Preliminary Report on

Evaluating the classifiability of gerbil auditory ECoG AM patterns in gamma band

6/16/14, revised 6/19/14 by ys, rk

Summary

This report contains results of a preliminary analysis of gerbil auditory data measured by Prof. Ohl's Lab in LIN, Magdeburg. We describe AM pattern discrimination between Go-NoGo conditions, as learning progresses during a 4-day learning sequence. The main goal of this exercise is making sure we have some fundamental understanding of the data we will use in the US-German collaborative project. Some tentative results may be encouraging and indicative of improved classifiability of auditory AM pattern as learning progresses. We also introduce open questions and possible tasks for future studies.

1. Data acquisition and selection of artifact-free channels

Data were obtained on one gerbil during a 4-day experiment on 4/29/14 – 5/2/14. In this study auditory cortex (AC) data are analyzed. In general we have 20 channels with spatial arrangement of surface array electrodes as shown in Fig. 1. From the 20 channels, we included only 16 in the following studies due to significant movement artifacts in channels 1, 10, 12, and 26.

28	12	26	10	24
8	22	6	20	4
18	2	23	7	21
5	19	3	17	1

Figure 1. Spatial arrangement of the electrodes
over the auditory cortex on the gerbil.

For each day, we were looking for a 3 s window during the 6s and 10s periods of auditory stimuli in trials with Go or NoGo conditions, respectively, which were free of movement artifacts. Movement artifacts are defined by a threshold amplitude size exceeding > 0.0005V. As the result, we made sure the selected 3s windows do not contain movement artifacts. In general, there are different numbers of trials with such artifact-free 3s-windows for different days. These artifact-free trials are denoted by 2 asterisks in Table 1, and they were selected for future analysis. Depending on the days, approximately 30-Go and 40-NoGo trials were without artifacts. Trials with shock are marked by yellow in Table 1.

Table: 1

Overview of the experiments during the 4-day period

29/04/14		30/04/14		01/05/14		02/05/14	
Go	NoGo	Go	NoGo	Go	NoGo	Go	NoGo
1**	3**	1	3	1	3**	1	3**
2**	4	2	4	2	4**	2	4**
5**	8**	5	8**	5	8**	5	8
6**	9**	6	9**	6	9**	6	9**
7**	10**	7**	10**	7**	10**	7**	10**
11	12**	11	12**	11	12**	11**	12**
14	13**	14	13**	14	13**	14**	13**
15**	17**	15	17**	15**	17**	15**	17**
16	18**	16	18**	16**	18**	16**	18**
20**	19**	20	19**	20**	19**	20**	19**
22	21	22	21**	22	21**	22	21**
23	24**	23**	24**	23	24**	23**	24**
25	27**	25	27**	25	27**	25	27**
26**	28**	26	28**	26**	28**	26**	28**
29**	32	29	32**	29**	32**	29**	32**
30	33**	30	33**	30	33**	30**	33**
31**	34	31	34**	31	34**	31**	34**
35**	36**	35	36**	35**	36**	35**	36**
38	37**	38	37**	38	37**	38	37**
39**	41**	39	41	39**	41**	39**	41**
40	42**	40	42**	40	42**	40	42**
44**	43**	44	43**	44**	43**	44**	43**
46**	45**	46	45**	46	45**	46	45**
47**	48**	47	48**	47	48**	47**	48**
49	51**	49	51**	49	51**	49**	51**
50**	52**	50	52**	50**	52**	50	52**
53**	56**	53	56**	53**	56**	53**	56**
54	57**	54	57**	54**	57**	54	57**
55**	58**	55	58**	55	58**	55**	58**
59**	60**	59	60**	59**	60**	59**	60**
62**	61**	62	61**	62**	61**	62**	61**
63**	65**	63	65**	63	65**	63**	65**
64**	66**	64**	66	64**	66**	64	66**
68**	67**	68	67**	68**	67**	68	67**
70**	69**	70	69**	70**	69**	70**	69**
71**	72**	71	72**	71**	72**	71**	72**
73	75	73	75**	73**	75**	73**	75**
74	76**	74	76**	74	76**	74**	76**
77	80**	77	80**	77**	80**	77**	80**
78	81**	78	81**	78**	81**	78	81**
79**	82**	79	82**	79**	82**	79	82**
83**	84**	83**	84**	83**	84**	83**	84**
86**	85**	86	85**	86**	85**	86**	85**

