Faculty of Social Sciences

Emotions, breathing and all that jazz:

Investigating the effects of music on emotions and respiration

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Abstract

Music seems to have a significant effect on our emotions, but not everyone experiences music in the same way. Emotion can be measured by examining the emotions themselves, but this method may be insufficient because of self-report biases. Another way to measure emotions is through their somatic underpinnings. In this research, we focus on measuring the effect of individually selected music on emotions and respiration as their somatic marker. We specifically focus on the extent in which emotionally charged music influences one's respiration and the emotional dimensions valence (negative vs. positive affect) and arousal (not-active vs. active affect) states.

The participants listened to either two happy and two sad songs, or to two calm and two annoying songs. They indicated their valence and arousal with the Self-Assessment Manikin (SAM) questionnaire during baseline and after each song. Respiration values were measured with two piezoelectric respiration sensors, placed on the chest and on the abdomen.

The results revealed that music experienced as sad or annoying causes them to experience less positive emotions (low valence levels). The results also revealed a tendency that happy and calm music causes one to experience more positive emotions, but these results were not significant. Furthermore, the results suggest that sad music decreases the respiration peak to peak distance, meaning that it increases the respiration rate. Happy music seems to have similar effects, but this was not significant. The order of the music seemingly did not have significant effects on experienced emotions or respiration features.

In conclusion, music does have an effect on the positivity of experienced emotions and on at least one of the respiration features. The results of this thesis strengthen the idea that these effects may depend on emotional associations with music, as the songs were self-selected. Further but similar research should be conducted with a greater sample size.

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Chapter 1: Introduction

Beauty is in the eye of the beholder – and the same principle goes for music. Not everyone experiences music in the same way. However, one way or another, music seems to have a significant effect on our emotions. One can describe an experience of nostalgia or sadness while listening to certain songs. Yet, in the scientific field there exists a long debate on this matter. There are two prominent theories in play: emotivism and cognitivism. Emotivists are convinced that music can elicit emotional responses in listeners, independently of the expressed emotion. On the other hand, cognitivists believe that listeners can only identify the emotions that are expressed in a song, not experience these emotions (Krumhansl, 1997). This distinction is important, as in the first case music can have a direct influence on a person's affective states, whereas in the second, it can not. However, for the experiment in this research, we will assume the emotivist theory.

There are multiple reasons why this assumption can be substantiated. In the eighties, researchers let participants listen to music and plainly ask them to describe the emotions they were feeling through questionnaires (Goldstein, 1980; Davis & Thaut, 1989). This method has certain disadvantages. For example, listeners could accidentally report the emotion they *think* they are supposed to feel based on what they assume the music tried to express. Or they have difficulty with accurately reporting their emotions.

Thus, we are in need of additional methods to measure emotions. For instance, we could observe somatic aspects of emotions. Numerous research has been done on the physiological correlates of emotions. For example, people with a more negative affective style have a different immune response compared to people with other affective styles (Barak, 2006). More specifically, an interesting somatic underpinning of emotions is respiration. Homma and Masaoka (2008) summarized a range of literature demonstrating how emotions evoke respirational changes. One example is that people breathe more rapidly during an arousal state, as is expected. Another review states a number of studies that show that the respiration rate increases during fear, anxiety and anger (Boiten, Frijda & Wientjes, 1994).

Research on the effect of music on these emotionally evoked physiological changes showed that music listening elicits positive emotion and a slower respiration rate (Baltes, Avram, Miclea & Miu, 2011). These studies seem to indicate that emotions do influence respiration and that music in some way plays a role in this causality. But some questions remain unanswered: *in which way* does music influence emotions and thus respiration? And, more specifically: which aspects of music evoke the involved emotions?

It may be possible that music has an influence on respiration while bypassing the step of emotions as a mediator at all. However, it seems logical that all three are connected in a reciprocal relation. For this reason, it is interesting to find out to which extent music influences emotions, and to which extent emotions influence respiration. And, finally, to explore the potential (non-causal) correlation between the experienced emotions and respiration. To create an overview of the connection between these three factors, the following research question is formulated:

> To what extent does self-selected emotionally charged music influence one's respiration and emotional states?

Here, "self-selected" refers to the fact that in this study, participants chose the songs that they will listen to. "Emotionally charged" addresses the fact that the participants were asked to select songs that make them feel a certain kind of way – songs that are associated with personal emotions. The reasons for these research design choices will be explained in chapter 2, "Theoretical framework" and chapter 3, "The experiment: methodology".

Understanding the connection between music, respiration and affective states is not only relevant to expand evidence on the physiological underpinnings of affective states. Why specifically research respiration as an autonomic measure? Firstly, influencing one's respiration could be used to influence mental and physical health. Respiration is not only an automatic function of the body, but it can also be controlled. If we learn how we can control our emotional state by influencing our respiration through listening to specific music, we could use this in a clinical setting. For instance, Gillespie et al. (2012) showed that slow, deep respiration as used in mindfulness techniques affects vagal modulation of the heart and even the functioning of certain neural circuits of the prefrontal cortex and amygdala, which are involved in emotional regulation.

Secondly, the analysis of respiration patterns could contribute to pattern recognition. A better understanding of respiration patterns could be used in addition to clinical assessment to diagnose mental illness in patients with unclear psychological symptoms. Or, the respiration recordings collected here can advance other automatic emotion processing algorithms. In this way, this research can contribute to the scope of research that has been done in the fields of AI and psychology.

Lastly, focus on respiration is relevant because the research on it is only starting to expand recently, unlike the research on other somatic markers (for example, the galvanic skin response). This research will thus provide new findings to the research already done regarding the effects of music. Where existing research mainly focuses on the internal aspects of music, the current research builds on the fact that emotion elicitation by music may be mainly caused by the personal associations people have with music and not by objective factors in the music. With this in mind, we had participants choose their own music, whereas former research focused on experimenter-chosen music or played the same music to all participants.

To find a structured and academically grounded answer to the research question, some sub-questions must be answered. Firstly, to substantiate the emotivist view, we will have to look into to what extent music does induce emotions (1). Secondly, it is important to research the extent to which emotions influence respiration (2). Thirdly, we will research to what extent music influences both respiration and emotions together (3). The answers to these questions will be based on existing literature. Finally, we will construct an answer to the question of to what extent self-selected emotionally charged songs influence respiration and emotional dimensions (Q4). This last question will be based on the answers brought by the literature research and on the music-listening experiment. In this way, the first three sub-questions are intended to embed the fourth question, with which we can formulate an answer to the main research question.

Outline and main contribution

In chapter 2, “Theoretical framework”, we will look into the first three sub-questions by exploring existing literature on the topic of emotions, music and respiration. In chapter 3, we will explain the methodology of our current experiment. In chapter 4, we discuss the results of our experiment. Chapter 5 consists of a general conclusion, in which the main research question will be answered.

The main purpose of this thesis is to contribute to the scope of research that has already been done on eliciting emotions through music, and to expand knowledge about the way that emotions influence autonomic functions, specifically, respiration. Compared to existing literature, this research will shed light on the influence of personal emotional association as a specific emotion-elicitation method, on respiration. This will open practical gateways to ultimately influence autonomic functions through emotion elicitation, or even vice versa.

