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COMMUNICATION OF EMOTION THROUGH MUSIC

KOMUNIKACE EMOCÍ HUDBOU

Bachelor thesis

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Firstly, I would like to express my gratitude to my family for supporting me in the decision to study psychology and to my thesis supervisor for guidance in writing of this thesis.

I hereby acknowledge that the thesis with the title "Communication of Emotion Through Music" is my own work, I have written it under the supervision of the thesis supervisor and I have listed all used sources and references.

22nd February 2022, Olomouc Signature ....

Contents

I THEORETICAL PART 1

1 Introduction 1

2 Music 3

2.1 Definition of music . . . 3

2.1.1 Melody . . . 3

2.1.2 Rhythm . . . 5

2.1.3 Harmony . . . 6

2.1.4 Dynamics, timbre, texture and form . . . 6

2.2 Music across cultures . . . 7

2.3 Evolutionary theories of music . . . 8

3 Communication 10

3.1 Key elements of communication . . . 10

3.2 Process of communication . . . 11

3.3 Types of communication . . . 12

3.4 Role of perception in communication . . . 13

4 Emotions 15

4.1 Definition of emotions . . . 15

4.2 Adaptive value of emotions . . . 16

4.3 Emotions classification . . . 17

4.3.1 Basic emotions . . . 18

4.3.2 Dimensional models of emotions . . . 18

4.3.3 Compound emotions . . . 20

5 Literature review 22

II EMPIRICAL PART 25

6 Research question 25

7 **Methodology** **26**

7.1 Experimental design 26

7.1.1 Used framework for emotions 26

7.1.2 Experimental setup for creation of music 27

7.1.3 Survey of listeners 28

7.2 Statistical model and methods 29

7.2.1 Modelling correct recognition of emotion 29

7.2.2 Mixed Effect Logistic Regression 30

8 **Data** **32**

8.1 Music snippets 32

8.2 Sample of respondents 33

8.3 Resulting dataset used 35

9 **Results & discussion** **38**

9.1 Interpretation of the regression results 38

9.2 Disscussion of the results 40

9.2.1 Fit of the model 40

9.2.2 Limitations of the used dataset 41

9.2.3 Robustness check 42

9.2.4 Results in light of previous literature 43

10 **Conclusions** **44**

III SUMMARY **46**

11 **Bibliography**

12 **Appendix**

Part I

THEORETICAL PART

1 Introduction

Why does music exist? From evolutionary perspective, this is a non-trivial question.

Music has emerged in all major human cultures across the world with common elements such as melody or rhythm. At the same time, there is no single universally accepted explanation on whether music is only by-product of adaptations to auditory perception, language, motor control and affect, or whether it serves some evolutionary purpose of its own (Mehr et al., 2019).

If we assume the latter is true, one of possible explanations of adaptative role of music for human experience lies in communication. Communication is of utmost importance for survival in socially organised human societies. It allows for coordination, but also spreading and preserving of information, knowledge and experience.

While language is very effective for communication of facts and information, humans have developed wide variety of other means of communication as well to supplement factual basis of language. Among those we can include facial expressions or gesticulation but also non-verbal sounds – all of those often primarily communicating emotions and moods much more effectively than spoken (or written) language.

Music is often described as expressive (Gabrielsson & Juslin, 2003). But to what extent can it contribute to communication of specific information?

Answering this question would help to uncover the evolutionary logic behind emergence of music as a phenomenon in human societies. Moreover, investigation of effects of music on human consciousness is crucial for understanding human cognition. On top of that, better understanding of the mechanism of transmission of information through music can have practical applications – starting with more targeted using of music in therapy all the way to marketing applications and, for example, selection of right music to boost sales in a grocery store.

The objective of this thesis is to investigate how efficient is music as a medium to communicate emotions. Specifically, how complex emotions can be conveyed in a short piece of instrumental piano music and whether the precison of reading emotions in music is increased for individuals who are trained in contemporary music. This should help to understand whether music can serve as a medium for communication, but also to what extent is communication through music natural or learned from cultural context surrounding an individual.

The thesis is structured as follows: Section 2 explores definition of music and its core elements to establish clear baseline for further investigation. Section 3 reviews understanding of human communication, its purpose and most commons forms. Section 4 defines emotion and reviews available theoretical frameworks for emotions classification. Section 5 reviews existing literature on communication of emotion through music. Section 6 specifies research question and hypotheses investigated in this thesis, while section 7 outlines the used experimental design and methodology. Followed by section 8 which gives detailed description of the gathered dataset and section 9 where results are presented and discussed and section 10 concludes on the overall findings in light of existing literature.

2 Music

2.1 Definition of music

As Godt (2005) points out, various definitions of music are used by ethnomusicologists, sociologists, philosophers or philologists. However, for the puprposes of this thesis it is not important to engage in theoretical discussions on right and comprehensive definitions of music in terms of objectives of conveying beauty or aesthetics value (Davies, 2012), but rather to identify key structural elements of music as a product of human actions to enable investigation of its effects on human cognition.

Most definitions of music that go beyond the semantic combination of sounds to produce beauty or harmony mentions several elements (or primitives) of music – most common out of these being melody, rhythm and harmony (Scruton, 2011). Several other primitives are also often mentioned, such as dynamics, timbre, texture and form. While different categorizations are also available (e.g. instead of treating melody as standalone primitive using separately tonality or pitch and arrangement over time), these 7 primitives are suitable for defining music in a way which will serve the purpose of this paper.

2.1.1 Melody

Melody is usually understood as a linear succession of tones in time which is percieved as a single entity by the listener (Stefani, 1987).

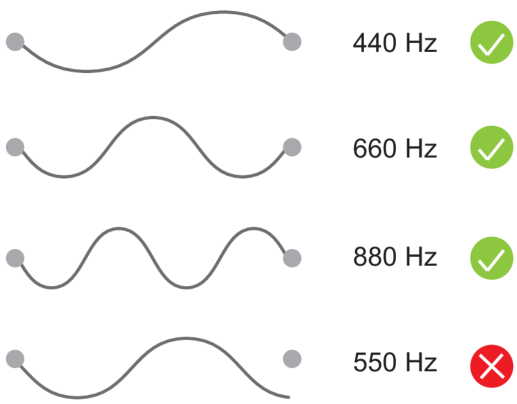
Tone is a sound with defined pitch – meaning specific frequency of the sound vibrations. While the pitch of a sound can change gradually over time, vast majority of human music is based on subsets of pre-defined tones called keys or scales, where most of individual tones are discrete sounds of a fixed pitch. Keys used for arabic music differ significantly from keys used for traditional chinese or european music (Rechberger, 2018), common elements can be observed.

Firstly, vast majority of keys use multiples of a certain base frequency. In western world this interval between two tones would be called an octave (Papadopoulos, 2002) and noted by same letters (for example A_4 is usually denoted as a tone of the frequency of 440 Hz while A_5 is a tone of the frequency of 880 Hz. Secondly, the subset of tones used is not defined thorough linear division on the frequency scale, but rather trhough division of an octave into smaller sub-steps in the pitch shift (e.g. 12 semitones in an octave for usuall minor and major keys) and sub-selection of these sub-steps (e.g. only 8 of the twelve are used in most common diatonic scales used for western moder music, 5 are used in large part of traditional chinese music and arabic music uses more granular division of the octave than the 12 semitones).

Previous research has shown that two tones with an octave difference (i.e. double or half frequency of the soundwaves) are percieved as "equal" to some extent by human listeners (Pedersen, 1975). Also some other specific intervals between tones are universally percieved as very harmonious – namely the fifth which corresponds to 50% increase in the sound frequency and is therefore somewhat in the non-linear middle of an octave.

It should be noted that specific intervals, which are percieved especially harmonious and are part of nearly any key used in music, often emarge naturally through the physics of sound vibrations. A string tuned to vibrate at 220 Hz and therefore producing A_3 will also produce simultaneously less strong vibrations at 440 Hz, even weaker vibrations at 660 Hz and so on.

Figure 1: Illustration of overtone series



However, as is illustrated in figure 1, such a string cannot vibrate at random frequencies (550 Hz used as illustration in the figure 1) at wavelenght which does not fit the natural vibration frequencies of the string defined by velocity of the material and fixed points at ends of the string. Only vibrations of specific frequencies can occur and be sustained over time within the string. These are called harmonic series or overtone series and without divig deeper into physics of sound virbations, we can conclude that some elements of most keys or scales used in music are natural (based on physics of sound vibrations) while other elements are purely human-constructed (e.g. selection of specific harmonics used to construct a full musical key and later on sub-selection of tones to compose a melody).

While musicologists sometimes use different definitions of melody (Thurstone, 1920), the popular definition mentioned above which is based on the sequence of tones is sufficient for the purpose of study of music as a communication tool.

As Bolinger & Bolinger (1989) points out, melody is to some extent present in human communication also beyond music – changing pitch is important for comprehensibility of spoken language and for example in disctinstion of questions or emotional affect in the language. Morover, in some languages such as mandarin chinese the intonation can change meaning of even invdividual words.

2.1.2 Rhythm

In terms of etymology "rhythmos" signifies "a particular way of flowing". In Philosophy the term was used already by Plato for "the order of the movement", emphasising also elements of rapidness and sloweness (Pangle, 1988).

Moving beyond etymology to cognitive psychology, rhythm can be characterised as perceptional quality linked to certain successsions (in case of music typically successions over time). Also important concept to define rhythm is anticipation – as opposed to arrythimc arrangements which are random, in rhytmic arrangments some level of predictability is possible due to the organized manner over time (Fraisse, 1982).

Finally, moving on to more practical definitions, Oxford dictionary defintes rhythm as "a strong, regular repeated pattern of movement or sound" (*Oxford English dictionary (Online)*, n.d.)

2.1.3 Harmony

While melody is based on sequential organization of tones, harmony is often defined as sound of several (two or more) notes heard simultaneously (Tymoczko, 2010).

