

Supplementary Information

Bidirectional plasticity of cortical pattern recognition and behavioral sensory acuity

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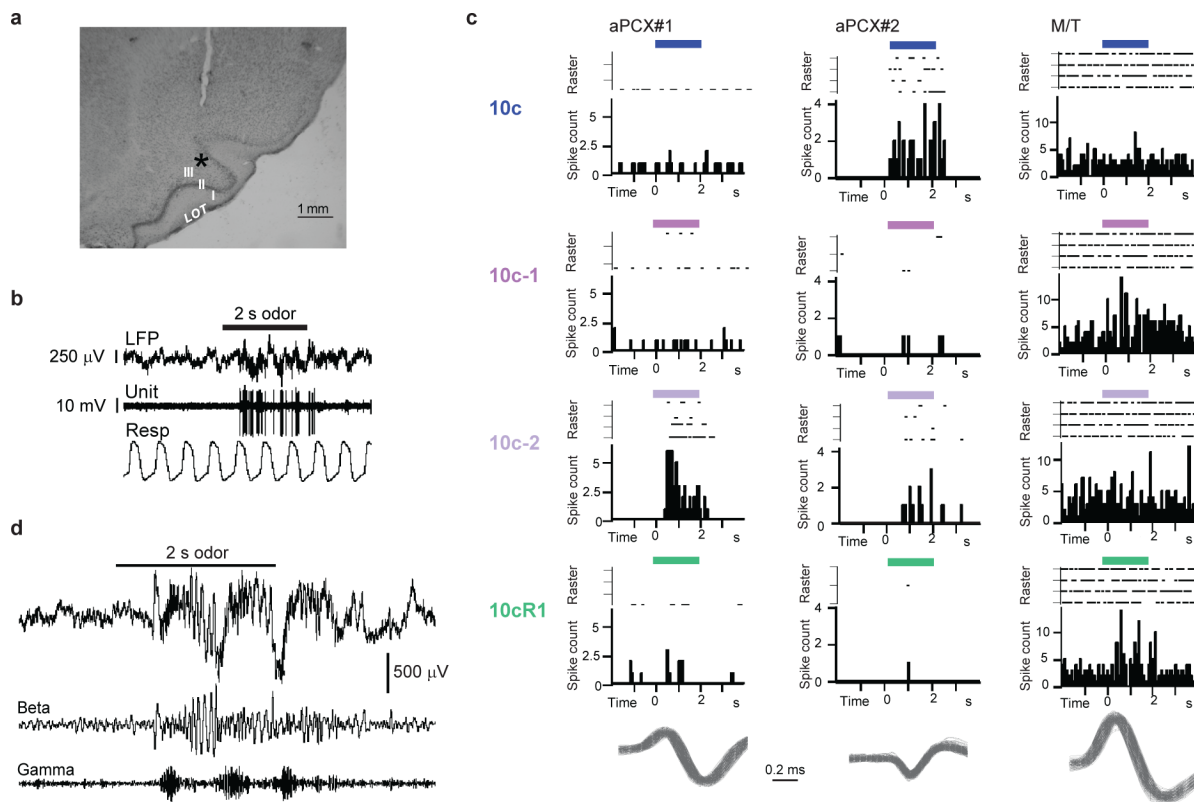
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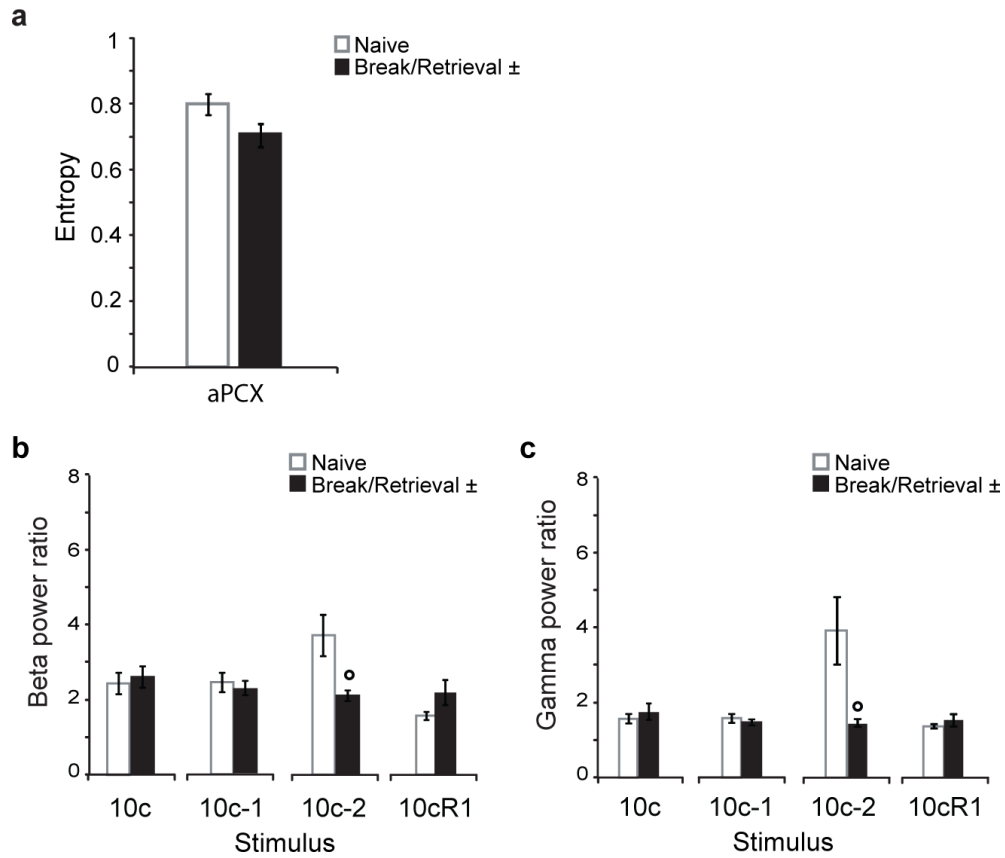
Supplementary tables and figures

