Analysing Physiological Data Collected During Music Listening: An Introduction

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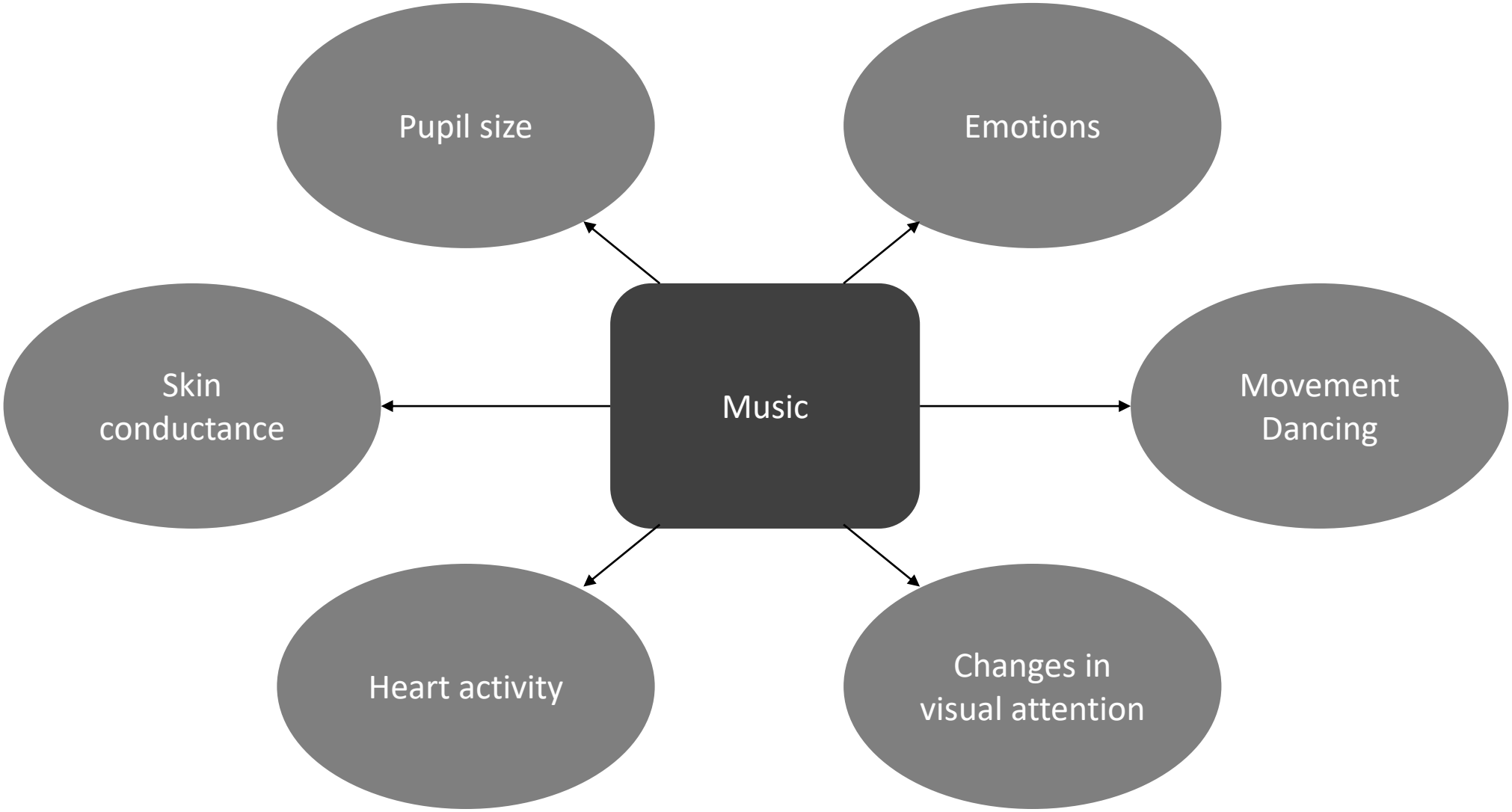
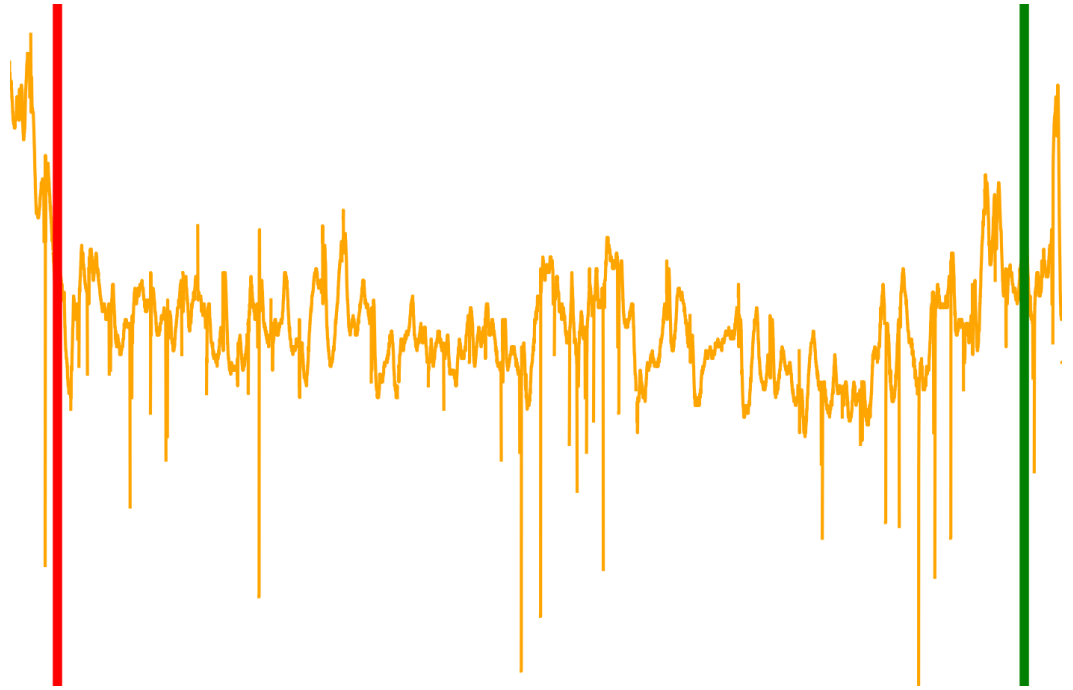

Pupil size
Emotions
Skin conductance
Music
Movement Dancing
Heart activity
Changes in visual attention

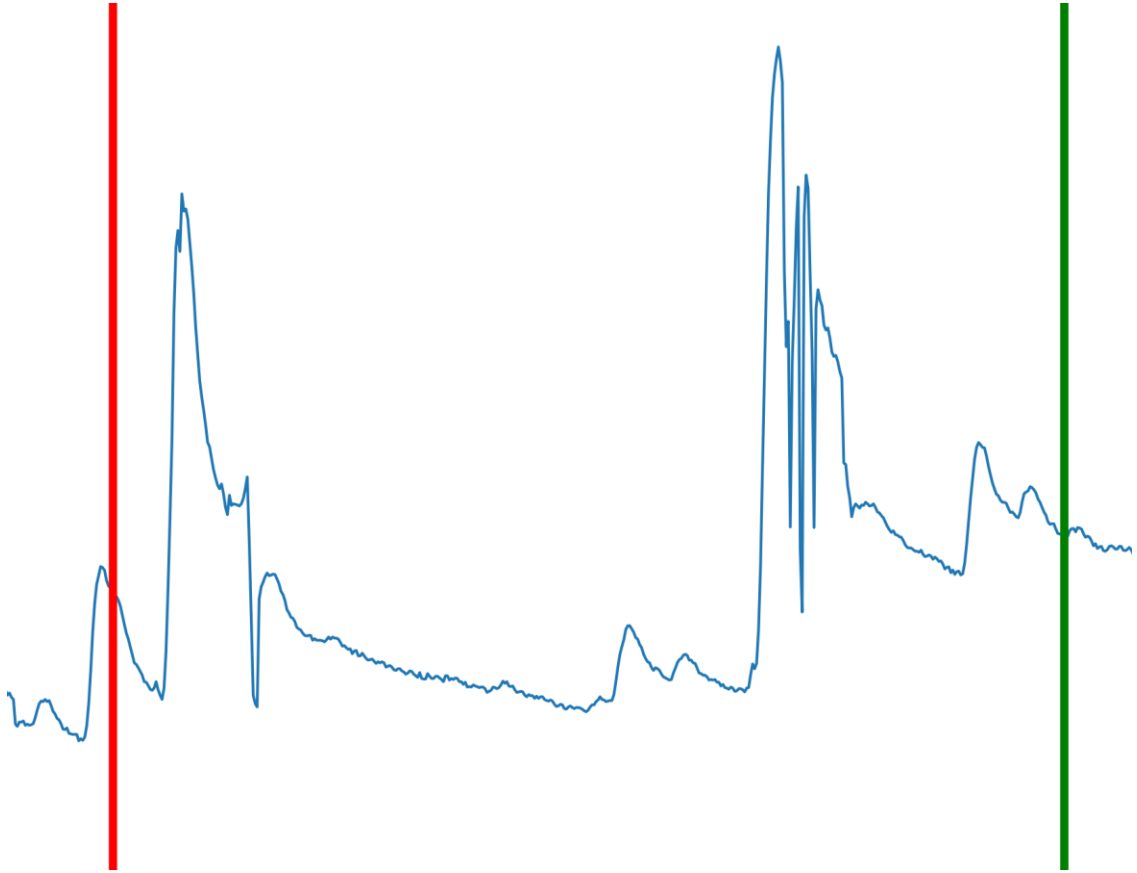
Subjective data from questionnaires


```
{
  "liking": 7,
  "familiarity": 6,
  "effort": 15,
  "relaxed": 7,
  "motivation": 7,
  "fatigue": 2
}
```

Pupil diameter during music listening



Electrodermal activity during music listening



Content of the tutorial

Part 1: Collected dataset and important concepts

Part 2: Demo

Part 3: Analyses

Part 4: Questions

Part 1

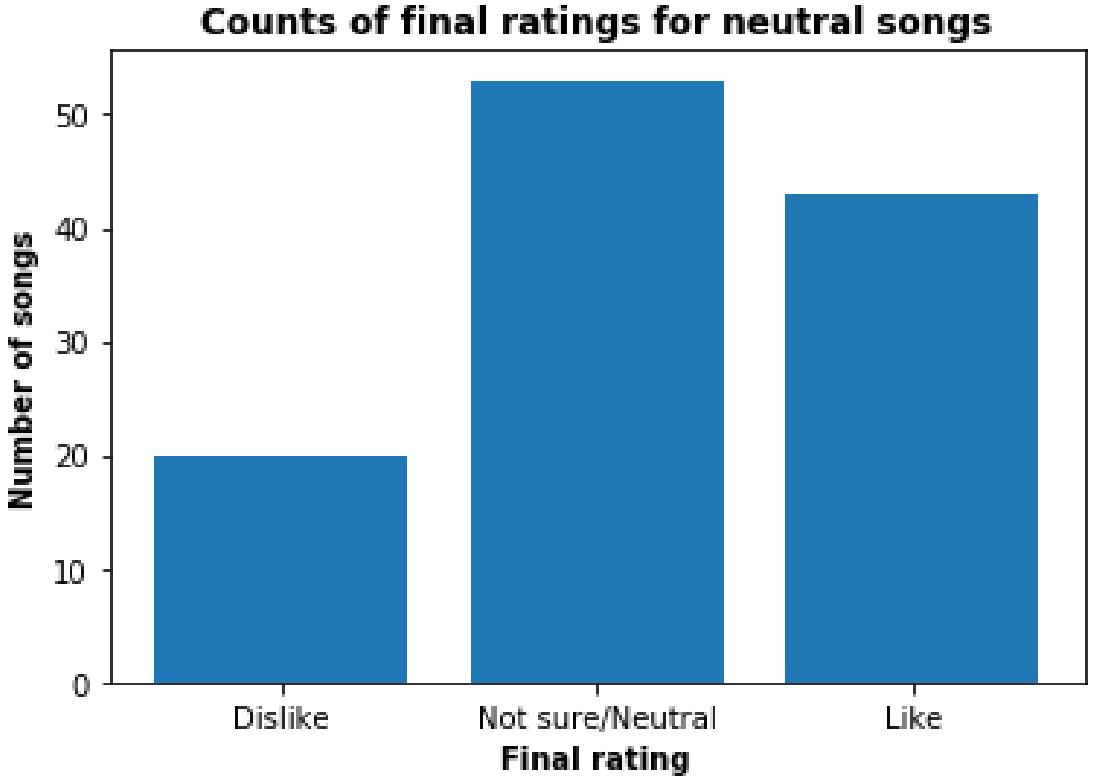
Presentation of the dataset

Why was the data collected?

