

Brain Beats Tempo Extraction from EEG Data

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ISMIR, New York City

*with photos by Евгений Крофто



Research Focus Cognitive Sciences
Machine Learning in Cognitive Science Lab

Not so long ago... HAMR@ISMIR2015

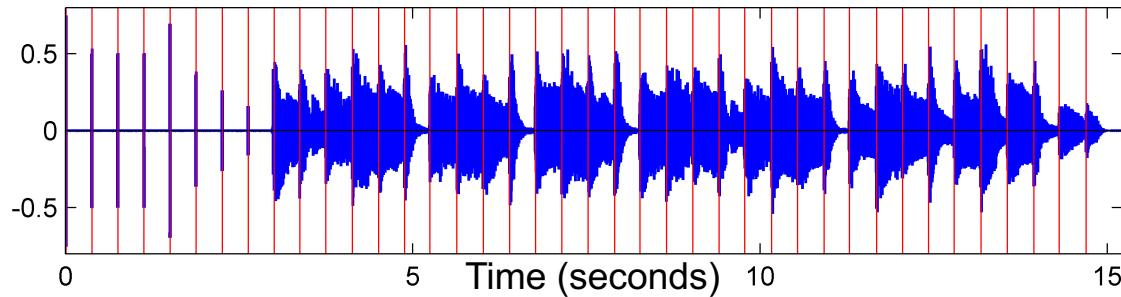
*Can we **track the beat or the tempo** of
a music piece **in brain waves** recorded
during listening?*

*Hang on!
What?*

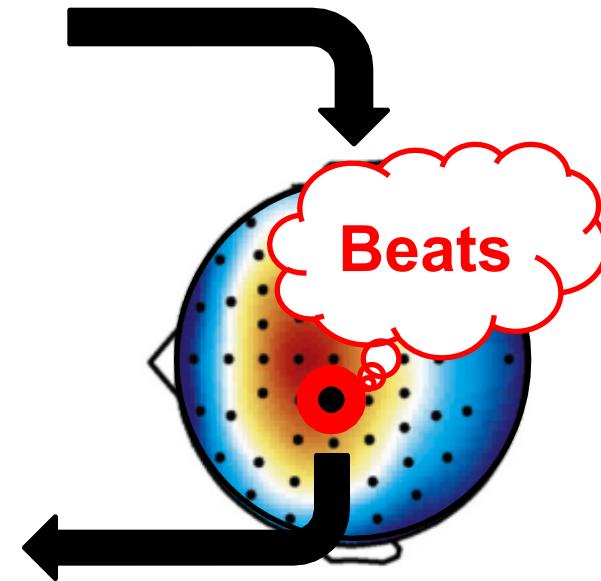
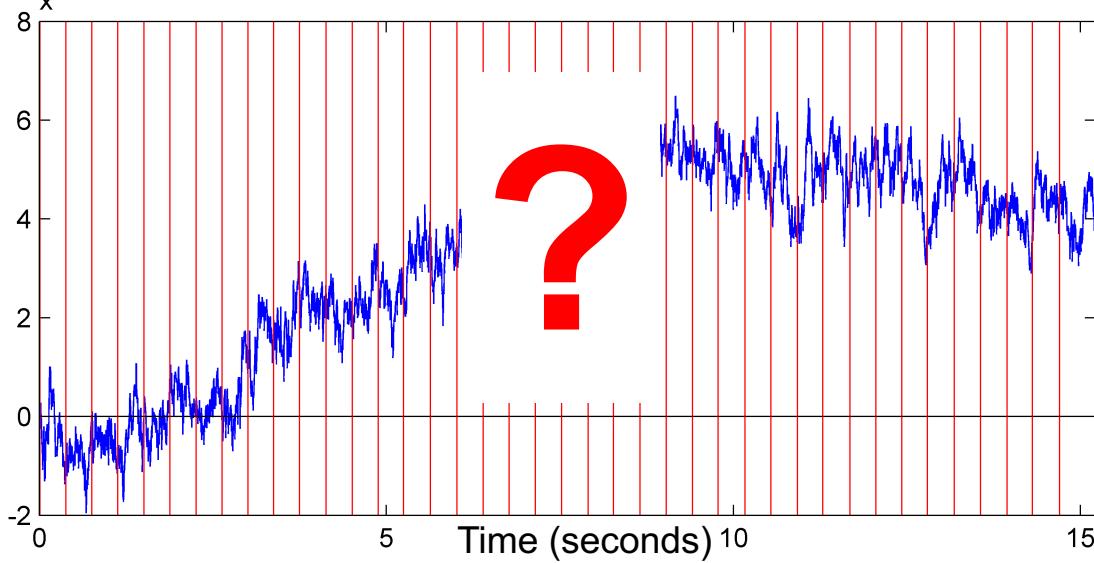


Tracking Beats & Tempo in EEG?