Chapter 2: Theoretical framework

In chapter 2, we will discuss the existing literature to answer the first three sub-questions: 1) to what extent does music induce emotions, 2) to what extent do emotions influence respiration and 3) to what extent does music influence both respiration and emotions?

Subsection 2.1 – Music and emotion elicitation

In this subsection, we will explore the extent to which music induces emotions. In order to do so, we will build on the emotivist view on emotion elicitation: music does not only have the power to convey emotions, but can really evoke them within the listener. Within this view, however, there is no complete clarity on the extent to which emotions are evoked by music.

The use of music listening in emotion elicitation has gained ground in the last decades. In 1980, Goldstein researched how music can elicit emotional responses in the form of so-called "thrills" – a tingling sensation or chill on the body. He conducted a questionnaire that participants had to fill out while listening to music. The participants indicated that certain music gave them thrills through the association with an emotionally charged event or person in the subject's past. Goldstein's research exhibits a clear example of how music is emotionally charged and can even elicit bodily responses.

In later studies, the focus was shifted to evoke specific emotions. In a study, subjects could select music they found to be relaxing (Davis & Thaut, 1989). They had to fill in an anxiety and relaxation questionnaire before and after listening to their self-chosen musical excerpts. Their musical excerpts were all played one after another, for a maximum time of twenty minutes. It became clear that their subjectively reported anxiety significantly decreased after listening. Relaxation also decreased, albeit not significantly. This can be explained by a range of things. For example, the anticipation of the fact that they *knew* the music was supposed to relax them, flattened the true effect of their reported relaxation; or that not every emotion can be influenced by music listening. Or, it could be that not the music but just sitting down for twenty minutes made the participants less anxious than they were at the beginning of the experiment. These results could support the cognitivist theory, but may also be caused by poor measurement of emotions; discrete emotion categories, like "anxiety" or "relaxation", may have different meanings for separate individuals.

To overcome these categorical problems, researchers started looking at emotions from a more dimensional perspective. The start of this perspective was already set out by James Russell in 1980. In his circumplex model, emotions are distributed in two dimensions in a circular space: valence and arousal. The center of the circle represents a medium level of arousal and valence. The two values of an emotion can lie on any point in this circle. An example of this model is presented in figure 1 (based on Russell, 1980; Russell & Barrett, 1999; Egger, Ley & Hanke, 2019). The x-axis represents valence, operating from most negative to most positive valence. The y-axis represents arousal, ranging from lowest to highest activity. An emotion as anger, for instance, could then be plotted high on the arousal scale and high on the negative valence scale.

The advantages of the use of dimensional values are that they are more universal and less ambiguous than discrete emotional categories like fear or anger (Russell and Barrett, 1999; Thomson & Coates, 2021). Russell and Barrett (1999) substantiated their dimensional model on the idea that emotion is too broad a class of events to be a single scientific category. An emotion has too many different ways of manifesting itself – the boundaries of the discrete

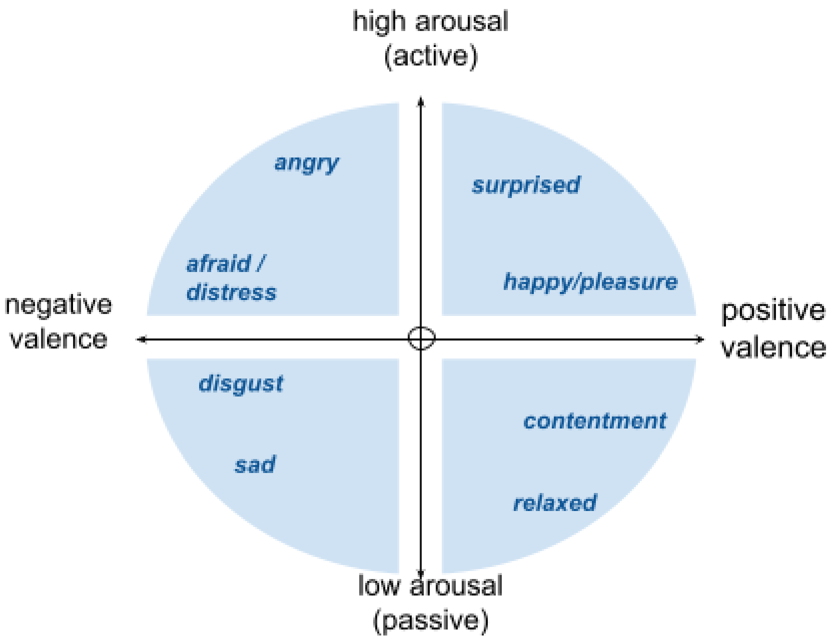


Figure 1. The circumplex model. The x-axis represents valence, where the most negative valence score is to the left side and the most positive score to the right. The y-axis represents arousal. The most active score is on the top and the most passive score on the bottom. The middle of the circle represents a neutral level of both valence and arousal. The words in blue represent where categorical emotions could fall in regard to these dimensions.

concept of emotions are blurry. This makes it harder to conceptualize it and thus to measure it in a valid and reliable way. Different emotional categories may overlap as boundaries are vague. However, arousal and valence are dimensional and thus circumvent the problem of boundaries. Discrete categorical emotions may overlap which makes it harder for individuals to differentiate between them. By describing emotions with two-dimensional components, the differentiation becomes less ambiguous. The circumplex model adds to these benefits by making it possible to map out the discrete emotion categories – also called 'prototypical emotional episodes' by Russell and Barrett – based on where they typically would fall in the dimensional values (Russell & Barrett, 1999). The last important advantage of using the dimensional model is that someone is always in a certain state of arousal or valence but not necessarily always in a certain level of anger or sadness. When someone describes their affective state, their description will probably be more valid and reliable when using dimensions of emotion.

A research that made use of these dimensional emotions let ninety-nine participants listen to twenty-five classical music excerpts (Kreutz et al., 2007). These excerpts represented either happiness, sadness, fear, anger and peace. The songs were assigned to the happy and sad categories based on existing literature, and the other excerpts were assessed by the authors themselves. The participants had to indicate how intense they felt these emotions and they had to rate valence and arousal. In twenty out of twenty five of the excerpts, participants gave significantly higher ratings for the emotion that was intended to be induced, compared to the other emotions. This means, for instance, that music categorized as sad, induced sadness in the participants. However, valence and arousal measurements revealed partly different findings.

Excerpts of the happy category caused high valence and high arousal. Excerpts that induced fear and anger had a low valence and high arousal. Excerpts inducing peacefulness and sadness both had high valence and low arousal. Thus, sad excerpts induced positive affect. This seems contradictory to the expectations, as sadness is characterized by low valence according to the circumplex model. Another study tried to explain this contradictory finding (Kawakami, Furukawa & Okanoya, 2014). Participants had to report how they perceived three classical music pieces. They also had to report how the music made them feel, by rating the extent to which they agreed with emotion-related descriptive words and phrases.

The results uncovered that sad music was perceived as tragic, but not felt as tragic (e.g. as miserable). Moreover, participants indicated to feel more romantic emotions (e.g.

fascinated and in love) than tragic emotions. They list a few explanations for the fact that people experience both pleasant and sad emotions when listening to sad music. One of them is that people tend to anticipate what is coming next, when listening to music. When the expectation is violated or confirmed, this evokes certain emotions. When confirmed, it elicits positive emotions, a phenomenon also known as “sweet anticipation”. Another explanation is that emotions evoked by music are not considered as “real-life” emotions. When people know they are listening to sad music, they may not experience *true* sadness. The last explanation is that music is considered as art; the aesthetic aspects of music may be experienced as pleasant, even when the music is sad.