Collaboration between RITMO, Loria and Ullo

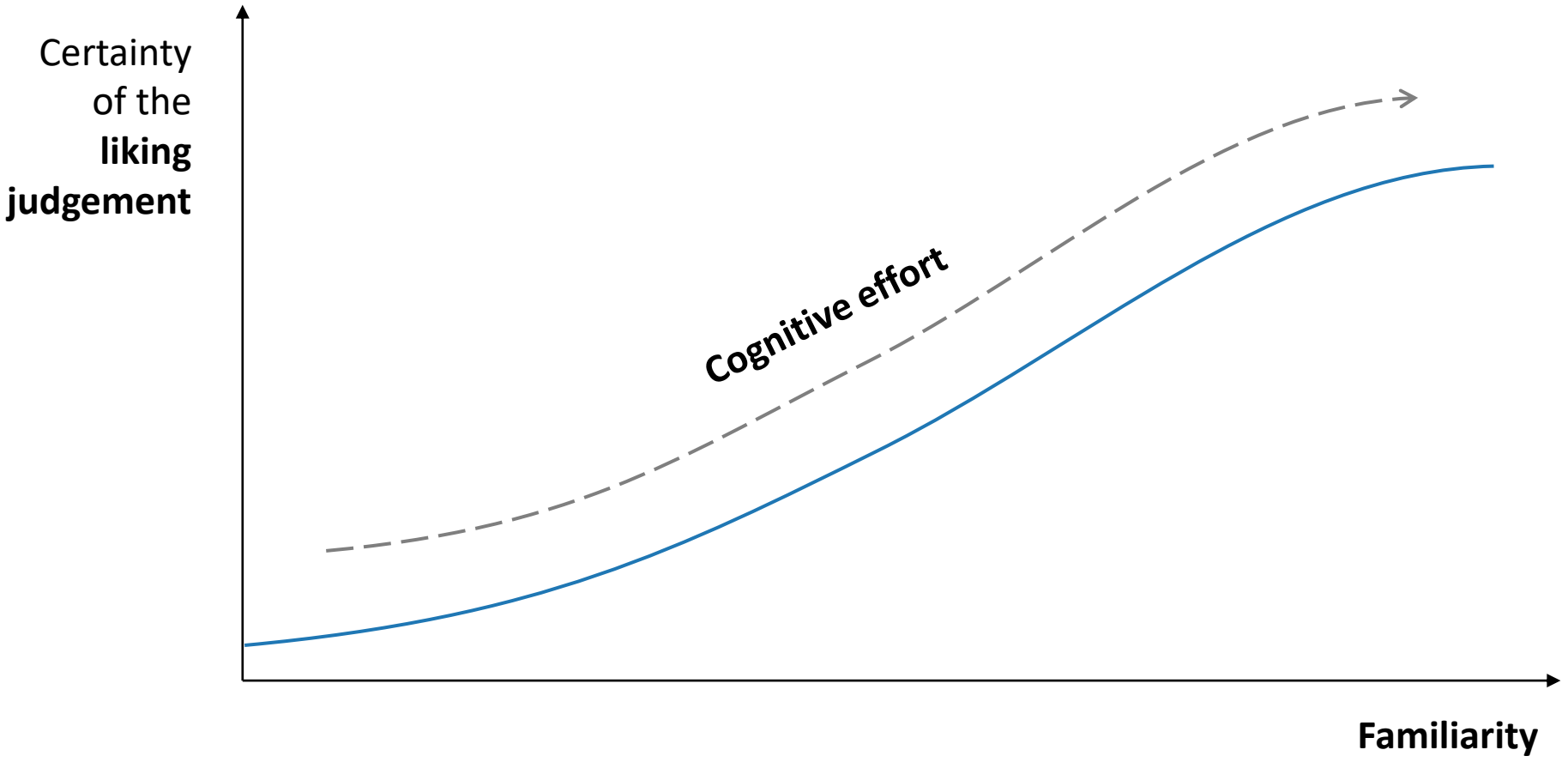
- Discovery-oriented music listening
- What is music discovery?
- What factors influence music discovery?
- How can these factors be characterised?

Effect of repetition on liking judgement

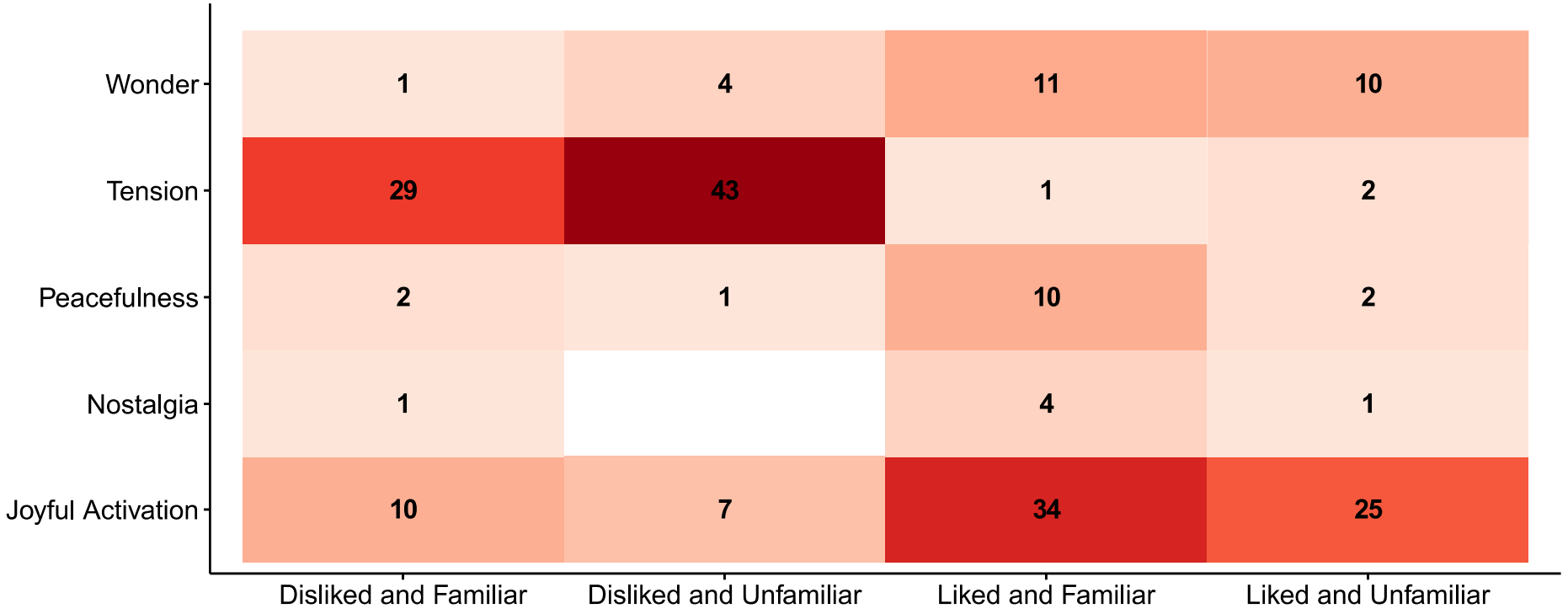


The rating changes of neutral songs with more than one presentation (Manolovitz and Ogihara, 2020)

Music discovery, a definition

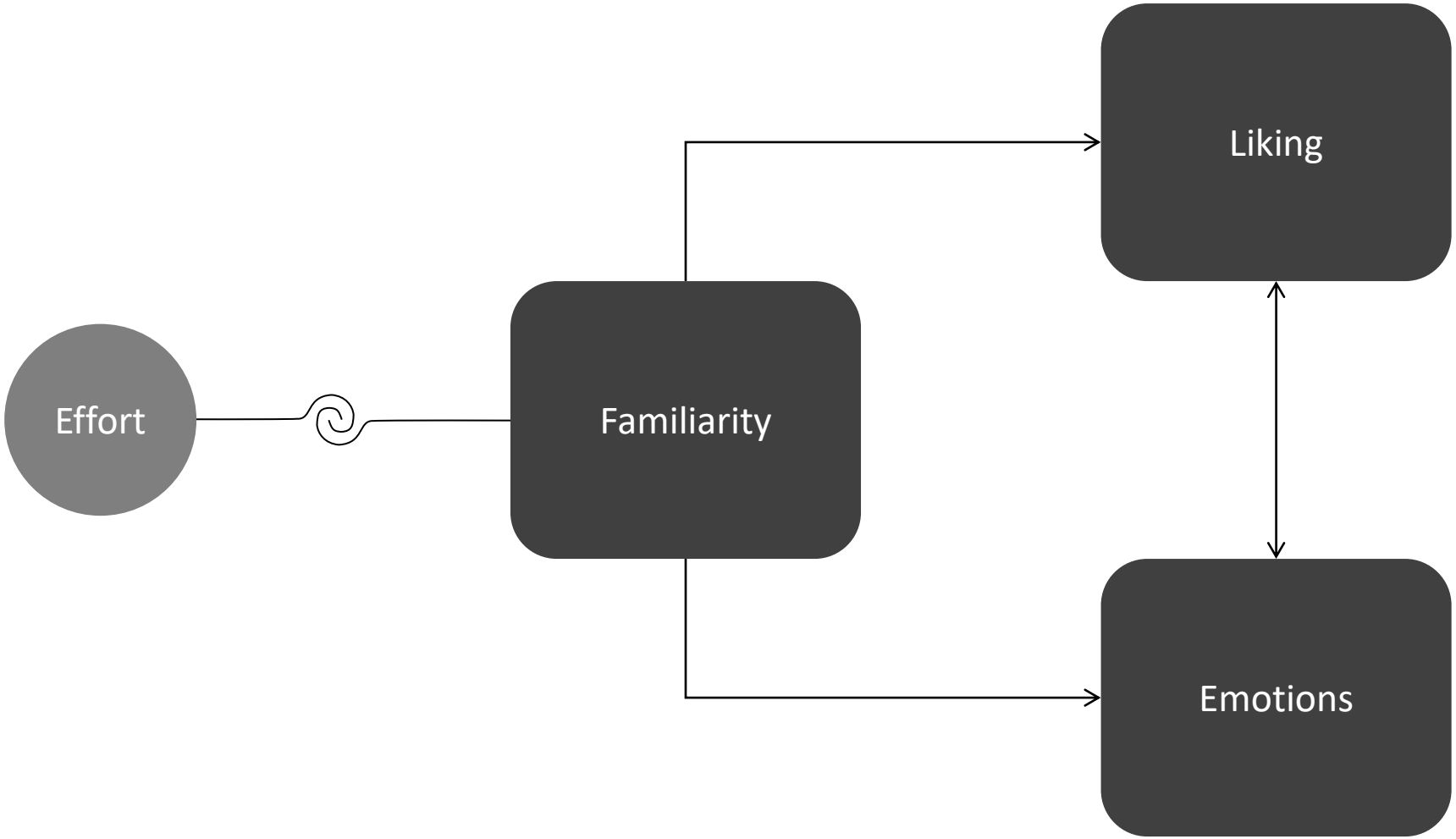


Liking, familiarity and emotions

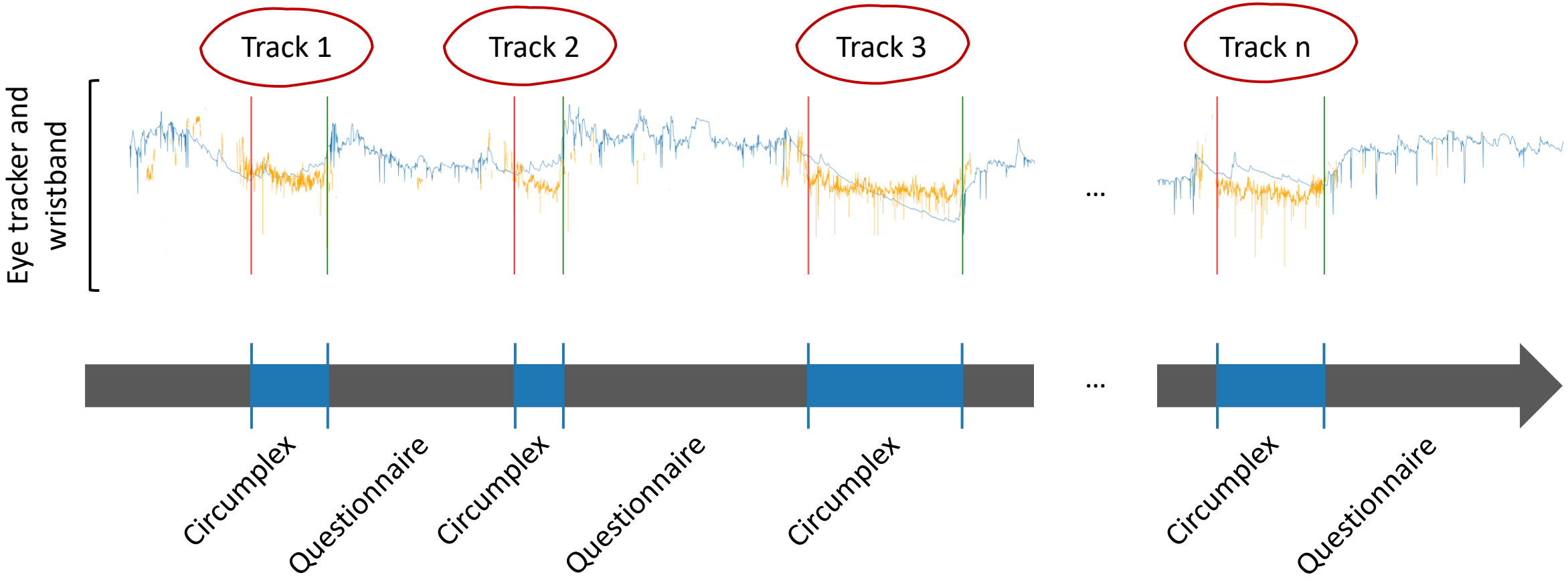


Induced emotions depending on liking and familiarity
(Doumbia et al, 2023)

