Match in emotional content in lyrics and melody enhances likeability.

Manuela Skov Thomasen (202107872@post.au.dk)
School of Communication and Culture, University of Aarhus, Denmark

Abstract

We experience music in multiple parts of our everyday life, when we are transporting ourselves from one place to another, at work, watching TV or going to the store. Music can make us happy or sad and we like and dislike different pieces of music. This study examines how the emotional content of melody and lyrics influence our likeness of a song. Functional MRIs will be conducted while participants listen to music where the sound of the music is either sad or happy and the sentiment of lyrics is either positive or negative. The sound of the melody is determined based on the tempo (fast or slow) and key (minor or major) while the sentiment of the lyric is defined using VADER, a sentiment analysis tool. The studies hypotheses is that when there is a match between melody and lyric (happy/positive or sad/negative) it will enhance the blood oxygen level dependent signal in the four ROIs: the amygdala, the putamen, the ACC and the hippocampal compared to when the melody and lyric mismatch (sad/positive or happy/negative).

Keywords: emotional content, lyric, melody, music, enhanced likeability, BOLD signal, fMRI

AARHUS UNIVERSITY

Introduction – Assignment #2

Music is integrated in our everyday life. We actively listen to it at home, at work, when participating in sport or just when we relax, furthermore it is present in film and series and in most stores you can hear it playing (Brattico, 2015; Rentfrow, 2012). Technological changes have made it possible to have music with us everywhere and use it in whatever context we want (Krause et al., 2015; North et al., 2004; Reddy & Mascia, 2006). This have made music a resource, where the way each individual engage with it and in what context is what gives it value (North et al., 2004). Music is a way to bring people together, it's a form of communication and self-expression and it is heavily intertwined with emotional experiences (Juslin, 2019; Mori, 2022). People use music to change their mood, release emotions, to experience joy or comfort or to pass time without the feeling of loneliness (Juslin, 2019; Krause et al., 2015).

The pleasure of listening to music has been suggested to share similarities to the core effect: how we feel at any given time (Brattico, 2015; Schutz & Lynde, 2010). When we give this pleasure value through top-down processes, such as personal associations, knowledge, social culture or memory, it generate the liking of a music piece (Brattico, 2015). The liking of a piece of music is not dependent on the emotional response to the piece (Brattico, 2015), meaning that a music piece that is experienced as negative or sad, can still elicit pleasure and a liking response to the piece (Brattico, 2015; Kawakami & Katahira, 2015). The emotional response to music is due to features in music that elicit positive or negative emotions e.g., songs in major mode are mostly produce a positive emotional responses (Gagnon & Peretz, 2003; Khalfa et al., 2005). The link between multiple brain regions and the likeness of a song have been proposed, however the influence of various features that contribute to the emotional content in a song have yet to be linked to the likeability of said song (Hunter et al., 2008; Putkinen et al., 2021).

Emotional content in music

When the emotions happiness and sadness are induced by music it rely mostly on tempo and key of the melody (Gagnon & Peretz, 2003; Khalfa et al., 2005). A fast tempo, 120-156 bpm, and major key in melodies arouse happiness, while a slow tempo, at 45-60 bpm, and minor key arouse sadness (Chase, 2020; Gagnon & Peretz, 2003; Green et al., 2008; Khalfa et al., 2005; Mori, 2022). The lyrical content of songs can also contribute to the musically induced emotions (Brattico et al., 2011). The mean sentiment score of a text is

determined based on a sentiment dictionary where words a rated on their emotional content (Enevoldsen & Hansen, 2017), the rate can be binary (positive/negative), categorical (sad, happy, angry) or continuous e.g. a valence scale going from -5 to 5. VADER is a sentiment analysis tool compatible with python that makes it possible to classify text as negative, neutral or positive and se the percentage of negative, neutral and positive words in the text (Hutto & Gilbert, 2014; Ilyas et al., 2020; Van Rossum & Drake, 2009).

fMRI and Regions of interest

fMRI works by detecting the blood oxygen level all over the brain, meaning it does not directly measure neural activity but the blood flow and volume in the brain. The good spatial resolution of fMRI gives higher allowance to discriminate between brain regions and is why it is the preferred tool in the current study, where the placement of the activation is what will be used to determine whether or not the participant liked the song (Laumann et al., 2017; Logothetis & Pfeuffer, 2004; Putkinen et al., 2021).