Thus, these studies have shown that music may elicit emotions. Other evidence that music evokes emotions is brought upon by the discipline of neuroscience. Scientists have found that the amygdala, well known for its role in emotion processing, is involved while listening to music (Koelsch, 2014). The same review states specifically that music-evoked pleasure is associated with activity in the dopaminergic mesolimbic reward pathway. This pathway belongs to an important reward network, together with the ventromedial orbitofrontal cortex, the anterior cingulate cortex, the amygdala, the anterior insula and the mediodorsal thalamus. This review furthermore found that musical tension arises from internal aspects of the music. For example, when progressing tones and harmonies are played, predictions that the listener had regarding the music are violated, and thus the tension grows. Next to internal aspects of the music, they found that the hippocampus – essential for the creation and processing of memories – plays a role in the generation of emotions. The hippocampus is active when music evokes social or attachment-related emotions, like love, joy, compassion, empathy and sadness. As the hippocampus plays an important role in memory, this suggests that emotions may be connected to memory–associations. And lastly, they found that the auditory cortex even has specific connections with a range of other structures in the brain that are involved in emotion processing. The auditory system of the human seems to be *programmed* to process emotions.

In conclusion, music seems to be able to induce different types of emotions. For example, anxiety decreases after listening to relaxing music. Research revealed that music classified as happy, fearful, angry and peaceful all seem to induce the intended emotion. Fearful and angry music is characterized by a low valence and high arousal. Peaceful music is characterized by a high valence and low arousal. Sad music, interestingly, seems to be characterized by a low arousal and high valence as well. This seems counter-intuitive, but could be explained by the fact that we feel satisfied when music that we expected to be sad truly is sad. It could also be explained by the fact that music can be aesthetically pleasing and does not elicit real-life emotions.

Furthermore, when music is played, parts of the brain that are involved in emotional processing are active. For instance, the hippocampus plays a role in memories and therefore also in associations. Music-evoked emotions that trigger hippocampal activity are more social or attachment emotions like tenderness, joy and sadness. The effect of emotion induction through music is especially present if you measure emotions not from a categorical but a dimensional perspective. For our experiment, we will thus use the circumplex model to measure emotional dimensions.

Subsection 2.2 – Emotions and respiration

Now that we have substantiated the assumption that music influences emotions, we can build on this. In this subsection, we make an effort to explain the link between emotions and respiration. This is relevant to understand, because we want to know whether emotions indeed show themselves physiologically in the form of changes in respiration. If that is the case, this would offer a possible explanation for *how* music changes respiration patterns – through emotion elicitation.

In daily speech, there are numerous expressions and terms that link respiration with emotions. Think of “to hold one’s breath”, “take my breath away”, “breathe easily” or “waiting with bated breath”. Furthermore, breath is used to imply boredom or annoyance by sighing or to indicate a surprised, shocked or startled affect when gasping for air. And indeed, in the introduction we already spoke about how there seems to be an established link between emotions and respiration in science too.

Boiten, Frijda and Wientjes (1994) describe three models regarding the relationship between emotions and physiological parameters. The first is called the specificity model, which claims that specific emotions are associated with specific respiration patterns – and these patterns differentiate between the emotions. The second model is the dimensional model, which harks back to the dimensional model we already spoke about in subsection 2.1. It assumes that respiration patterns are related to dimensions of emotions, like pleasant–unpleasant or low arousal–high arousal. The response requirement model states that respiration patterns correspond to particular response requirements of the given emotional situation. In other words, an emotional situation can evoke different bodily responses based on what is required of the individual to ‘survive’ the emotional situation. For example, the emotion ‘sad’ can trigger either a flight or fight response in different situations. According to this model, emotions can be accompanied by certain respirational patterns, but it still depends on the emotional situation. With these different models in mind, we will zoom in on the connection between emotional states and the respiration rate and depth.

Respiration rate and depth

We will discuss the results of different studies on the effects of various emotions on respiration rate and depth. In the review by Boiten, Frijda and Wientjes (1994) is described how as early as 1911 researchers (Rehwoldt) asked participants to imagine emotions. These emotions were classified by the participants as positive or negative, and as calm, excited or tense. Tense emotions, like hope and suspense, were associated with a higher respiration rate, whether negative or positive. Excited negative emotions like anger and fear resulted in an increase of respiration rate as well and an increased depth. Calm emotions tended to go with a decrease in respiration rate and depth. However, this study was based on three subjects who self-reported these dimensions of emotions.

A few decades later, Ruckmick (in Jastrow, 1936) let his participants view faces with pleasant emotional expressions. His observations were that they adapted a fast and shallow respiration pattern while doing this. In 1953, Ax showed how fear and anger increased the respiration rate and depth. The rate increased more strongly with anger than fear.

Schachter (1957) replicated Ax' (1953) study, but added pain as a stimulus by conducting a cold pressor test. That fear and anger strongly increase the respiration were confirmed in his study. With pain, however, there was a smaller increase in respiration rate. Dudley et al. (1964) tried to examine the relationship between emotions and respiration from a different angle: they induced emotions through hypnosis. They found that also in a hypnotic state, anger and anxiety increased respiration rate. Pain only increased the respiration rate when there was noticeable unconcealed anger or anxiety, caused by the pain. Pain thus seems to trigger a change in respiration rate only when it triggers accompanying emotions. He also induced relaxation, which caused a decrease in respiration rate.

Later, other researchers built on hypnosis as a method of induction. Freeman et al. (1986) hypnotized patients with hyperventilation syndrome and a control group. They used images that participants picked out beforehand, which are meaningful to each of the participants. While showing the images, both groups had an increase in respiration rate – which was stronger compared to when relaxation was induced. In the same year, Santibañez and Bloch (1986) researched both awake and hypnotized participants. They made their participants recall emotional events. With fearful and anxious events, the participants significantly showed shallower respiration. Anger increased the respiration rate, but showed no changes in depth. Sad participants, while actively crying, and happy participants, while laughing, both showed an increase in depth. Furthermore, as to be expected, there were specific forms of respiration for crying and laughing. Crying participants showed high frequency oscillations while breathing in, whereas laughing participants showed high frequency oscillations while breathing out.

Later on in the research on respiration, reviews and meta-analyses began to arise. Kreibig (2010) made an overview of modal autonomic responses to different emotions, based on 134 articles. Among other autonomic responses, she reviewed which was the most common effect on respiration rate and depth of a range of emotions. The emotions that are the most important for the current research are as follows: anger increases the respiration rate but seems to have a variable depth. This may have to do with the fact that anger can also be covert and overt. Fear, as anger, also evoked a higher respiration rate and a variable depth. Anxiety increased the respiration rate but decreased respiration depth. Sadness while crying increased the respiration rate and decreased the respiration depth. Non-crying sadness also showed a higher respiration rate but evoked a more deep respiration pattern. Amusement and happiness both increased the respiration rate, but the depth was again variable. Kreibig (2010) did not review relaxation on itself, but did review contentment, in which he included relaxation, calmness and pleasure. His results on this, however, were not conclusive, as contentment seemed to both increase and decrease respiration rate and depth. On the contrary, the review by Boiten, Frijda & Wientjes did find that respiration rate tends to decrease in relaxation (Boiten, Frijda & Wientjes, 1994). This is in line with the results of the early sixties' hypnosis research (Dudley, 1964; Freeman et al., 1986). The differences between the results of Boiten, Frijda & Wientjes (1994) and Kreibig (2010) may exist because relaxation and calmness are dimensionally very different from pleasure, but they were grouped together by Kreibig (2010).