Factors/concepts related to music discovery



Experimental protocol

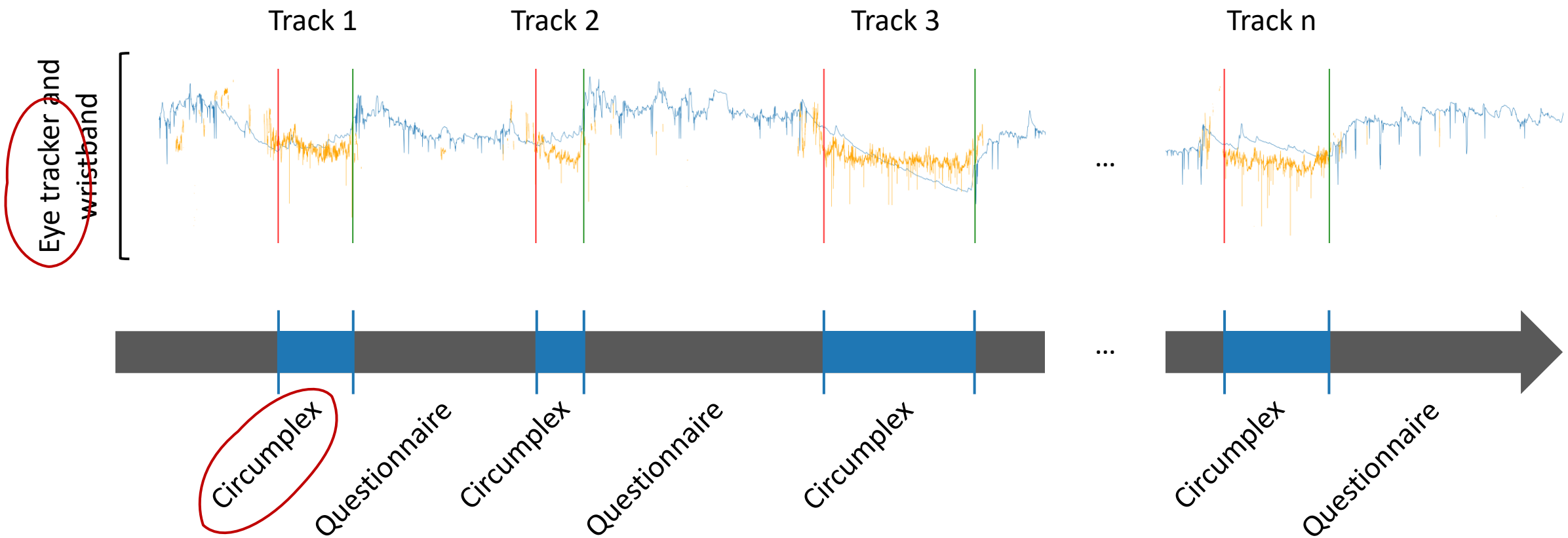


Track selection

Based on

- Pre-questionnaire (5 liked tracks)
- Spotify recommendations
- Spotify popularity score

Experimental protocol



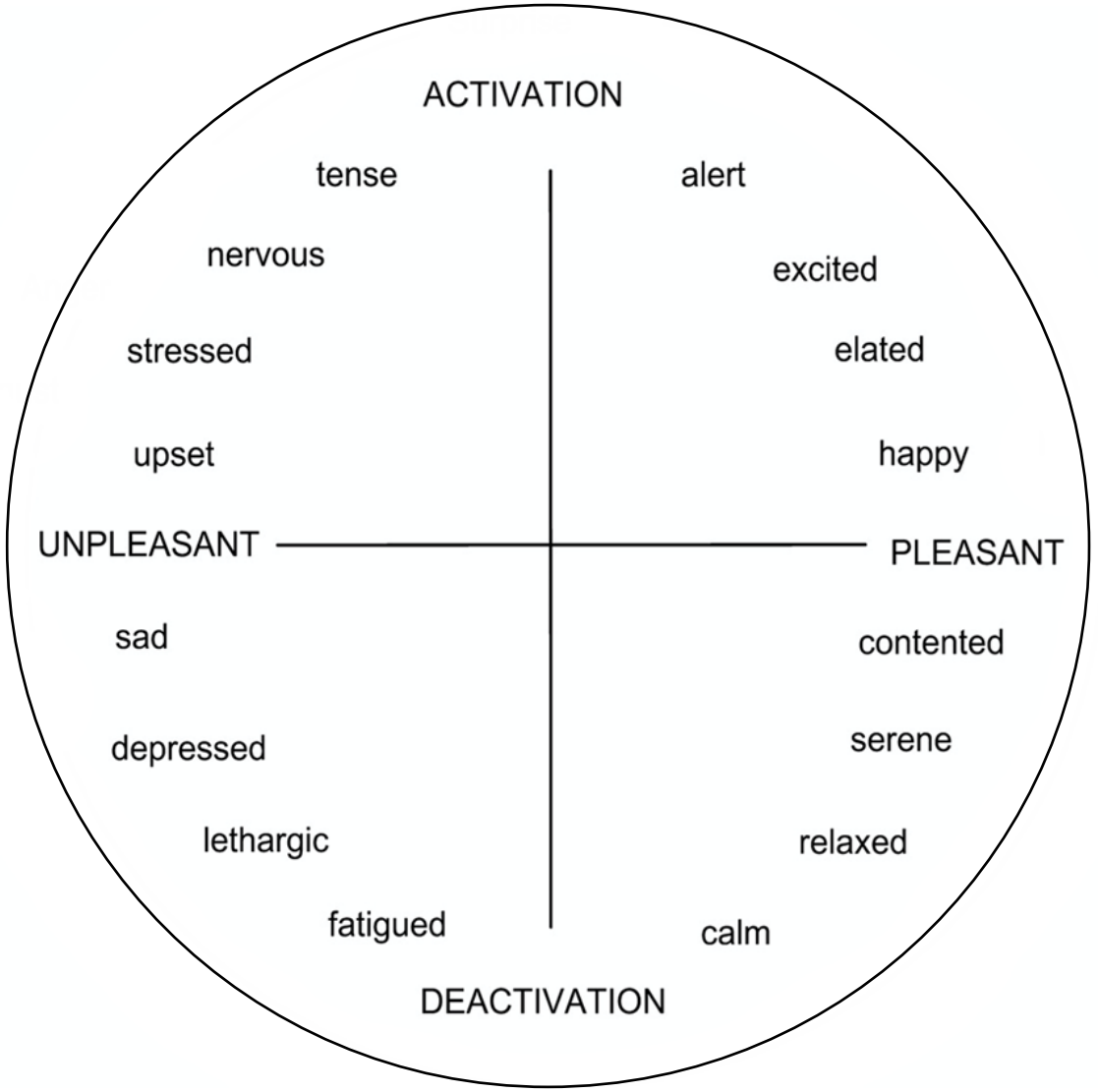
Eye tracking bar

Tobii Nano

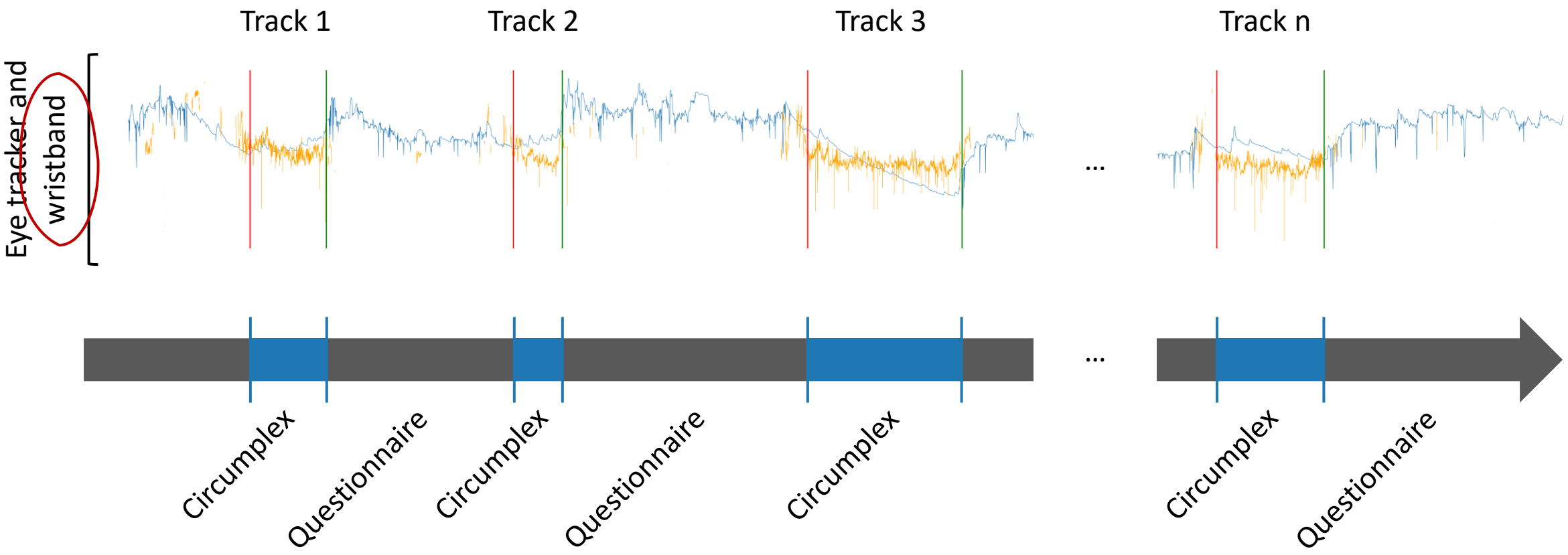
Recording at 60 Hz

- Gaze point X
- Gaze point Y
- Fixation point X
- Fixation point Y
- Pupil diameter
- AOI

Russell's Circumplex model of emotions



Experimental protocol



Wristband equipped with sensors

Empatica E4

Recording at 4Hz

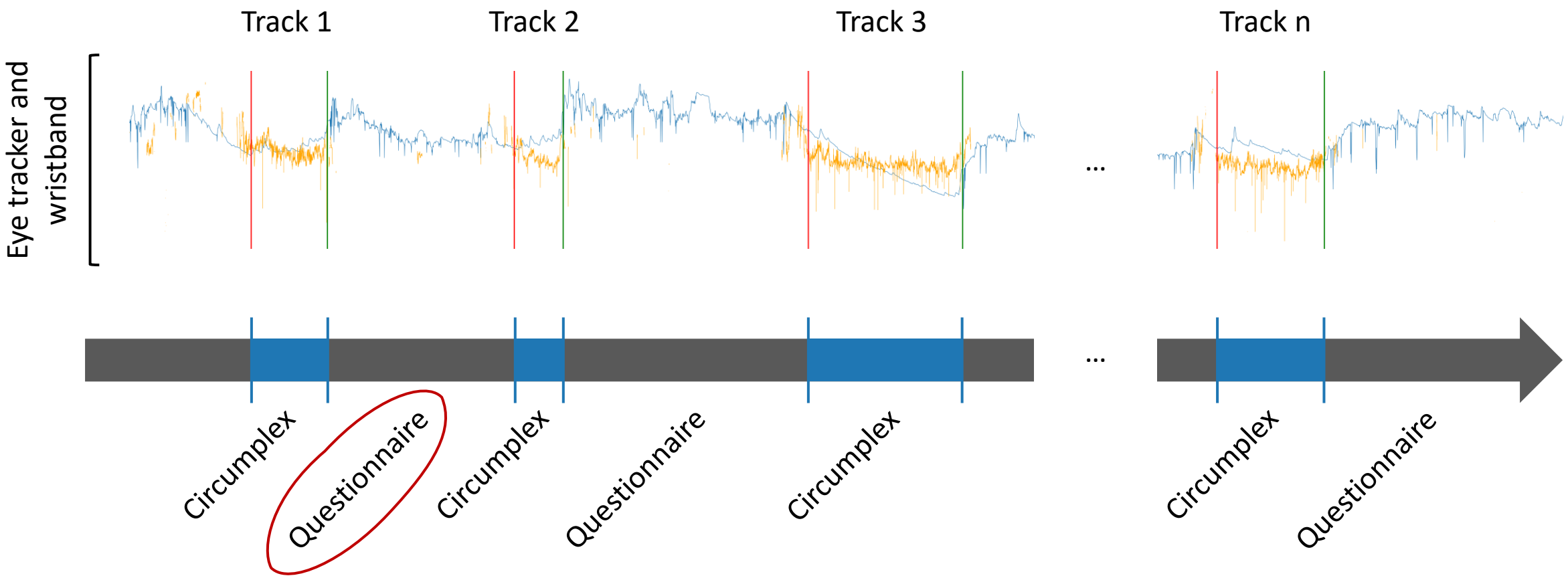
- Electrodermal activity (EDA)
- Temperature

Recording at 64Hz

- Blood Volume Pulse (BVP)

+ Heart Rate (HR) derived from BVP

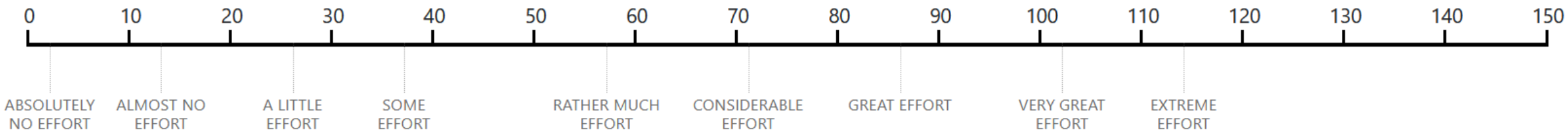
Experimental protocol



Questionnaire data

	Strongly disagree	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree	Strongly agree
I liked this music	1	2	3	4	5	6	7
I am familiary with this genre	1	2	3	4	5	6	7
I am familiar with this artist	1	2	3	4	5	6	7
I am familiar with this track	1	2	3	4	5	6	7
I felt relaxed while listening to this track	1	2	3	4	5	6	7
I am enthusiastic to carry on with the experiment and discover new music	1	2	3	4	5	6	7
I am feeling tired	1	2	3	4	5	6	7

Perceived effort ratings



Rating Scale of Mental Effort (RSME)
(Zijlstra and Van Doorn, 1985)

A few more details

- Each participant listened to a metronome once
- Each participant made 2 sessions (with the same tracks)
- We asked participants how many times they had listened to each track between both sessions
- We asked the occupation of the participants
- Participants could also provide free comments in text fields