Putkinen et. al. (2021) conducted a functional magnetic resonance imaging (fMRI) study with the goal to decode music evoked emotions, such as sadness, happiness, fear and tenderness as well as likeness(Putkinen et al., 2021). The study found significant differences in BOLD signals in the amygdala, the putamen, the ACC and the hippocampal between when participants like or disliked a song. Further they suggested these four regions could accurately be used to determine whether or not a participant liked the song (Putkinen et al., 2021). Based on this the current study's region of interest (ROIs) will be those four regions.

This study aims to determine **how the match or mismatch between the sentiment of the lyrics and the sound of the melody affect the BOLD signal in the four regions of interest (ROIs): the amygdala, the putamen, the ACC and the hippocampal (Research Question Statement: Assignment #1).** This question led to the hypothesis that the blood oxygen level-dependent (BOLD) signal in the four ROIs is enhanced when the sentiment of the lyrics is matched with melodies of corresponding sound. More hypotheses interpretation can be seen in table 1, along further design plans.

Manuela Skov Thomasen
202107872
Au650504

Table 1 – *Design table*

Question	**Hypothesis and null hypothesis**	**Sampling plan**	**Analysis plan**	**Interpretation given different outcomes**
How does the match or mismatch between the sentiment of lyrics and the sound of the melody affect the BOLD signal in the four ROIs: the amygdala, the putamen, the ACC and the hippocampal?	**H1:** The blood oxygen level-dependent (BOLD) signal in the four ROIs is enhanced when the sentiment of the lyrics is matched with melodies of corresponding sound. **H0:** the BOLD-signal in the four ROIs is the same both, when the sentiment of the lyrics and the sound of the melody, match and mismatch.	The data will be collected through an experiment with a within-subject design, where participants will be exposed to various songs while their BOLD signal is measured by fMRI.	To analyze the data a linear mixed effect analysis will be conducted using R (R core Team, 2019). The outcome variable will be the BOLD signal, the sound of the melody and sentiment of the lyrics will be entered as fixed effect, while the participant ID is entered as random effect because I expect each individual to have their own baseline.	If a significant difference is found it would imply the likability of music is dependent on the match between the sentiment of the lyrics and the valence of the melody.

Methods – Assignment #3

All referenced code and data are available at GitHub, for more see the Code availability and Data availability section.

Ethics

If the study was to run it would be conducted in accordance with relevant ethical regulations and approval from the Research Ethics committee would be sought. Before the experiment all participants would be presented with a written consent form and informed written consent would need to be given for further participation. The participants would be informed withdrawal of consent is always possible, but after data anonymization it would no longer be possible to remove specific data. The participants would be compensated congruently to standard pay, around a 100DKK per hour, for their participation.

Manuela Skov Thomasen
202107872
Au650504

Pilot study

33 participants (22 female) were a part of the study, had a mean age of 22.45(sd=5.97) and their ages ranged from 15-52. The experiment was conducted using Google survey, where the participants were presented eight sound clips. The study had a within-subject design. The songs used as stimuli were collected from Epidemic Sound (https://www.epidemicsound.com/music/featured/) from the genre Indie Pop with a mean tempo of 100.5 BPM (sd = 2.673). The 8 songs were edited using Win Movie Maker (Microsoft, 2021) and ended up having a mean length of 1 minute and 4 seconds (sd =6.22 seconds). Table 2 Show how the songs were divided into four conditions (the appendix is available in GitHub as Appendix_pilot_study.doc) (Thomasen, 2022).

Table 2

Experiment Stimulus

Condition	Key	Type	Song 1	Song 2
1.	Major	Lyric	Particle House, *Guardian Eyes*	Chasing Madison, *Summer City*
2.	Major	Instrumental	Arch Tremors, *Eventually (Instrumental Version)*	Lars Lowe, *It Ain't the Way I Want It (Instrumental Version)*
3.	Minor	Lyric	Gamma Skies, *You Drift Away*	Particle House, *We Need to Calm Down*
4.	Minor	Instrumental	Johannes Bornlöf, *Monsoons (Instrumental Version)*	Can't Find Ollie, *Obsessions (Instrumental Version)*

Note: for each song the artist is mentioned first and then the song title, see the appendix for copyright attribution and link to the edited songs.