Similarly as in the case of melodies, in vast majority of human music only sub-selection of all possible tones is used. These tones are used to compose harmonies which are part of the musical compositions and described by a specific key. Also similarly as for melodical steps between the tones, harmonies with intervals between tones, which can be observed among natural harmonics, are most commonly used.

Cornerstone of modern music is a chord and chord progressions. Chord is a harmony of at least three tones, chord progression is a sequence of chords, typically of equal lenght and typically repeated throughout a song or part of a song (Greene, 1985).

2.1.4 Dynamics, timbre, texture and form

Dynamics in musics is variation between loudness and softness of elements of music (Schmidt-Jones, 2012).

Timbre is often described vaguely as a unique quality or color of an instrument or a sound (Schmidt-Jones, 2012). Based on timbre we can tell apart different music instruments even when those play exactly the same note, melody, harmony or a song. While tone determines the overall frequency of a vibration, the shape of the vibration may vary. However, thanks to fourier transformation it is easy to prove that any shape of a soundwave of a certain frequency can be decomposed into combination of basic sinus waves of different frequencies. (Bracewell & Bracewell, 1986). Typically result of the decomposition will show strong representation of natural harmonics of the main tone. What is different between intruments and timbres is however how strong are which harmonics. Key difference between A_4 played on piano and on saxophone will be how much of waves of different frequencies than 440 Hz will be simultaneously produced. It should be noted that the profile of harmonics showed by fourier transformation evolves significantly even in the course of a short tone, which further helps the listener to distinguish timbre of specific instrument (Patil et al., 2012).

Texture is often understood as layers of sound and its overall perception (Levy, 1982). It can be thought of as emergent cognitive phenomennon – overall "feel" of the quality of the sounds percieved, resulting from combination of different tones, dynamics, harmonies and timbres. What is interesting from cognitive point of view is that perception of texture might be determined also by single elements which are not all percieved – for example musically untrained people are generally surprised if presented individual layers of popular songs, as those include many instruments which the listeners do not notice if all the layers are played at once as a finished product.

Finally, form is arrangement and order of the musical parts in a song of composition (Rolison & Edworthy, 2013). Structure within the form and repetition is a basis for large part of modern music. Typical form of a popular song is based on verses and repeating chorus. While chorus is typically repeated in nearly unchanged manner after each verse, lyrical variety is introduced in verses. Each of the elements (chorus, verses, but also other elements like intro, bridge or outro) is composed of the elements mentioned previously – harmonies, melodies, rhythms, timbres and overall texture.

2.2 Music across cultures

Music is universal to all human cultures and societies (Mehr et al., 2018). While some use cases of music are culturally specific, other social uses of music can be observed across cultures. For example music is widely used to soothe babies (typically in the form of singing). Another wide spread use case is role in social events – with music typically accompanying dance. Very often songs are also used to communicate love. As Mehr et al. (2018) has shown, fit of a song for one of these basic use cases of music (e.g. soothing, dance, love) is nearly universally recognized across cultures – meaning that love song composed by hunter-gatherer societies will be recognized as such even by a modern wester european listener.

While research shows universality of human music applies in some cases, it is on the other hand clear that differences exist in music across different human cultures (Thompson et al., 2019). This can be easily demonstrated on emergance of music genres – music genre is a category identifying specific piece of music as belonging to set of conventions or tradition. The conventions might include any of the elements of music mentioned earlier – typical form, conventions in terms of used harmonies and melodies, texture, timbre or structure. Often typical set of musical instruments is used in each given genre of music (such as electric guitar in rock music and piano & other instruments included in orchestra for classical music).

2.3 Evolutionary theories of music

There is no single universally accepted explanation on why music has emerged. While some scholars have argued it is only by-product of other evolutionary adaptations, many theories on standalone evolutionary purpose of music exist as well (Mehr et al., 2019).

Darwin (1871) originally argued that survival value of music lies in its role as a courtship device to improve on reproductive success. In his view music was similar to any advertisement calls performed during breeding and mating rituals. Ability to produce a good love song would therefore indicate superior health and reproductive powers of especially males. This original hypothesis still recieves some attention in contemporary research, for example evolutionary biologist Geoffrey Miller (Miller et al., 2000) has shown relation between musical production of jazz musicians and their reproductive success.

However, Darwin's originall explanation does not correspond much with real context on how and where music appears in human societies most often. As has been described in many anthropological studies, music mostly appears in social contexts connected to group functions – for both within-group interactions and between-group interactions (Brown, 2000). This group-functionalist approach of ethnomusicology literature focuses on group coordination and mechanics such as promoting group identity, group coordination and synchronization, communication, cognition or catharsis. Music can then be also viewed as a reinforcement device and reward mechanism – through the percieved beauty of music individuals strive to align with other group members on pitch, rhythm and so on during rituals, helpsing broader coordination and synchronization of the group.

In line with the group-functionalist view of music's role in human communication was developed (Cross, 2014). However as Cross (2014) points out, even though this view fits the broader group-functionalist theories of music, it has so far recieved only limited attention in both psychological and anthropological research. Some psychology scholars have argued (Gfeller, 2002) on role of music in communication of emotions, most often in connection to music as a therapeutic medium

Investigations of evolutionary purpose of music often leads to more general discussion of evolutionary purpose of aesthetics – no matter whether connected to hearing or visual perceptions (Friedmann, 2014). From this persepctive it is clear that general preference for harmony, symetry and natural sound qualities, even though developed for different purposes, might extend also to perception of music. Music could then also be viewed as a by-product of adaptations to auditory perception, language, motor control and affect.

To conclude, it is likely that some aspects of human preference for music are result of aesthetical adaptations, while other elements serve standalone evolutionary purposes of its own – such as group coordination or role in mating rituals.

3 Communication

Many definitions of communication are used in literature across scientific fields, each stressing different elements of communication. Oxford dictionary defines communication as follows:

> "Activity or process of expressing ideas and feelings or of giving people information"
> (*Oxford English dictionary (Online)*, n.d.)

Interesting in this definition is focus on the expression but not necessarily understanding. On the other side of the spectre stands definition of communication from a psychologist S. S. Stevens:

> "Communication is the discriminatory response of an organism to stimulus"
> (Stevens, 1950)

With sole focus on the recieving side of communication and its response. Other definitions bring in more nuanced view with focus both on communicator, reciever, and achieved understanding or exchange of information. For example Keith Davis defines communication as

> “Process of passing information and understanding from one person to another”
> (Davis, 2006)

3.1 Key elements of communication

Based on the definitions above we can derive key elements of communication. Fristly, communication assumes communicator and reciever.

Communicator is sometimes identified also as sender or issuer. It is a person (or potentially also an animal or a machine) who intends to convey some kind of idea or message.

Reciever is the other party in the communication, who recieves the communication. It might or might not be the intended reciever by the communicator.

Thirdly, key element of communication is the information itself – it might be an idea, message or any kind of informative content which the communicator intends to communicate.

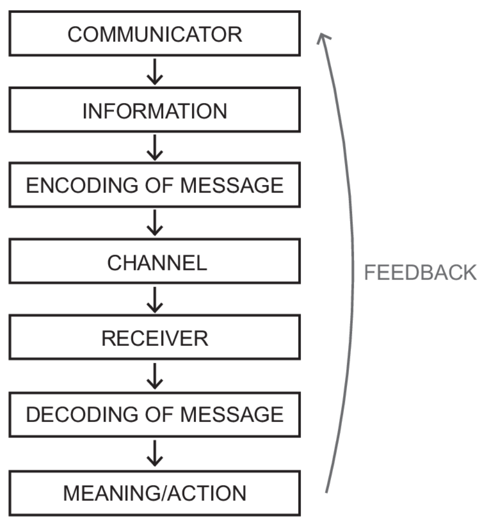
Another important element is the channel of the communication – means used to convey and communicate the information itself. The channels can range from verbal spoken sentences to letters, or for example gestures. It serves as a link between the communicator and reciever.

Finally, some kind of response or feedback is also part of many definitions of communication. It is kind of measure of the communication success and can sbe contrasted with the purpose of the communicationl. Also from empirical perspective without any measurable response it would be difficult to investigate the phenomennon of communication.

3.2 Process of communication

The above mentioned elements typically interact in conceptually fairly unified way in what can be described as a process of communication. The process can also be observed in many classical models of communication such as the transactional model of communication (Barnlund, 2013) or the mathematical model of communication introduced by Shannon and Weaver (Shannon, 1948).

Figure 2: Process of communication



First step in the process is formation of communicative motivation or reason by the communicator. Then the idea is formulated into specific information which the communicator intends to convey – a specific message is composed. The information is already a spefic formulation of what should be expressed in terms of the content. Once the information is clarified, next step is encoding. Message can be encoded for example into written text, speech, gesture or any other form. Type of the encoding medium is specified as the communication channel – those can range from verbal to non-verbal channels. Through the chosen communication channel the message is then transmitted to the reciever. Imperfect transmission often heppens in real world settings, influenced by various types of noise (e.g. wet paper blurrs writing, hearing distortion due to strong wind, etc.). The reciever then re-assembles the recieved message and starts decoding. Decoding in simple words means try to understand the message, obivously if different coding system is used by the communicator and the reciever, further distrotions might arise. Finally, the reciever tries to depicit the message meaning, processes it and potentially acts on it.

The last step is especially important for assesing the success of the communication and also for further enhancement of the communication process going further. The actions taken by the reciever often serve as a feedback loop for the communicator, in many real world settings the former reciever takes up the communicator role for the next cycle of the communication and communication becomes two-way interactive phenomena.

3.3 Types of communication

Different communication interactions can be classified based on the used medium for communication. Usual distinction of the communication mediums used is between verbal and non-verbal (Ferguson & Terrion, 2014).

Verbal communication is based on messages conveyed in written or spoken form, but articulate Singing would classify as verbal communication as well. While verbal communication always uses language, usage of language does not necesarilly imply verbal communication. Language is a structured communication system of symbols and grammars (rules) on how these are manipulated, however, some languages would qualify as non-verbal (e.g. sign language) and definition of language as such can be broadly extended to nearly any combination of channel and encoding mechanism in the communication process.