Stimulus: Music

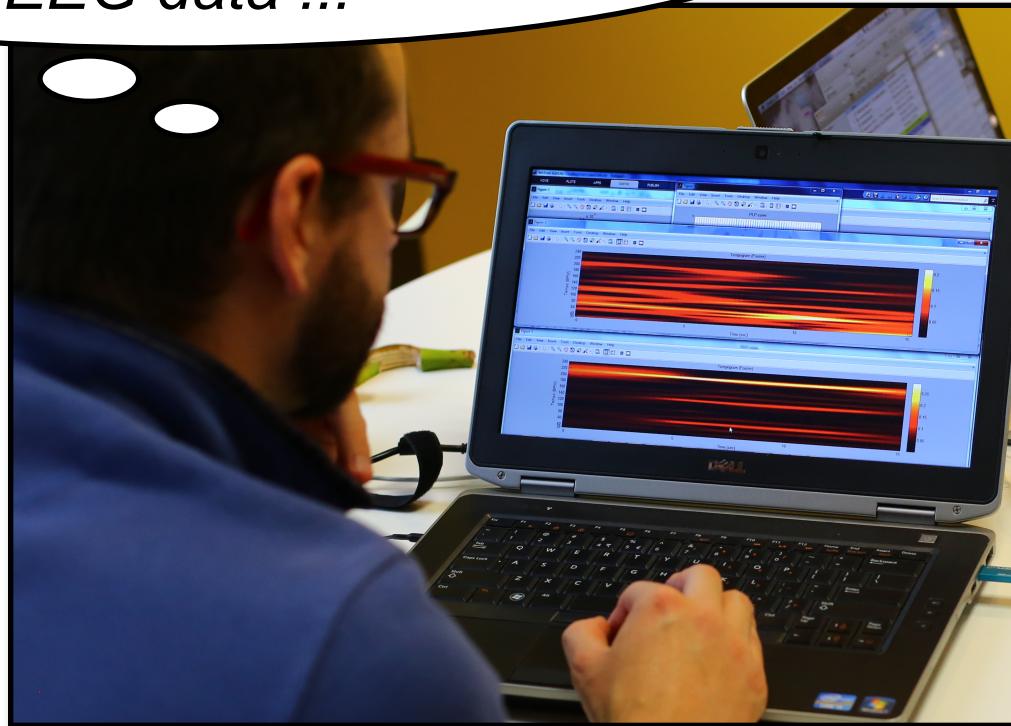


Measurement: EEG



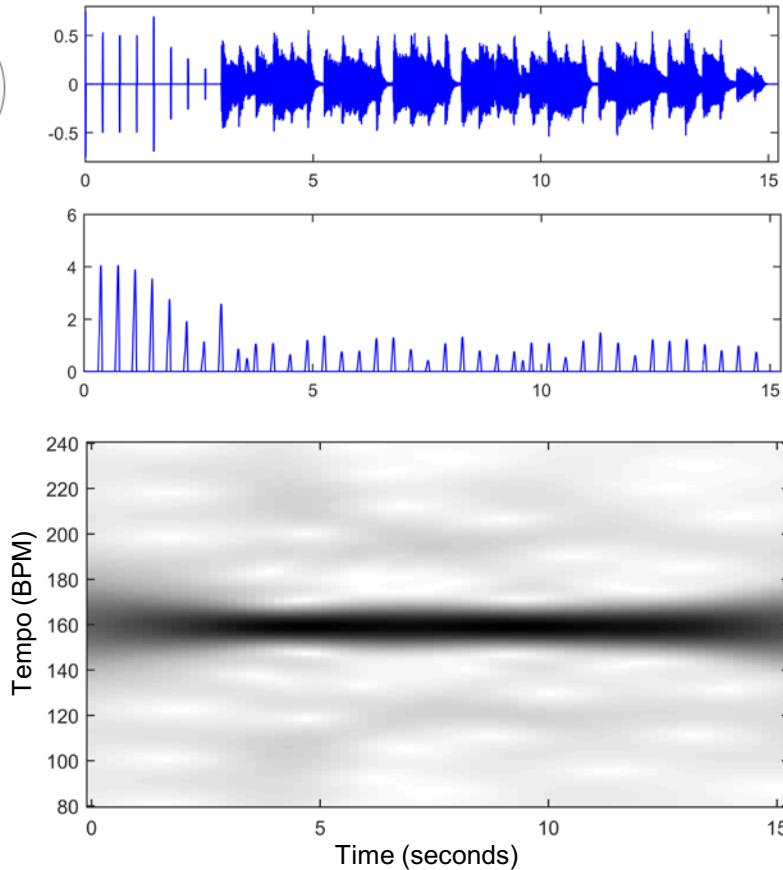
The Hack

*Maybe we can use our
Tempogram Toolbox also for
EEG data ...*



<https://www.audiolabs-erlangen.de/resources/MIR/tempogramtoolbox>

Processing Audio with the Tempogram Toolbox



Audio

Novelty Curve
(indicates note onset candidates)

Tempogram
(reveals local tempo characteristics)

<https://www.audiolabs-erlangen.de/resources/MIR/tempogramtoolbox>



openMIIR

**public domain dataset of EEG recordings
for music imagery information retrieval**

- 12 audio stimuli from 8 music pieces
 - 4 songs recorded each with and without lyrics
 - 4 instrumental pieces
- complete musical phrases
- with cue clicks to indicate tempo

<https://github.com/sstober/openmiir>



The 12 Music Stimuli

songs **with** / **without** lyrics:

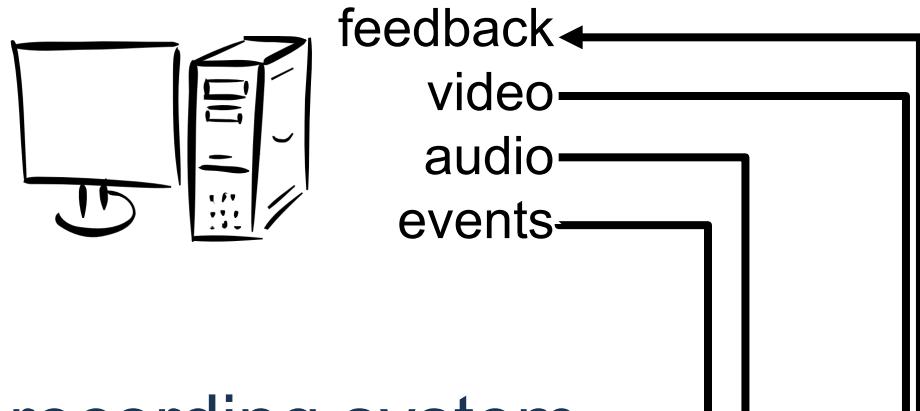
		meter	tempo	length (s)	
1	Chim Chim Cheree	3/4	213	14.9	15.1
2	Take me out to the Ballgame	3/4	188	9.5	9.6
3	Jingle Bells	4/4	199	12.0	11.3
4	Mary Had a Little Lamb	4/4	159	14.6	15.2

instrumental pieces:

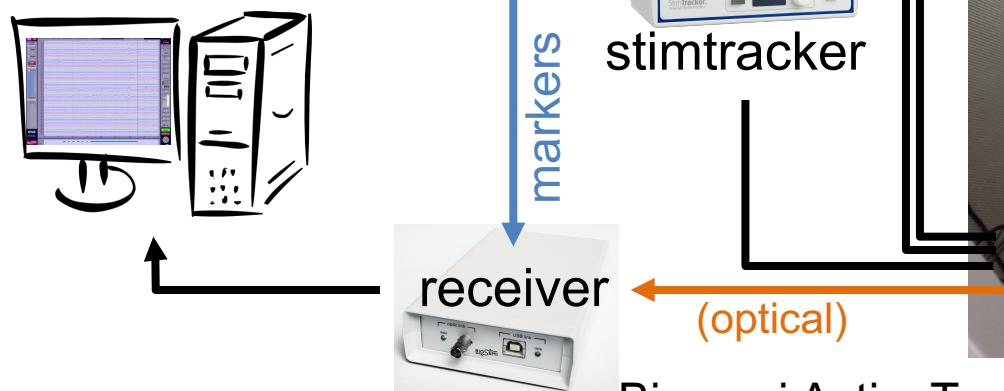
1	Emperor Waltz	3/4	174	10.3
2	Harry Potter Theme	3/4	165	18.2
3	Imperial March (Star Wars Theme)	4/4	104	11.5
4	Eine Kleine Nachtmusik	4/4	140	10.2

Experiment Setup

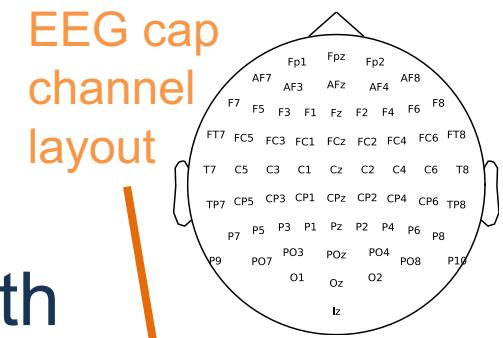
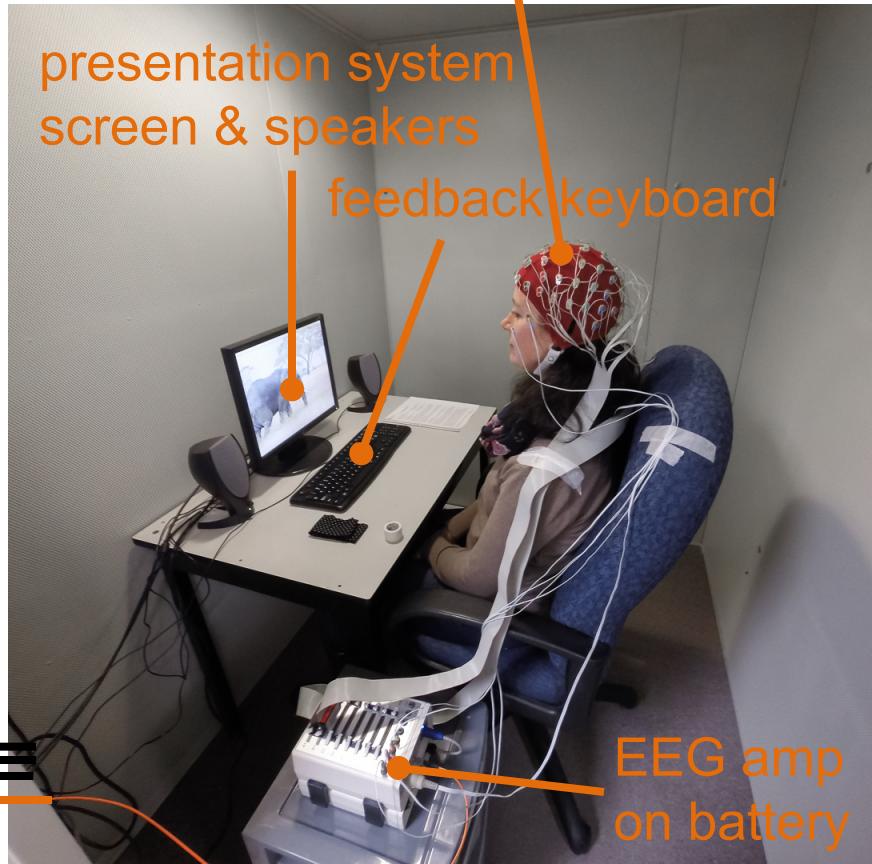
presentation system



recording system



sound booth



Biosemi ActiveTwo, 64 EEG + 4 EOG channels @ 512 Hz

EEG Pre-Processing

- ~~band-pass: 0.5 – 30 Hz~~
- bad channel removal & interpolation
- ~~down-sampling from 512 to 64 Hz~~
- eye-blink removal through ICA
 - remove components with highest correlation with the 4 EOG channels