In reviewing this literature, a pattern seems to arise: emotions that are 'active' emotions with medium to high arousal, such as fear, anger, happiness and (crying) sadness, all increase the respiration rate, in spite of their valence level. Regarding the role that valence plays in respirational changes, Boiten, Frijda & Wientjes (1994) conclude from their analysis that mainly respiration depth seems to be influenced by valence. They found that excitement (*positive*) provoked by a stressful situation, is associated with rapid but deep breathing, while tenseness (*negative*) is associated with rapid shallow breathing.

Thus, the level of arousal of an emotion seems to influence the respiration rate the most, while valence and the function of the emotional response (fight or flight) have more influence on the respiration depth. This is in line with the dimension and response requirement model by Boiten, Frijda and Wientjes (1994).

Respiration regularity

Not only respiration rate, but also the regularity of respiration differs when different emotions are elicited. Stevenson and Ripley (1952) found this effect in people suffering from anxiety disorders. Their participants showed more irregular respiration, particularly when they were angry. Of course, this does not have to imply that there is a causal relationship between emotions and respiration. In later years, experiments were conducted to research the causality between the two. Santibañez and Bloch (1986) not only measured the respiration rate of their hypnotized and awake participants, but also respiration regularity. They found that certain specific emotions coincided with a more irregular respiration pattern. They found that participants who were crying while they were sad, or laughing when they were happy, had an irregular respiratory pattern. This makes sense, as we tend to breathe in a typical way when laughing or crying actively. However, they also found an irregular pattern with anger and fear. This seems to be in line with Stevenson and Ripley's (1952) findings. Boiten, Frijda & Wientjes (1994)'s review also stated that when excited or fearful emotions were elicited, the respiration became more irregular.

In conclusion, irregularity of respiration seems to increase when someone is experiencing negative emotions that are high in arousal, or when someone is crying or laughing.

Emotion recognition through respiration

Other researchers investigated if people are better at recognizing emotions when specific respiration patterns occur (De Melo, Kenny & Gratch, 2010). They developed virtual humans as a model to simulate respiration. Respiration was simulated by animating respiration videograpically. Fourteen emotions and their accompanying respiration patterns – as described in the literature – were chosen: excitement, relaxation, focus, pain, relief, boredom, anger, fear, panic, disgust, surprise, startle, sadness and joy. They used several respiration parameters: respiration rate, respiration depth and respiration curve, which defines how the depth differs over the respiration cycle. The researchers showed videos of the virtual humans expressing emotions with or without these respiration patterns. For example, a virtual human showing sadness, would display a sad facial expression and neutral posture without visible respiration in the control condition. In the respiration condition, the agent had a slow and deep respiration. The participants had to state which emotion they were perceiving in the agents. The results of the study showed that it was easier to detect emotion when the agents were displaying excitement, pain, relief, anger, fear, panic, boredom and startle. There was no significant difference for relaxation, disgust, surprise, sadness and joy and even a negative effect regarding perceiving focus correctly.

Even though these results were not significant for every emotion they tried to portray, they do make clear that humans use some sort of induction of one's emotions by observing the respiration.

In short, these results suggest that emotions do influence respiration in a variety of ways. There are different theories on how respiration is influenced, for example that each discrete emotion has a specific respiration pattern, or that each emotional dimension level is accompanied by a certain respiration pattern or that it depends on the required fight–flight response. The results of numerous studies over the years seem to point to a combination of the second and the third theory.

Based on the literature, it seems that negative emotions where people are aroused, like anger and fear, seem to increase respiration rate and depth. However, recent research shows that fear also can cause shallow breathing, for example during anxiety. The depth in fearful emotions thus seems to be variable, and depends on what type of fear is at play. This seems to be in line with the second and third theory. The effect of sadness on respiration most likely depends on whether there is crying involved or not. Crying sadness increases the respiration rate, and probably lowers the depth, even though the literature on this is ambiguous. Non-crying sadness also increases the respiration rate and increases respiration depth. Happiness seems to heighten the respiration rate, but causes a variable respiration depth. Relaxation seems to decrease the respiration rate. Each of these categorical emotions are coupled with their dimensional arousal and valence values (indicated with 'low', 'medium' or 'high') in table 1, as this overview will be useful to formulate hypotheses for the experiment and to compare the results with current literature (based on Russell, 1980; Russell & Barrett, 1999; Egger, Ley & Hanke, 2019).

	Emotional dimension		Respiration feature		
Emotion	Valence	Arousal	Respiration rate	Respiration depth	Respiration regularity
Anger	Low	High	Increase	Increase	Potentially irregular
Fear	Low	High	Increase	Increase	Potentially irregular
Anxiety	Low	Medium to high	Increase	Decrease	*Unclear*
Crying sadness	Low	Medium to high	Increase	Variable	Irregular
Non-crying sadness	Low	Low to medium	Increase	Variable	*Unclear*
Calmness	Medium to high	Low	Decrease	Decrease	*Unclear*
Happiness	High	Medium to high	Increase	Variable	Irregular (when laughing)

Table 1. An overview of the effects of emotions on emotional dimensions (valence and arousal) and on respiration features, based on existing literature.

Subsection 2.3 – Music, respiration and emotions

Now that we have established a grounding on how music influences emotions and how emotions influence respiration, we can examine the relationship between all three. The aim of this subsection is therefore to construct an answer to the following question: to what extent does music influence both respiration and emotions together? This subsection differentiates itself from the previous two subsections by basing the answer on existing literature that specifically focused on music and respiration together.

Back in 1969, Ries already studied the effect of emotional reactions to music on the respiration amplitude. He recorded the respiratory reactions of nineteen subjects while they listened to a variety of complete songs. The subjects had to rate the music in terms of its affective reaction (liking or disliking) and effective reaction (did they feel like it had an effect on them or not). They found two significant correlations. The first one was a positive relationship between the modal respiration amplitude and affective responses to music, which means that the more a subject likes a musical selection, the deeper his respiration tends to become. The second relationship was a positive one between the modal respiration amplitude and effective responses to music, which means that the more a subject reports being affected by the music, the deeper his respiration becomes.

Krumhansl (1997) also measured respiration – among other autonomic functions – while participants were listening to music. This music was judged beforehand to belong to a category of either happiness, sadness or fear representation. The participants had to indicate how they felt while listening to the music. The correlations between the pre-selected emotion category and the subjectively reported emotions were all significantly high.

The results showed that the respiration rate increased for all three emotions. The same counts for the decrease of respiration depth and respiration–sinus asynchrony. However, happy and fearful songs were related to the biggest change in respiration rate, compared to sad music. Happy music fragments had a big effect on the respiration depth, compared to the other two types of music.

Baltes, Avram, Miclea & Miu (2011) showed that music listening elicits positive emotion and a lower respiration rate. However, they also found that participants who were told about the sad plot of the song, actually had reduced positive emotions while listening to the music a second time, but the autonomic arousal was maintained.