On the other side non-verbal communication uses non-linguistic representations and communication channels. These can include gestures, mimics or pictures. Instrumental music (music without articulate vocals, usually based on instruments and sounds only as opposed to singing) if approached as communication medium can also be classified as non-verbal communication medium.

Complex academic debate exists around importance of different mediums for human communication. While the popular "7%-38%-55%" rule introduced by Albert Mehrabian (Mehrabian, 1972) has been widely misinterpreted and criticised (Yaffe, 2011), it still poits out important aspect of communication of emotions. When communicating emotions, words itself have smaller significance (the 7% in the famous rule) than tone of voice (the 38%) and non-verbal communication (the assumed 55%). While the rule was result of methodically questionable combination of different studies, the general result of large importance of non-verbal communication in communication of emotions have beed validated in further research (Yaffe, 2011). If traditianal spoken language is not a suitable medium for precise communicartion of emotions, it would justify the evolutionary argument of development of further communication mediums to compensate this and suggest possibility of also explaining emergance of music through the logic of a emotional communication medium.

3.4 Role of perception in communication

Perception plays a key role in the transmission and decoding of the communicated information, therefore its role in communication deserves closer investigation. Perception is the organization, identification, and interpretation of sensory information in order to represent and understand the presented information or environment (Hammad et al., 2018). Perception strongly influences success of communication due to differentiated responses to sensory stimuli driven partially also by the perception process.

First important note on perception relevant to our context is that perception is not shaped by sensory information only, but also by learning, memory, expectation, or attention (Gregory, 1974). This means that success in using music as communication medium can be influenced by factors such as musical education and training.

Secondly, types and forms of perception go far beyond simple sensory information. While perspection is often classified into visual, hearing or sound, touch, taste and smell, other not all perceptions would fit into those categories (Broadbent, 2013). Already speech perception goes way beyond simple hearing with comprehension and perception of speech pauses that do not actually exist between words in a sentance. For example also time perception can be investigated, or social perception. These perecptual phenomena are in a way emergent from lower sensory information and show integrating nature of perception from lower level sensory signals to entire patterns and gestalts. This means that communication through music cannot be fully explained through specific sound qualities only, but rather comprehensive view on various elements of the emergant perceptive qualities need to be taken into account.

4 Emotions

4.1 Definition of emotions

Definition of emotions is a controversial subject in the academic debate. While the need of a unified definition has been widely demonstrated, no universally accepted definition of emotions exist (Lindsley, 1951; Cacioppo & Gardner, 1999; Keltner & Lerner, 2010; Denzin, 2017; Rolls et al., 2005).

> “A definition of emotion common to the affective sciences is an urgent desideratum. Lack of such a definition is a constant source of numerous misunderstandings and a series of mostly fruitless debates. There is little hope that there ever will be agreement on a common definition of emotion, given the sacred traditions of the disciplines involved and the egos of the scholars working in these disciplines.”
> (Mulligan & Scherer, 2012)

This is obviously a problem for any study of emotions – without proper conceptualisation of the phenomenon, it is difficult to progress in research and development of the theory (Scherer, 2005).

Most profound scholar in the debate around suitable definition of emotions is Swiss psychologist Klaus Scherer, who most recently used following definition of emotions:

> "An episode of interrelated, synchronised changes in the states of all or most of the five organismic subsystems in response to the evaluation of an external or internal stimulus event as relevant to major concerns of the organism"
> (Scherer, 2005)

While Scherer’s definition does good job in general enough descriptive definition of the physiological processes behind emotions, it is quite far from common understanding of emotions among most of psychological theory. Simpler definitions of emotions based more on description of introspective emotional experience often operate with combination of feelings, thoughts or behaviours and certain degree pleasure or displeasure.

> "Emotion is any mental experience with high intensity and high hedonic content"
> (Cabanac, 2002)

While defining emotional states through pleasure is tempting, pleasure itself is not an easy concept to define. Explanations of pleasure are most often connected with feeling good, enjoyment and happiness as opposed to pain or suffering, however all of those concepts are again intuitively clear to most humans but quite difficult to formally define and therefore use as solid baseline for construction of conceptual space for any research or theory.

For purpose of this paper it is sufficient to understand emotions somewhere between the formal definition of Scherer and common understanding of most scholars as psychological states triggered by neurophysiological changes but also associated with feelings of pleasure or displeasure.

4.2 Adaptive value of emotions

To further understand the phenomenon of emotion, it is usefull to consider its evolutionary justification. In other words – why do we have emotions?

According to popular theory of functional accounts of emotion (Keltner & Gross, 1999), emotions facilitate adaptive response to environmental stimuli which triggers response that was good enough behavioral rule for our ancestors to emerge through natural selection (Ekman, 1992b).

Functional accounts theory is based on two main areas of adaptive functions of emotions. First one is intrapersonal – in regulating individuals own mental environment and behavior. For example anger is triggered by unjustice in envornment. As justice as a principle is desirable for development of commnity, the emotion prepares individual for reactions aiming at restoring justice in the environement. This can be for example through agression, which is supported by increased heart rate.

Interpersonal functions on the other side focus on social interactions alone. Specifically, display of emotions commnicates socially valuable information (such as feeling of love, friendship or on the other side hatred). All of those can be read from phisiological changes triggered by the emotional experience, especially changes of expression.

However, the functional accounts theory, while clearly logical, misses broader context of how emotions interact with human behavior. In this sense, emotions can be viewed as playing crucial role in reward and punishment evaluation system of human mind. Reward and punishment mechanisms are key for adaptive behavior. Emotions can play role of reward and punishment system for broader phenomenon rather than partial and individual decisions – in other word emotions can drive broader motivations and goals (Rolls, 2002). This observation is interesting in the light of development of AI – while neural networks are able to perfect tasks with clearly set objectives, determination of broader existential objectives seems limited to human brain and emotion, as opposed to purely rational decision-making system. At least rational in terms of selecting the happiness maximizing alternative in each presented choice and situation.

4.3 Emotions classification

In order to distinguish between different emotions, it is crucial to establish a suitable framework or classification of emotions.

Firstly, it is important to note two general approaches to emotions classification can be identified. While some scholars see emotions as discrete and disctinct (Ekman, 1999), other scholars approached classification of emotions as multidimensional space (Gershenson, 1999) where individual emotions differ by quantity on the specific dimensions rather than quality. Naturally these two approaches could be synthetised into a mixed approach where the discrete elements of emotions would be described through the dimensions where actual emotions could then be placed. However, such a setup would assume either existence of perfectly opposite emotions to the basic emotions defining the dimensions (which is not the case for most classifications based on the discrete logic) or limitation of the multidimensional space to unipolar interpretation which makes the whole concept of emotions as a multidimensional continuous space less attractive as its interpretation is then limited to discreate elements and their volumes.

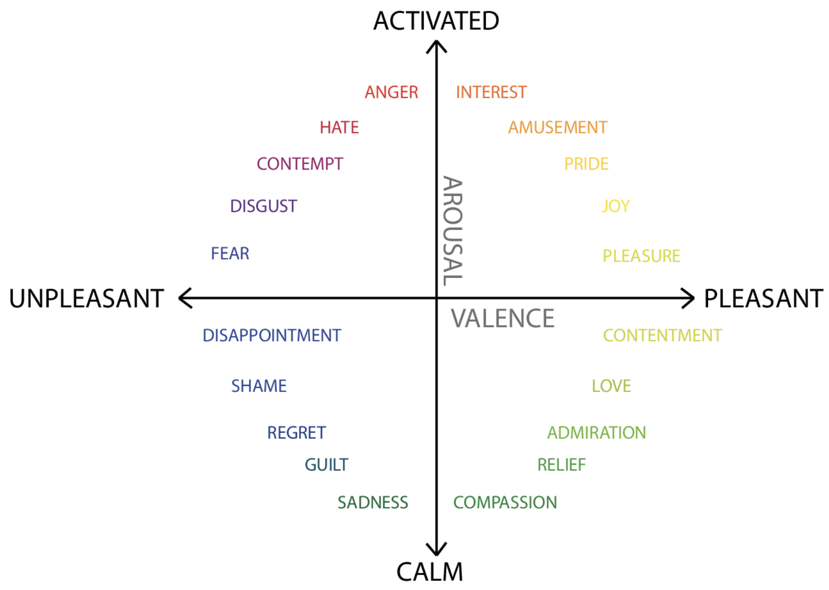
4.3.1 Basic emotions

Historically, classification of emotions by psychologists started with attempts to identify basic emotions. As early as in 1890, William James (James, 1890) proposed four basic emotions – joy, sadness, fear, and anger. Vast majority of scholars after James used these four emotions as well, often expanding the list. For example Ekman (1992a) initially used in his research six basic emotions – joy, sadness, fear, anger, disgust and surprise, identified based on human expressions and universality across cultures. These six are most common among the basic emotions theories, however, many more proposed basic emotions can be found in literature. Even Ekman himself later expanded his initial list. However, many additions to the list of basic emotions were challanged and not universally accepted (Ortony, 1987). Examples of further proposed basic emotions would include emotions like guilt, amusement, contempt, embarassment, relief, satisfaction, sensory pleasure, pride, shame, hope, excitement, patiance and many more (Robinson, 2008).

4.3.2 Dimensional models of emotions

Among the dimensional models of human emotions, most popular is the two dimensional model based on arousal and valence.