EEG Pre-Processing

*We need to improve the
signal-to-noise ratio!*

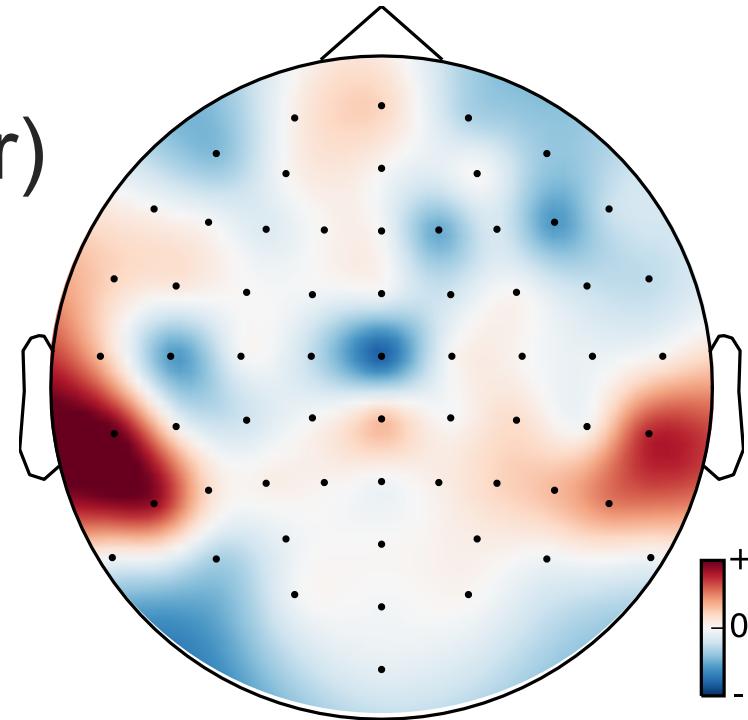


Aggregating the 64 EEG Channels

pre-trained filter
(as convolutional encoder)

for similarity constraints
 $\text{sim}(A, B) > \text{sim}(A, C)$

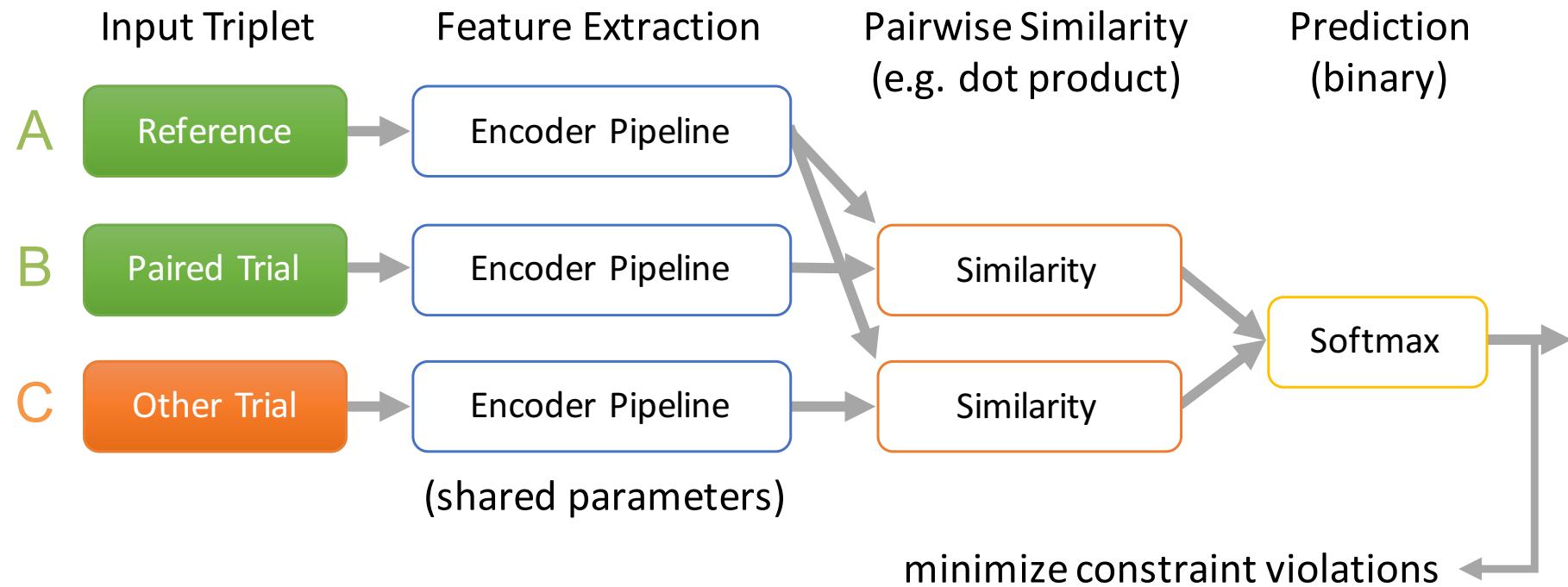
A, B – same stimulus trial
C – different stimulus trial



<http://arxiv.org/abs/1511.04306>

Training the Filter

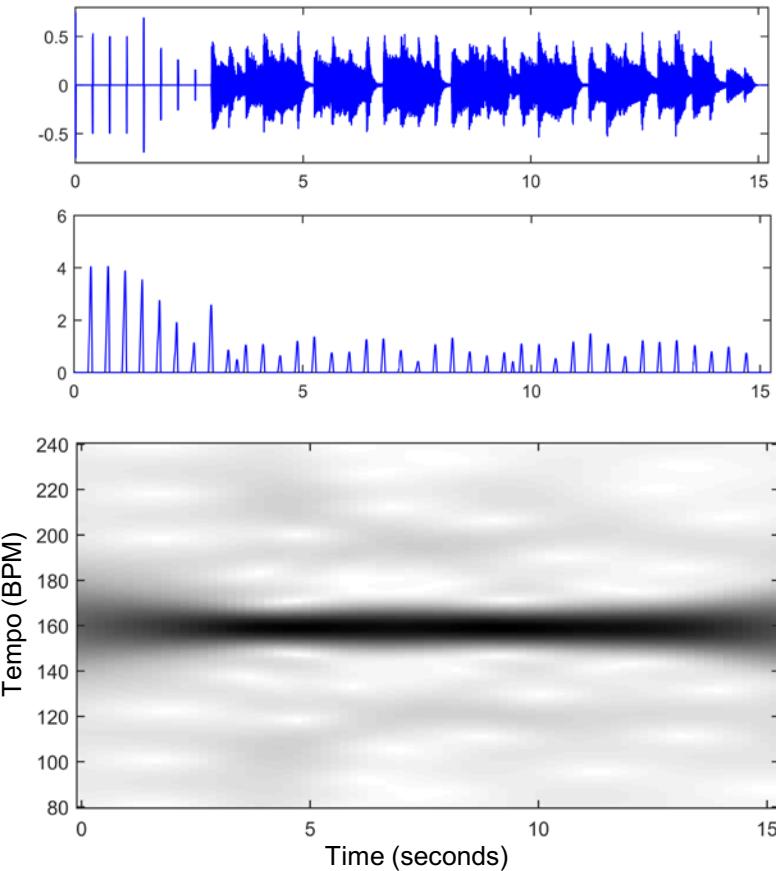
[Similarity-Constraint Encoder]