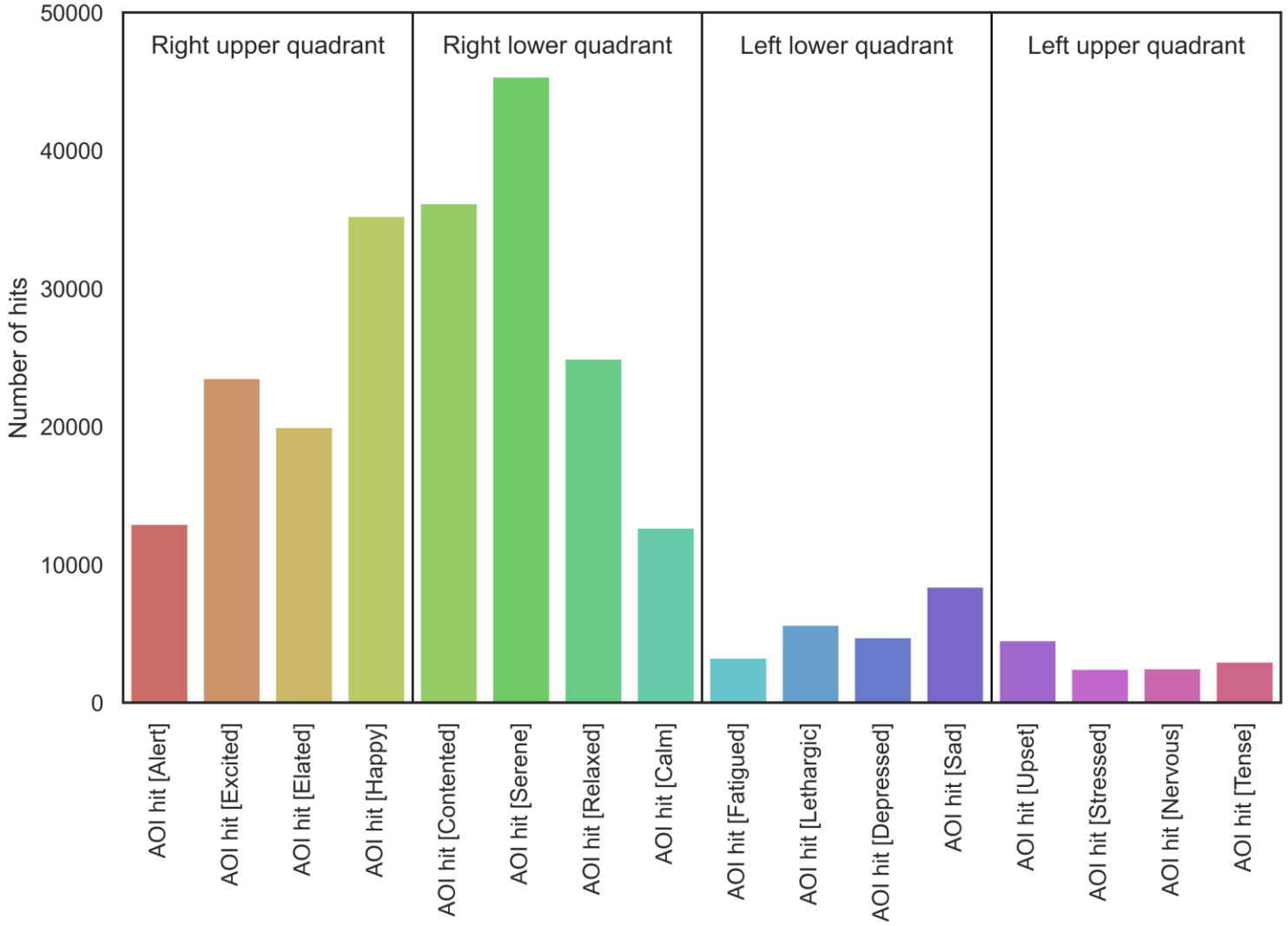
Summary of the collected data fields

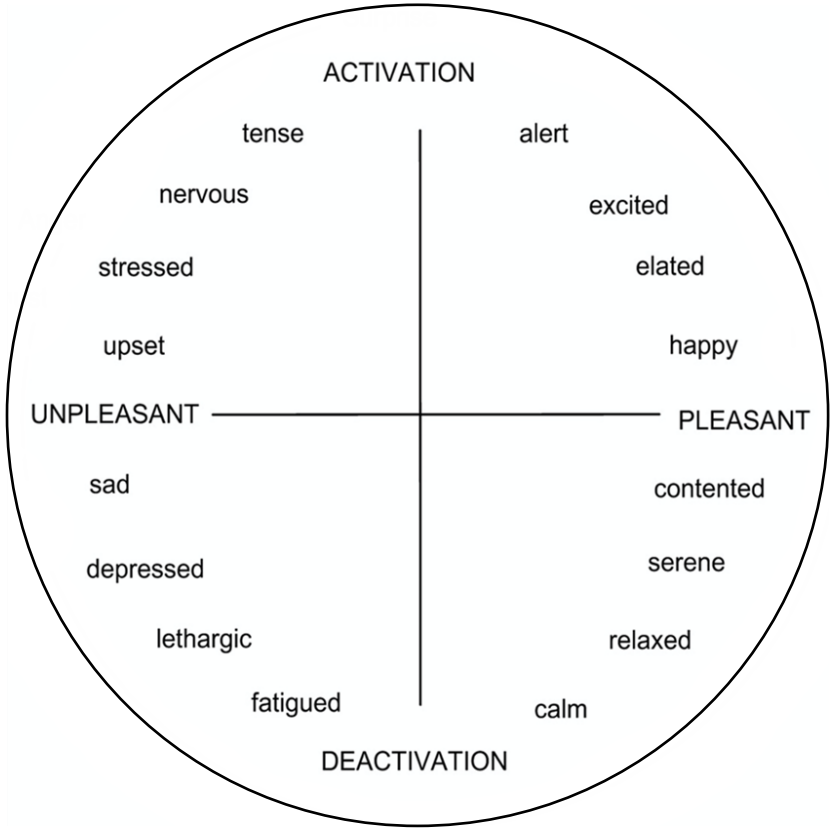
- Artist, song title, duration, Spotify id (null if metronome)
- Gaze points, fixation points, pupil diameters
- Electrodermal activity (EDA), Heart Rate (HR), temperature
- Induced emotions from Eye tracker + Circumplex
- Track liking judgement ratings
- Genre, artist and track familiarity ratings
- Effort ratings using the Rating Scale Mental Effort (RSME)
- Responses to additional questions about fatigue and relaxation
- Listening session (first or second)
- Participants' occupation
- Number of times each track was played between sessions
- Free comments

Collected dataset

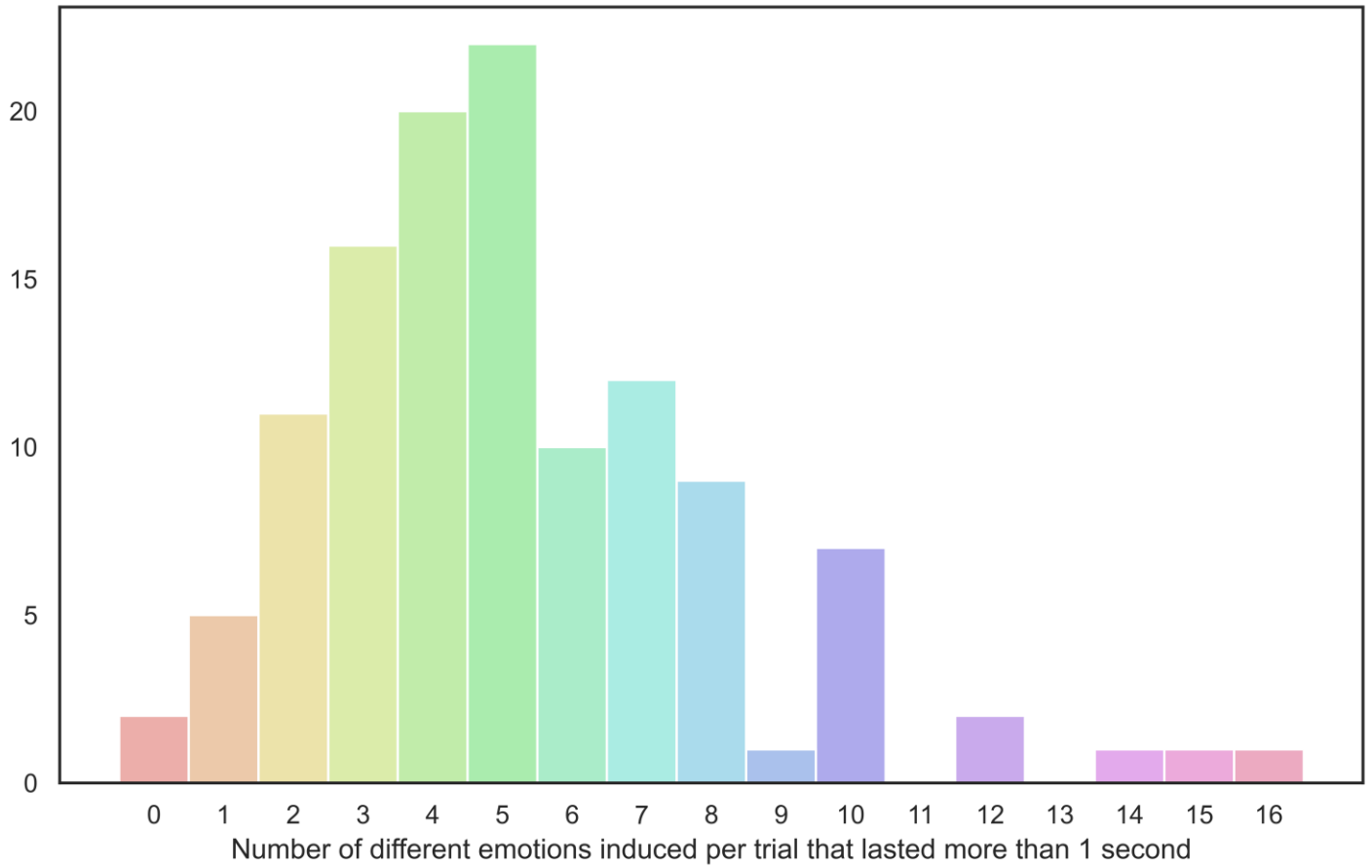
- 9 participants
  - 6 students, 2 researchers and one former executive
  - One participant did not show up for session 2
  - Missing wristband data
    - For one track of one participant
    - For two tracks of another participant
- 130 trials, 61 distinct tracks