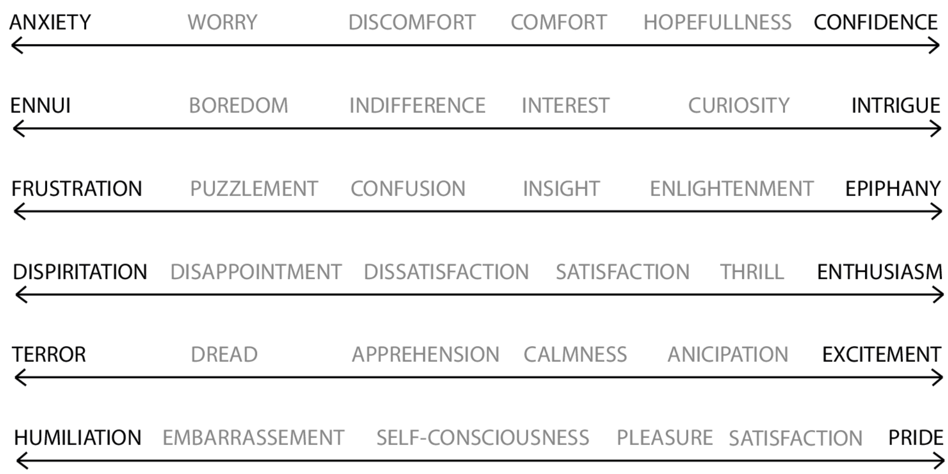
Figure 3: Circumplex model of emotion



The model was original developed as circumplex model by Russell (1980) and while the valence dimension is clearly bipolar, arousal rperesents simply volume of arousal, starting at "no arousal" described as "calm" in figure 3, going up to "full arousal" describ ed as "activated". Figure 3 is schematic only, but many experiemtns measuring arousal and valence in a quantified way were conducted in psychological research.

While the circumplex model is usefull in its simplicity, it has been argued it does not fully capture the breadth and width of richness of the human emotional experience. Many more detailed dimensional models of emotions were developed by psychological scholars. One example is six dimensional model of emotions by Kort et al. (2001) shown in figure 4.

Figure 4: Six dimensional model of emotion



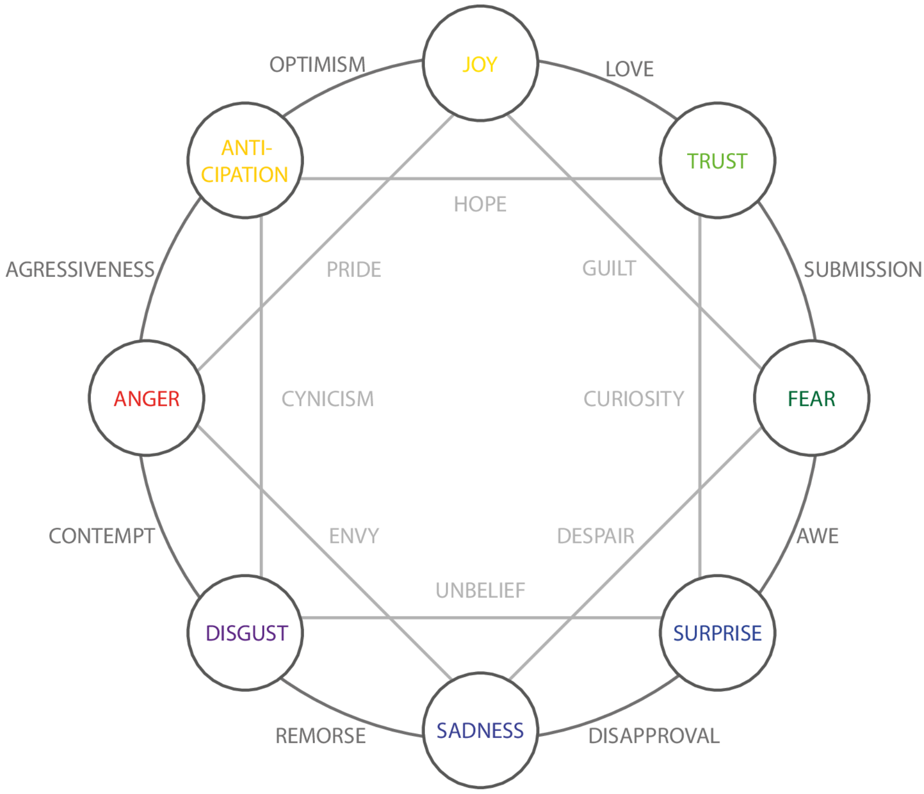
4.3.3 Compound emotions

Compound emotions are also an important concept for the discussion of emotions classification. Many scholars have argued that some emotions are result of combination of more basic emotions. In the dimensional models of emotions, this could be dicipited by placing of emotions on various axes as opposed to emotions which would sit in the intercept for all but one dimension. In the models of basic emotions, this concept would be a complement to the basic discrete emotions.

This logic leads to the popular model of emotions developed by Robert Plutchik (Plutchik, 2001), which is based on 8 basic emotions, dyads (emotions composed of two basic emotions) and triads (emotions composed of three basic emotions). On top of that Plutchik uses framework for organization of the eight basic emotions, with each of the basic emotions having two "neighboour" emotions, resulting int a conceptual "wheel of emotions". It can be noted this "wheel" is quite similar to organization of emotions in the circumplex model of emotions.

Primary dyads describe combinations of neighboring emotions in the wheel (e.g. love is primary dyad as it is combination of joy and trust). Secondary dyads are combinations of emotions one place apart in the wheel (e.g. hope).

Figure 5: Plutchik’s wheel of emotions



5 Literature review

Large body of research exists on perception of emotions in music.

Hevner (1935) provided review of available experiments on expression of music already in 1935 – concluding that certain cues (i.e. pitch, tempo, scales, rhythm) in music can be generally associated with basic emotions. He also notes musically trained listeners are more efficient at distinguishing the cues.

Balkwill et al. (2004) showed this applies also to music outside of euroatlantic area – through conducting experiment of Japanese listeners listening to excerpts of Japanese music. Similarly as for earlier findings, excerpts with faster tempo and simpler melodies were more often percieved as joyfull whereas excerpts with slow tempo and complex melodies as sad.

Balkwill & Thompson (1999) extended the study of musical cues linked to percieved emotion to cross-cultural context. In their study, 30 Western listeners rated the degree of joy, sadness, anger, and peace in 12 Hindustani raga excerpts. Balkwill & Thompson (1999) conclude that while some musical cues related to emotions are culturally specific, universal cues also exist and most of the listeners identified correctly joy, sadness and anger most of the time.

Pavlović & Marković (2011) investigated emotion in music from slightly different angle – they used movie excerpts and their soundtracks to investigatge emotional reponse of the viewers. In most cases they confirmed music described as sad increases the level of sadness in viewer for a sad movie sequence and joyfull music increses level of joy for viewer of a joyfull movie sequence. However, for more complex emotions the results were mixed, e.g. music described as trustfull increased level of disgust for disgusting movie sequence.

Eerola & Vuoskoski (2011) compared discrete and dimensional models of emotion in music – for discrete anger, fear, sadness, happiness and tenderness were used, for dimensional three dimensions were considered – valence, tension arousal and energy arousal. 110 excerpts of film music were then rated for both the discrete and dimensional models' assessment by 116 listeners without musical education. Higher correlation between ratings of the listeners was found for the dimensional model when compared to the discrete one, especially for excerpts with milder emotional message. Also the authors concluded energy and tension arousal dimensions could have been merged into one as the results across these two dimensions were highly correlated.

Vuoskoski & Eerola (2012) investigated to what extent can music influence the emotional state of a listener. In experiment conducted on 120 listeners and utilizing various methods to measure their emotional state before and after the listening experience, they managed to find statisticaly significant evidence for sad music inducing sad feeling, however marginal in terms of practical magnitude.

However, research on communication through music as such, i.e. relation of the percieved emotions to original intention of music authors (as opposed to perception of emotion in music only) is much more limited. Most relevant research in this area has been conducted by swedish psychologist Patrik Juslin, who leads the Music Psychology Group of Uppsala University and specialises in both emotions and music psychology.

Firstly in a study in 2000 (Juslin, 2000), Juslin investigated cues used by three professional guitar players who were asked to play short melodies on anger, sadness, happiness, and fear. Juslin concluded the cues used by the guitar players to express the emotions were similar for all the four emotions (i.e. relation of tempos, complexity of melodies, dynamics, relation to musical scale used). Also listeners generally recognised the four emotions.

In later studies Juslin investigated precision of the emotions communication (Juslin, 2001; Juslin & Laukka, 2003) and concludes that communication of emotions through music is possible, but imprecise and lot of noise is created through processing of the musical emotional cues by listeners. However, clear distinction of what emotions and how can be communicated through music is missin even in Juslin's work.

Juslin & Timmers (2010) investigated how performers express emotion trhough performance of pre-composed pieces of music. They identified tempo and dynamics as key elements – with tempo in some parts of piano pieces varying to large degree across individual performers.

Some scholars have created theories of communication of emotions through music without empirical justification. Among those for example Budd (1989) focuses on on two types of emotional response to music – reactive and matching. On examples of classical music and intentions of the athors Budd (1989) demonstrates that using music as communication medium might be possible and certainly is intended by some of the authors of the music, but does not provide definitive answer on its quality. Davies (1980) argues emotional communication in music is limited to expressive emotions, i.e. emotions humans can recognize based on facial and behavioral responses, but also does not provide empirical justification.

While some advancements have been made, it is clear further research is needed for development of full theory around communication of emotion through music. It is clear that listeners can identify some emotions in music through clues in melody, harmony, tempo or dynamics, however it is unclear what is the level of precision of communication of emotions which is possible through music and also what is the importance of different cues for the listeners.

Part II

EMPIRICAL PART

6 Research question

Our key objective is to investigate how well can music serve as a medium for communication of emotions and what factors have influence on the communication success. Three key questions we try to answer are the following:

- Can music be used as a communication medium for emotions?
- Does efficiency and precision of the communication depend on musical education or general exposure to music of the individual in previous life?
- Does it work only for simplest and most basic emotions or also for more complex emotions?

