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Olfactory bulb plasticity during complex perceptual learning in mice

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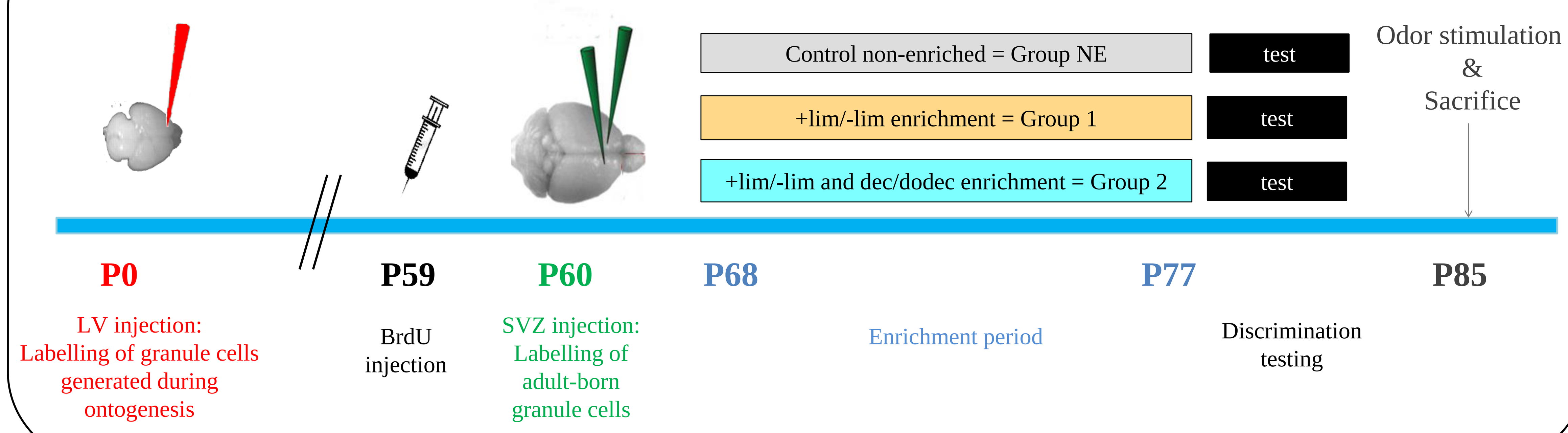
Introduction

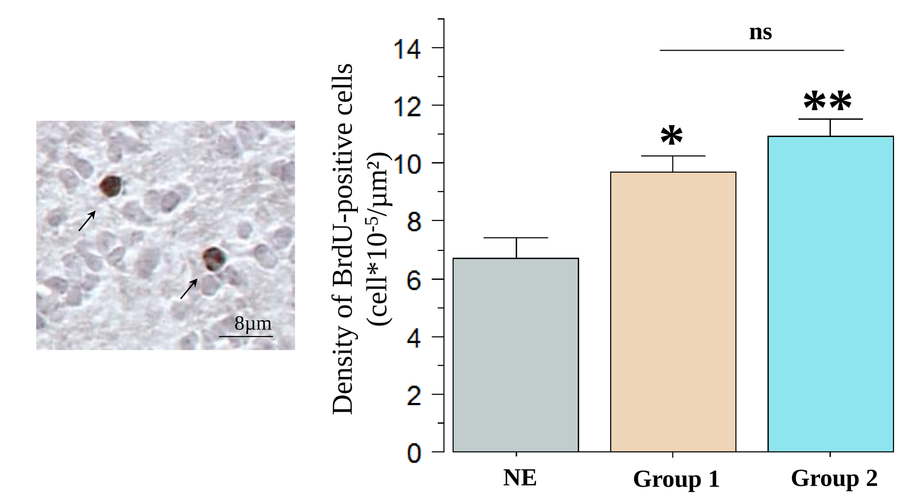
Olfaction is critical in many behaviors, such as research for food, predator avoidance or reproduction. To accomplish these behaviors successfully, an animal must be able to discriminate very close olfactory stimuli with great accuracy. Discrimination performances can be modified by perceptual learning which is defined as an increase in discrimination capabilities of two perceptually close odorants after exposure to this pair of odorants. One of the key supporting structures of this learning is the olfactory bulb (OB) (Mandairon et al. 2008, Neurobiol Learn & Mem). Interestingly, in the OB, granule cells, a type of inhibitory interneurons, are the target of an important adult neurogenesis originating in the subventricular zone of the lateral ventricles. Previous work showed that adult-born neurons are required for perceptual learning in mice (Moreno et al. 2009, PNAS).