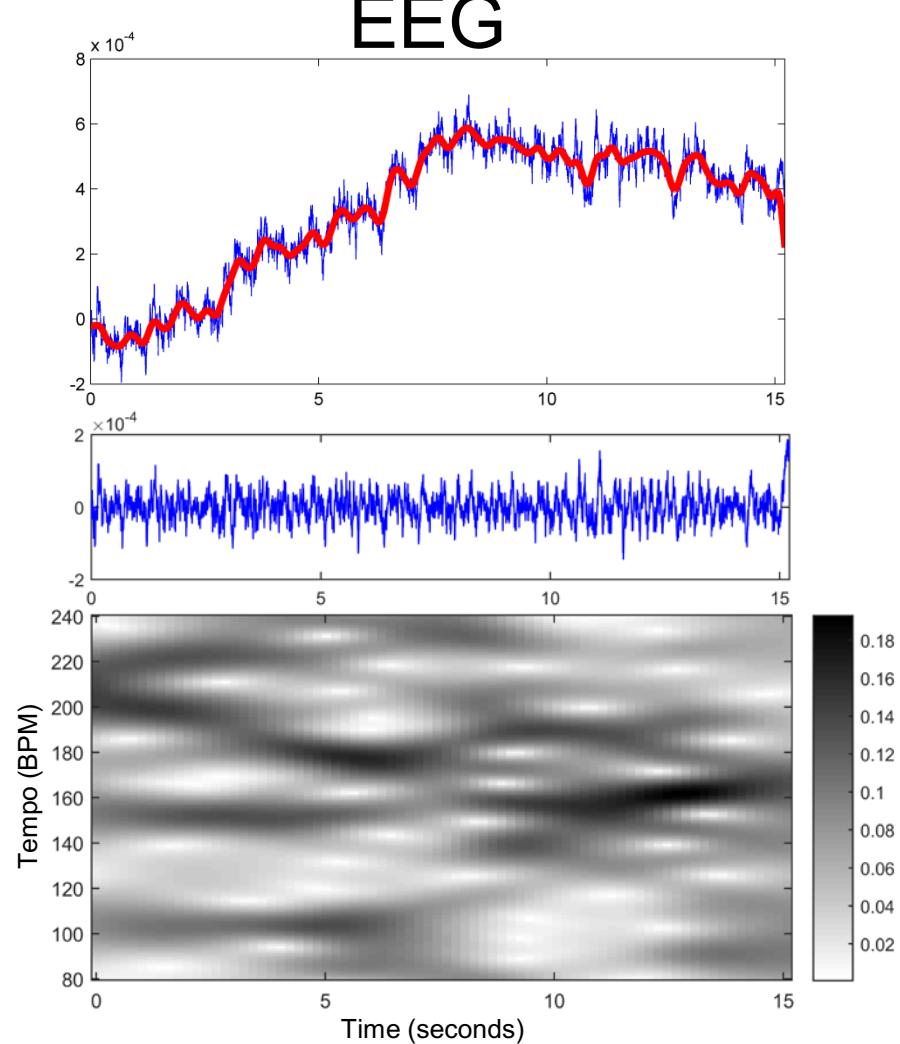
<http://arxiv.org/abs/1511.04306>

Tempogram Computation

Audio

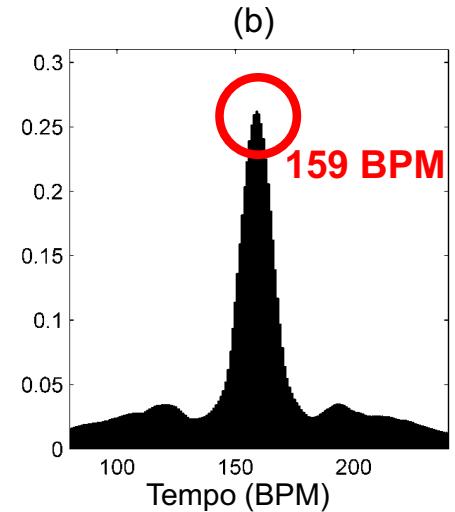
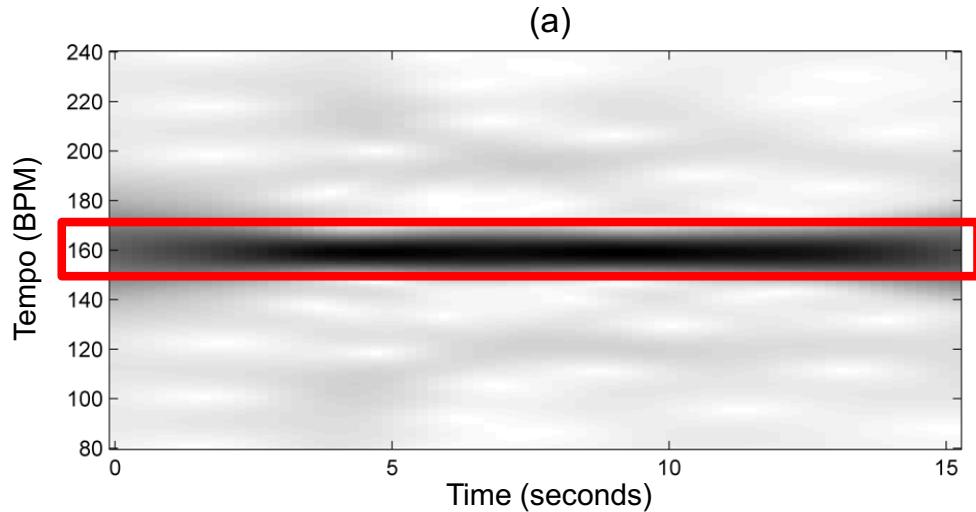