Structure	Group	Fig. related	No of rats	No of cells	Cell count/rat
aPCX	Naive	1b	6	20	4,2,7,2,3,2
aPCX	Easy/Short	2b	3	23	7,5,11
aPCX	Easy/Long	2b	4	28	4,8,7,9
aPCX	Difficult/Short	4a	3	21	5,6,10
aPCX	Difficult/Long	2b	3	25	9,9,7
aPCX	Difficult/Long+2weeks	2g	5	35	7,5,10,8,5
aPCX	Pseudo/Easy	4c	3	27	7,3,17
aPCX	Pseudo/Difficult	4c	5	26	7,2,8,8
aPCX	Group/Close	3d	3	31	11,8,12
aPCX	Group/Distant	3d	2	19	12,7
OB	Naive	1b	3	28	9,10,9
OB	Difficult/Short	4a	3	27	10,8,9
OB	Difficult/Long	2b	3	25	12,9,5
OB	Group/Close	3d	3	24	8,6,10

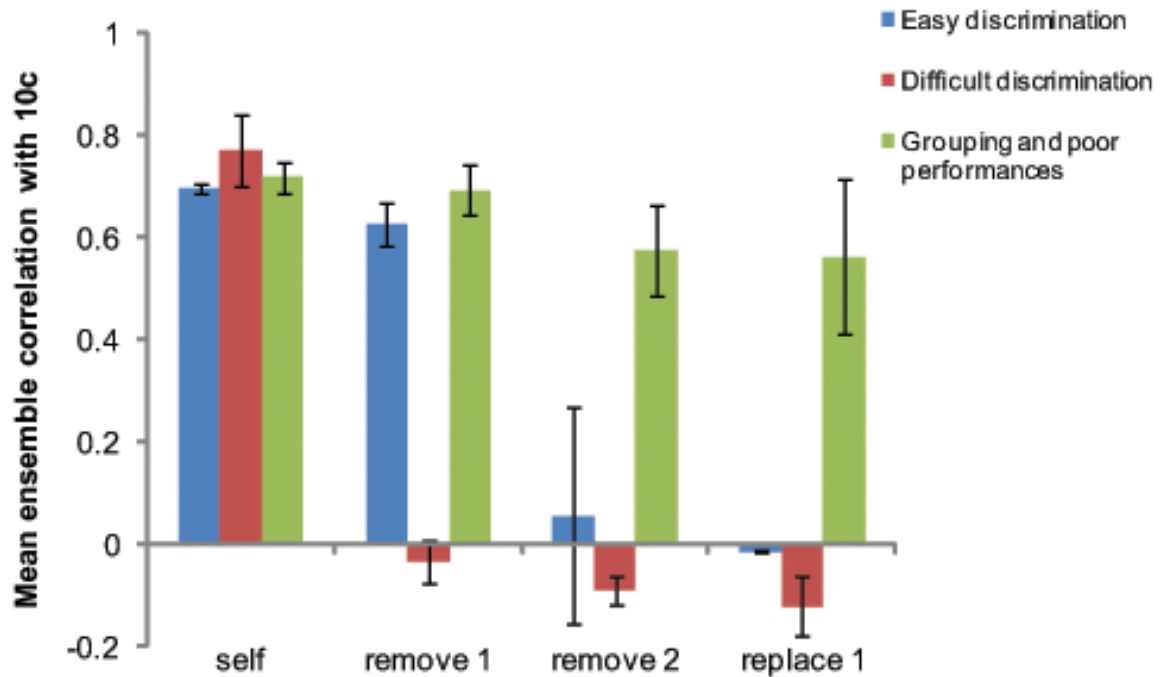
Supplementary table 1 Cell count per experimental condition and animal.



Supplementary Figure 1 Representative electrophysiological recordings. **(a)** Recording sites were confirmed to be within layer II/III of anterior piriform cortex histologically. The star indicates the location of the electrode tip. LOT, lateral olfactory tract. **(b)** Typical example of recording showing in aPCX the local field potential (LFP, 100 Hz low-pass filter), multiunit activity and respiration over the course of 2 s odor stimulation in urethane-anesthetized rat. **(c)** Representative responses of two different aPCX single units and a mitral/tufted (M/T) cell to the full 10c olfactory mixture and its partial (10c-1, 10c-2) or transformed (10cR1) versions. Spike raster plots and peri-stimulus time histograms show responses to four repetitions of 2-s stimulus. The average spike waveform of each neuron is displayed at the bottom of the panels. **(d)** Representative LFP trace sampled from the piriform cortex: the stimulation with complex mixtures induced a succession of oscillatory bursts alternating in the beta (15-35 Hz) and gamma (40-80 Hz) frequency bands. Top: raw signal; middle and bottom: same signal filtered in the beta and gamma bands.



Supplementary Figure 2 Long term memory of the difficult discrimination training (see also Fig 2f,g). Breadth of tuning of aPCX cells (**a**) and power modulation of cortical odor-evoked beta (**b**) and gamma (**c**) oscillatory activities after a two week break in the training. Break/Retrieval ± signifies that animals had a two week break from training and then were either recorded immediately after this break (-) or given a behavioral test and then recorded (+). No difference between these conditions was observed and so the groups are combined here. °significant decrease in power compared to naïve animals, $P < 0.05$.



Supplementary Figure 3 Cortical ensemble correlations for the different experimental conditions combined across replicates (*e.g.*, Easy Discrimination data obtained from the short-term and long-term training. Difficult discrimination data obtained from long-term training and after the 2 week memory test). A shift toward more pattern separation is observed in case of difficult discrimination while a shift toward more pattern completion appeared for the grouping task and poor performances. Data are shown as mean \pm s.e.m.

