximate phonemes)
- Japanese – Syllabic (symbols approximate syllables)
- Chinese – Logographic (symbols approximate morphemes)
- Devnagari – Alphasyllabic (symbols approximate akshara)

- The three writing systems symbolise different parts of speech (phonemes, syllables and morphemes).
- Symbols are arbitrary.
- Readers must recognize primitive features or shapes of symbols.

Written input

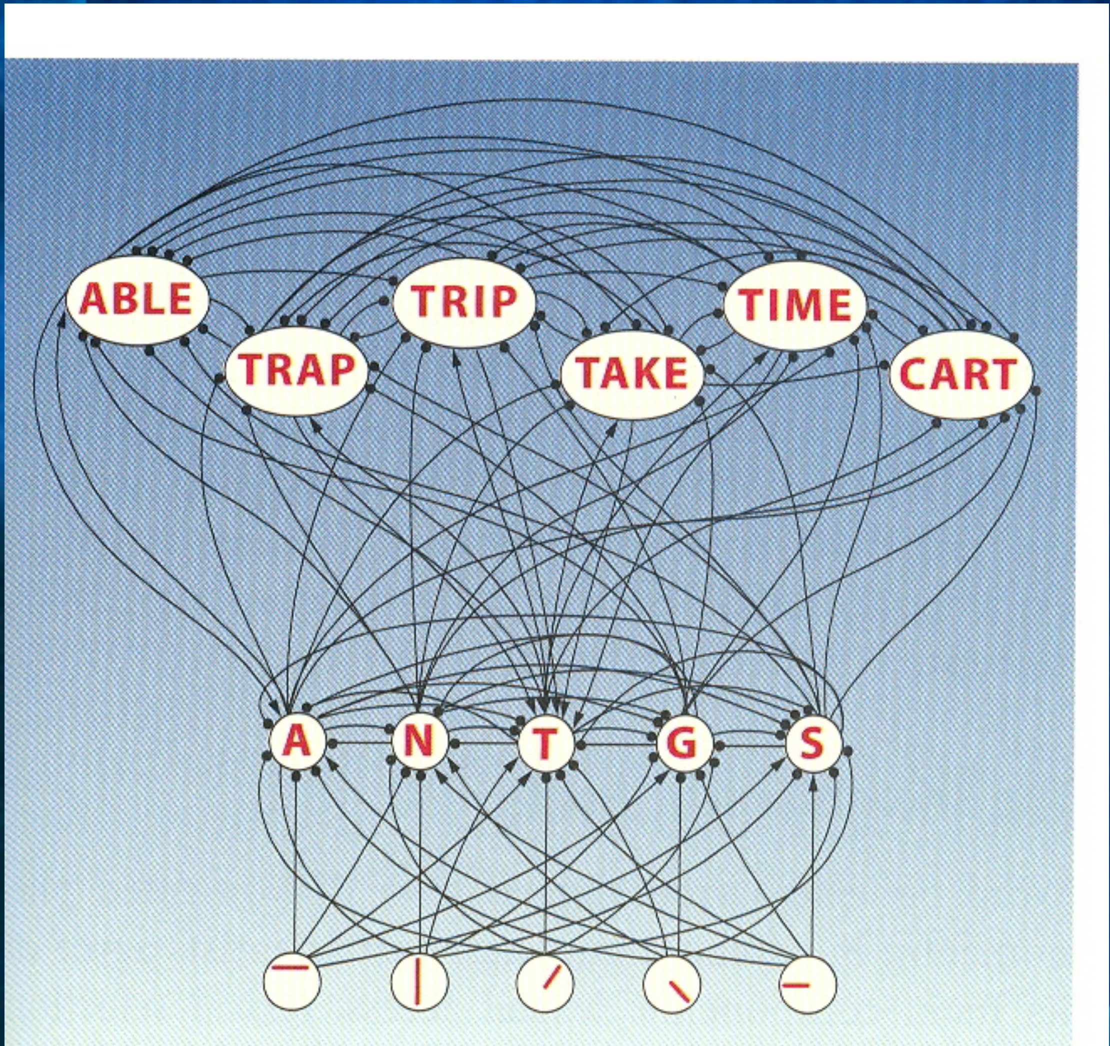
Readers must recognise the visual input
In alphabetic system,involves visual analysis of elementary shapes