Number of emotion hits

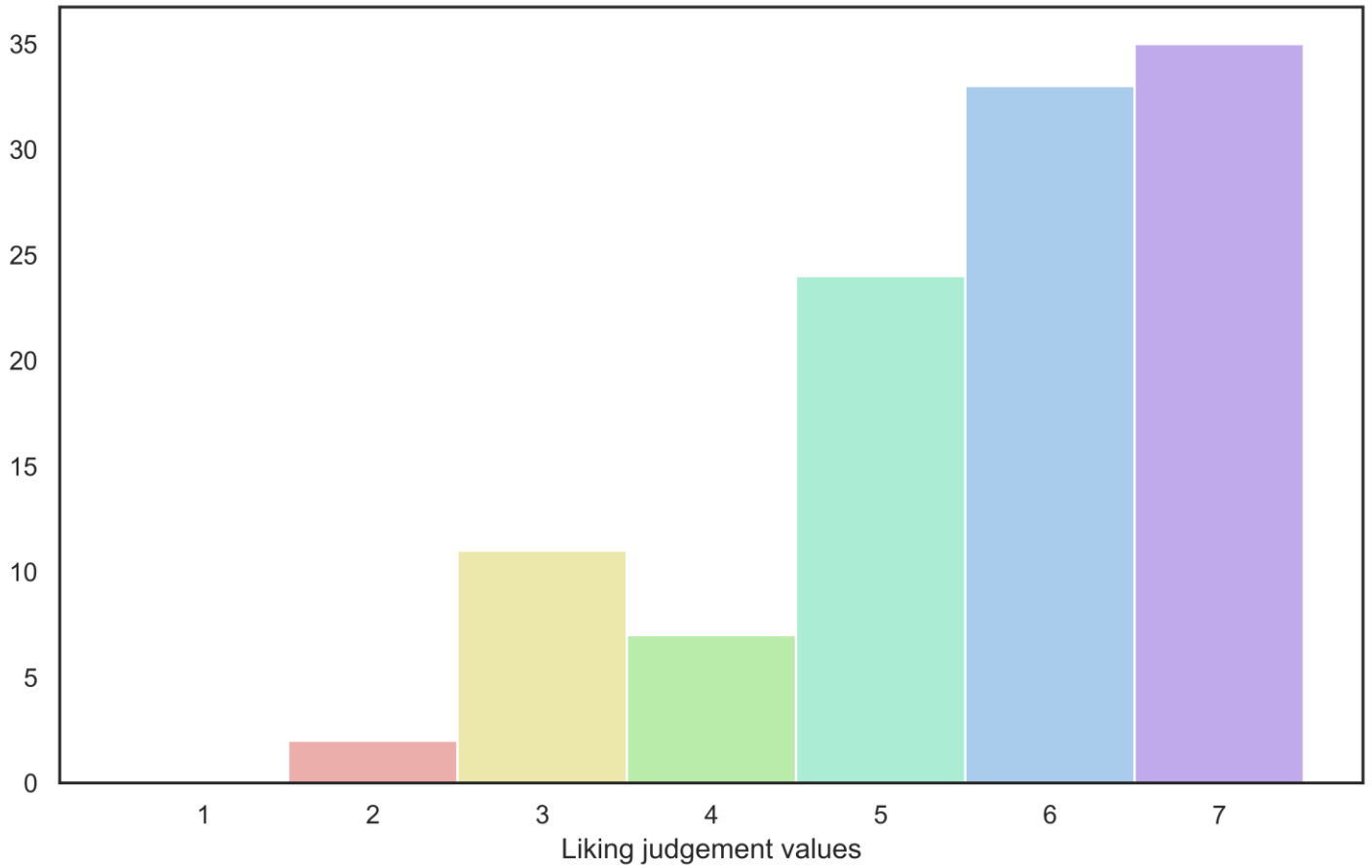




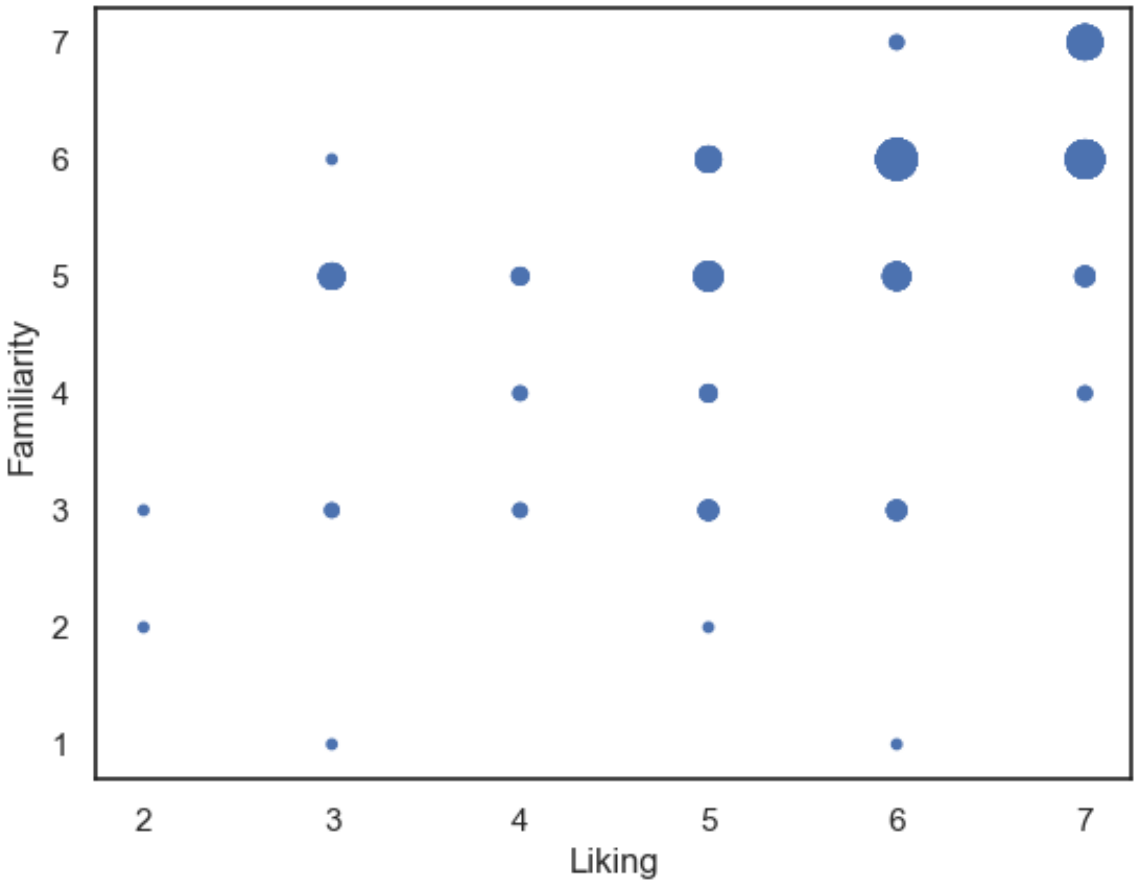
Usefulness of the Circumplex model



Distribution of track liking judgement



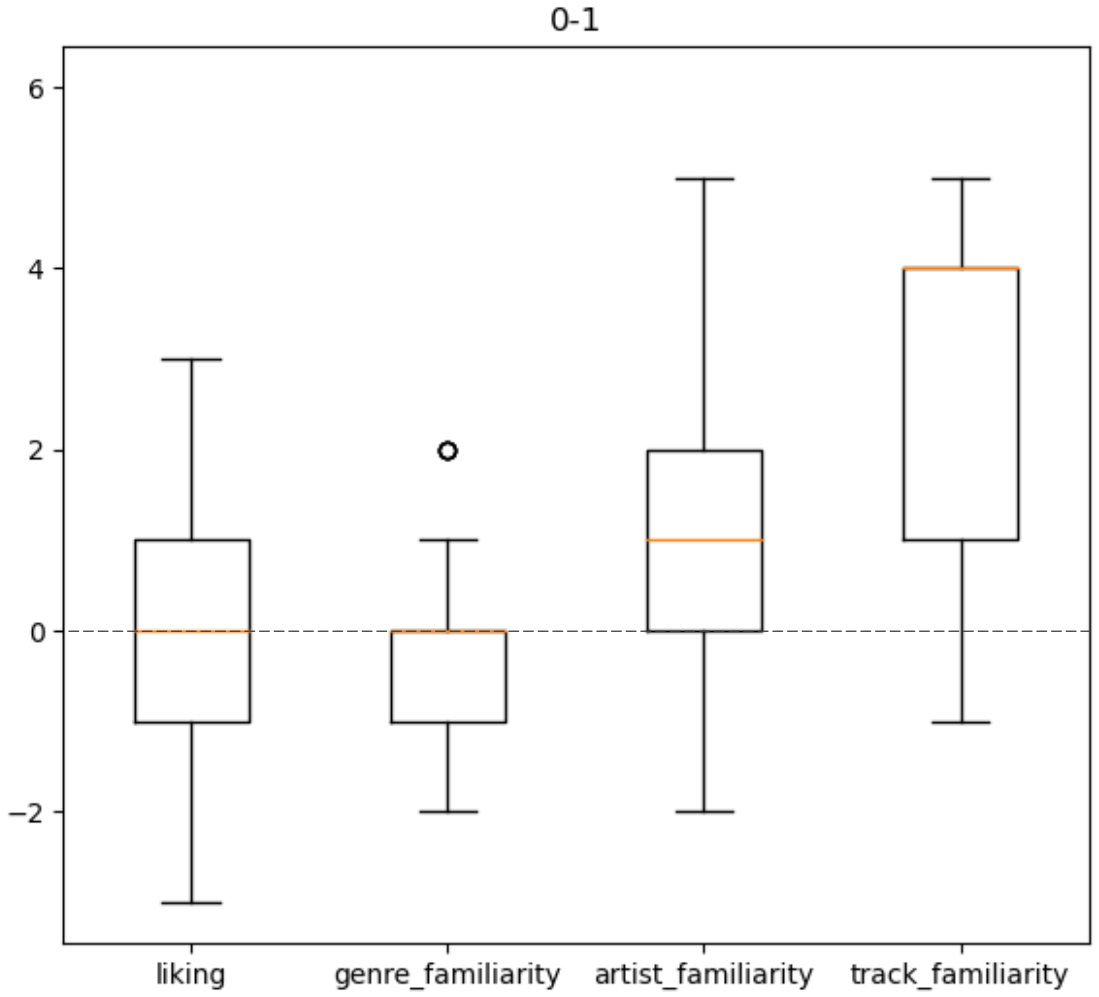
Relationship between liking and familiarity

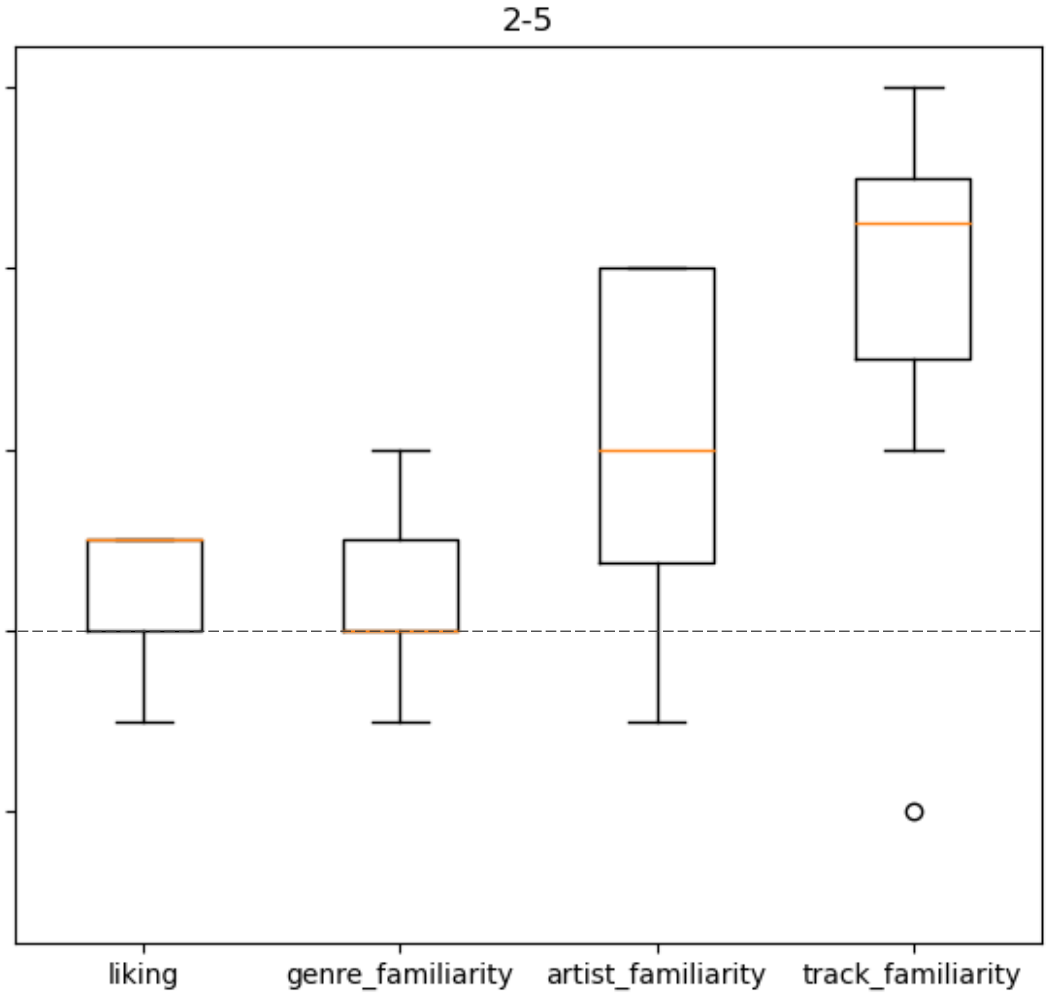


Spearman correlation of 0.6
($p = 10^{-12}$)

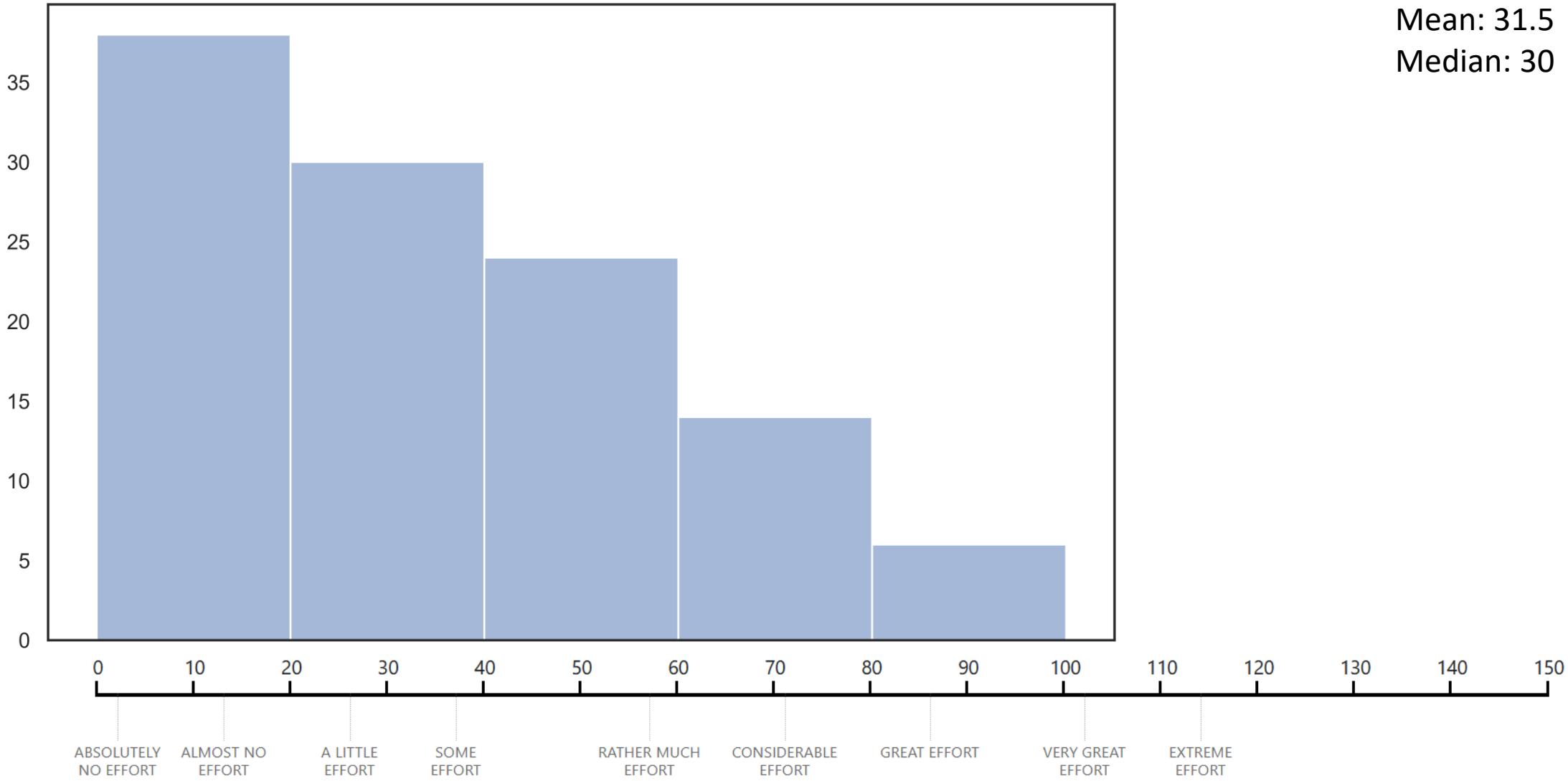
Linear regression
Familiarity ~ liking
$R^2 = 0.29$
($p = 0.01$)