After being presented with each sound clip the participants had to report on the valence of the clip on a scale from -5 to 5, where -5 meant the participant had a strong negative emotional response and 5 meant the response were positive. The scale was thoroughly explained before the experiment. Key (major or minor) and type (instrumental or lyrical) were the predictor variables and valence were the outcome. I expected the music in major mode would evoke a more positive emotional response compared to music in minor mode, further I expected lyrics to intensify this effect. Figure 1 is a visualization of the data from the pilot study (Thomasen, 2022).

Figure 1

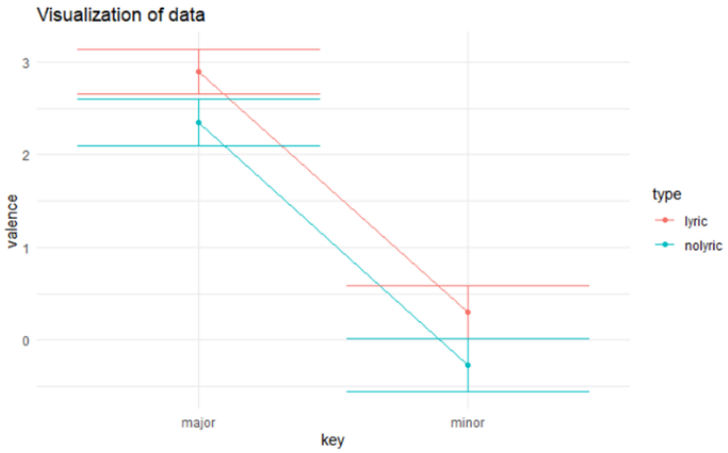


Figure 1: Visualization of data, the mean valence of each condition with belonging error bars

R (R core Team, 2019) and lmerTest (Kuznetsova, Brockhoff and Christensen, 2017) were used to perform a linear mixed effect analysis. Model 1 and 2 were built with the following R syntax:

Model 1, $valence \sim key + (1 \mid ID)$ and model 2, $valence \sim key + type + (1 \mid ID)$

In both models the participant ID was added as a random effect because I expected the participant to have individual baselines, due to using the scale and experiencing emotions differently.

The results showed participants rated their emotional response more positively ($\beta = 2.6211, SE = 0.1896, t = 13.824, p < 0.001$) when the songs were in major and more negative when the songs were in minor mode ($\beta = -2.6061, SE = 0.2650, t = -9.834, p < 0.001$). Further the study found that lyrics have an additive effect so both songs in major and minor were rated more positively than songs without lyrics (Thomasen, 2022).

Participants

For the experiment English-speaking individuals will be recruited, the participants must be over the age of 18 and must not currently have any neurological or psychiatric disorders, further they must not have suffered from any brain injuries and cannot be taking any psychoactive medication as this could affect the results of the fMRI measurement. The experiment will be done as a within-subject design and therefore randomization will be used in the presenting of the stimulus.

Sample size

When conducting experiments we want a large statistical power, which is the probability of rejecting the null hypothesis. Statistical power is influenced by the effect size, the probability of a type 1 error occurring, also referred to as alpha, and the sample size (Desmond & Glover, 2002). The aim is often a power of 80%, meaning that if the difference truly existed we would detect it in 80 out of a 100 studies (Mumford, 2012). Effect size is often determined based on the experimental design and can therefore be hard to manipulate. Alpha is based on the significance level and the number of hypotheses being tested, however in fMRI studies this is dependent on either the number of regions of interest or the number of voxel you wish to analyze (Desmond & Glover, 2002; Mumford, 2012). In this study four ROI's where determined this led to alpha being adjusted using the Bonferroni correction:

$$\alpha = \frac{0.05}{number\ of\ ROIs} = \frac{0.05}{4} = 0.0125$$

Desomnd & Glover, 2002 estimated the needed sample sizes for fMRI studies to insure a power of 80%. They suggested a minimum of 12 subjects when alpha was 0.05 and 24 subjects if alpha was stricter, further they found the benefit of increased number of participants to lessen after a 100. Therefore a minimum of 24 participants should be sufficient to insure a power of 80% (Desmond & Glover, 2002).