We can conclude that research on emotions associated with music and respiration showed that respiration can either become deeper or more shallow for a range of emotions and that there are no clear directions in this. This may depend on how emotionally affected people are by the music; emotion elicitation intensity brought on by the music seems to have an effect on the respiration. Furthermore, research showed that music can elicit happy, sad and fearful emotions and that these all increase the respiration rate. Respiration rate tends to increase regardless of the reported positivity of emotions that are experienced.

Even though these results are partly in line with the results of subsection 2.1, “Music and emotions” and 2.2, “Emotions and respiration”, subsection 2.1 revealed that sad music can also elicit positive emotions. This may indicate that the increase of respiration rate during sad music is due to the experienced high valence. However, subsection 2.2 showed that the increase in respiration rate is also seen when inducing sadness through other ways than music. In these situations, reported valence probably was lower. This may indicate that respiration rate does not depend on experienced valence levels.

This chapter revealed that music can induce emotions. Parts of the brain that are involved in emotion processing become active when one listens to music. The effect of emotion induction through music is especially present if you measure emotions not from a categorical but a dimensional perspective. Furthermore, research on emotions and respiration show that music-induced emotions with a high arousal and low valence seem to increase respiration rate. Emotions with high arousal and high valence, like happiness, also increase respiration rate. Additionally, as stated in the paragraph above, sadness is expected to induce a low valence and relatively low arousal, but can also induce high valence levels. In both cases, sadness increases respiration rate. Lastly, relaxing music, characterized by low arousal and medium to high valence levels, seems to decrease the respiration rate.

Chapter 3: The experiment – methodology

In this chapter, the experiment design will be discussed. First, we will go into the objective and chosen variables. Then we will treat the selection of participants, the instruments, experiment procedure, data analysis and the experiment set-up.

Experiment objective and variables

The goal of chapter 3 and chapter 4, "Experiment results", is to shed light on whether and how self-reported emotionally charged songs influence respiration and emotions. The objective of the experiment is to examine to what extent the types of self-selected music truly elicit emotional responses, expressed in the dimensions of valence and arousal, and to what extent they change certain respirational features that may underlie these emotions. We chose this design based on existing literature, which showed that little research has been done on the associative-emotional aspect of music and because dimensional emotion measurement is more specific than prototypical emotion measurement.

In order to do this, we conducted an experiment in which two groups of participants had to listen to four different emotional types of self-selected music: either music they found to be happy or sad, or music they found to be calm or annoying. While listening, the participants' respiration and afterwards, emotions were measured.

We chose these four emotions to represent all four quadrants of the circumplex model: happiness representing (medium to) high arousal and high valence; sadness low (to medium) arousal and low valence; calm representing low arousal and (medium to) high valence; and annoying representing high arousal and low valence, visualized in figure 2. For the rest of this thesis, these four emotion categories are referred to by the term *emotionally charged music categories*.

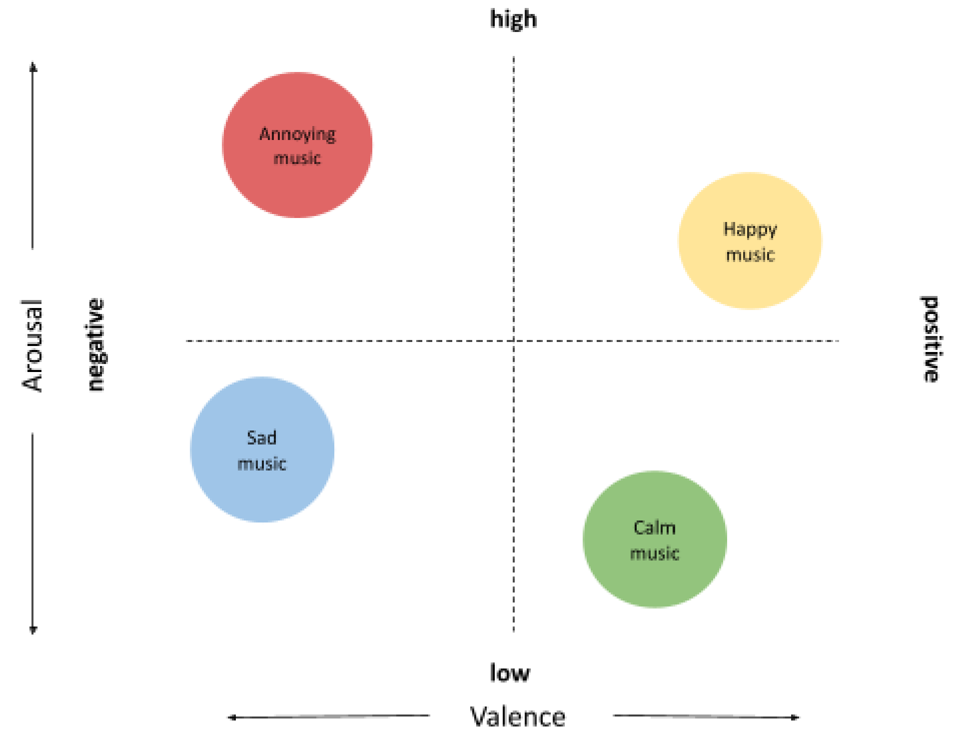


Figure 2. The circumplex model, with estimated and expected dimensional scores of the four relevant emotions. The x-axis represents valence, where the most negative valence score is to the left side and the most positive score to the right. The y-axis represents arousal. The most active score is on the top of the graph and the most passive score on the bottom. Happiness is estimated to consist of medium to high arousal and high valence levels; sadness of low to medium arousal and low valence levels; calm of low arousal and medium to high valence levels; and annoying of high arousal and low valence levels.

Instead of making participants choose music that made them angry, we let them choose annoying songs. In this case, annoyance probably is a more realistic representation of anger-like emotions, as it may be hard to elicit true anger with music. We coupled happy with sad music and calm with annoying music because these are diagonally opposing each other in the arousal and valence circumplex model, indicating a relevant difference in both arousal and valence levels between the types of music.

For the breathing features, we chose respiration frequency (in breath cycles per minute) and peak to peak distance (in seconds) to represent respiration rate. Furthermore, we calculated the slope of each inhalation to represent inhalation speed, as this may be influenced differently than respiration rate when listening to certain music. For the depth, we calculated a proportional measure by adding the peak and minimum amplitude values of a respiration cycle together (in volt). Lastly, we calculated each participant's standard deviation of the peak to peak differences as an estimated measure of mean respiration variation (in seconds). This served as a reflection of the regularity of the breathing patterns: the higher the variation, the more irregular the breathing pattern (frequency–wise).

We expect happy music to increase the valence and slightly increase arousal compared to when sad or no music is played. Sad music should decrease valence and have a medium high arousal. Calm music is expected to go along with a low arousal and a medium to high valence. Lastly, we expect annoying music to strongly decrease valence and increase arousal, compared to when calm or no music is played.

Furthermore, we expected happy, sad and annoying music to increase the respiration rate, and calm music to decrease respiration rate. Happy music should increase respiration depth, whereas we have no specific expectations for the effect of sad and annoying music on depth. We expect calm music to decrease respiration depth.