Until now, studies have analyzed behavioral performances and neurogenic correlates during simple olfactory perceptual learning, involving only one pair of odorants. However, in real life, animals are exposed to more complex olfactory environments. Thus, in this study, we investigated how the animal adapts its perceptive abilities when exposed to more odor pairs and examined the underlying neurogenic modulations and structural plasticity.

Experimental design



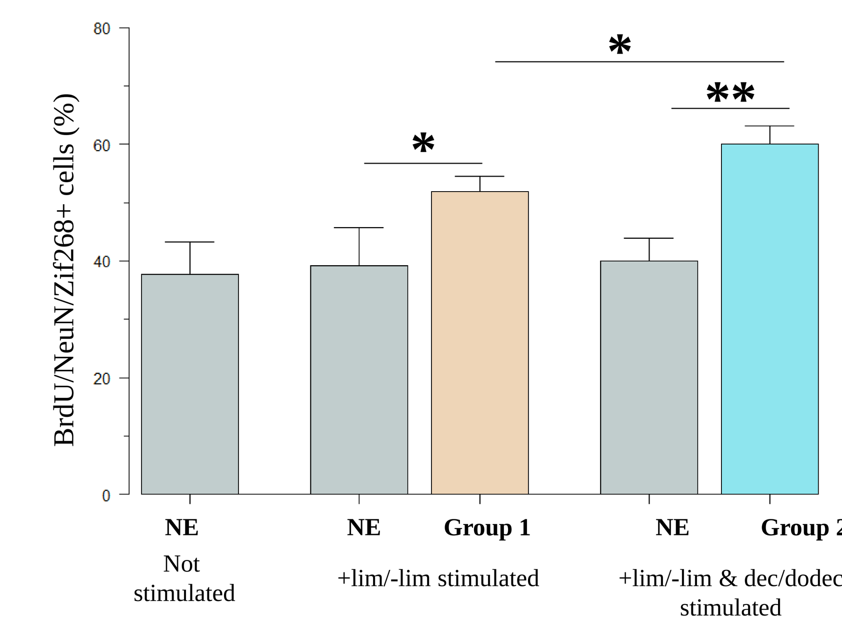
Perceptual learning increases adult-born cell density independently of the complexity …

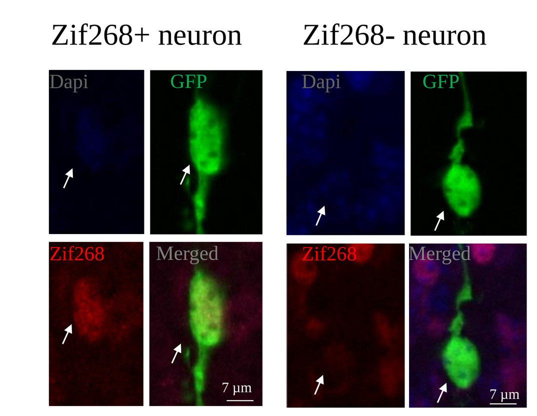


ANOVA was used to compare overall density differences followed by Tukey *post hoc* tests. *p<0.05. **p<0.01 for comparison with NE group.

Data are expressed as mean±sem.