Impact of playcounts between sessions



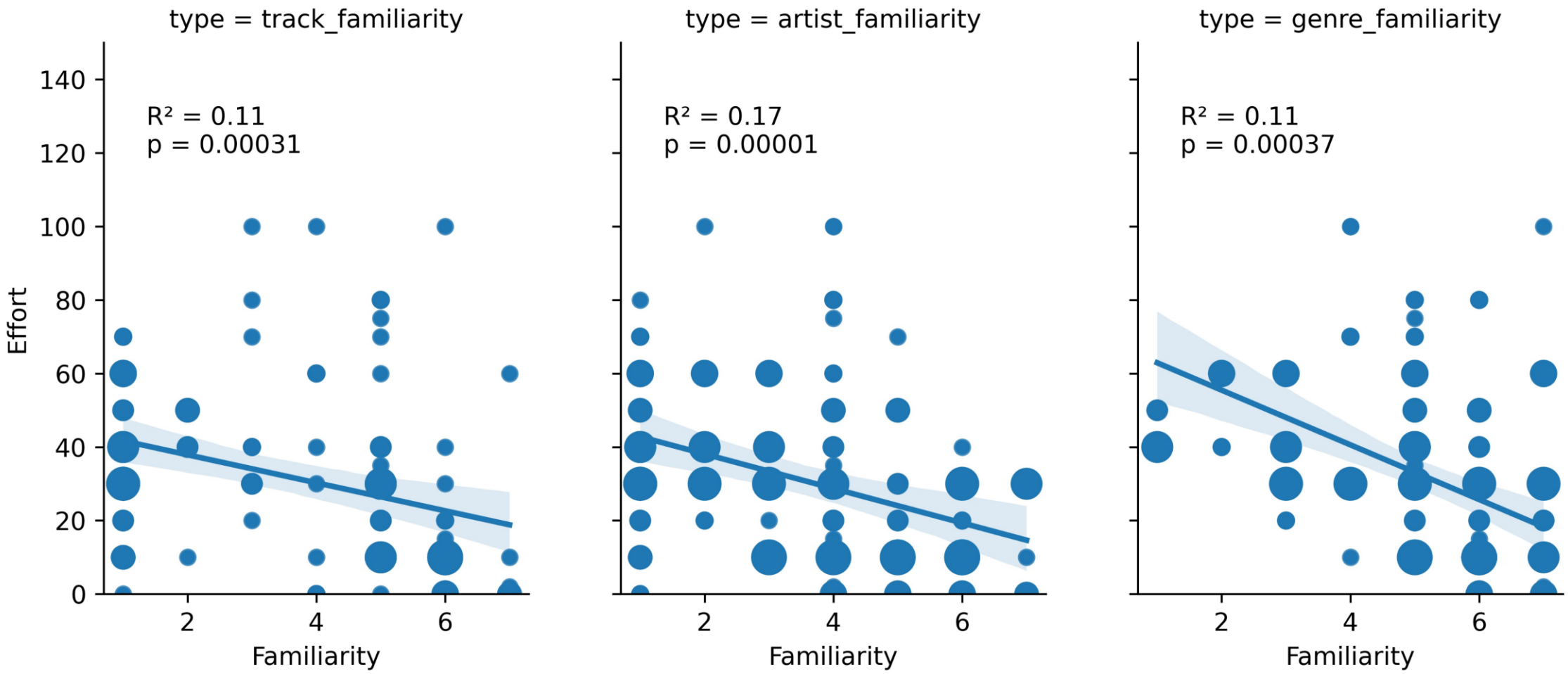


Distribution of effort ratings



Mean: 31.5
Median: 30

Impact of familiarity on effort



Eye-tracking & pupillometry

Pupil response

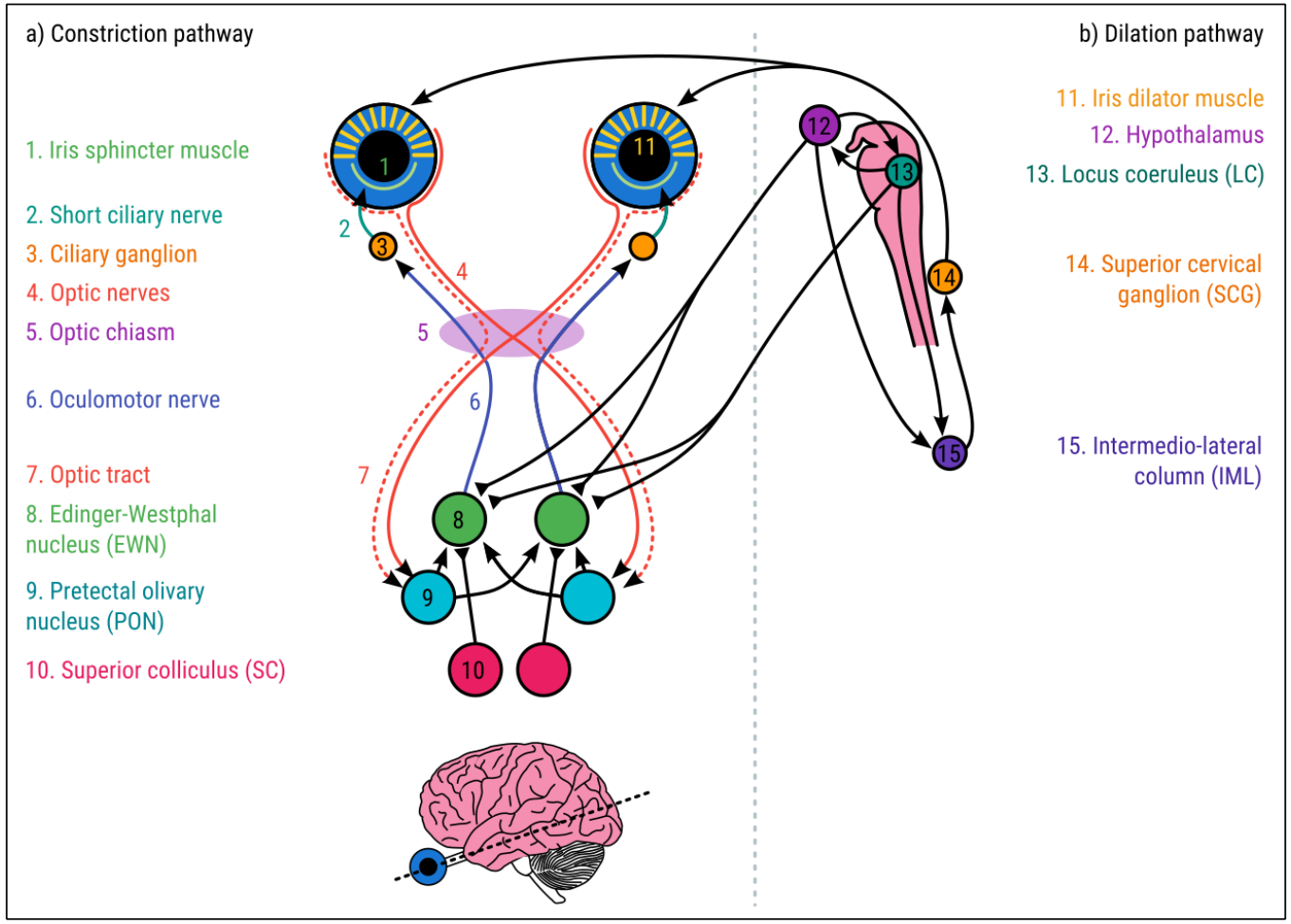
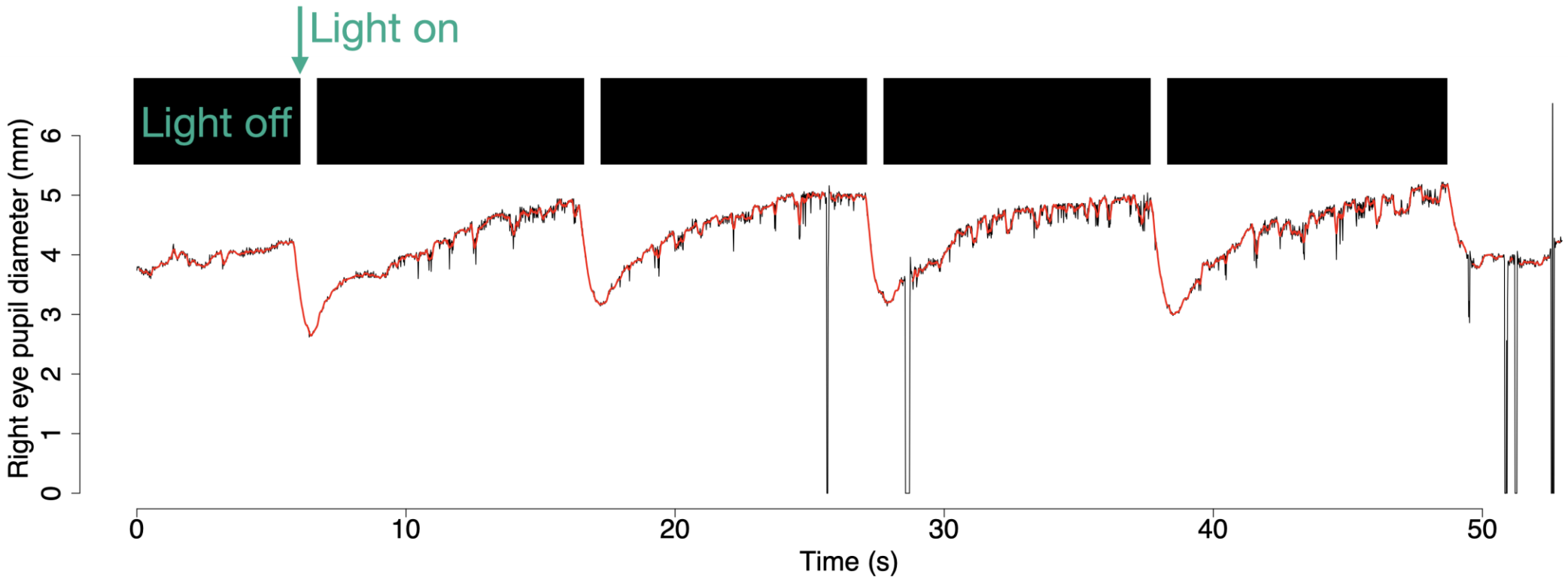


Figure from Mathôt, S. (2018). Pupillometry: Psychology, physiology, and function. Journal of Cognition, 1(1): 16, 1—23.