Participants

In total, twenty-two people completed a preliminary digital survey. Two people could not partake in the experiment because of logistic or planning reasons. This brings the total number of participants partaking in the experiment to twenty (N = 20). Of those, nine were men (45%), ten were women (50%) and one person indicated their gender as 'other' (5%). They mostly consisted of university students and their age ranged from between 18–21 years old (40%), to 22–25 years old (55%) and 26–29 years old (5%) (mode: 22–25 years), see table 2. The participants were collected through convenience sampling, by sending an e-mail or social media message to direct contacts of the researchers. The participants were randomized into one of both groups through the automatic programmed randomization of two different versions of the survey. Because of this, one group underwent the baseline, annoyed and relaxed conditions, whereas the other group underwent the baseline, happy and sad conditions. These four emotions were divided into two groups because it did not seem ethically and academically feasible to let the participants undergo four different emotions in a short period of time. The participants' respiration, arousal and valence were measured during baseline and throughout the experiment.

Participants were excluded if they had currently active diagnosed muscle or lung disorders (e.g. COPD, asthma) or if they had other factors at play that lead to respiratory problems. Furthermore, people with diagnosed hearing problems were excluded.

Participants' descriptives		
Age groups	Frequency (N)	Percentage (%)
18–21	8	40
22–25	11	55
26–29	1	5
Gender		
Female	10	50
Male	9	45
Other	1	5
Total	20	100

Table 2. The descriptive statistics of the participants. In the outer left column, the ages of the participants are depicted (in a range of 3 years) in the upper rows and the gender in the lower rows. In the middle column, the number of participants pertaining to that age group or gender are noted. In the right columns, these numbers are displayed in the form of a percentage.

Instruments

The music was participant-selected through the preliminary digital survey. As there were two groups of participants, there were two versions of the survey: one that asked for them to fill in sad and happy songs, and one that asked for relaxed and annoying songs. Participants were randomly and evenly divided into one of either groups, through a randomizing option in the survey. In this survey they were asked to choose at least three songs for each category (happy and sad; relaxed and annoyed). They were explicitly asked to not choose songs based on what they think the artist wanted to represent or express, but to really consider what the music makes *them* feel. With every selected song, they also had to fill in a scale from 1–5 how intensely it makes them feel that emotion (e.g. 1: a little bit happy; 5: extremely happy). After they submitted their questionnaire answers, two ninety-second fragments of two of the three songs were selected, preferably containing a verse, chorus and, if possible, a bridge. The two songs that were chosen were the ones with the highest intensity rating. If there were two ratings of the same intensity, the first of the two songs in the list was picked. The songs and their corresponding emotion category are depicted in appendix 1, tables 1–4.

In total, each participant listened to four of their own personalized song fragments, as they listened to two songs of two conditions. The last three seconds of each fragment had a fade-out effect to prevent an abrupt ending of the music. The fragments were presented over headphones, to prevent external auditory distraction and to prevent music-noise from entering the microphone. The participants could adjust the sound intensity beforehand during a practice round with a researcher chosen song ("Hey Soul Sister" by Train).

The affective states of the participants were measured through a digital version of the Self-Assessment Manikin (SAM). This 9-point pictorial scale measured valence and arousal values. In the valence questionnaire, the first picture indicated the lowest level of valence, whereas the ninth picture indicated the highest level of valence. There was a similar order in the arousal questionnaire. Examples of this questionnaire are pictured in figure 3 (based on Bradley & Lang, 1994 and Soares et al., 2013).

Respiration was measured with the biosignalsplux© piezoelectric respiration sensor (PZT: a respiration belt) and a bluetooth controlled microphone attached to the neck. One PZT was placed around the thorax and one around the abdomen. Based on research by biosignalsplux© on when peak to peak amplitude is highest, we placed the thoracic sensor on the lateral side of the body two centimeters under the nipple line (PLUX – Wireless Biosignals, 2020). For the same reason, we placed the abdominal sensor frontally, between the eighth and tenth rib. The locations of the sensors are visualized in figure 4. The movement signals (in volt) were recorded in OpenSignals (r)evolution (PLUX – Wireless Biosignals, 2020). The sensors could measure signals in the range of –1.5 volt to 1.5 volt. The microphone receiver was connected to a Canon Legria HF650 video camera, so that the audio and video were synchronously recorded. Calibration measurement was done by instructing each participant to inhale and exhale as deep as possible for multiple times.

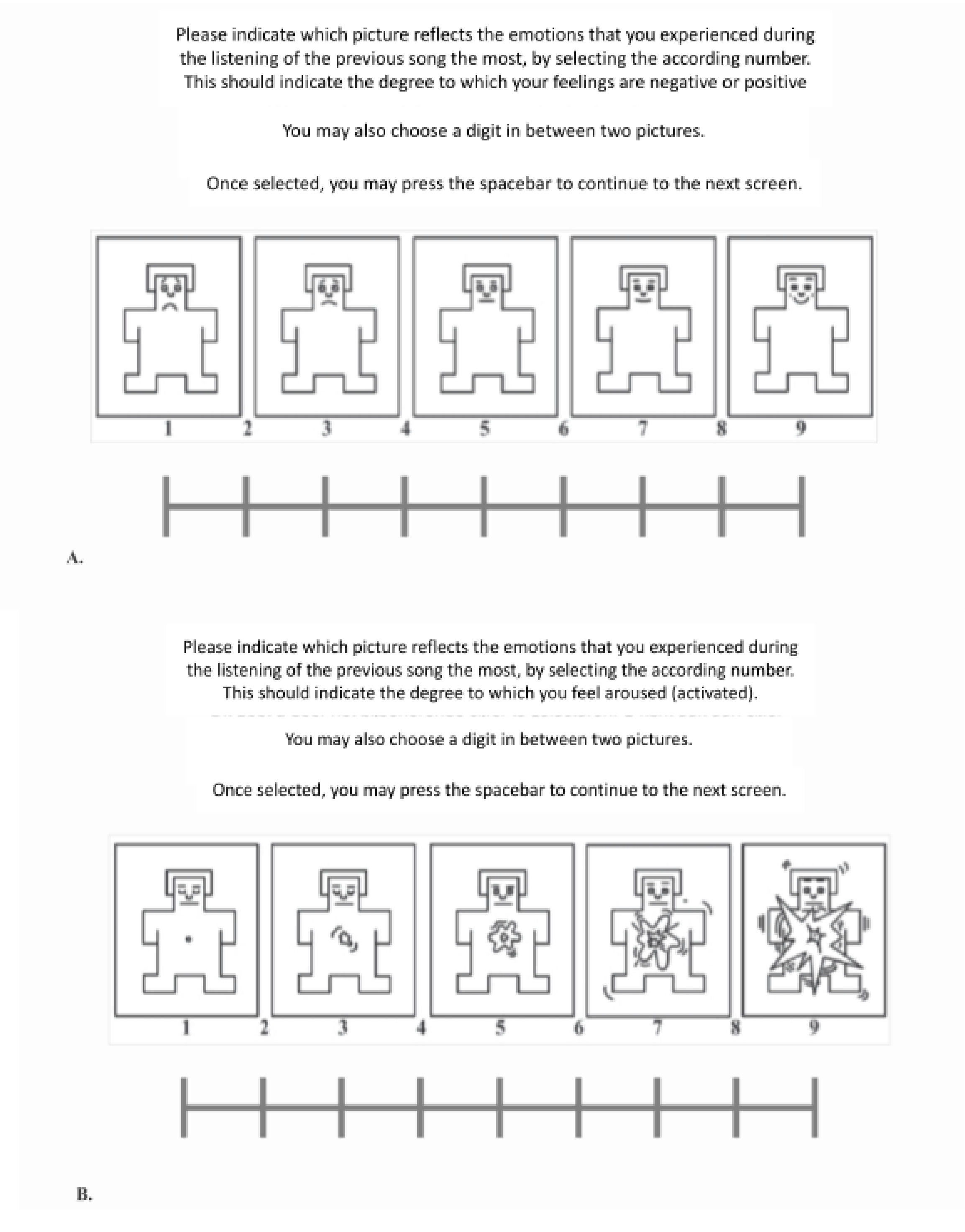


Figure 3. Examples of the SAM questionnaire as used in the experiment. In the upper picture (4A), we can see how the participant was asked to describe their valence – by selecting one of the digits that belong to the picture that reflected their feelings the most. In the lower picture (4B), the same was asked, but for arousal.