…but an increasing complexity increases the recruitment of adult-born neurons

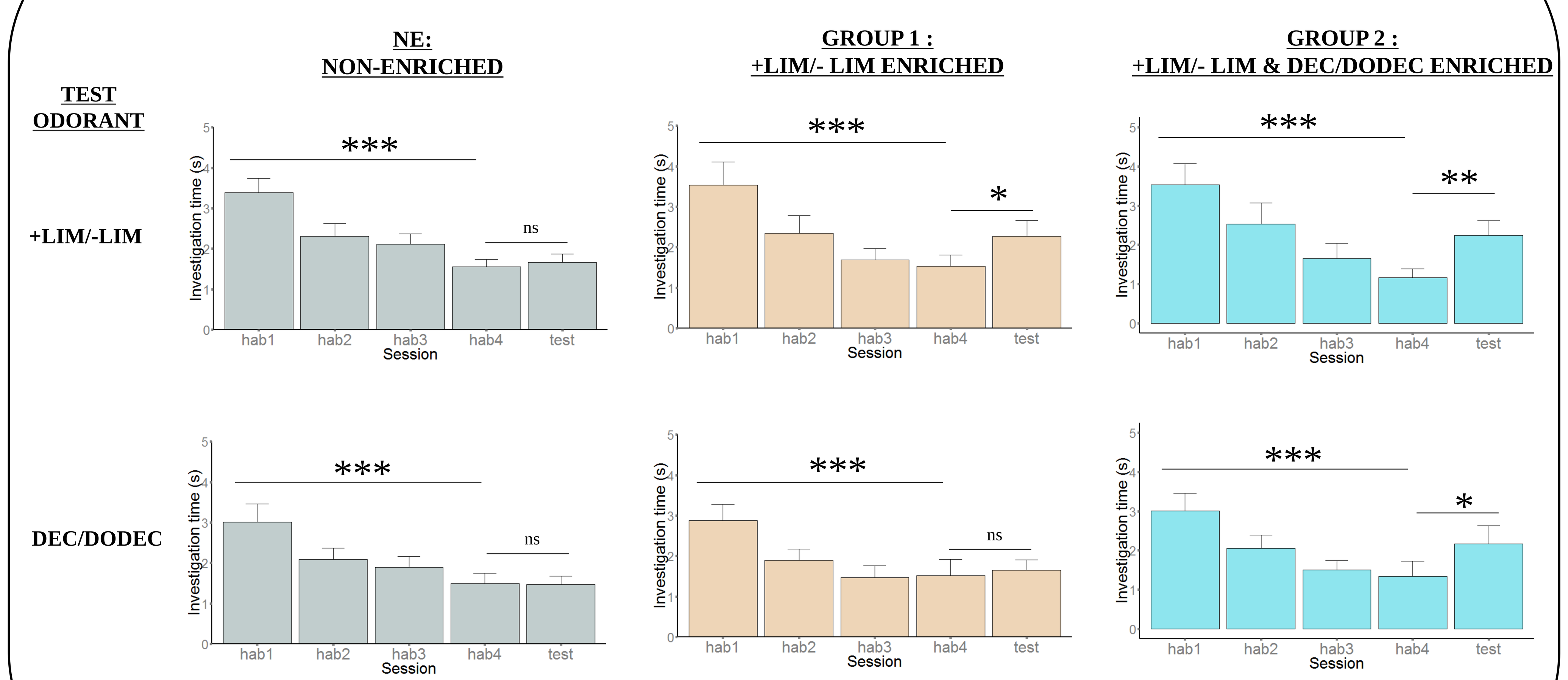




ANOVA was used to compare overall differences followed by *post hoc* t-tests *p<0.05. **p<0.01.

Data are expressed as mean±sem.

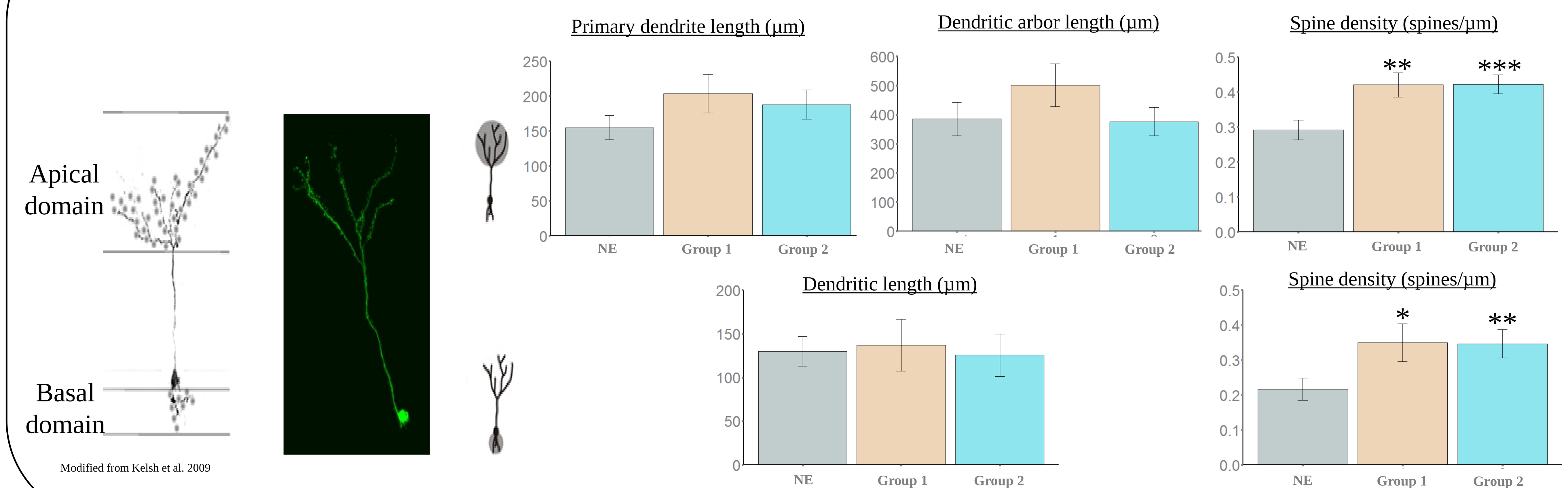
Increasing the complexity of perceptual learning leads to the discrimination of more odor pairs



Habituation was assessed by non parametric Friedmann tests (hab1 to hab4), discrimination by Wilcoxon tests (hab4 versus test) *p<0.05. ***p<0.001. Data are expressed as mean±sem.