EEG

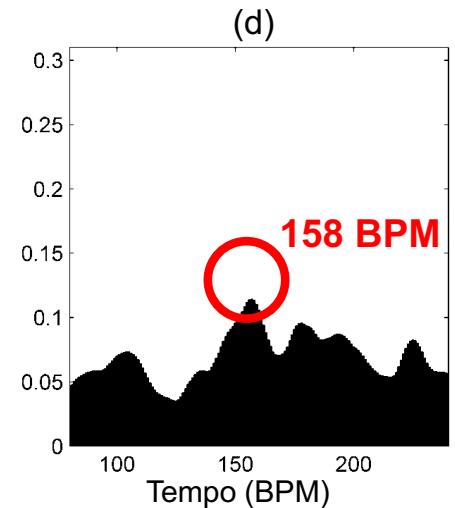
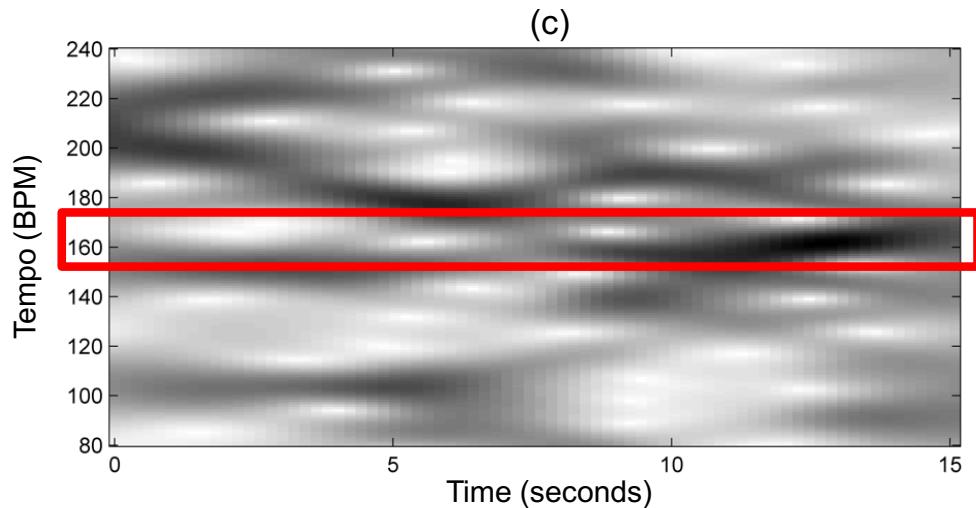


Tempo Histograms

Audio



EEG



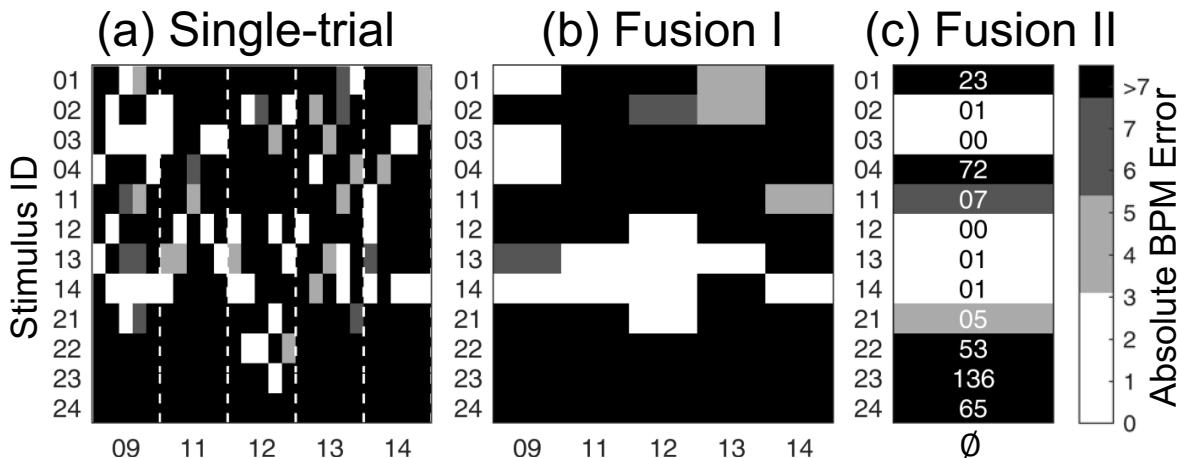
Fusion Strategies

- a) Single-trial tempo extraction
 - $12 \text{ stimuli} * 5 \text{ participants} * 5 \text{ trials} \Rightarrow n=300$
- b) Fusion I
 - average tempo histograms over 5 trials per stimulus and participant
- c) Fusion II
 - average tempo histograms over $5*5$ trials per stimulus