Pandemonium model of letter recognition of Selfridge

Computational model

Three layers



Representation of words

Layers of letters

Features of letters

(McClelland &Rumelhart)1981

Differences between Selfridge and McClelland

- Mc - Allows for top down information too – in contrast to Selfridge

Difference between modularity and interactivity)

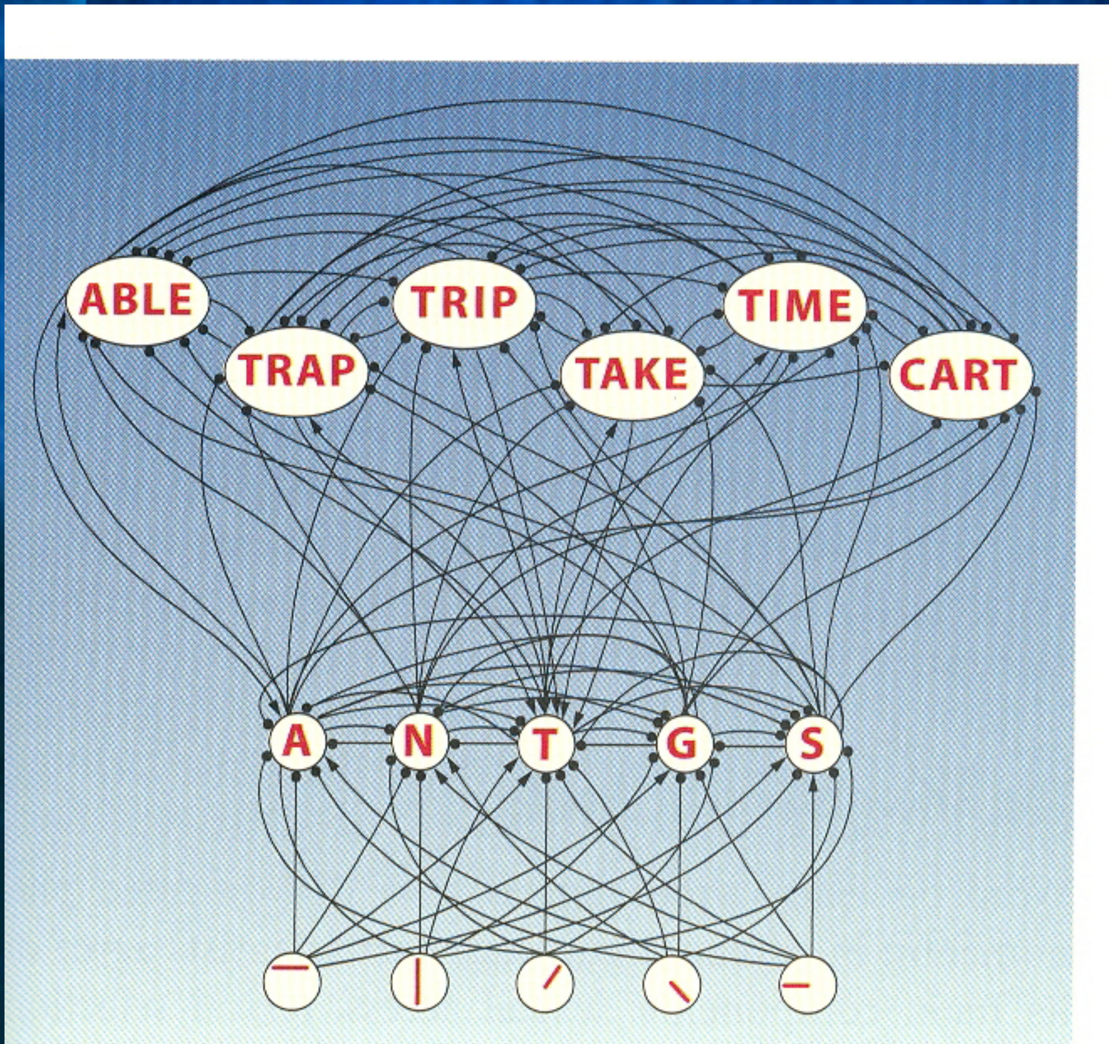
Mc – Processes can take place in parallel