Figure 4. In this figure, the position of the two breathing belts is pictured. The upper belt, measuring chest respiration, was placed at the height of the nipple line. The sensor (light blue) was placed laterally on the thorax. The lower belt, measuring abdominal respiration, was placed at the height of the umbilicus. This sensor was put at the center of the abdomen. Both sensors were the same size, while the belts could be adjusted according to the measurements of the participant's body.

Procedure

The experiment procedure is visualized in figure 5. The survey was sent through different social media approximately two to three weeks before the start of the experiments. In the survey the participants filled out an informed consent form and an exclusion criteria form. On the day of the experiment, they could manually sign the consent form. The experiment consisted of one session for each participant and lasted approximately 30 minutes.

Participants were placed on a padded office chair, in front of a table on which the computer running the experiment interface was placed. Participants were told that their songs would be played for them in a random order, and that they should actively attend to the fragments for the entire time they were playing. They were also instructed to fill in the SAM questionnaire once before the start of the fragments and after each fragment. They were reminded that they should try to fill in this questionnaire according to how they felt during the listening. After filling in the questionnaires, they were also instructed to talk about their experienced emotions during the song (a segment called reflection). These data, however, were not used for the current research. Lastly, they were asked to hold their hands on two crosses on the table to minimize movement. The monitor indicated when they had to do this.

Then, the belts and the microphone were attached. After instrument installation and the explanation of the experiment, they were allowed to do a test round with both the SAM questionnaire and a practice fragment. At this point, the experimenter left the room to avoid observer effects.

The baseline condition after calibration lasted 45 seconds; participants were asked to sit still and try to relax before the true experiment started. After that, the four musical fragments were played in a random order for each participant to account for order or fatigue effects. After each fragment, there was an interstimulus period of 30 seconds to reduce possible emotional effects induced by the fragments that were played before. The practice round, baseline measurements, questionnaires, music, reflection, interstimulus pauses and instructions during the experiment were all presented to the participant through the same experimenter interface on a monitor. At the end of each experiment, the participant was thanked and debriefed.

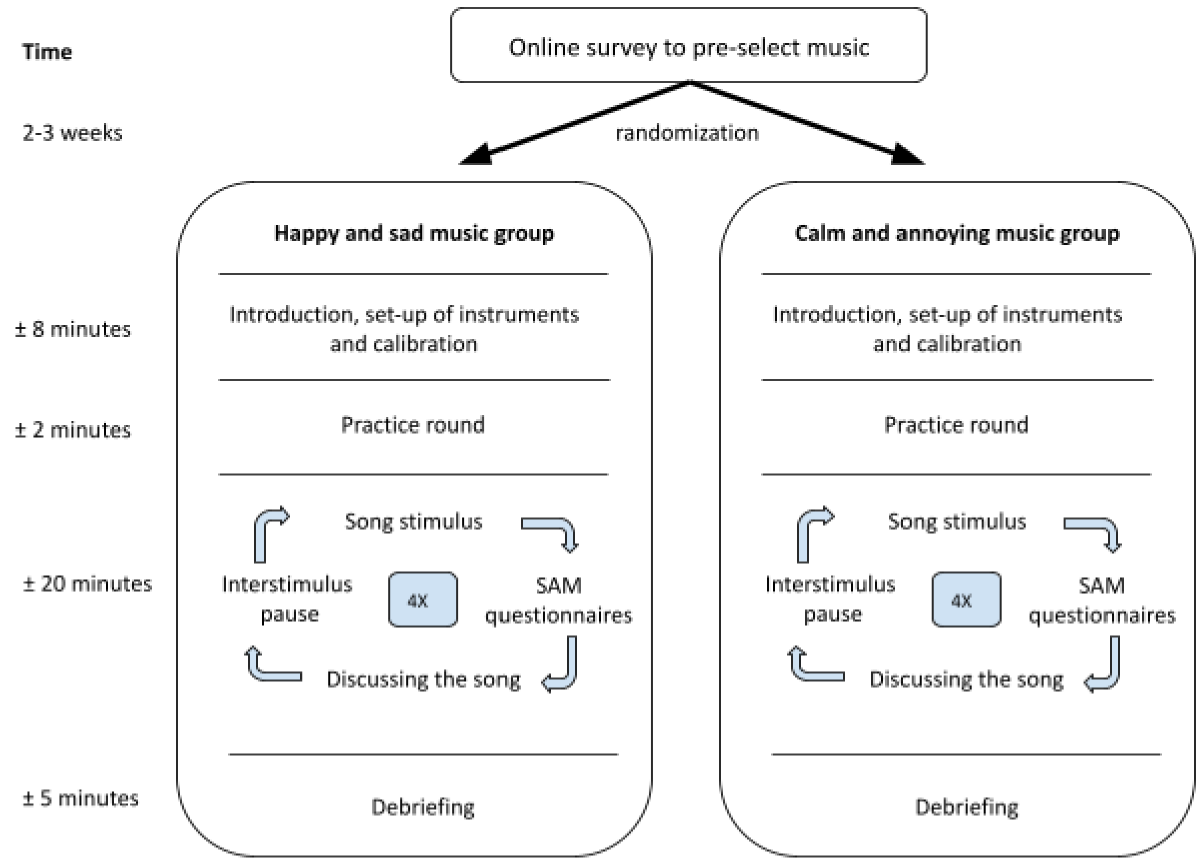


Figure 5. The segments of the experiment set-up (right) over time (left). Both rectangles show the same experiment set-up, but consist of different types of emotionally charged songs. In the left rectangle, the experiment for the participants undergoing the happy and sad music condition is depicted. In the right rectangle, the experiment for the participants undergoing the calm and annoying music condition is depicted.

Experiment Set-Up

In figure 6, the experiment set-up is depicted.