Perceptual learning induces modifications of adult-born neurons' structural plasticity

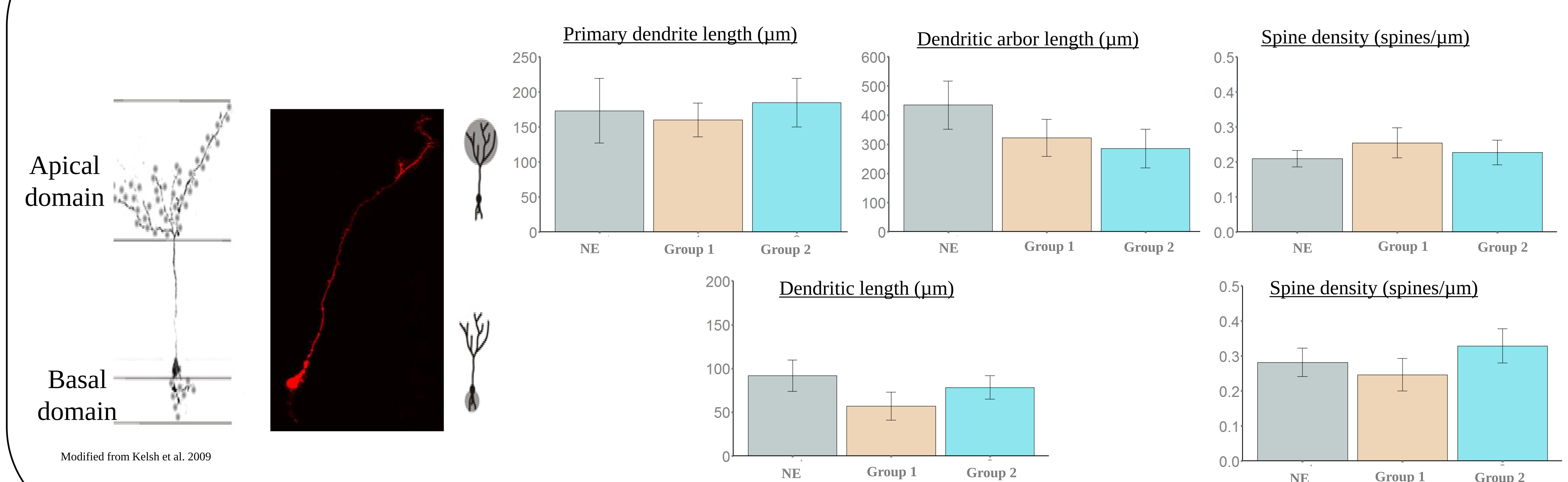
Zif268- neurons morphology was similar across groups and thus only data from Zif268+ neurons are shown here.



Difference between groups was assessed using Kruskal Wallis analysis followed by *post-hoc* Wilcoxon tests. *p<0.05, **p<0.01, ***p<0.001. Data are expressed as mean±sem.

Perceptual learning may not induce structural plasticity in preexisting neurons (preliminary data)

Zif268- neurons morphology was similar across groups and thus only data from Zif268+ neurons are shown here.



Difference between groups was assessed using Kruskal Wallis analysis. Data are expressed as mean±sem.

Conclusion

1- Increasing task complexity allows for discrimination of multiple odor pairs.

2- Functional involvement of adult-born neurons in processing the learned odorants (Zif268-positive neurons) increases with task complexity.

3- Increase in spine density both on the apical and basal dendritic domains of adult-born granule cells is observed. This increase is similar across task complexity and selective to Zif268-positive adult-born neurons.

4. Interestingly, preexisting neurons (born during ontogenesis) were so far not found to be subject to structural plasticity following perceptual learning.

All together, these data suggest that learning complex tasks relies on the functional involvement rather than the absolute number of adult-born neurons and on adult-born neurons rather than preexisting ones. Furthermore, given that structural plasticity is observed only in Zif268-positive adult-born neurons and that Zif268-positive adult-born neurons increase with task complexity, one can propose that the more complex the task, the more neurons exhibiting increased spine density are needed.

These structural changes may contribute to increased inhibition of mitral cells, olfactory pattern separation and ultimately better discrimination performances, but this remains to be tested. Nevertheless, these results put forth the essential role of adult-born neurons in the fine-tuning of the olfactory bulb to its environment.

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