Stimuli

The songs used as stimulus are picked based on various criteria. The songs will all be lyrical and in English. In previous fMRI studies with participants listening to music, the participants have been presented with 16-34 music pieces varying between 10-30 seconds (Brattico et al., 2011; Khalfa et al., 2005; Mitterschiffthaler et al., 2007). In this study participants will be presented with 24 pieces of music lasting 20 seconds. The pieces will be selected from various genres to make the results more generalizable (Hunter et al., 2008) and to minimize the effect of musical preference on the results (Kreutz et al., 2008). Further, the songs are picked based on key and tempo of the melody and sentiment of the lyrics and sorted into four conditions (table 3) with six songs in each condition. The sound of the melody, either sad or happy, will be determined on the key and tempo of the melody as it is some of the features often used to classify songs as either sad or happy (Gagnon & Peretz, 2003; Khalfa et al., 2005). Songs classified as fast will have a tempo between 120-156 bpm and slow songs will be between 45-60 bpm (Chase, 2020). To determine the sentiment of the

lyrics a sentiment analysis will be conducted on all lyrics (see sentiment_analysis_example.ipynb in GitHub). The sentiment analysis example was made using python (Van Rossum & Drake, 2009) and the VADER sentiment analysis tools (Hutto & Gilbert, 2014) on the song My Valentine by Roy Edwin Williams (courtesy of www.epidemicsound.com), which has a tempo of 130 BPM and is in C major.

Table 3

Experiment conditions

	Tempo	*Melody key*	*Melody sound*	*Lyric sentiment*	*Match*
Condition 1	Fast	Major	Happy	Positive	Matched
Condition 2	Fast	Major	Happy	Negative	Mismatched
Condition 3	Slow	Minor	Sad	Positive	Mismatched
Condition 4	slow	Minor	Sad	Negative	Matched

Note: experiment conditions, based on tempo, key and sentiment

Procedure

Upon arrival the participants will be informed about the study protocol and then give informed written consent. Participants will be encouraged to ask any question they had before the start. All participants will be required to remove ferromagnetic material. In the fMRI machine participants' heads will be resting on foam padding and a Velcro strap will be placed across their forehead for comfort and to restrict head movements. The stimuli will be presented to the participant though high-fidelity headphone system (Hall et al., 1999) and at a comfortable sound level around 75-80 db (Brattico et al., 2011; Wehrle et al., 2007). Before the start the participants will be encouraged to focus on the music in a relaxing way. The participants will be presented with the 24 song pieces with a delay of five seconds between each piece during the fMRI measurement in a randomized order. To indicate the start of the next song pieces a sinusoidal tone would be played. The fMRI session will last about 10 minutes for each participant.

Experiment equipment and sampling

The fMRI measurements will be sampled to visualize cortical activity, using an MRI with a 3T field strength. For anatomical localization for all participants high-resolution structural T1-weighted images were obtained. To depict the BOLD contrast during the

stimulus presentation a T2*weighted echoplanar imaging sequence were acquired (Brattico et al., 2011; Khalfa et al., 2005). Some data may be excluded due to stochastic and systematic errors, first after exclusion of this data statistical methods will be used (Wüstenberg et al., 2003).

Analysis plan

The influence of match between the sound of the melody and sentiment in lyrics on the liking network will be assessed by statistical comparison of the BOLD signal in the four regions of interest: the amygdala, the putamen, the ACC and the hippocampal. There will be conducted a mixed effect analysis using R (R core Team, 2019) and lmerTest (Kuznetsova, Brockhoff and Christensen, 2017) where the outcome variable will be the BOLD signal in each region of interest. The melody sound and sentiment of lyrics will be the fixed effect while participant ID is set as random intercept to account for individual differences. The models will be built with the following syntax (the model is an example for the ROI, the hippocampal):

$$BOLD\_hippocampal \sim melody\_valence + lyric\_sentiment + (1|ID)$$

Assumption testing will be run on all models to check they meet the assumptions of homoscedasticity and linearity for linear mixed effect analysis.