These three questions motivate following key hypothesis we want to test:

- Listeners can identify emotions in music with higher success rate than if they would use random guesses.
- People with music education (including training on an instrument) are more successfull in identification of the emotions expressed in music.
- People who spend generally more time listening to music are more successfull in identification of the emotions expressed in music.
- Probability of successfull communication is higher for four basic emotions (sadness, joy, fear, anger) than for other emotions.

7 Methodology

7.1 Experimental design

Profesional musicians composed and recorded short instrumental piano pieces trying to express list of 6 pre-defined emotions in a controlled setting. These musical snippets were then played to general public to assess how different people were successfull in recognized the intended emotions. In this section, we provide details on the experimental design.

7.1.1 Used framework for emotions

In the experiment we use closed list of six discrete emotions initially used by Ekman – joy, sadness, fear, anger, disgust and surprise. This design was chosen because of several considerations.

Firstly, using discrete and distinct emotions classification seems more suitable for initial research than more complex models based on multidimansional space. As we want to investigate basic relationships rather then refine quantiative assessment of known relationships, introducing a framework of emotions based on quantitative assessment of various dimensions seems like an unnecessary complication and complexity

Secondly, we want to use universally accepted clasification of emotions, therefore focus on subset of basic universal emotions which were previously identified and verified in large body of research (for more details see section 4.3) is a natural choice.

Finally, we forsee a limited sample size by resources available for our assessment and therefore we use framework of emotions which is not too granular for assessment based on lower hundreds of respondents. Ability to test all emotions on all respondents significantly decreases needed sample size to effectively control for random individual effects, therefore we select only small number of basic emotions for investigation.

While it would be tempting to use only the four basic emotions used by James (1890), it would not enable us to test the hypothesis that the four basic emotions are more easily recognized than more complex emotions. Because of this we select the (slightly broader) list of six basic emotions used initially by Ekman (1992a).

7.1.2 Experimental setup for creation of music

Controlled setting was used for composing and recording of the music snippets. For each of the music professional involved in creation of the snippets, following procedure was used.

Firstly, the musician was contacted online. They were explained goals of the experiment (measuring how well can music be used to communicate emotions), informed about the high level setup (that they would be required within 1 hour to create few music snippets of music using a keyboard) and offered small financial incentive to participate in the experiment (CZK 5000, which is eqal to approximately EUR 200 or USD 230).

Secondly, the music professional (if agreed to participate in the experiment) was invited for a 75 minutes individual experimental session to recieve detailed isntructions, create and record the snippets. This session was conducted in a calm room with a small sofa and basic musical equipment. The musical equipment included small keyboard (midi controller), laptop with pre-installed music recording software, basic external USB audio interface and a speaker.

All the equipment was already set up in a way so that it was possible to play the keyborad and record with a sound of simulated classical piano. It was not allowed to change the software instrument to anything else than simulated classical piano. Also, only one recording track was available in the recording software, so it was not possible to reccord and overlay multiple tracks. Basic editing functionalities were allowed to export specific region from the recorded track into and audio file. Time in seconds was displayed in the recording software, but metronome functionality was not allowed. Only a small 25-keys keyboard was provided, however including the functionality to change the starting Octave. The keyboard used was also velocity sensitive (i.e. able to record force applied for each note and therefore able to capture dynamic range or loudness of the individual notes played).

Figure 6: Setup for composing and recording the music snippets

First 5 minutes of the session were used to give detailed intstructions. The music professional was informed that they would be asked to create simple 10 seconds snippets of music for 6 predefined emotions, always using 10 minutes of time to compose, record and save a snippet for each of the emotions. They were given freedom in the creative process, but were required always by 10 minute mark to save an audio file of max 10 seconds communicating the specific emotion. This means they could for example record several snippets for each of the emotions and then select the "best" one by the 10 minute mark. Importantly, it was communicated to them that their objective should be to achieve best possible recognition of the emotion in the music snippet by listeners recruited from general population.

After the instructions, 10 minutes were used to get the music professional familiar with the equipment setting. Instructor explained to them how to use the basic recording software to create the audio snippets. Finally, they were given the list of the 6 emotions and a timetable of by when they were required to save each of the snippets to the computer. For the following hour the instructor left the rooms to allow concentration of the music professional on the task.

7.1.3 Survey of listeners

The music snipets were then played to general public and for each the snippets respondents selected which emotion they feel in the music from a pre-defined list of 6 possible emotions.

An online survey was used to gather data on recognition of emotions in the music snippets.

In first section of the survey short overview of the research objectives was introduced and participants were informed that they will be asked to assess snippets of music in terms of which emotion is expressed through those. Also, they were notified that speakers or headphones are needed to enable listening to the audio.

Second section of the survey included the individual music snippets in randomized order. Respondents were able to play each of the snippets repeatedly if needed. Responses were recorded for each snippet in the form of single choice question where the respondent always had to select one of 6 possible answers from a list (Anger, Disgust, Fear, Joy, Sadness, Surprise). The order of six emotions as possibles answers was also randomized for each snippet.

Third section of the survey included questions on basic demographics, experience with music and other information about the respondent. Detailed overview of the gathered variables is available in Section 8.

The survey was distributed through facebook, using three types of open facebook groups. First type of groups were groups focused on music fans in the Czech Republic. Second type was groups of students of different universities in the Czech Republic and third type were facebook groups gathering inhabitants of mid-size cities in the Czech Republic. The survey was posted to 26 facebook gorups in total.

7.2 Statistical model and methods

7.2.1 Modelling correct recognition of emotion

When deciding on the optimial statistical model to use for recognition of emotion in music, the inherent nature of the observed outcomes needs to be taken into account. While we can directly observe only the final choice of the emotion by the respondents, it is desirable to model the underlying probabilistic function and how the probability of correct guess by the respondent is influenced by various factors.

Second factor to take into account is the probabilistic nature of the dependent variable we want to investiagte – which directs as to class of limited dependent variable models for binary responses. Our interest lies primarily in the response probability:

$$P(y = 1|x) \tag{1}$$

where y is the dependent variable which denotes correctness of the guess of the emotion and x represents vector of the determining characteristics we want to investigate.

Due to the obivous limitations of modelling probability as a linear function, two basic alternatives for specification of the model were considered – logit and probit. As both rarely produce different results and logit allows for slightly easier results interpretation, logistic function was used to model the correct guess probability. Moreover, as logistic function has slightly fatter tails than standard normal cdf, it might be seen as more robust to outlier values of the observed characteristics. This leads us to specification of the probabilistic model as follows:

$$P(y = 1|x) = \frac{1}{1 + e^{-}(\beta_0 + x\beta)} \tag{2}$$

7.2.2 Mixed Effect Logistic Regression

Another challange for our model lies in the nature of (missing) independence of our observations which, if not corrected for, would lead to bias in estimates of the standard errors. While we are most interested in effect of potential explanatory variables like type of emotion, previous music education, etc., it would be very daring to assume the modeled relationship between probability of correct recognition of emotion and the emotion type or music education is completely independent of the specific author of the music snippet or of the inidvdual listener. On the other side, any attempt to relax the assumed general nature of the relationship completely (i.e. assume the relationship varies accross listeners and authors both in slopes and intercepts) would naturally lead to overfitting of the model and limit level of insight obtained from the analysis.

Usefull for conceptualization of this problem might be the concept of random and fixed effects used in older literature which distinguishes between random intercepts and random coeffitients. Assuming random coeffitents across individual would lead to zero or negative degrees of freedom for the estimation. At the same time assumption of random incercepts across individuals seems to be a reasonable choice, as otherwise we would need to assume all personality characteristics which systematically determine probability of successfull recognition of the emotion are captured in our data, which is clearly not the case (i.e. likely example might be general level of cognitive abilities which was not measured for the individuals). While this could be accounted for in the model through inclusion of binary explanatory variable for each individual, more elegant (and mathematically equal) way is to use mixed effect logistic regression with assumption of random intercepts across individuals.

Similar logic could be applied for grouping the observations by the authors of the music snippets. However, as we have only two authors in the sample, we can correct for the random intercept through inclusion of a single binary variable. For potential random coefficients, we could control through inclusion of interaction terms of composer variable with individual emotions (as each composer provided only one snippet per emotion), which provides flexibilty on assumptions which exact coefficients are treated as random per author of the music.

Such a mixed effect logistic regression can be estimated in most statistical packages, using random intercept specified by the individual (respondent) ID. For detailed list of used explanatory variables including the interaction terms please refer to the section 8.3.

8 Data

8.1 Music snippets

Two music professionals were involved in role of the composers of the music snippets. In the following text we will refer to them as "Composer 1" and "Composer 2".

Composer 1 identifies himself as a male and was 24 years old when creating the music snippets. He has worked as popular music producer for the past 5 years. He does not have formal music education.