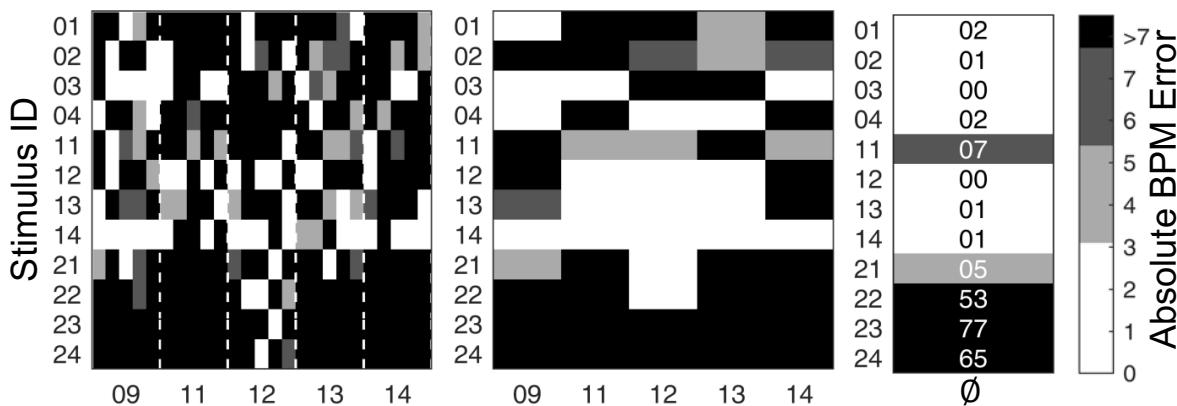
#peaks

tempo error (%)

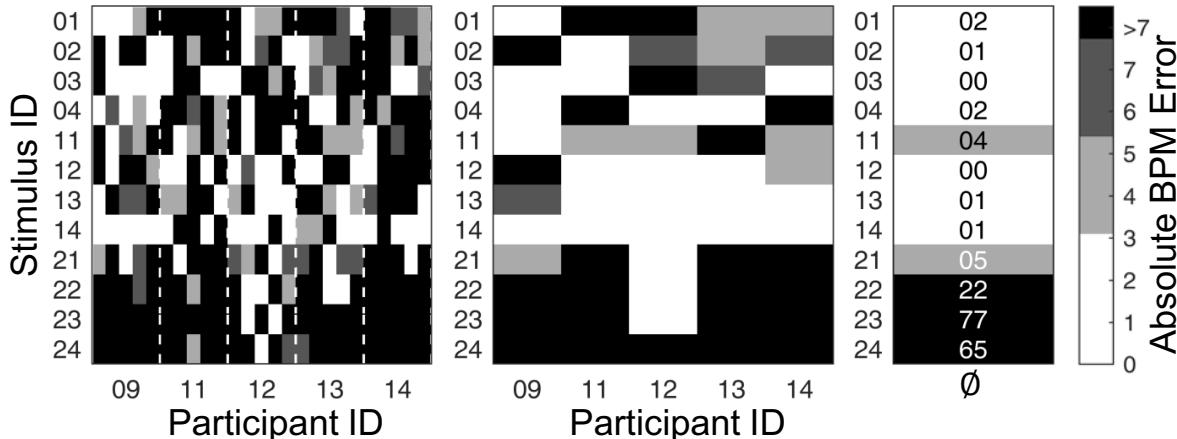
	δ	(a)	(b)	(c)
$n = 1$	0	98	97	83
	3	84	80	58
	5	78	75	50
	7	75	72	42



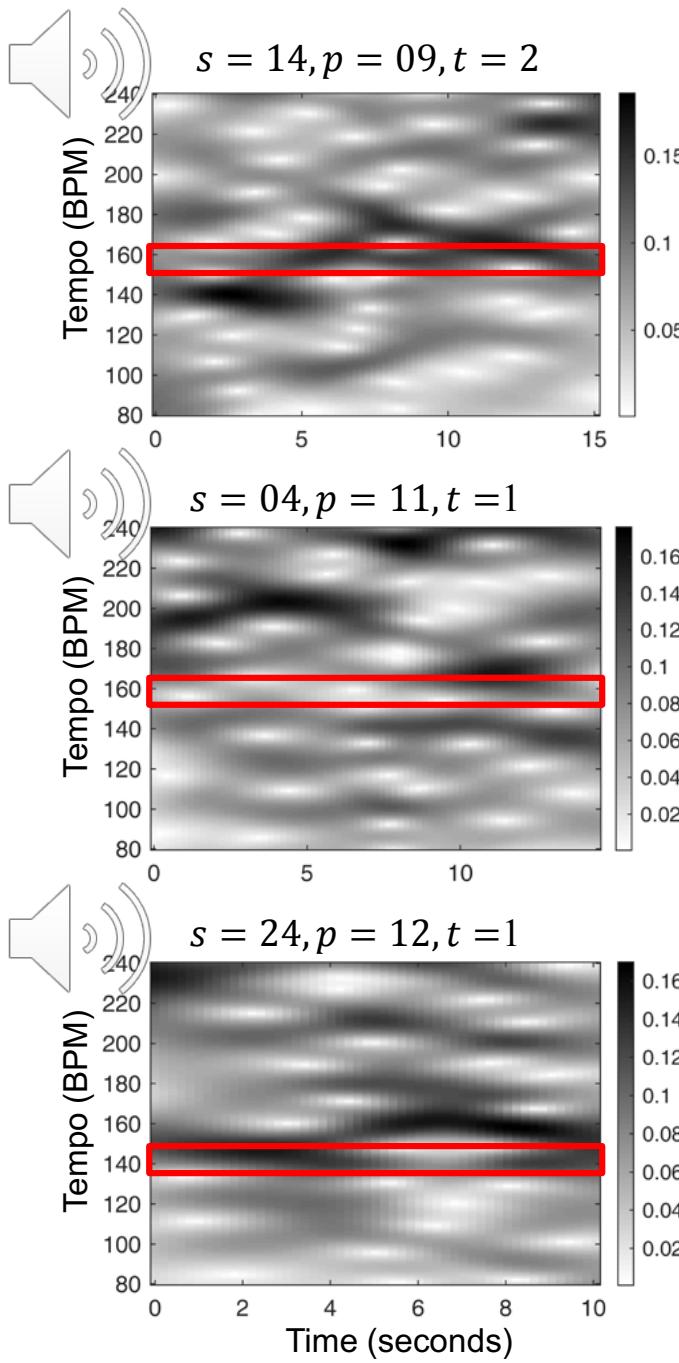
	δ	(a)	(b)	(c)
$n = 2$	0	96	97	83
	3	79	67	42
	5	71	57	33
	7	65	52	25