Several letters can be processed at the same time

Selfridge – Serial – one letter at a time

TRIP

Excitatory and Inhibitory Links between Layers



Representation of words

Layers of letters

Features of letters

(McClelland &Rumelhart)1981

Network models

- Extensive connectivity – hallmark of neural circuitry
- Network models are constructed to explore the computational potential of such circuitry using both analysis and simulations.

- Neocortex - convoluted outer surface of the human brain, neurons lie in six vertical layers highly coupled within cylindrical columns.
- Columns have been suggested as basic functional units and patterns of connections both within a column and between columns are repeated across cortex.

- Three main classes of interconnections.

Three main classes of interconnections in the cortex

Feed forward – i/p to a given region from another region located at an earlier stage along a particular pathway

Recurrent – interconnect neurons within a particular region that are at the same stage along the pathway (connections within a column as well as connections between nearby and distant columns)

Top down – carry signals back from areas located at later stages

- In general neurons within a given region send top down projections back to the areas from which they receive feedforward input, and receive top-down input from the areas to which they project feedforward output.

  (Equal nos of top down and feedforward connections)

- However recurrent connections outnumber both these.

- The most direct way to simulate neural nets is to synaptically connect model spiking neurons

- Simulate these neural networks by constructing networks of neuron like units with outputs consisting of firing rates rather than action potentials.

Sequence of spike generated by a neuron is completely characterised by the neural response $\rho(t)$, which consists of δ functions spikes located at times when the neuron fired action potentials.

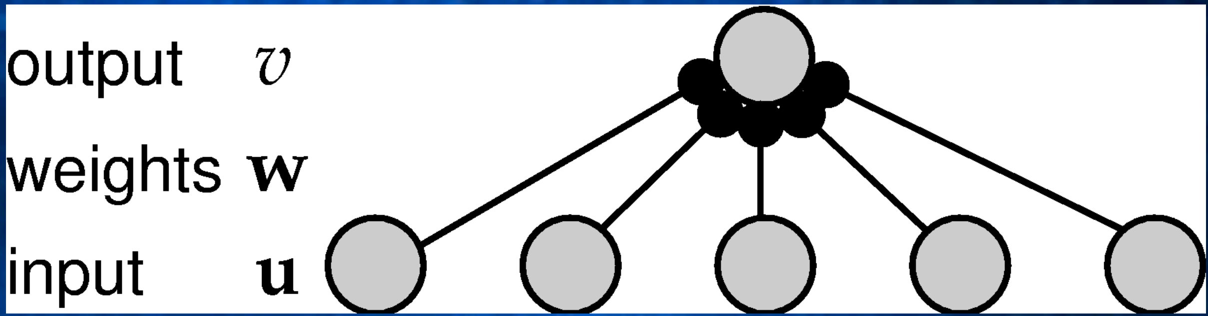
- In firing rate models, the exact description of a spike sequence provided by $\rho(t)$ is replaced by the approximate description provided by the firing rate $r(t)$
- Replacement of the response function by firing rate - quantities of relevance for network dynamics are insensitive to trial to trail fluctuations.