Composer 2 also identifies himself as a male and was 28 years old during the experiment. He holds professional undergraduate degree in classical singing

The resulting snippets of music created by the authors are summarized in the table below:

		Anger	**Disgust**	**Fear**	**Joy**	**Sadness**	**Srprise**
Composer1	*Key type*	Minor	?	?	Major	Minor	?
	Tempo (BPM)	200	103*	?	133	103	203*
	Loudness (LUFS)	-4.4	-7.1	-5.0	-5.8	-8.2	-6.9
	# of notes used	49	26	5	38	7	15
	Melody	Yes	Yes	Yes	Yes	Yes	Yes
	Harmony	Yes	Yes	Yes	Yes	Yes	No
	Length (seconds)	4.9	8.0	7.3	5.2	9.6	5.1
	# of notes / sec	10.1	3.3	0.7	7.2	0.7	3.0
Composer2	*Key type*	?	?	?	Major	Minor	?
	Tempo (BPM)	144	134	120	175	98	165
	Loudness (LUFS)	-1.6	-4.1	-13.0	-17.1	-19.0	-14.2
	# of notes used	24	21	18	34	11	18
	Melody	Yes	Yes	Yes	Yes	Yes	Yes
	Harmony	Yes	Yes	Yes	No	Yes	Yes
	Length (seconds)	7.0	8.5	7.8	7.5	8.9	6.5
	# of notes / sec	3.4	2.5	2.3	4.5	1.2	2.8

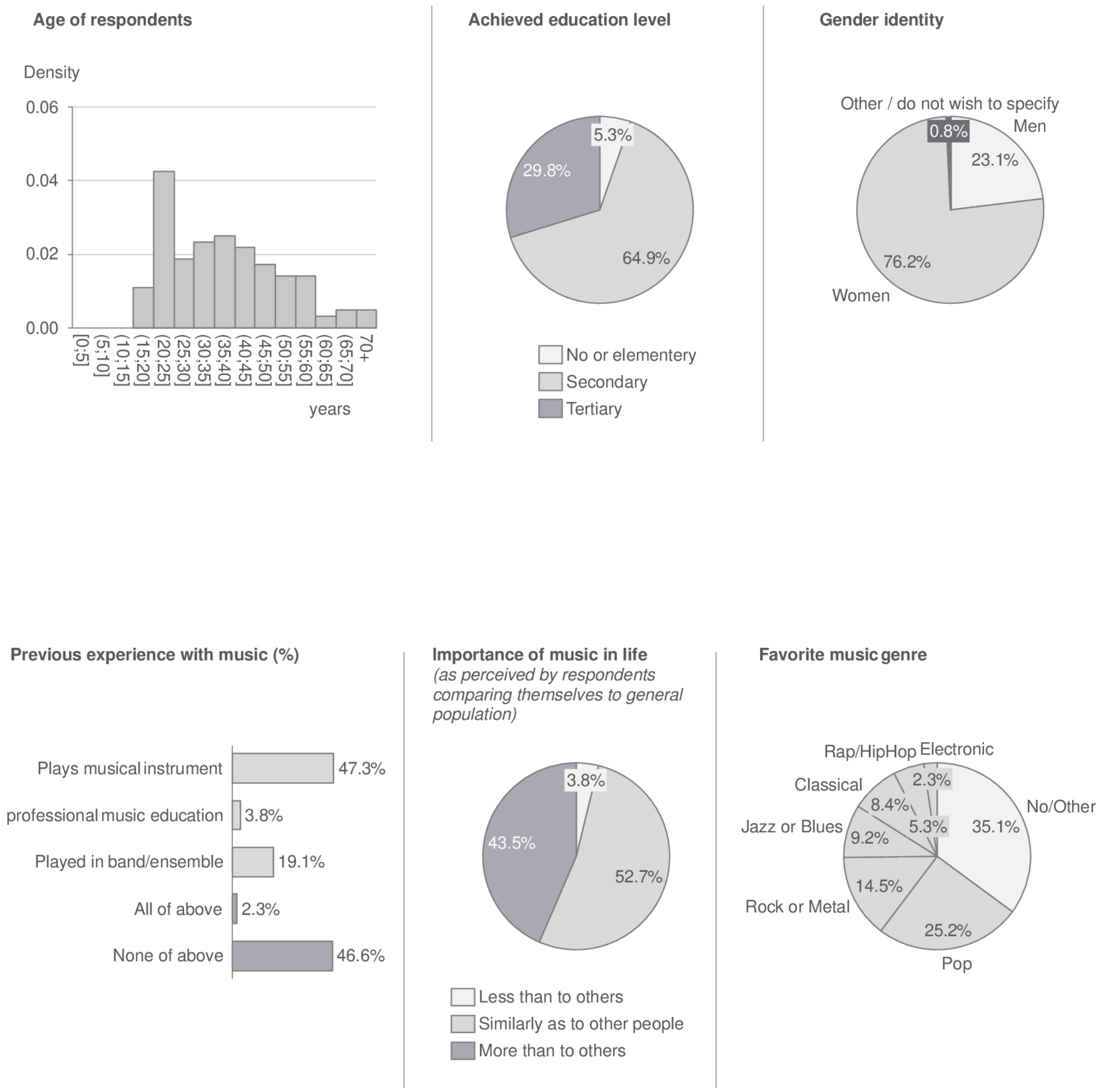
In terms of loudness, "Anger" was the loudest snippet for both composers and similarly "Sadness" was the softest. For rest of the emotions loudness was mixed between the authors, but "Surprise" was among the 3 softest for both authors. In terms of length of the snippet (measured from first to last sound recorded), Sadness was the longest snippet for both authors, followed by "Disgust" as second longest. "Anger" and "Surprised" were among the two shortest snippets for both authors. In terms of "density" measures as notes per second, "Sadness" was the least dense snippet for both authors with 0.7-1.2 notes per second, followed by "Fear" at 0.7-2.3 notes per second. On the other side of the spectre "Joy" was among the top 2 most dense snippets for both authors with 4.5-7.2 notes per second. "Surprise" and "Disgust" were for both authors close to average density across all the snippets, while densities for "Anger" were mixed (very high for one of the authors and relatively low for the other). The snippets were also assessed for musical characteristics – nearly all included both melody and harmony and very few were possible to be classified as fully in Minor or Major key. However, both "Joy" snippets were clearly part of a Major key and both "Sadness" snippets were in a Minor key. In terms of the tempo recognizable in the snippets, the fastest tempos were used for "Anger" and "Joy" by both authors whereas the slowest tempo was used for "Sadness". However, it needs to be noted that in some of the snippets the tempo was not clearly recognizable. The general notion of sadness asociatted generally with slower tempos in music than joy is in line with insights from previous research conducted in this field (Hunter et al., 2010; Khalfa et al., 2008).

This rather technical analysis of the music snippets brings to light quite interesting insight – snippets for "Joy" and "Sadness" were most extreme across several dimensions (loudness, density, tempo, clearly distinguishable Major, respectively Minor key), while most of the other emotions were not very distinguishable in terms of the technical characteristics of the snippers (maybe with exception of "Anger" which was clear outlier in terms of dynamics or in other words loudness). This might create a hypothesis that these distinctive technical characteristics of "Joy" and "Sadness" in music might be useful also for the listeners and serve as clues to the communicated emotion.

8.2 Sample of respondents

In this section we provide key summary information on the survey respondents. For more information on the process of gathering the survey data please refer to section 7.1.3.

Figure 7: Summary statistics on respondents and responses



As depicted in figure 7, from basic summary statistics it is clear that our sample is not representative of whole population. Firstly, there is strong overrepresentation of the age group of 20-25 years – which is likely result of gathering the data through posting the survey to (among other) social networks groups of students. Also, women are strongly overrepresented in our sample which is likely result of usage patterns of social networks. Even though the survey was posten also to social networks groups focused on students of music, only 3.8% of our respondents have professional music education. This will limit possible insight into effect of professional music eductaion on the ability to recognize correctly emotions in music. While 43.5% of respondents claim music is for them personally more important than for general population, only 3.8% claim it is the other way around. While this might be partially result of focus of the survey and therefore attracting more music-conscious respondents to fill it, majority of this discrepancy can likely be attributed also to cognitive biases (Roy & Liersch, 2013).

8.3 Resulting dataset used

In this section we provide key information on the resulting dataset used for the analysis. In terms of structure of the data, each "guess" was recorded as an individual response.

A total of 131 respondents filled the survey, however only 127 continued all the way to assessment of the music snippets. Because of this we omitted the 4 respondents who did not assess the music snippets. As each respondent was asked to assess 12 music snippets, our dataset includes 1524 observations.

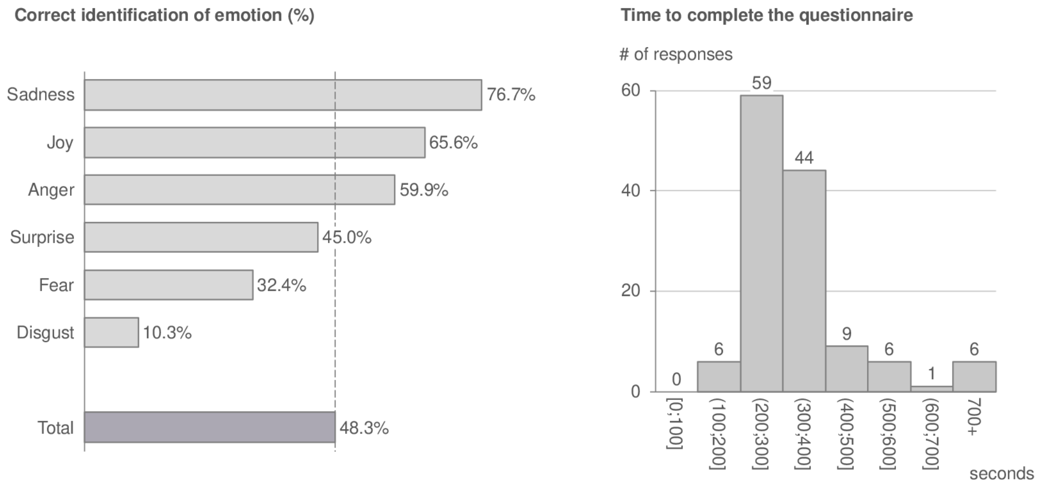
All variables used in the analyses are summarized in table below:

Variable	Description
answercorrect	Dummy variable on whether the guess on the played emotion was correct
ID	ID of the respondent
composer	Dummy variable denoting ID of the composer
surprise, sadness, anger, joy, fear, disgust	set of dummy variables denoting which emotion was played
composer_surprise, composer_sadness, composer_anger, composer_joy, composer_fear, composer_disgust	set of interaction terms of composer dummy variable and played emotion (i.e. identifies uniquely each music snippet)
playsinstrument	Dummy variable describing whether the respondent can play any musical instrument
dailylisteningtime	Estimated time in hours on average spend listening to music by the respondent
concertslastyear	Estimated number of concerts attended by the respondent over past 12 months
gender	Dummy variabile describing gender identify of the respondent, 1 used for women, for non-binary left blank
age	Variable describing age of the respondent in years
education	Dummy variable for achieved tertiary education

As most of the variables are dummy variables, usuall summary statistics on the dataset (i.e. means, standard deviations) are not very meaningfull. Figure 8 in this section provides overview of selected summary statistics.