	δ	(a)	(b)	(c)
$n = 3$	0	96	97	83
	3	73	60	42
	5	62	47	25
	7	54	40	25

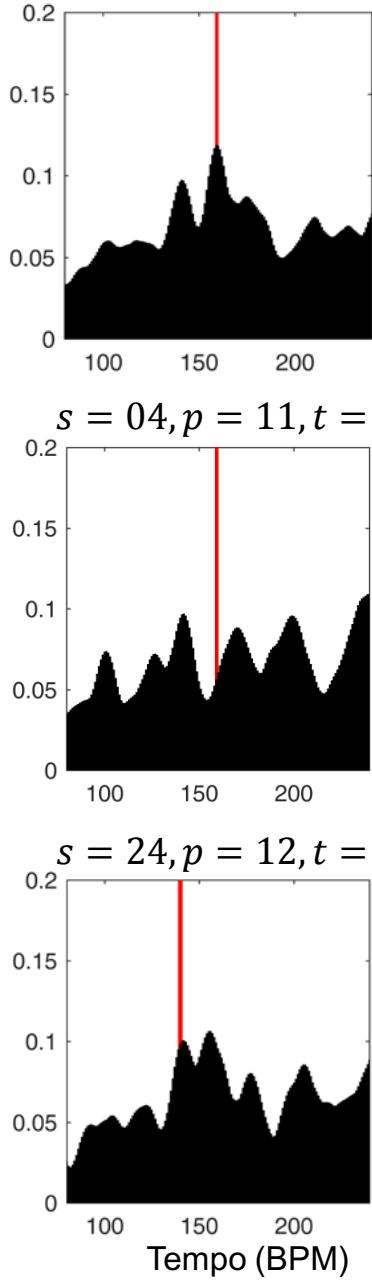


error tolerance (BPM)



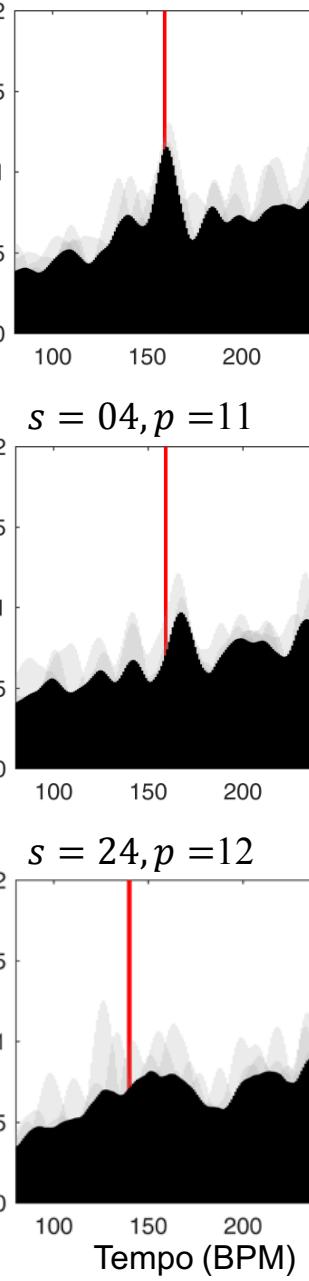
Single-trial

$$s = 14, p = 09, t = 2$$



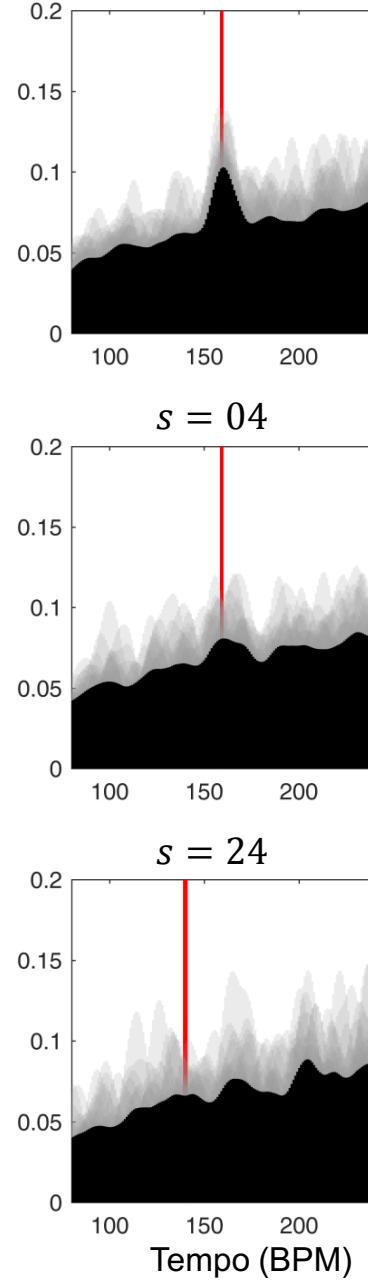
Fusion I

$$s = 14, p = 09$$



Fusion II

$$S = 14$$



Conclusions

It works!

Sometimes.

- applied MIR tech to EEG data
- compared extracted tempo with results on audio stimuli
- histogram fusion stabilizes results
- results strongly depend on the music stimuli
- stimuli with systematically adapted tempi could give more insights

Outlook: From MIR to MIIR

Music Imagery Information Retrieval

= “*retrieving music information
from brain signals*”



Thank You!

SHARE.

Tell us about your
experiences and everything
you have learned.
You will grow up and
help many people
like you.

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<https://dx.doi.org/10.6084/m9.figshare.3398545>