Firing rate description

Neural activity is described in terms of firing rate $r(t)$ instead of actual spikes $\rho(t) = \sum_i \delta(t - t_i)$.

This description is adequate, when the neuron receives many independent inputs, but not when inputs are strongly correlated.

Construction of a firing rate model



O/p from the neuron and I/p to the neuron are characterised by firing rates

u - presynaptic firing rate

v - post synaptic firing rate

W – synaptic weight

Multiple I/p - vector **u**

vector **v**

Synaptic current

Consider single neuron with $b = 1, \ldots, N_u$ inputs.

Synaptic current generated by single presynaptic spike is $w_b K_s(t)$, with w_b the synaptic strength and $K_s(t) = \exp(-t/\tau_s)/\tau_s$ the synpatic kernel (see fig. 5.14).

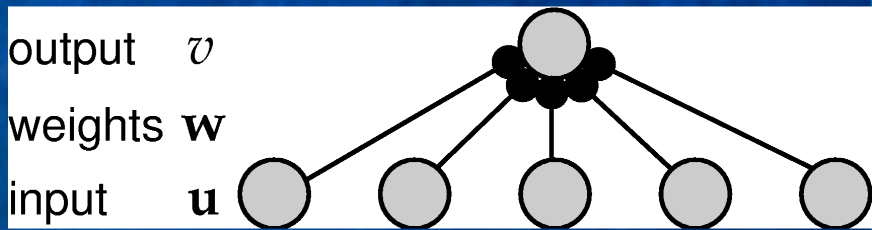
Total input to neuron:

$$I_s = \sum_b w_b \sum_{t_i < t} K_s(t - t_i) = \sum_b w_b \int_{-\infty}^{t} d\tau K_s(t - \tau)\rho_b(t)$$

$\rho_b(t)$ is the spike train from input b.

$w_b > 0$ for excitatory synapse

< 0 for inhibitory synapse



Synaptic current

Replace ρ (response function) with firing rate u

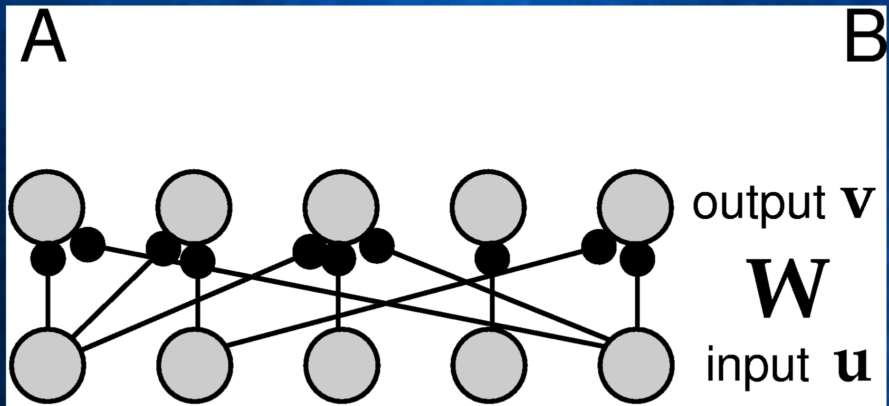
We approximate the spike train by its instantaneous rate $u_b(t)$. Then

$$
\begin{aligned}
I_s &= \sum_b w_b \int_{-\infty}^{t} d\tau K_s(t-\tau) u_b(\tau) \\
\frac{\partial I_s}{\partial t} &= \sum_b w_b \left(K_s(0) u_b(t) + \int_{-\infty}^{t} d\tau \frac{-1}{\tau_s} K_s(t-\tau) u_b(\tau) \right) \\
&= \frac{1}{\tau_s} \left(\sum_b w_b u_b(t) - I_s(t) \right)
\end{aligned}
$$

K describes the temporal evolution of the synaptic current due to both synaptic conductance and dendritic cable effects.