We can observe large differences in proportions of correct answers for snippets of different types of emotions. While the summary statistics provide only indicative view, disgust seems to be by far most difficult emotion to communicate through music out of the six. Sadness, joy and anger are at the other side of the spectrum.

Figure 8: Selected summary statistics of the data



9 Results & discussion

In this section, results of the estimation of the statistical model are provided. Central to the analysis is the mixed effect logistic regression of *answercorrect* on *age*, *gender*, *education*, *playsinstrument*, *dailylisteningtime*, *concertslastyear*, *surprise*, *sadness*, *anger*, *joy*, *fear*, *disgust*, *composer*, and random intercepts by respondent ID, *ID*. We provide also results of selected complementary models to verify robustness of the results and improve interpretability.

9.1 Interpretation of the regression results

The results of the main mixed effect logistic regression are summarized below.

answercorrect	Coef.	Std. Err.	z	P>|z|
age	0.001	0.004	0.15	0.881
gender	0.148	0.145	1.02	0.307
education	0.057	0.112	0.49	0.623
playsinstrument	0.284	0.128	2.22	0.026
dailylisteningtime	0.022	0.035	0.63	0.529
concertslastyear	-0.025	0.037	-0.67	0.504
surprise	1.952	0.244	8.00	0.000
sadness	3.489	0.261	13.37	0.000
anger	2.633	0.246	10.68	0.000
joy	2.862	0.249	11.49	0.000
fear	1.464	0.247	5.93	0.000
disgust	0	(omitted)		
composer	-0.666	0.118	-5.65	0.000
_cons	-2.214	0.337	-6.57	0.000

Supplementary information		
Mixed-effects logistic regression		
Group variable: ID		
Number of obs	=	1524
Number of groups	=	127
Obs per group	=	12
Integration points	=	10
Log likelihood	=	-870.451
Wald chi2(12)	=	255.37
Prob > chi2	=	0.000

playsinstrument is the only listener level variable which is statistically significant. This suggest that active experience with music and music reproduction or creation on the side of the listener influences probability of successfull recognition of the emotion intended to be communicated in music, while passive exposure to music (*dailylisteningtime* and *concertslastyear* used as proxies) does not. Similarly *age*,*gender* and *education* of the listener are not significant predictors of the correctness of identification of the emotion. Not only that the estimates are not statistically significant, but also the estimated coefficients do not seem to be of a meaningful size for those variable. Below we provide results of the regression in odds ration format:

answercorrect	Odds Ratio	Std. Err.	z	P>|z|
age	1.001	0.004	0.15	0.881
gender	1.160	0.168	1.02	0.307
education	1.060	0.125	0.49	0.623
playsinstrument	1.328	0.169	2.22	0.026
dailylisteningtime	1.023	0.036	0.63	0.529
concertslastyear	0.975	0.036	-0.67	0.504
surprise	7.041	1.718	8.00	0.000
sadness	32.756	8.549	13.37	0.000
anger	13.919	3.45	10.68	0.000
joy	17.492	2.355	11.49	0.000
fear	4.325	1.068	5.93	0.000
disgust	1	(omitted)		
composer	0.514	0.061	-5.65	0.000
_cons	0.109	0.037	-6.57	0.000

Supplementary information		
Mixed-effects logistic regression		
Group variable: ID		
Number of obs	=	1524
Number of groups	=	127
Obs per group	=	12
Integration points	=	10
Log likelihood	=	-870.451
Wald chi2(12)	=	255.37
Prob > chi2	=	0.000

While active experience with playing a musical instrument of a listener increases the odds of correct identification of emotion by $\sim$33%, estimated effect (while not statistically significant) of listener indentifiyng herself as woman increases the odds of correct guess by $\sim$16% and all other listener level variables have estimated impact on the odds of less than 6%.

Our model suggests strong differences between probability of successfull guess between snippets of different emotions. While smallest odds of correct guess are predicted for disgust, sadness, joy and anger seem to be easiest emotions to be communicated through music. However, before strong conclusions regarding the specific emotions, we need to take into account limitations of our model and data. Firstly, variability at composer level is very low - having snippets of music only from two composers in the sample. Secondly, our model assumes fixed effect of each composer on the general odds of correct guess, but does not allow for differing slope estimates of effect of individual emotions per composer. This needs to be considered as a rather strong assumption - there is likely other characteristics of each of the musical snippets which influence probability of correct guess than the communicated emotion and general fixed effect on odds of the individual composer. As our sample of composers and snippets per emotion is very limited (two snippets per emotion and two composers), results in terms of comparison of the individual emotions' effect on the odds of correct guess need to be interpreted as indicative only.

Finally, it is usefull to compare overall probability of successfull guess of an emotion in our sample to a hypothetical random guess. As the deduction from our main model would be quite cumbersome, we report below results of a simple one-sample test of proportion.

One-sample test of proportion			Number of obs	= 1527
Variable	Mean	Std. Err.	[95% Conf. interval]	
answercorrect	0.483	0.013	0.459	0.508

p = proportion(answercorrect   z = 33.703
H0: p = 0.167

Ha: p < 0.167	Ha: p != 0.167	Ha: p > 0.167
Pr(Z < z) = 1.000	Pr(|Z| > |z|) = 0.000	Pr(Z > z) = 0.000

We can clearly reject the null hypothesis and conclude the probability of correct guess of an emotion based on the music snippet is higher than $\frac{1}{6}$, which would correspond to a random guess. This implies that music indeed can be used successfully as a medium to communicate emotions. Moreover, converting the baseline probability to odds-ratio, the odds of a successffull guess seem to be $\sim$5 times higher than for a random guess.

9.2 Disscussion of the results

9.2.1 Fit of the model

In this section we assess fit of our main regression model. Firstly, we report the c-statistic - area under the ROC curve.

			-Asymptotic Normal-	
Obs	ROC Area	Std. Err.	[95% Conf. interval]	
1524	0.785	0.012	0.761	0.807

The value of c-statistic at 0.78 suggest solid fit and predictive power of the model.

Secondly, we assess suitability of usage of the mixed effect logistics regression model. To do this, we run likelihood ratio test with null hypothesis that a fixed logistics effect regression model would provide equal goodness of fit as our mixed effect logistics model.

LR test vs. logistic regression: chibar2(01) = 0.47 Prob>=chibar2 = 0.247

Even though we cannot reject the null hypothesis based on the LR test, we take a conservative approach and stick to the mixed-effect logistics model to avoid potential downward biases on the estimated standard errors as the observations per same individual are clearly not fully independent.

9.2.2 Limitations of the used dataset

There are several shortcomings of the dataset which should be explicitly noted.

Firstly, we have only two composers and two sets of the music snippets in our dataset. This significantly limits the scope of possible insights and generalizations. While we can effectivelly investigate effect of listener level variables on the probability of successfull identification of the communicated emotion, it is not fully true for music snipet or composer level variables. This is why we do not even include most of such variables (i.e. information on composer demographics or the characteristics of the individual music snippets as described in section 8.1. The exception in this respect is identification of the emotion which was meant to be expressed through the music snippets. While our dataset can give us indicative view on impact of the communicated emotion type on the successfull identification, we cannot hope to obtain representative and statistically significant results of the statistical inference in this respect from only two sets of the music snippets.

Secondly, the listener level variables are all self reported by a non-representative sample of the general population. This might have created systematic biases in the data, i.e. in reporting of daily listening time and experience with music.

Thirdly, the observations in our dataset are not independent – however we deal with this fact through using the mixed effect logit model as outlined in section 7.2.2. What should still be noted is that even though we have 1572 observations, the level of variance in the dataset is limited by the dependency of the observations, dummy nature of vast majority of the variables and also covariance in some of the variables.

9.2.3 Robustness check

In this section we estimate an alternative model to assess robustness of the estimation reuslts of our main model. Specifically, we add interaction terms of composer and the dummy variables for individual emotions. This adjustment removes any doubts about potential factors influencing the odds of correct guess for the individual music snippets beyond fixed odds effect of the composer and the communicated emotion itself. This is becuase this model speciufication actually allows for estimation of effect on odds of correct guess of each of the individual music snippets.

answercorrect	Coef.	Std. Err.	z	P>|z|
age	0.001	0.005	0.15	0.88
gender	0.161	0.158	1.02	0.307
education	0.063	0.128	0.49	0.623
playsinstrument	0.309	0.139	2.22	0.026
dailylisteningtime	0.024	0.039	0.63	0.529
concertslastyear	-0.027	0.041	-0.67	0.503
surprise	2.720	0.343	7.92	0.000
sadness	3.172	0.353	8.98	0.000
anger	3.214	0.354	9.07	0.000
joy	3.983	0.388	10.27	0.000
fear	0.839	0.358	2.34	0.019
disgust	0	(omitted)		
composer	-0.084	0.410	-0.20	0.838
composer_surprise	-1.661	0.498	-3.34	0.001
composer_sadness	0.598	0.513	1.16	0.244
composer_anger	-1.139	0.493	-2.31	0.021
composer_joy	-1.974	0.517	-3.82	0.000
composer_fear	1.137	0.498	2.28	0.022
composer_disgus	0	(omitted)		
_cons	-2.516	0.406	-6.20	0.000

Supplementary information		
Mixed-effects logistic regression		
Group variable: ID		
Number of obs	=	1524
Number of groups	=	127
Obs per group	=	12
Integration points	=	10
Log likelihood	=	-821.584
Wald chi2(12)	=	319.48
Prob > chi2	=	0.000

The adusted specification of the model does not change the conclusions from our main model on the listener level variables and their impact on probability of the correct guess. Both the significance levels and estimated coefficients remain nearly unchanged. This is good news as it illustrates robustness of those results towards the model specification.