87**	89**	87	89**	87	89**	87**	89**
88**	90**	88	90**	88**	90**	88**	90**
92	91**	92**	91**	92**	91**	92	91**
94**	93**	94**	93**	94**	93**	94**	93**
95	96**	95**	96**	95	96**	95	96**

2. Data processing algorithm

Using data selected following Table 1, power spectral density (PSD) functions were determined for each channel using standard FFT-based method. To evaluate the PSDs, a 3s long window was determined in each experiment. The FFT was determined by averaging over time segments from a 1s long sliding window with 50% overlap. Examples of PSD are shown in Fig. 2.

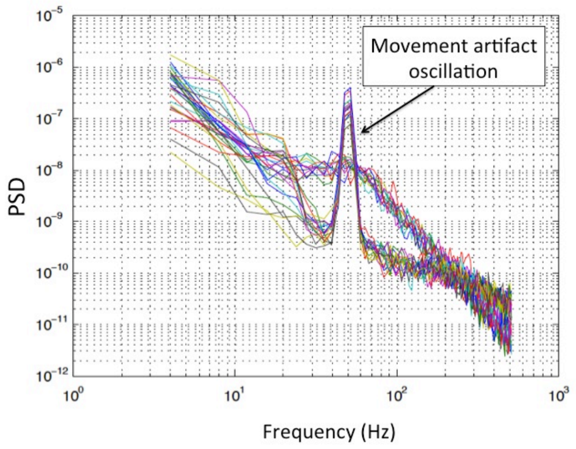

Figure 2. PSD functions determined in NoGo condition on day 04/29/14.
The sharp peak at 50Hz is associated by movement artifact and experiments with such artifacts have been omitted from the present studies.

Once the PSD were determined (Nyquist frequency 512Hz), we calculated the power in the frequency band 20-80Hz by summing up the amplitudes and determined the RMS using the formula:

$$\mathrm{RMS}_{\{i\}} = \sqrt{\sum_{k=20Hz}^{80Hz} \mathrm{PSD}_{\{i\}}(k)}\,,$$

where i is a channel, i=1,…, 16. This preprocessing step lead to a series of feature vectors of size 16, i.e., each dimension corresponding to the gamma-band power of that specific channel. These will be the AM patterns in the 16-vector space. Finally, amplitude modulation (AM) patterns were created for each trial with asterisks by using RMS values:

Day 29/04/14: 16x29 GO, 16x43 NOGO

Day 01/05/14: 16x27 GO, 16x48 NOGO

Day 02/05/14: 16x31 GO, 16x47 NOGO

Day 04/30/14 has been omitted from the present experiments, as it contained too few artifact-free data.

3. Classification of AM patterns

The main question to be answered is whether it is possible to classify AM patterns by some method. In order to answer the last question, a multiplayer artificial neural network was considered. All trials with asterisks in Table 1 were divided into testing and training sets. We created MLPs of 16 inputs, 3 hidden nodes and 1 output, with log-sigmoid transfer functions. We trained these MLPs using 16 GO and 16 NOGO patterns in each day separately. We used standard Levenberg Marquart learning, with about 60 training iterations. At the end of the training, all training examples were classified correctly. We optimized training to avoid/minimize overtraining.

Results of the testing are summarized in 2x2 confusion matrices A, where a confusion matrix is defined by components as:

a_{11} = number of Go trials which were classified as Go;
a_{12} = number of Go trials which were classified as NoGo;
a_{21} = number of NoGo trial which were classified as Go;
a_{22} = number of NoGo trial which were classified as NoGo.

Classification results are gives as follows:

- Day 140429

$$A_1 = \begin{bmatrix} 9.54 & 3.46 \\ 4.46 & 22.54 \end{bmatrix}$$

Correct classification of patterns with Go trials is 73%, and with NoGo trials is 83%.

- Day 140501

$$A_2 = \begin{bmatrix} 8.6 & 2.4 \\ 0.26 & 31.74 \end{bmatrix}$$

Correct classification of patterns with Go trials is 78%, and with NoGo trials is 99%.

- Day 140502

$$A_3 = \begin{bmatrix} 12.94 & 2.06 \\ 0.66 & 30.34 \end{bmatrix}$$

Correct classification of patterns with Go trials is 86%, and with NoGo trials is 97.8%.