Feedforward networks

$$\tau_r \frac{d\vec{v}}{dt} = -\vec{v} + F(\vec{W} \cdot \vec{u}), \qquad \tau_r \frac{dv_a}{dt} = -v_a + F\left(\sum_{b=1}^{N_b} W_{ab} u_b\right)$$

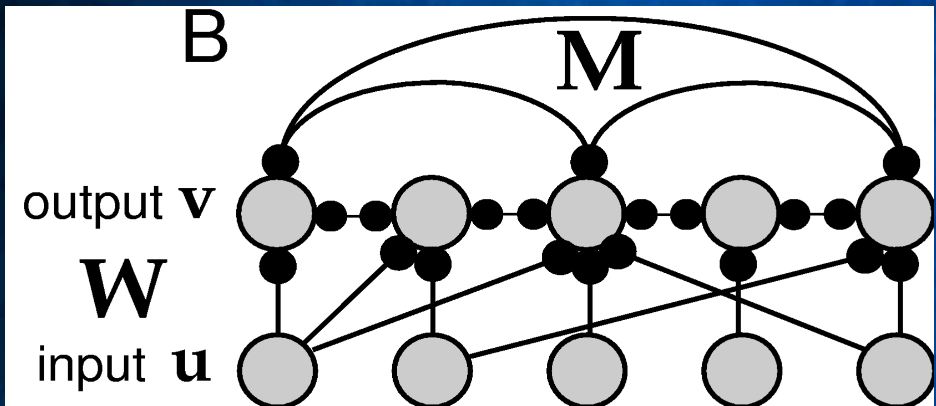


Feedforward and recurrent networks

When recurrent connections are included we get

$$\tau_r \frac{d\vec{v}}{dt} = -\vec{v} + F(\vec{h} + \vec{M} \cdot \vec{v})$$

with $\vec{h} = \vec{W} \cdot \vec{u}$ the input to the network.



Dale's law

Neurons are typically classified as either excitatory or inhibitory, meaning that they have either excitatory or inhibitory effect on all their postsynaptic targets (Dale's law).

$$
\begin{aligned}
\tau_E \frac{d\vec{v}_E}{dt} &= -\vec{v}_E + F_E(\vec{h}_E + \vec{M}_{EE} \cdot \vec{v}_E + \vec{M}_{EI} \cdot \vec{v}_I) \\
\tau_I \frac{d\vec{v}_I}{dt} &= -\vec{v}_I + F_I(\vec{h}_I + \vec{M}_{IE} \cdot \vec{v}_E + \vec{M}_{II} \cdot \vec{v}_I)
\end{aligned}
$$

with $\vec{M}_{EE}, \vec{M}_{IE} > 0$ and $\vec{M}_{EI}, \vec{M}_{II} < 0$. Dale's law implies non-symmetric connectivity between neurons.

Connectivity can be made effectively symmetric by assuming $\tau_I \to 0, \vec{h}_I = 0$ and F_I the identity. Then

$$
\begin{aligned}
\vec{v}_I &= (1 - \vec{M}_{II})^{-1} \vec{M}_{IE} \vec{v}_E, \\
\tau_E \frac{d\vec{v}_E}{dt} &= -\vec{v}_E + F_E(\vec{h}_E + \vec{M} \cdot \vec{v}_E) \\
\vec{M} &= \vec{M}_{EE} + \vec{M}_{EI}(1 - \vec{M}_{II})^{-1} \cdot \vec{M}_{IE}
\end{aligned}
$$

and $\vec{M}$ can be chosen symmetric.

