Neuronal plasticity in the olfactory bulb during simple and complex perceptual learning

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Olfactory system

Human

Food search

Danger avoidance

Social interactions

Mice

Olfactory system
Olfactory system

Modified from Forest, Midroit and Mandairon, 2017, Pollution atmospherique.
Olfactory system

Nasal cavity

Olfactory epithelium

Olfactory bulb

Adapted from Adam and Mizrahi 2010 Curr Opin Neurobiol

ORN

Glomerulus

PGN

M/T cell

Granule cell

To higher brain areas

Buck and Axel, Cell, 1991; Duchamp-Viret et al., Science, 1999; Shepherd, Physiol Rev, 1972
Adult neurogenesis

From Tong and Alvarez-Buylla, 2014, Neuron

Lledo et al. Nat Neuro 2006; Rocherfort et al. J Neuro 2002; Mandairon et al. Behav Neuro, 2006; Mandairon et al., J Neuro, 2011; Alonso et al., J Neuro, 2006; Moreno et al., PNAS, 2009
Perceptual learning

Significant improvement of the discrimination abilities of perceptually close odorants after repeated exposition to these same odorants (= enrichment).

Mandairon et al., 2006
Moreno et al., 2009, 2012
• **Simple perceptual learning** paradigm = 1 pair of odorants. Real olfactory environment is **more complexe** = several pairs of odorants

• There are **adult-born neurons** in the olfactory bulb but also **preexisting neurons**, born during ontogenesis

Up to which point can we push neurogenesis?

Are adult-born neurons always necessary and/or sufficient?
Neuronal plasticity in the olfactory bulb during simple and complex learning

- Non-Enriched: No odor, Post-test, Sacrifice
- Group 1: +lim/-lim
- Group 2: dec/dodec, +lim/-lim
- Group 3: acetic a./propionic a., dec/dodec, +lim/-lim
- Group 4: butanol/pentanol, +terp/-terp, propylac/butylac, acetic a./propionic a., dec/dodec, +lim/-lim
1 – Behavior:

Increasing the complexity of perceptual learning leads to the discrimination of more odor pairs
Perceptual learning increased adult-born cell density independently of the enrichment’s complexity.
Increasing the complexity of perceptual learning enhances the recruitment of adult-born neurons in the processing of the learned odorants.
3 - Newborn neurons and preexisting neurons morphology:
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NeuronStudio
3 - Newborn neurons and preexisting neurons morphology:
3a – Adult-born neurons

Increasing the complexity of perceptual learning induces a higher structural plasticity of adult-born neurons.
Perceptual learning induces more limited morphological changes in preexisting neurons.
4 – Optogenetic

Adapted from Zhang et al. 2007, Nat Reviews Neuroscience
Optogenetically inhibiting either preexisting or adult-born neurons reveals their functionally distinct involvement in simple and complex perceptual learning.

<table>
<thead>
<tr>
<th>Inhibiting adult-born neurons</th>
<th>Discrimination</th>
<th>Discrimination</th>
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<tbody>
<tr>
<td>Inhibiting preexisting neurons</td>
<td>Discrimination</td>
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![Optogenetic](image.png)
Conclusion
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- Increased survival of adult-born neurons independently of learning complexity
**Conclusion**

*Perceptual learning* is associated with:
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- Increased recruitment of adult-born neurons to the processing of the learned odorants with increased complexity
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Perceptual learning is associated with:
- Increased survival of adult-born neurons independently of learning complexity
- Increased recruitment of adult-born neurons to the processing of the learned odorants with increased complexity
- Increased spines density at the apical distal, apical proximal and basal domains of adult-born neurons both in simple and complex learning paradigms
Conclusion

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And:
- Adult-born neurons are sufficient and necessary to underlie simple but not complex perceptual learning
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And:
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- Preexisting neurons are necessary for complex but not for simple perceptual learning

**Take home message:**
Adult neurogenesis exhibits limits in its adaptive abilities to answer complex behavioral demands but at the same time can be both necessary and sufficient for simple learnings.
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