Data availability

All future data and materials will be made available upon acceptance of the stage two manuscript. Data for the pilot study and other referenced material and data is already available in the following GitHub repository in the ‘data_and_material’ folder (https://github.com/mthomasen/cognitive_neuroscience_of_music_and_language).

Code availability

All code will be shared publicly upon acceptance of the stage two manuscript. Code for the pilot study and other referenced code is already available in the following GitHub repository in the ‘code’ folder (https://github.com/mthomasen/cognitive_neuroscience_of_music_and_language).

References

Brattico, E. (2015). *From pleasure to liking and back: Bottom-up and top-down neural routes to the aesthetic enjoyment of music* (pp. 303–318). https://doi.org/10.1093/acprof:oso/9780199670000.003.0015

Brattico, E., Alluri, V., Bogert, B., Jacobsen, T., Vartiainen, N., Nieminen, S., & Tervaniemi, M. (2011). A Functional MRI Study of Happy and Sad Emotions in Music with and without Lyrics. *Frontiers in Psychology*, *2*. https://www.frontiersin.org/articles/10.3389/fpsyg.2011.00308

Chase, S. (2020, June 15). *What Is Tempo In Music? A Complete Guide | HelloMusicTheory*. https://hellomusictheory.com/learn/tempo/

Desmond, J. E., & Glover, G. H. (2002). Estimating sample size in functional MRI (fMRI) neuroimaging studies: Statistical power analyses. *Journal of Neuroscience Methods*, *118*(2), 115–128. https://doi.org/10.1016/S0165-0270(02)00121-8

Enevoldsen, K. C., & Hansen, L. (2017). Analysing Political Biases in Danish Newspapers Using Sentiment Analysis. *Journal of Language Works - Sprogvidenskabeligt Studentertidsskrift*, *2*(2), Article 2.

Gagnon, L., & Peretz, I. (2003). Mode and tempo relative contributions to "happy-sad" judgements in equitone melodies. *Cognition and Emotion*, *17*(1), 25–40. https://doi.org/10.1080/02699930302279

Green, A. C., Bærentsen, K. B., Stødkilde-Jørgensen, H., Wallentin, M., Roepstorff, A., & Vuust, P. (2008). Music in minor activates limbic structures: A relationship with dissonance? *NeuroReport*, *19*(7), Article 7. https://doi.org/10.1097/WNR.0b013e3282fd0dd8

Hall, D. A., Haggard, M. P., Akeroyd, M. A., Palmer, A. R., Summerfield, A. Q., Elliott, M. R., Gurney, E. M., & Bowtell, R. W. (1999). "Sparse" temporal sampling in auditory fMRI. *Human Brain Mapping*, *7*(3), 213–223. https://doi.org/10.1002/(SICI)1097-0193(1999)7:3<213::AID-HBM5>3.0.CO;2-N

Hunter, P. G., Schellenberg, E. G., & Schimmack, U. (2008). Mixed affective responses to music with conflicting cues. *Cognition & Emotion*, *22*(2), 327–352. https://doi.org/10.1080/02699930701438145

Hutto, C., & Gilbert, E. (2014). VADER: A Parsimonious Rule-Based Model for Sentiment Analysis of Social Media Text. *Proceedings of the International AAAI Conference on Web and Social Media*, *8*(1), Article 1. https://doi.org/10.1609/icwsm.v8i1.14550

Ilyas, S. H. W., Soomro, Z. T., Anwar, A., Shahzad, H., & Yaqub, U. (2020). Analyzing Brexit's impact using sentiment analysis and topic modeling on Twitter discussion. *The 21st Annual International Conference on Digital Government Research*, 1–6. https://doi.org/10.1145/3396956.3396973

Juslin, P. N. (2019). *Musical Emotions Explained: Unlocking the Secrets of Musical Affect*. Oxford University Press.