Supplementary Results and Discussion

Effects of easy versus difficult discrimination training on spontaneous and odor-evoked single-unit activity

No significant difference in spontaneous firing rate of aPCX and OB units were found between naive animals and the animals trained in the discrimination tasks (ANOVA, OB: $F_{1,53}=0.348$, $P=0.5575$; aPCX: $F_{3,92}=0.616$, $P=0.6061$). The average spontaneous firing rates were (mean \pm s.e.m.) 10 ± 2 Hz and 5 ± 1 Hz for OB and aPCX cells, respectively.

In response to odor, for both OB and aPCX, the most consistent effect observed in response to complex odorant mixtures stimulation in the naïve animals was an excitation (62% of the samples in OB, 54% in aPCX), against 11% (OB) and 18% (aPCX) suppressive responses, and 27% (OB) and 28% (aPCX) of units showing no significant response to the mixtures. Although these proportions were preserved for all the mixture tested (10c, 10c-1, 10c-2, 10cR1) regardless of training condition, the improvement of discrimination capacities had an effect both in OB and aPCX on the relative proportion of cells responding to odors (excitations and suppressions pooled). In aPCX, we found a significant attenuation of odorant-evoked activity in animals showing good performance in the difficult 10c/10c-1 discrimination task (59% of cells responding) compared to naïve animals (73 % of the cells) ($X^2=4.367$, $P=0.0366$). In OB, a large decrease in the proportion of cells responding to odours was also found in animals trained in the difficult task (54% of cells) compared to naïve animals (73 % of the cells) ($X^2=7.788$, $P=0.0053$). No significant change in aPCX unit responsiveness was observed for the easy discrimination, either after the short (63% of the cells; $X^2=2.298$, $P=0.1296$) or the long training (71% of the cells; $X^2=0.099$, $P=0.7528$).

Effects of odor-grouping training on spontaneous and odor-evoked single-unit activity

No significant difference in the spontaneous firing rate of aPCX units was detected between naive animals and the animals trained in the grouping task (ANOVA, $F_{2,67}=1.589$, $P=0.2118$). In addition, and contrary to the rats trained in the discrimination task (see previous section), there was no attenuation in odorant-evoked activity for the animals trained in the

regrouping task compared to the naive condition (group/close: 74% of cells responding to odors, $X^2=0.026$, $P=0.8727$; group/distant: 70 % of cells, $X^2=0.221$, $P=0.6394$).

Effects of a break in the training on odor-evoked single-unit activity and oscillatory activities

In **Fig. 2f,g**, we showed that a long break in the training was not detrimental to the cortical ensemble pattern separation ability or the behavioral capacity to make difficult discrimination. However, while the ensemble changes were long-term and predicted the behavioral performance, the single-unit selectivity and local field potentials were more transient. After a two week delay, the measure of entropy, though in the same direction as 24 h after training, did not significantly differ from those of naïve animals (see **Supplementary Fig. 2a**; $t_{44} = 1.505$, $P=0.1394$). Furthermore, in contrast to 24 h after training, no increase in power of the odor-evoked beta (**Supplementary Fig. 2b**) or gamma (**Supplementary Fig. 2c**) frequency bands was observed for the animals recorded after the 2 weeks break compared to naïve situation. These transient changes in single-unit receptive fields and local oscillations are similar to other studies showing a disengagement of some markers of plasticity with time, overtraining or habit¹⁻³, while other markers and the behavioral performance remained stable. These results strongly support the hypothesis that cortical ensemble activity is the best predictor of behavioral performance acuity.

References

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2. Reed, A. et al. Cortical map plasticity improves learning but is not necessary for improved performance. *Neuron* **70**, 121-31 (2011).
3. Martin, C., Beshel, J. & Kay, L.M. An olfacto-hippocampal network is dynamically involved in odor-discrimination learning. *J Neurophysiol* **98**, 2196-205 (2007).