It is easy to see that a classifier mostly improves its performance with respect to consequent days. We do not claim that the classifier is optimal and these classification results surely can be improved. Moreover, the classification results can be compared with behavioral observations, based on the number of shocks per day. It is summarized in Table 2 and in Fig. 2.

Table 2: Trials without shock for each day

140429		140430		140501		140502	
Go	NoGo	Go	NoGo	Go	NoGo	Go	NoGo
1/48	44/48	43/48	46/48	37/48	48/48	40/48	48/48
2%	91.6%	89.6%	95.8%	77%	100%	83%	100%

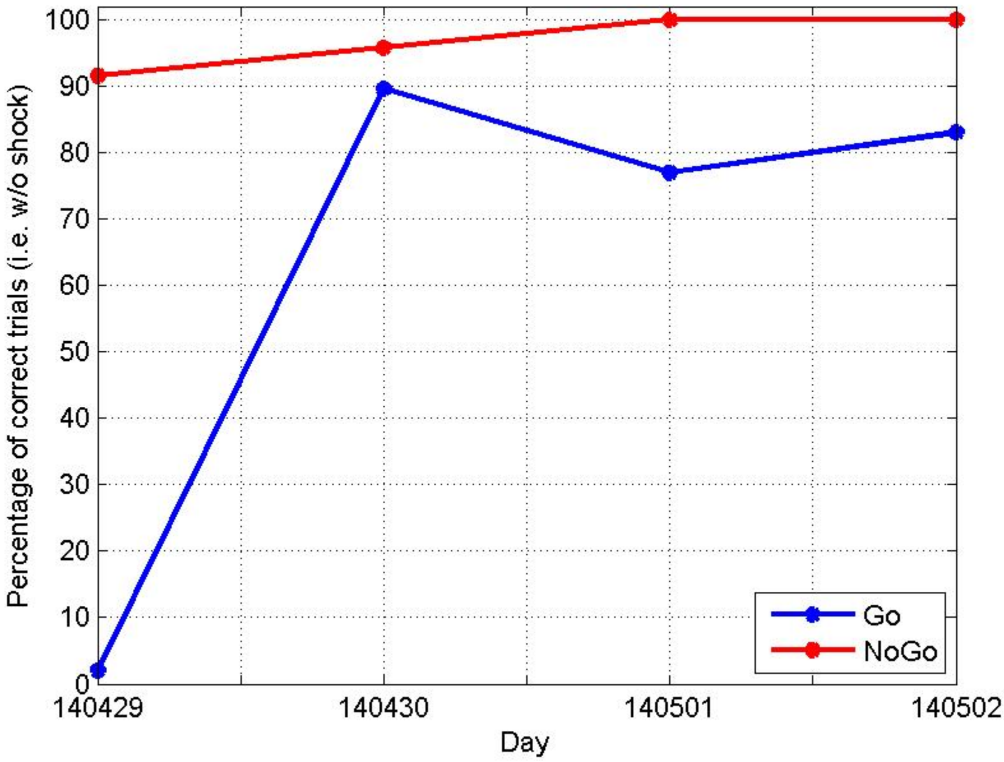

Fig. 2: Percentage of trials without shock.

4. Conclusions

1. Day 1 gives a classification performance significantly above random chance. This is counterintuitive and to be tested in more detailed evaluations.

2. The results of these preliminary evaluations show improvement in classification of the 16-elements vector patterns in days 3 and 4 as compared to day 1. This is in line with expectations.
3. Tests with new data with much less artifacts, expected to be delivered by Dr Ohl's team in the coming days, would be very valuable to give a statistically sound evaluation of the AM classification method and establish a relationship between AM-based and behavior-based learning conclusions.
4. It is desirable to refine the study regarding the frequency band. In addition to gamma 20-80Hz, other bands can be studied as well. Moreover, it is desirable to band pass the time series signals first, and then to calculate the RMS values over the complete, filtered PSD spectra.
5. Once the Am classification has been established, phase relationships should be studied in frequency and Hilbert domains. Finally, in addition to the auditory cortex, also other available cortical measurements should be used to evaluate intra-cortical relationships, perhaps causal loops as well.

5. References

- TBD