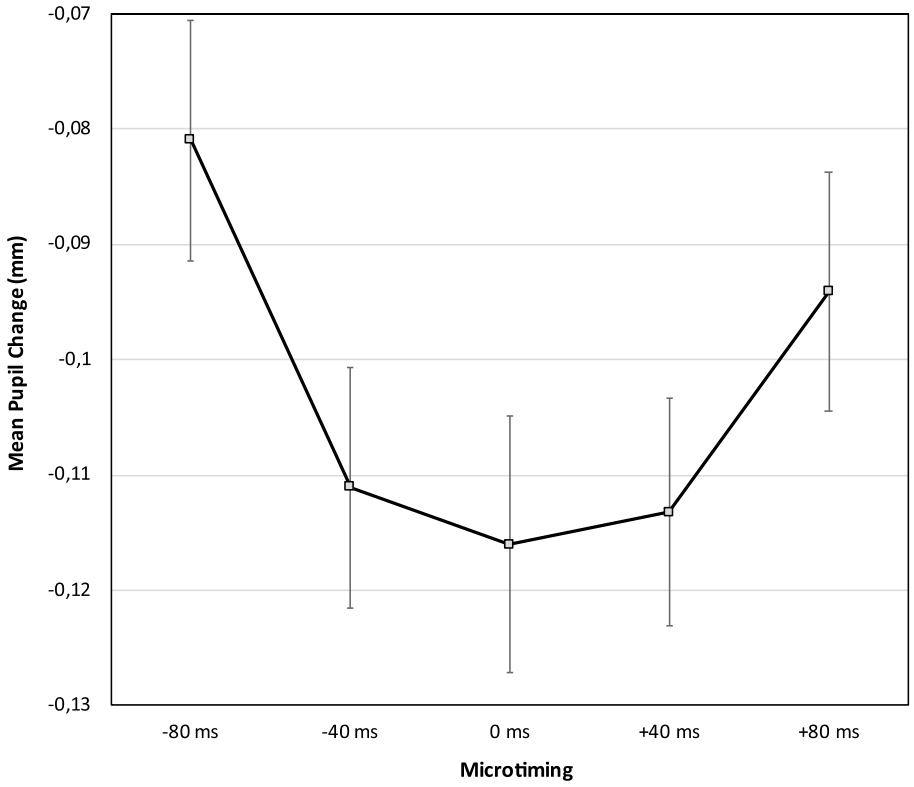
Pupil light response



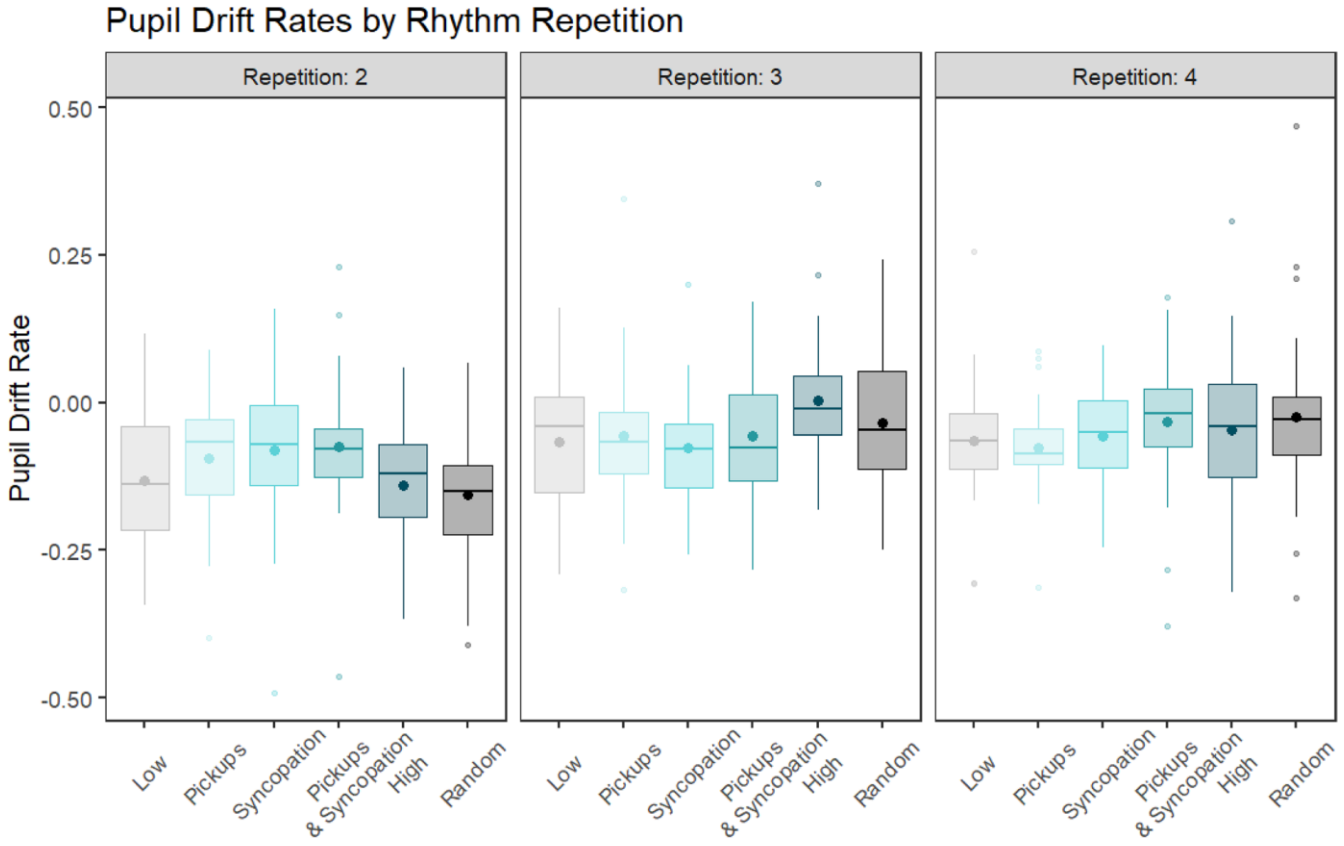
Psychosensory pupil response

- Anything that activates the mind/increases processing load causes pupil dilation
- Two types:
  - Orienting response – brief dilation
  - Effort-related response - slow dilation
    - Mental effort = amount of attention evoked during a task
    - Mental effort ≠ subjective effort
    - See Kahneman (1973), Bruya & Tang (2018)

Pupil dilation & music



Microtiming → pupil dilation
Skaansar, Laeng & Danielsen (2019)

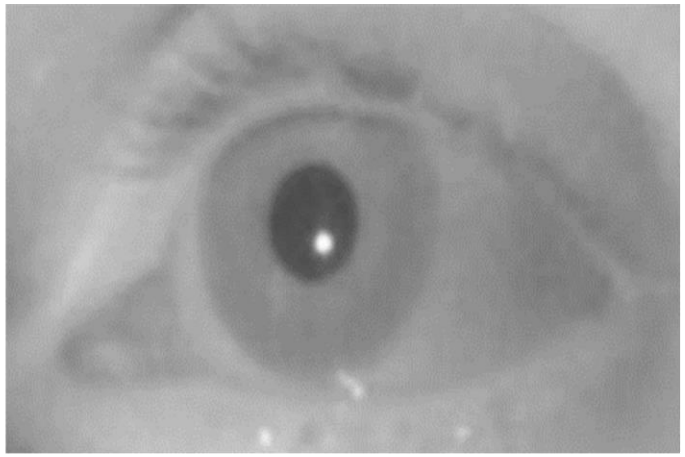


Groovier rhythms hold attention longer
Spiech, Sioros, Endestad, Danielsen & Laeng (2022)

Pupil dilation & music

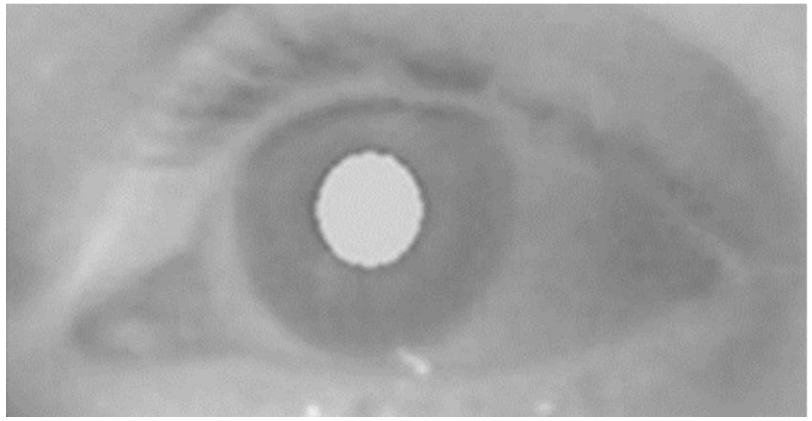
- Pupil signal shaped by rhythmic entrainment (Fink, Hurley, Geng & Janata, 2018)
- Pupils dilate for vocal or familiar music (Weiss, Trehub, Schellenberg & Habashi, 2016)
- Pupils dilate with musical “chills” (Laeng, Eidet, Sulutvedt & Panksepp, 2016)
- Positive relationship between pupil size and expressive difficulty of music (Bishop, Jensenius & Laeng, 2021)

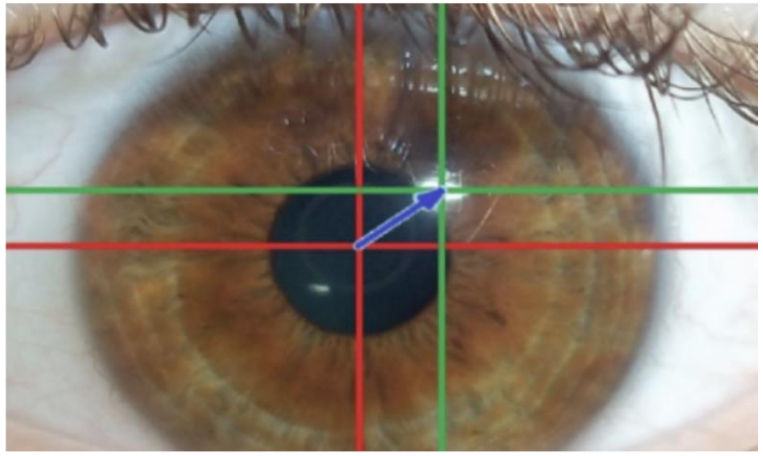
Eye-tracking technology



Dark pupil method

Bright pupil method





Cornea reflection method

Eye-tracking technology

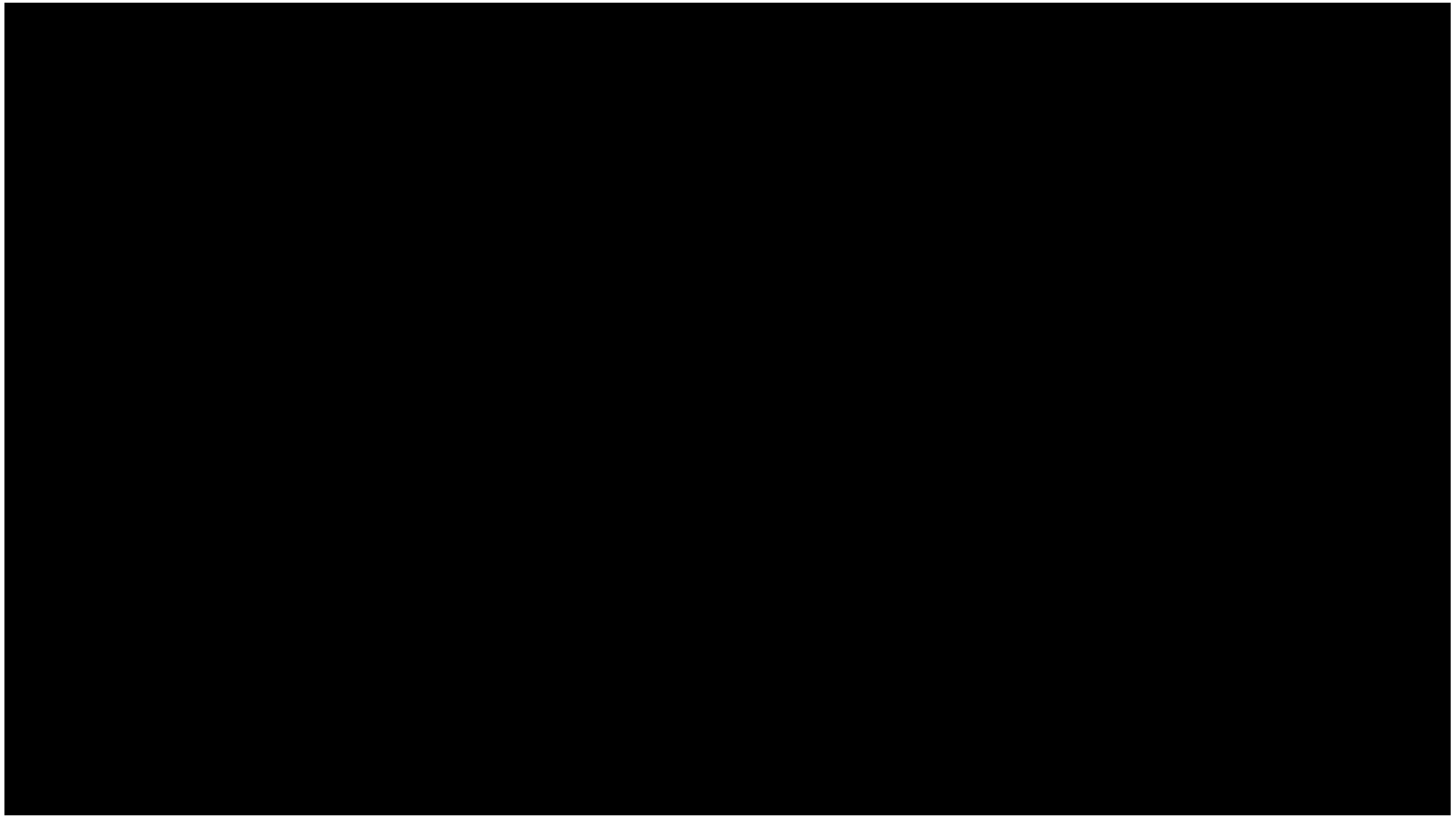
- Stationary vs. mobile eye-tracking

Eye-tracking technology

Example of a calibration procedure with a stationary eye-tracker

Eye-tracking technology

Eye-tracking recordings from two pianists during a duo performance

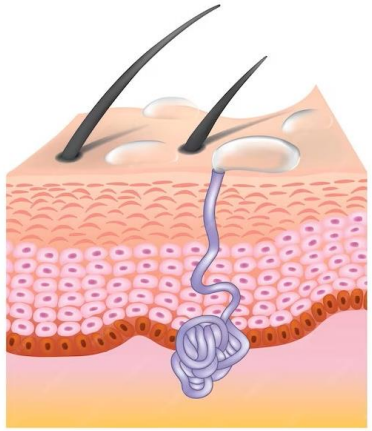


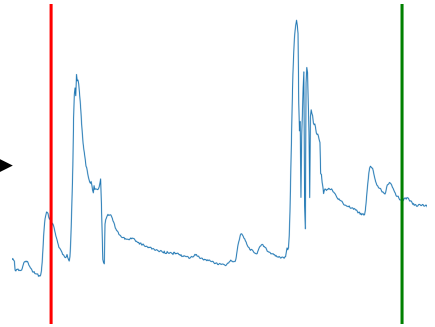
Challenges of pupillometry experiments

- Controlling all possible sources of influence (light, distance, background noise, eye movement, head movement, …)
- Designing tasks that allow you to link pupil dilations to specific events or musical features, also accounting for lag in the pupil signal
- Designing tasks that keep participants engaged
- Getting participants to keep their eyes open (not blinking at critical moments, not falling asleep, “I hear the music better with my eyes closed”)

Wristband and electrodermal activity (EDA)

What is Electrodermal activity?