Kawakami, A., & Katahira, K. (2015). Influence of trait empathy on the emotion evoked by sad music and on the preference for it. *Frontiers in Psychology*, *6*, 1541. https://doi.org/10.3389/fpsyg.2015.01541

Khalfa, S., Schon, D., Anton, J.-L., & Liégeois-Chauvel, C. (2005). Brain regions involved in the recognition of happiness and sadness in music. *NeuroReport*, *16*(18), 1981.

Krause, A. E., North, A. C., & Hewitt, L. Y. (2015). Music-listening in everyday life: Devices and choice. *Psychology of Music*, *43*(2), 155–170. https://doi.org/10.1177/0305735613496860

Kreutz, G., Ott, U., Teichmann, D., Osawa, P., & Vaitl, D. (2008). Using music to induce emotions: Influences of musical preference and absorption. *Psychology of Music*, *36*(1), 101–126. https://doi.org/10.1177/0305735607082623

Laumann, T. O., Snyder, A. Z., Mitra, A., Gordon, E. M., Gratton, C., Adeyemo, B., Gilmore, A. W., Nelson, S. M., Berg, J. J., Greene, D. J., McCarthy, J. E., Tagliazucchi, E., Laufs, H., Schlaggar, B. L., Dosenbach, N. U. F., & Petersen, S. E. (2017). On the Stability of BOLD fMRI Correlations. *Cerebral Cortex*, *27*(10), 4719–4732. https://doi.org/10.1093/cercor/bhw265

Logothetis, N. K., & Pfeuffer, J. (2004). On the nature of the BOLD fMRI contrast mechanism. *Magnetic Resonance Imaging*, *22*(10), 1517–1531. https://doi.org/10.1016/j.mri.2004.10.018

Microsoft. (2021). *Win Movie Maker* (2021.1.0.1).

Mitterschiffthaler, M. T., Fu, C. H. Y., Dalton, J. A., Andrew, C. M., & Williams, S. C. R. (2007). A functional MRI study of happy and sad affective states induced by classical music. *Human Brain Mapping*, *28*(11), 1150–1162. https://doi.org/10.1002/hbm.20337

Mori, K. (2022). Decoding peak emotional responses to music from computational acoustic and lyrical features. *Cognition*, *222*, 105010. https://doi.org/10.1016/j.cognition.2021.105010

Mumford, J. A. (2012). A power calculation guide for fMRI studies. *Social Cognitive and Affective Neuroscience*, *7*(6), 738–742. https://doi.org/10.1093/scan/nss059

North, A. C., Hargreaves, D. J., & Hargreaves, J. J. (2004). Uses of Music in Everyday Life. *Music Perception*, *22*(1), 41–77. https://doi.org/10.1525/mp.2004.22.1.41

Putkinen, V., Nazari-Farsani, S., Seppälä, K., Karjalainen, T., Sun, L., Karlsson, H. K., Hudson, M., Heikkilä, T. T., Hirvonen, J., & Nummenmaa, L. (2021). Decoding Music-Evoked Emotions in the Auditory and Motor Cortex. *Cerebral Cortex*, *31*(5), 2549–2560. https://doi.org/10.1093/cercor/bhaa373

Reddy, S., & Mascia, J. (2006). Lifetrak: Music in tune with your life. *Proceedings of the 1st ACM International Workshop on Human-Centered Multimedia*, 25–34. https://doi.org/10.1145/1178745.1178754

Rentfrow, P. J. (2012). The Role of Music in Everyday Life: Current Directions in the Social Psychology of Music. *Social and Personality Psychology Compass*, *6*(5), 402–416. https://doi.org/10.1111/j.1751-9004.2012.00434.x

Schutz, P. A., & Lynde, M. (2010). *Core Affect—An overview | ScienceDirect Topics*. https://www.sciencedirect.com/topics/psychology/core-affect

Thomasen, M. (2021, December 22). *cog com exam—YouTube*. https://www.youtube.com/

Thomasen, M. (2022). *The emotional content in music perception*.

Van Rossum, G., & Drake, F. L. (2009). *Python 3 Reference Manual*. CreateSpace.