- Computational models are important

1) Formalise components essential to cognitive processes and their interaction
2) Mc Clelland and Rumelhart – mimics word superiority effect

Flash 3 stimuli (trip, pirt, t)

Subjects asked whether they have seen t or k

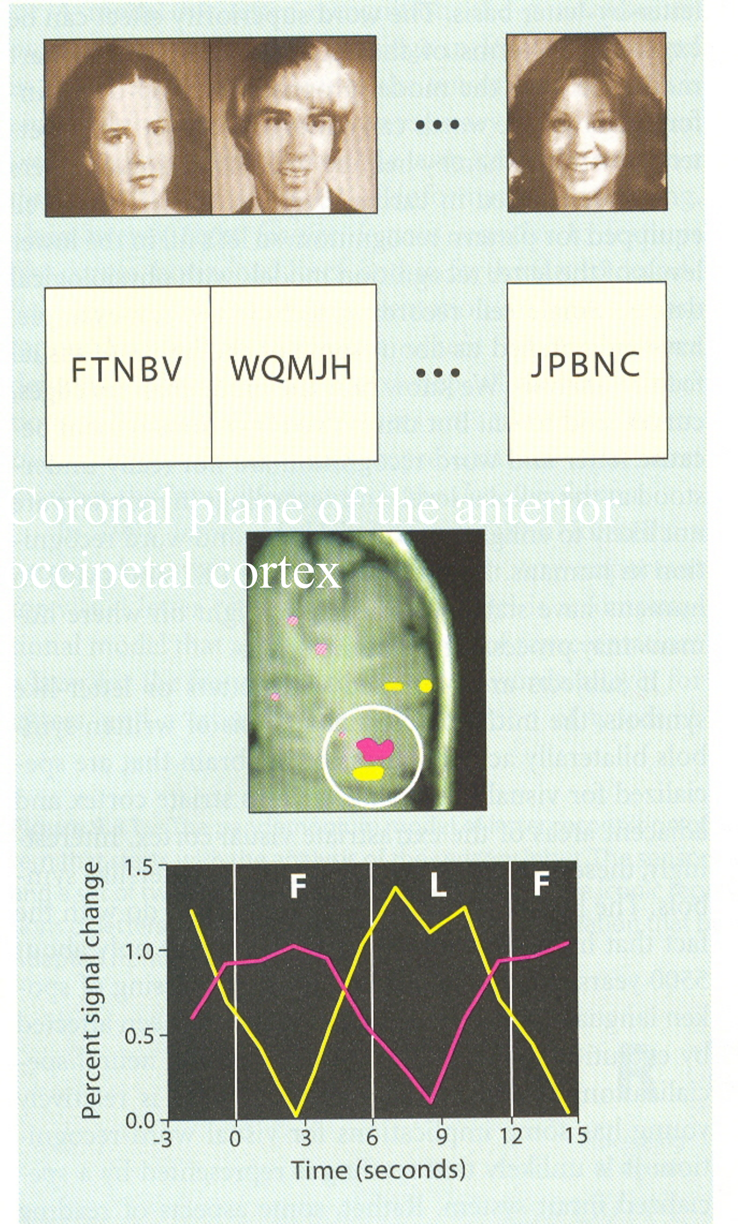
Subjects perform better when the letter is within a word compared to a non-word

Subjects are also better at identifying the letter when it is within a word rather than as individual letter)

Words perception – not letter by letter

- Presented of letters or letter-like objects – bilateral activationn of areas specialised for visual processing.
- Not specific to letter-like symbols.
- Written language only 5500 yrs old.
- Reading – processing written symbols – featural aspects of letters - feature analysis in general

Neural substrate for written word processing



Coronal plane of the anterior occipetal cortex

Faces activated a region of the lateral fusiform gyrus (yellow) whereas letter strings activated a region of the occipitotemporal sulcus (Puce et al, 1996)

Time course of activations

Cohen et al (2002): Visual Word Form Area (VWFA)

"Letter strings can be identified irrespective of their location in the visual field, of the color of the ink, of the case, size, type of font,etc." Critical to this process is the abstract representation of letter strings.

Hypothesis: "An area located in the mid portion of the left fusiform gyrus, which activates whenever literate subjects read printed words, contributes crucially to the cerebral basis of the visual word form"