On the other side the fact that four out of the six interaction terms are statistically significant is concerning towards any attempts to generalize our results regarding the odds of correct guess connected to specific emotion. The results show that in our sample of the music snippets there are many other factors than which emotion the snippet expresses which influence the odds of correct guess. While this limits potential to generalize our results, it is not surprising (given our dataset includes only two music snippets per each emotion). However, some patterns still emerge – probability of successfull recognition of disgust is the smallest out of the six emotions for both sets of our music snippets.

9.2.4 Results in light of previous literature

Recognition of emotion in music has been studied before. Our results are novel in two aspects. Firstly, most of existing research focuses on recognition of emotion in already existing music, without focus on creation of music with intention to communicate specific emotions. Secondly, we managed to identify listener level characteristics which influence the successfull recognition of emotions in music snippets created in a controlled setting, which was not the case in similar previous studies (e.g. Mohn et al. (2011) failed to prove any significant impact of listener exposure to music in previous life).

Our results reconfirm findings of previous research that in general music can serve to communicate basic emotions and that sadness and joy are the easiest emotions to communicate in music and allow its generalization to broader context. Also, the results enrich the debate on how much recognition of emotion is learned based on previous experience with music and to what extent it is natural (see Juslin (2013) for example of logic of learned recognition of clues in music) - larger success of listeners trained in playing musical instruments suggests the recognition is learned to some extent, but only through active production of music. This might serve as a basis for further research in neuroscience as it suggests interesting cognitive patterns - while listening to music passively does not help listeners' understanding of music, active reproduction of music does.

10 Conclusions

This thesis evaluates whether music can be used as means to communicate emotions. More specifically, we investigate whether such communication can be succesfull in terms of correct identification of the emotion which was meant to be expressed in music by the composer also by listeners. Also, we investigate whether listeners with larger exposure to music are more successfull in identification of the emotions meant by authors of the music and how complex emotions can be successfully communicated by music.

We used a mixed effect logistic regression model to model the probability of correct identification of the emotion by a listener based on listener level and music snipet level characteristis. The music snipets were created by music professionals in a controled experimental setting as few seconds (up to 10) of instrumental piano music. Each music professional composed and recorded music snippets for 6 pre-defined basic emotions. Later on, the music snippets were played to sample of general population in an online survey and the respondents identified which emotion (again from pre-defined list of the 6 emotions) they felt in the music snipet.

We found that odds of correct identification of the expressed emotion by the listeners were $\sim$5x higher than if the guesses of the listeners were random, therefore we conclude music can be used to successfully communicate emotions to some extent. Morover, listeners who have active experience with music (i.e. playing music instrument) are more succesfull in identification of the emotions with odds of correct guess $\sim$30% higher than people who do not have such experience. This might suggest the identification of clues in music connected to specific emotions is to some extent learned as opposed to natural to people. On the other hand we could not reject null hypothesis that passive experience with music (i.e. listening to music) has no effect on odds of the correct identification of the emotions in music. Similarly age, gender or education do not seem to have any influence. Finally, our analysis suggests most basic emotions (sadness and joy) are more succesfully communicated in music while for more complex emotions (disgust) the communication through music does not work (i.e. odds of correct guess are comparable to random guess). However, we cannot generalize those results (of differences between individual emotions in terms of odds of succesfull commu-

nication) beyond the specific music snippets used in the analysis as larger number of music snippets would be needed to make such a conclusion.
It should be noted our results should be tested also in different settings and research designs to assess universality of the findings. Also, broaded research in this area is needed to enable practical applications - eventually good understanding of recognition of emotion in music and transmission mechanisms of emotions in music can enable utilization of the findings in areas such as marketing, therapy, filmmaking, videogames or anthropology.

Part III

SUMMARY

The objective of this thesis is to investigate how efficient is music as a medium to communicate emotions. Specifically, how complex emotions can be conveyed in a short piece of instrumental piano music and whether the precison of reading emotions in music is increased for individuals who are trained in contemporary music.

Music has emerged in all major human cultures across the world with common elements such as melody or rhythm. At the same time, there is no single universally accepted evolutionary explanation on whether music is only by-product of adaptations to auditory perception, language, motor control and affect, or whether it serves some evolutionary purpose of its own (Mehr et al., 2019). If we assume the latter is true, one of possible explanations of adaptative role of music for human experience lies in communication. Communication is of utmost importance for survival in socially organised human societies. It allows for coordination, but also spreading and preserving of information, knowledge and experience.

Previous research suggests emotions can be succesfully communicated through music, but it is unclear whether this is because of culturally learned clues in music or natural perception of sounds.

We use mixed-effect logistic model to analyse probability of correct identification of six basic emotions — joy, sadness, anger, fear, surprise and disgust — in music by a listener. The explained variable in our model is dummy variable for correct identification of emotion (i.e. 1 for correct identification, 0 for incorrect). The model is based on logic of underlying probabilitic distribution and modelling effect of various factors on the probability of the correct identification of the emotion. Mixed-effect model is sutiable as the success of the communication is influenced both by the communicator (in our case music composer), the encoded message (in our case specific snippet of music) and the reciever (listener). The mixed-effect model allows us to assume random effects to control for the music snippet and composer level variables and focus on listener level variables (such as prvious expirience with music). In our analysis we include listener level variables (basic demographics and variables on pasive and active experience with music), but also music snippet level variables (expressed emotion). As we have only two authors of music in our sample, we do not include composer level variables, but instead we assume random or fixed effects of a specific composer on the resulting probability of successfull communication.

The analysis is carried on a dataset obtained through an online survey, where each of 127 respondents assessed 12 short music snippets. The music snippets were created by music professionals in a controlled experimental setting, where the music professional was always asked to express specific emotion from a pre-defined list thorugh an instrumental piano music snippet of maximum leght of 10 seconds. The music professionals had to compose and record the snippet for each emotion within 10 minutes.

We found out listeners successfully identified the emotions with $\sim$5 times higher odds than if they were guessing randomly. Listeners with active music experience — playing a musical instrument — identified correctly the emotions with $\sim$33% higher odds than rest of the population. Easiest emotion to identify was sadness, while most difficult was disgust. No significant effect on success rate of correct identification of emotions was found for pasive experience with music (i.e. average daily listening times, concerts visited per year). Based on this we can make several conclusions. Firstly, music can be used as a communication medium for emotions. Secondly, while it works well for basic emotions, for more complex emotions the results are mixed. Thirdly, there is some role of learned cues in music in the communication process - people who have experience with active reproduction of music are better at identifying the emotions, however pasive exposure to music does not lead to learning in terms of identification of the emotions in music.

As previous attempts to assess effect of previous experience of listener with music on the probability of successful communication of emotion through music failed, this lays out basis for future research on what specific learned clues in music serve to communicate emotions.

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12 Appendix

ABSTRACT OF THESIS

Title: Communication of Emotion Through Music

Author: Bc. Ondřej Dočkal, M.Phil.

Supervisor: PhDr. Daniel Dostál, Ph.D.

Number of pages and characters: 47 pages, 83 504 characters

Number of appendices: 2

Number of references: 77

Key words: Communication, Music, Emotion

Abstract (800-1200 characters):

Music emerged in all human civilisations without clear evolutionary rationale. One possible explanation is through role of music in communication. Previous research suggests emotions can be communicated through music, but it is unclear whether this is because of culturally learned clues in music or natural perception of sounds. We use mixed-effect logistic model to analyse probability of correct identification of six basic emotions — joy, sadness, anger, fear, surprise and disgust — in music by a listener. The analysis is carried on a dataset obtained through an online survey, where each of 127 respondents assessed 12 short music snippets. The music snippets were created by music professionals in a controlled experimental setting. We found out listeners successfully identified the emotions with $\sim$5 times higher odds than if they were guessing randomly. Listeners with active music experience — playing a musical instrument — identified correctly the emotions with $\sim$33% higher odds than rest of the population. Easiest emotion to identify was sadness, while most difficult was disgust. As previous attempts to assess effect of previous experience of listener with music on the probability of successful communication of emotion through music failed, this lays out basis for future research on what specific learned clues in music serve to communicate emotions.

ABSTRAKT DIPLOMOVÉ PRÁCE

Název práce: Komunikace emocí hudbou

Autor práce: Bc. Ondřej Dočkal, M.Phil.

Vedoucí práce: PhDr. Daniel Dostál, Ph.D.

Počet stran a znaků: 47 pages, 83 504 characters

Počet příloh: 2

Počet titulů použité literatury: 77

Klíčová slova: Komunikace, Hudba, Emoce

Abstrakt (800-1200 zn.):

Hudba vznikla ve všech lidských civilizacích bez jasného evolučního odůvodnění. Jedno z možných vysvětlení je v roli hudby v komunikaci. Existující literatura naznačuje, že emoce mohou být komunikovány hudbou, ale není jasné, zda je to díky kulturně specifickým naučeným vzorcům v hudbě nebo díky přirozenému vnímání zvuků. Používáme logistický model se smíšenými efekty k analýze pravděpodobnosti správné identifikace šesti základních emocí – radosti, smutku, zlosti, strachu, překvapení a znechucení – v hudbě posluchačem. Analýza je provedena na datasetu získaném z online dotazníku, kde 127 respondentů hodnotilo 12 krátkých útržků hudby. Útržky byly vytvořeny profesionálními muzikanty v kontrolovaném experimentálním prostředí. Zjistili jsme, že posluchači identifikovali emoce $\sim$5 krát úspěšněji, než by odpovídalo náhodnému hádání. Posluchači s aktivní zkušeností s hudbou – hrající na hudební nástroj – identifikovali správně emoce s o $\sim$33% vyšší šancí než zbytek populace. Nejjedodušší emoce k uhádnutí byl smutek a nejsložitější naopak znechucení. Vzhledem k tomu, že předchozí empirické pokusy posoudit vliv předchozí zkušenosti s hudbou na pravděpodobnost úspěšné komunikace emocí hudbou selhaly, naše výsledky dávají základ k budoucímu výzkumu – jaké přesně naučené znaky v hudbě komunikují emoce.