Combined recording of GPS positional data and EEG in freely flying homing pigeons reveals lateralised changes of hippocampal electrical activity upon approaching the home loft

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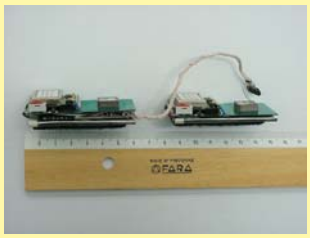
? *Does hippocampal EEG correlate with the homing behavior in pigeons?*

Lesion studies have shown that the pigeon hippocampus is a critical structure for spatial mapping of the home loft area [1,2]. More recently, it was found that the left hemisphere of pigeons appears to play a role in homing mechanisms [7], while studies in caged migratory birds have indicated a possible left-hemispheric predominance of magnetoreception [8]. Since the occurrence of theta rhythm in the EEG has been reported to be associated with navigational behaviour[3-5], we analysed the EEG of freely flying homing pigeons in relation to the position of the bird as recorded by GPS[6].

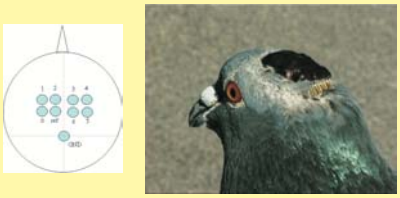
1 *How to register EEG in flight?*

- Just to make a small 8-channel EEG recorder:

- Attach it to the GPS datalogger:



- Implant electrodes:

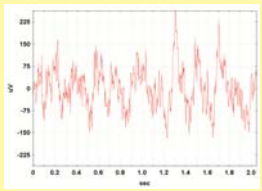


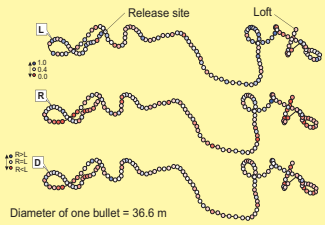
- Put EEG-GPS dataloggers on the pigeon:

- Let it fly:

- Wait and hope that the bird will return. Sometimes it prefers to take a rest:

2 *After wings artifact elimination normal EEG with a strong theta rythm can be observed*





Bullet plots visualizing relative proportion of theta power in color code for the left and right hemisphere of a pigeon flying to to its loft. Bullets represent bins of 2 sec EEG time and correspond to to GPS coordinates. The bottom graph shows the degree of hemispheric asymmetry in theta power, red bullets indicating left-hemispherc dominance. Asymmetries appear larger after release and when turning towards the loft.

3 *Theta power is bigger in both hippocampi if the pigeons are sitting elsewhere far from the loft than when they are sitting inside the loft*

	Theta Power		Statistics	
Hippocampus	Sitting outside the Loft (mean +/- SEM, n)	Sitting inside the Loft (mean +/- SEM, n)	Significance (mean differ.)	ANOVA (out vs. in)
Left	0.3678 +/- 0.0055, 441	0.3333 +/- 0.0042, 471	W, V, D***	H***
Right	0.3172 +/- 0.0046, 577	0.2874 +/- 0.0044, 617	W, V, D***	H***
Both	0.3391 +/- 0.0036, 1018	0.3073 +/- 0.0031, 1088	W, V, D***	H***

4 *In the left hippocampus theta power increases when pigeons verge towards the loft. No such dynamics was found in the right hippocampus*

	Theta Power		Statistics	
Hippocampus	First 30 sec (mean +/- SEM, n)	Last 30 sec (mean +/- SEM, n)	Significance (mean differ.)	ANOVA (1st vs. Last)
Left	0.3929 +/- 0.0152, 90	0.2895 +/- 0.0126, 90	S***,F***	F***
Right	0.3261 +/- 0.0148, 90	0.3305 +/- 0.0161, 90	no	no
Both	0.3595 +/- 0.0109, 180	0.3100 +/- 0.0103, 180	W, V***, D**	H***

4 Pigeons were observed in 6 sessions. Release distances from the loft: 1.1 km (2 sessions), 6.0 km (2 sessions), 10.5 km, 5.0 km. Theta power is considered as proportion Theta/(Delta+Theta) in the consecuitive 2000 ms window. We reduced the spectra range to 0 - 7 Hz because of the second order artifact from wings muscles in the range of 8 - 13 Hz. Statistics: parametric criteria: T (Student), F(Fischer); nonparametric criteria: W (Wilcoxon), V (van der Varden), D (Smirnov), H (Kruskal-Wallis). Significance: P < 0.05: "*", P < 0.01: "**", P<0.001: "***".

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! *Conclusions*

The proportion of bilateral theta activity is larger in pigeons far from the loft, theta being stronger in the left hemisphere. Upon approaching the home loft area, however, the proportion of theta decreased significantly in the left hemisphere only. These findings corroborate functional lateralization of homing in the pigeon brain, and promise new approaches to analyse brain mechanisms underlying homing and navigation.

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