Wehrle, R., Kaufmann, C., Wetter, T. C., Holsboer, F., Auer, D. P., Pollmächer, T., & Czisch, M. (2007). Functional microstates within human REM sleep: First evidence from fMRI of a thalamocortical network specific for phasic REM periods. *European Journal of Neuroscience*, *25*(3), 863–871. https://doi.org/10.1111/j.1460-9568.2007.05314.x

Wüstenberg, T., Jordan, K., Giesel, F. L., & Villringer, A. (2003). Physiologische und technische Grenzen der funktionellen Magnetresonanztomographie und die damit verbundenen Konsequenzen für die klinische Anwendung. *Der Radiologe*, *43*(7), 552–557. https://doi.org/10.1007/s00117-003-0917-4

Acknowledgement

The author received no funding for this work.

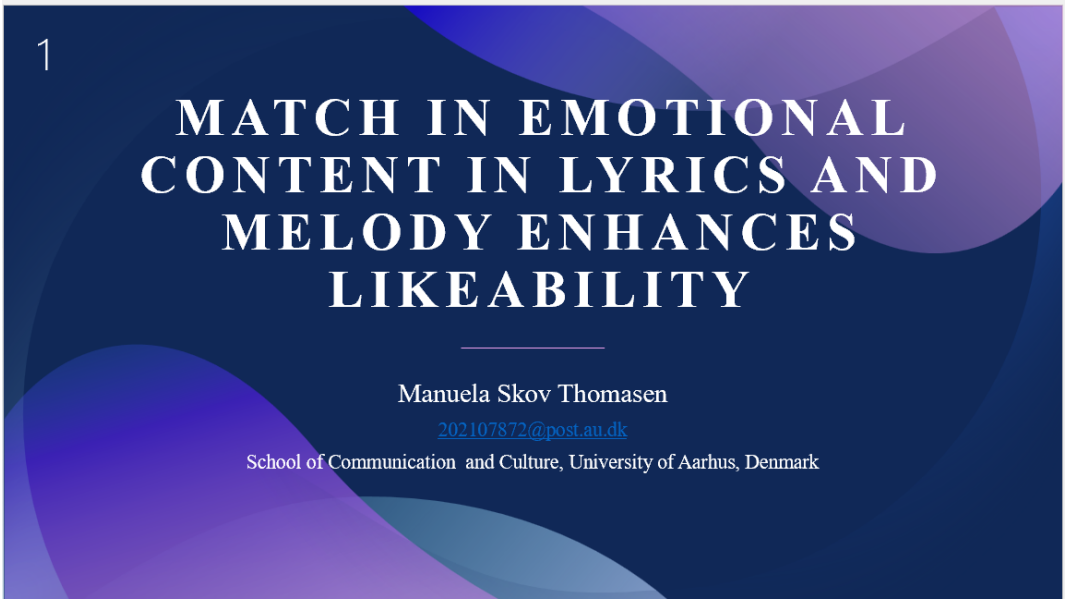
Author contributions

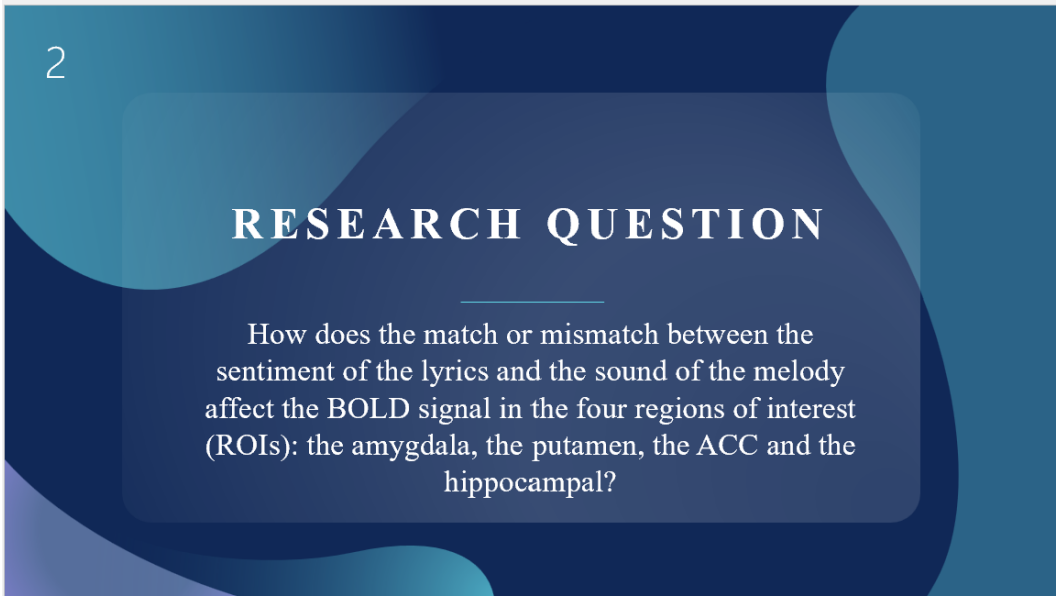
The main author, M.S.T., contributed to all sections.