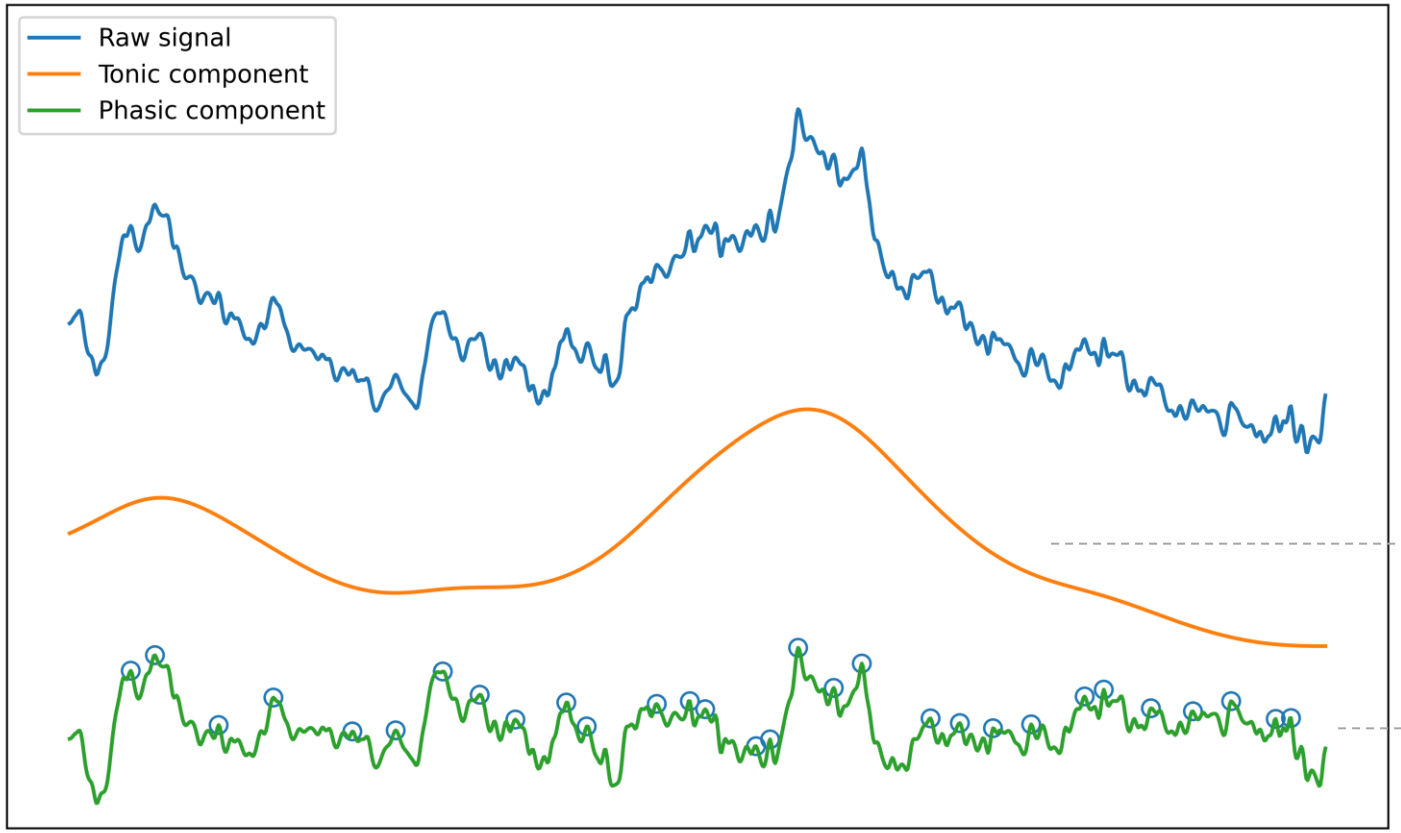


Sympathetic nervous system aroused

Sweat gland activity varies

Skin conductance varies

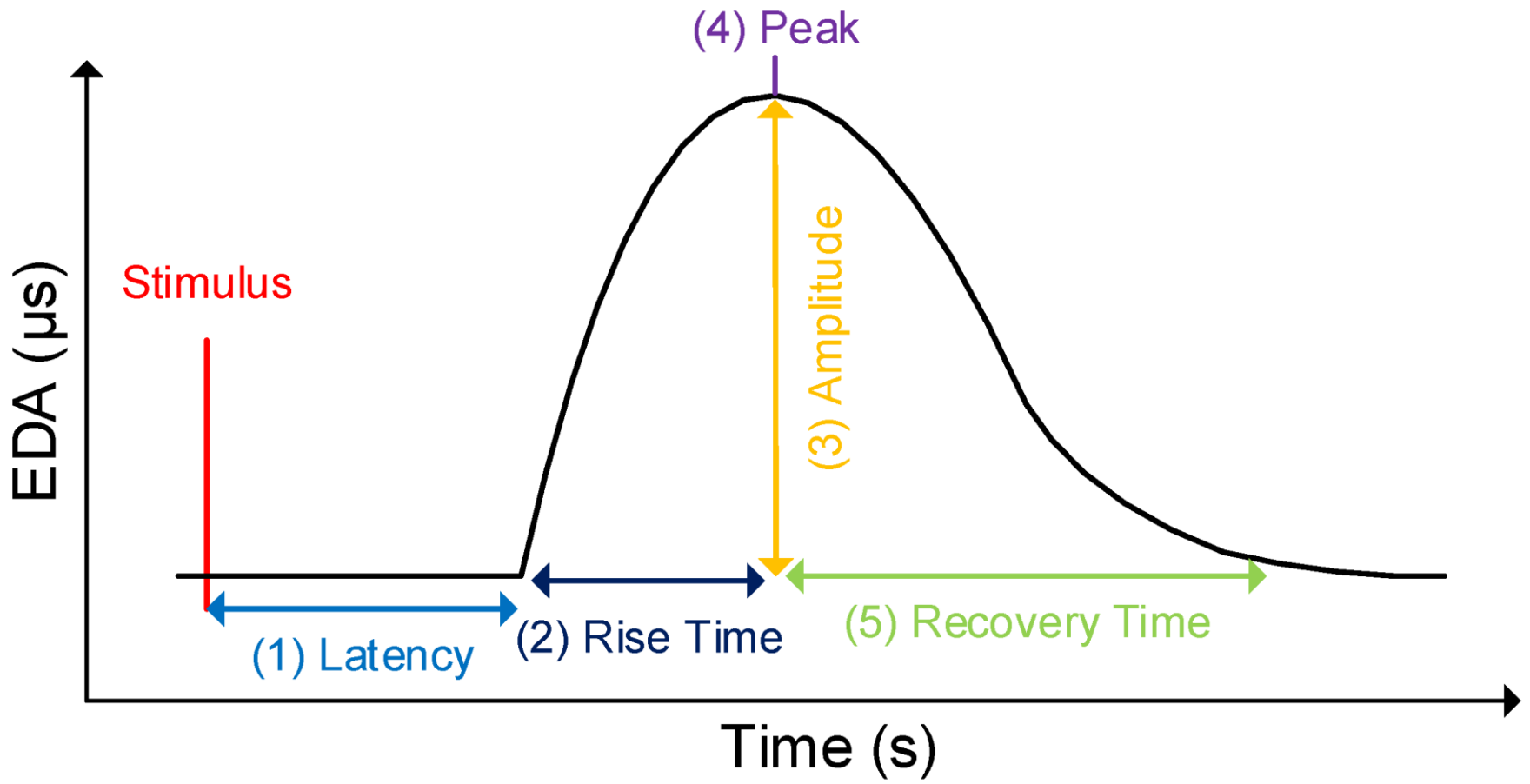
Tonic / phasic components and peaks



Slow variation of skin conductance
Reflects thermoregulation and general arousal

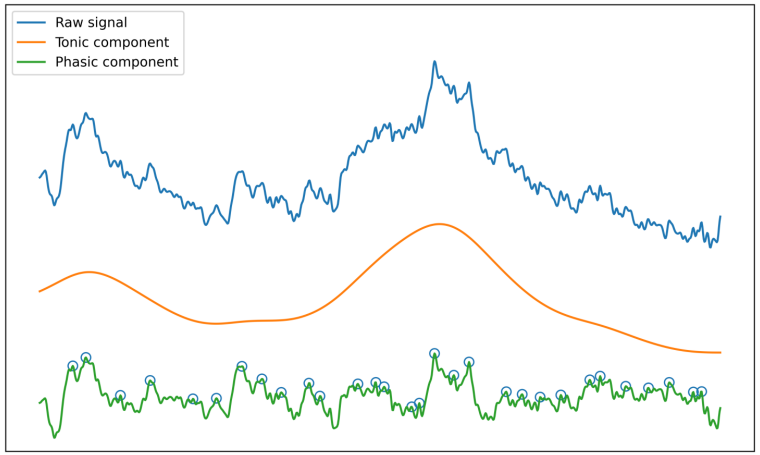
Fast variation of skin conductance
Reflects sympathetic nervous system activity

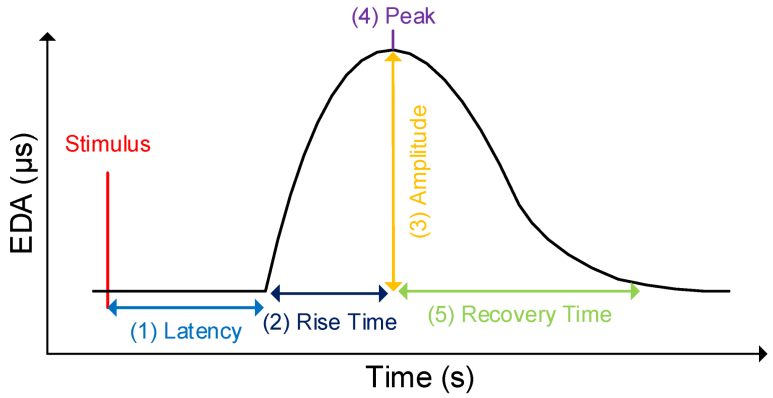
Peak-related EDA characteristics



Some possible EDA features

- Mean/Median/STD of phasic component
- Mean/Median/STD of tonic component
- Number of peaks
- AUC of phasic component
- Maximum/sum amplitudes
- Kurtosis of phasic component
- Skewness of phasic component
- etc.

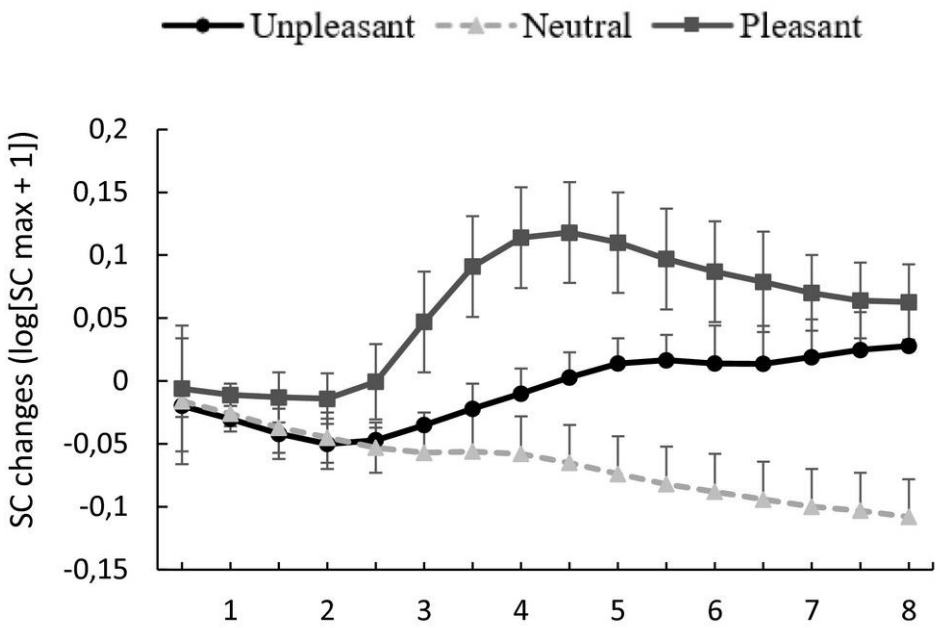




Some possible target variables

Physical activity intensity	(Chowdhury et al., 2019)
Stress	(Zontone et al., 2022)
Emotion	(Fuentes-Sánchez et al., 2021)
Physical pain	(Kong et al., 2021)
Mental workload	(Romine et al., 2022)

EDA and emotions induced by (film) music



Pleasant emotions can have a stronger impact on EDA in terms of amplitudes compared to 1 second before (Fuentes-Sánchez et al., 2021)

EDA and effort in the context of learning

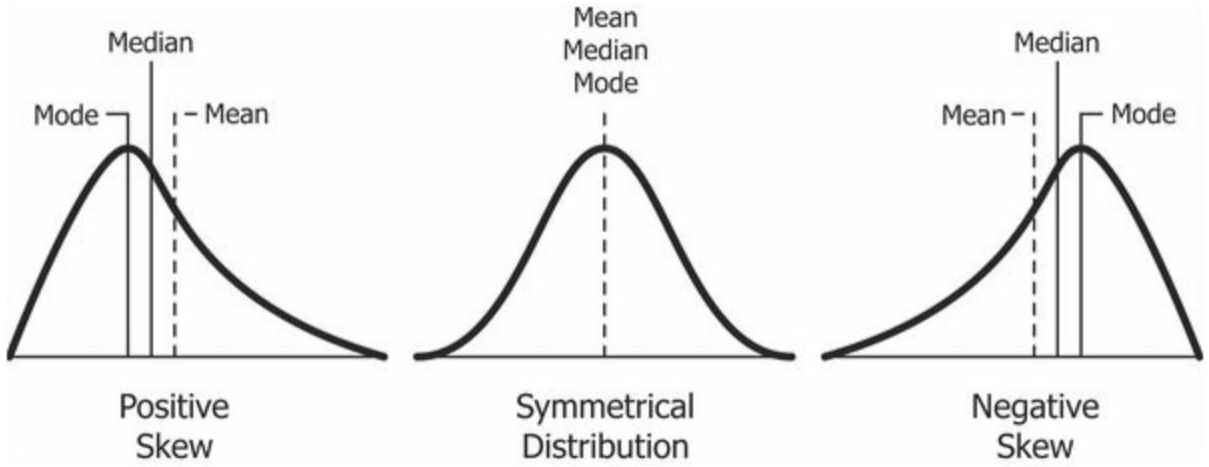
Feature	B	SE	Wald χ^2 (df = 1)	*p*-Value	OR
EDAGlobalMaxDeflection	55.46	23.01	5.81	0.016	1.22×10^{24}
EDAzMean	−4.50	1.95	5.34	0.021	0.011
EDAzp99	2.20	0.96	5.28	0.022	8.99
EDAskewness	−1.57	0.70	5.00	0.025	0.208
EDAskewness × EDAzp99	−0.67	0.34	3.76	0.052	0.513
EDAGlobalMean	22.09	11.40	3.76	0.053	3.93×10^{9}
EDAkurtosis	0.31	0.19	2.72	0.099	1.36
EDASCR	0.65	0.45	2.10	0.148	1.93
Intercept	−9.96	4.15	5.75	0.016	

Skewness seems a good indicator of effort
(Romine et al., 2022)

Logistic regressions (low and high effort)

- 12 initial features
  → $\chi2(12) = 16.5$, $p = 0.17$
- 5 non-significant features removed
  → $\chi2(7) = 14.8$, $p = 0.04$
- 1 addition: skewness by 99th percentile
  → $\chi2(8) = 19.4$, $p = 0.01$

Skewness of a distribution



More positive values indicate outlying data in the positive direction, which is indicative of peak activity
(one way of merging both: number of peaks and amplitude)

Challenges of wristband experiments

- Movements of the arm (clapping hands) can impair the recorded signal
- That’s about it!

Link to tutorial materials

- https://github.com/laurabishop/MusicDiscoveryPupil

Part 2

Demo

Part 3

Analyses

Part 4

Questions