Neurogenesis Drives Stimulus Decorrelation in a Model of the Olfactory Bulb

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What happens normally

In most parts of the brain the number of neurons is at its peak at birth and no new neurons are created during lifetime.

However:

- supportive cells are dividing and thus brain mass increases
- new connections are created
- the strength of connections is evolving with experience
- there is neurogenesis in hippocampus, subventricular zone and olfactory bulb
The brain learns by modifying the synaptic strengths between the neurons:

- Neurons that fire together, wire together
- Spike-time dependent plasticity
- Depends on calcium concentrations in the postsynaptic neuron
Olfactory bulb

The part of the brain that deals with sensing smells. 10 million chemical receptors in the nose.

It is evolutionarily important to filter out constant smells and discriminate between similar odours (e.g. chemical signals in urine)
New granule cells are created in the subventricular zone and migrate to the olfactory bulb, where old granule cells die if they do not receive enough activation.
The activity patterns in the glomerular layer in the model are based on the experimentally observed responses to 8 different stimuli.
Model granule cell

Receives input from a 8 of mitral cells, inhibits these same cells.

The results suggest that $G_{\text{min}} > 0$ helps to decorrelate very similar stimulus.
The evolution of correlation over time:

- **Time**: 0, 500, 1000, 1500
- **Correlation**: 0, 0.2, 0.4, 0.6, 0.8, 1

- **Graph**:
  - **Mean correlation $\bar{r}$**
  - **Top correlation $r^{(top)}$**
  - **Removal**

- **Legend**:
  - **Input**
  - $G_{min} = 0.6$
  - $G_{min} = 0$
Simple example of decorrelation

Let's imagine a toy example, with 3 granular cells and two very correlated inputs:

\[ S_1 = (S + s, S - s, 0) \text{ and } S_1 = (S - s, S + s, 0) \]

Only the glomerular cells getting input from MC-s 1 and 2 survive, decreasing in return the activity in those cells.
Robustness

The capacity of the system to decorrelate stimulus remains even if the connections are not perfectly symmetric, if the connection weights are not all equal or when self-inhibition is weakened.
Other results and conclusions

- It is the new-born cells that respond to a new stimuli in the environment.
- The more diverse is the mixture in the environment, the more capable is the olfactory system.
- The system learns to discriminate better if the stimuli are presented at the same time.

A Test Stimuli B C

| Stimuli | Correlation | Enrichment |
|---------|-------------|------------|
| +lim    | unrelated enrichment | lim |
| -lim    | related enrichment | car |

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Background
The simplified model

Behaviour of the model

Discussion
Computational interest

Robustness

A Test Stimuli
B
C Enrichment

[i] 

[unrelated enrichment]

[related enrichment]

[no neurogenesis]

[unrelated enrichment]

[related enrichment]

[no neurogenesis]
Limitations

- The reaction of the system to changing the intensity of odor is not shown
- There is no reference to how much the activity can change for the same stimuli
- Minimalistic neurons, simplified network
- No spike-time-dependent-plasticity
- There seems to be a top-down component to determining the survival of cells
Why might this interest us?

- Brain-inspired network
- Discriminates between highly similar stimuli
- There are clustering algorithms that include adding nodes to a network
- Growing self-organizing maps
- Adding nodes to a neural network (many articles if you google "dynamic node creation")
- Leads to online learning, adaptivity to changes in the input set
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Thank you for your attention!