Competing interests

The author declares no knowledge of any competing interests

Presentation – Assignment #4





3

INTRODUCTION

In our daily life music is present all around us, due to modern technology that gives access to massive amount of music all the time playing (Brattico, 2015; Krause et. al., 2015; Rentfrow, 2012).

Top-down processes as associations, knowledge and memory creates the like or dislike for a music piece (Brattico, 2015).

4

EMOTIONAL CONTENT IN MUSIC

Happiness, as an emotionally response, is often elicit by the melody being I major key and having a fast tempo (120-156 bpm), while sadness is elicited by a slower tempo (45-60 bpm) and the melody being in minor key (Chase, 2020; Gagnon & Peretz, 2003; Green et al., 2008; Khalfa et al., 2005; Mori, 2022)

The mean sentiment score is a way to classify a text as either negative, neutral or positive (Enevoldsen & Hansen, 2017),.VADER is one of the sentiment analysis tools used. It is based on a sentiment dictionary which contain the sentiment ratings of individual words (Hutto & Gilbert, 2014; Ilyas et al., 2020; Van Rossum & Drake, 2009).

5

FMRI AND REGIONS OF INTEREST

fMRI is used to detect the blood oxygen level throughout the whole brain and have good spatial resolution. Therefore, fMRI is the preferred tool when the goal is to determine where the changes in activation is happening, because the spatial resultion allows for accurate discrimination between brain areas (Laumann et al., 2017; Logothetis & Pfeuffer, 2004; Putkinen et al., 2021).

Putkinen et. al. (2021) investigated the link between emotional response to music and the difference in (BOLD) signal in various brain areas. The research found significant difference in BOLD signal in the amygdala, the puteman, the ACC and the hippocampal when participants liked the song compared to when they disliked it (Putkinen et. al., 2021)

6

HYPOTHESIS

H1: The blood oxygen level-dependent (BOLD) signal in the four ROIs is enhanced when the sentiment of the lyrics is matched with melodies of corresponding sound

H0: The BOLD signal in the four ROIs is the same both when the sentiment of the lyrics is matched with melodies of corresponding sound

7

STUDY DESIGN AND PROCEDURE

Participants

- Must be English speaking and over the age of 18
- Must not have any current neurological or psychiatric disorders, be taking psychoactive medication or suffering from traumatic brain injuries

Sample size

- Having 4 ROIs leads to a a probability of type 1 error of 0.0125, due to Bonferroni correction
- Therefore a minimum of 24 participant should be enough to insure a power of 80% (Desmond & Glover, 2002)

Stimuli

- 24 pieces of music lasting 20 seconds (Brattico et al., 2011; Khalfa et al., 2005; Mitterschiffthaler et al., 2007).
- The sound of the melody, either happy or sad, is based on key and tempo
- The sentiment of the lyrics is determined using python (Van Rossum & Drake, 2009) and VADER sentiment analysis tool tools (Hutto & Gilbert, 2014)

8

ANALYSIS PLAN

The data will be analyzed using R (R core Team, 2019) and by fitting a linear mixed effect model on it using lmerTest (Kuznetsova, Brockhoff and Christensen, 2017)

Meaning the model will have following R syntax:

$$BOLD\_hippocampal \sim melody\_valence + lyric\_sentiment + (1|ID)$$

ASSUMPTION TESTIG

- Homoscedasticity
- Linearity