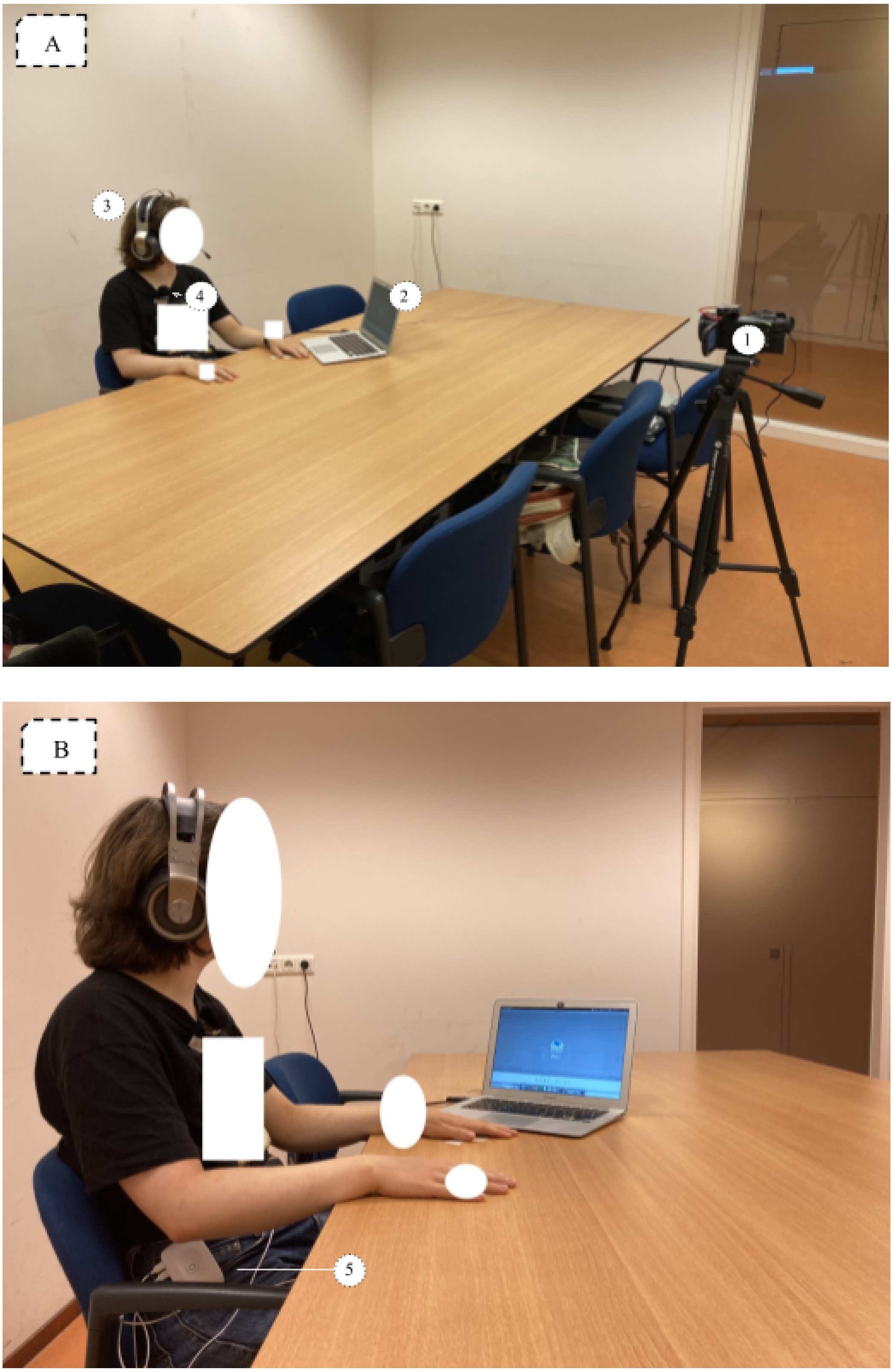


Figure 6. The experiment set-up. In figure 7A, we see the experiment from an oblique view with numbered objects. Object 1 is the video camera. Object 2 is the monitor on which the experiment interface was run and from which the music was played. Object 3 are the headphones, through which music was played. Object 4 is the bluetooth microphone. In figure 7B, we can see the experiment set-up from a side view. The number 5 refers to the biosignalsplux© channel hub, where the respiration sensors were plugged into. In figure 7C, we can see which parts of the experiment room were captured on video camera.

Data reduction and analysis

For this research, only the SAM questionnaire data and the respiration sensor data were analyzed. The video and auditory data were stored anonymously. We used repeated measures ANOVAs to test whether there were significant effects of the different separate songs on the dimensional emotion values and the respiration features, comparing each song to the other song category (happy versus sad; calm versus annoying) and each song to baseline. The data were controlled for outliers but no data were excluded because of the small sample size and because there seemed to be no remarkable measurement errors.

Furthermore, we applied paired t-tests to test whether there were significant differences between the first and second song of each music-emotion category. Independent t-tests were used to assess potential effects of the order in which each music category was played.

Repeated measures ANOVA was used again to analyze effects of the averaged emotional and respiration values.

Effect sizes for t-tests and ANOVAs are reported in Cohen's d and Hedges' g, the latter containing a correction that takes a small sample size into account ($N < 20$). These effect sizes can be interpreted in the following way: $d = 0.2$ or $g = 0.2$ indicates a small effect size; $d = 0.5$ or $g = 0.5$ indicates a medium effect size; and $d = 0.8$ or $g = 0.8$ indicates a large effect size (Cohen, 1988). Lastly, linear regression was used to test whether respiration features can predict the song type and the valence and arousal scores.

Chapter 4: Experiment results

In this chapter, the data analysis results will be discussed. In the first subsection, we will dive into the results of the influence of music on valence and arousal values. In the second subsection, we will discuss the respiration features. Each of these subsections will consist of an analysis of the effects of separate songs compared to baseline and each other. Furthermore, it will consist of an analysis of the differences in effects between separate songs. Then, the averaged effects of emotionally charged music will be examined. We will also analyze potential order effects in each emotionally charged music category. In the third subsection we will compose a prediction model for experienced emotions with given respiration features.

Subsection 4.1 – Valence and arousal

Effect of separate emotionally charged songs on emotional dimensions

First, we tested whether there were significant differences in arousal and valence for each song compared to each other and the baseline. Repeated measures ANOVAs were conducted to compare valence and arousal values between each song and baseline.

Valence in happy and sad songs

A repeated measures ANOVA indicated a significant difference between baseline, happy and sad songs, $F(4,40) = 45.7$, $p < 0.001$. A post hoc pairwise comparison with Bonferroni correction showed that there was a significant decrease in valence when comparing the first sad song ($M = 3.82$, $SD = 1.33$) compared to baseline ($M = 7.00$, $SD = 0.89$) , $p < 0.001$, and the second sad song ($M = 3.73$, $SD = 1.35$), compared to baseline, $p < 0.001$. Furthermore, the post hoc pairwise comparison showed that the first ($M = 7.73$, $SD = 0.91$) and second happy song ($M = 7.64$, $SD = 0.92$) valence scores both differed significantly from both the valence scores during the first ($M = 3.82$, $SD = 1.33$) and the second sad song ($M = 3.73$, $SD = 1.35$), all with $p < 0.001$. There were no significant differences between the valence during baseline ($M = 7.00$, $SD = 0.89$) and during the first happy song ($M = 7.73$, $SD = 0.91$), $p = 0.236$. And, there was no significant difference between baseline valence and the second happy song valence ($M = 7.64$, $SD = 1.33$), $p = 0.669$.

These results indicate that sad songs separately decrease valence, compared to when listening to no music. They also indicate that valence levels are higher during the listening to happy songs, compared to when listening to sad songs. But, there is no significant effect of happy songs on valence compared to when one is not listening to any music. In figure 7, the separate valence scores for baseline and each happy and sad song are depicted in a box plot.

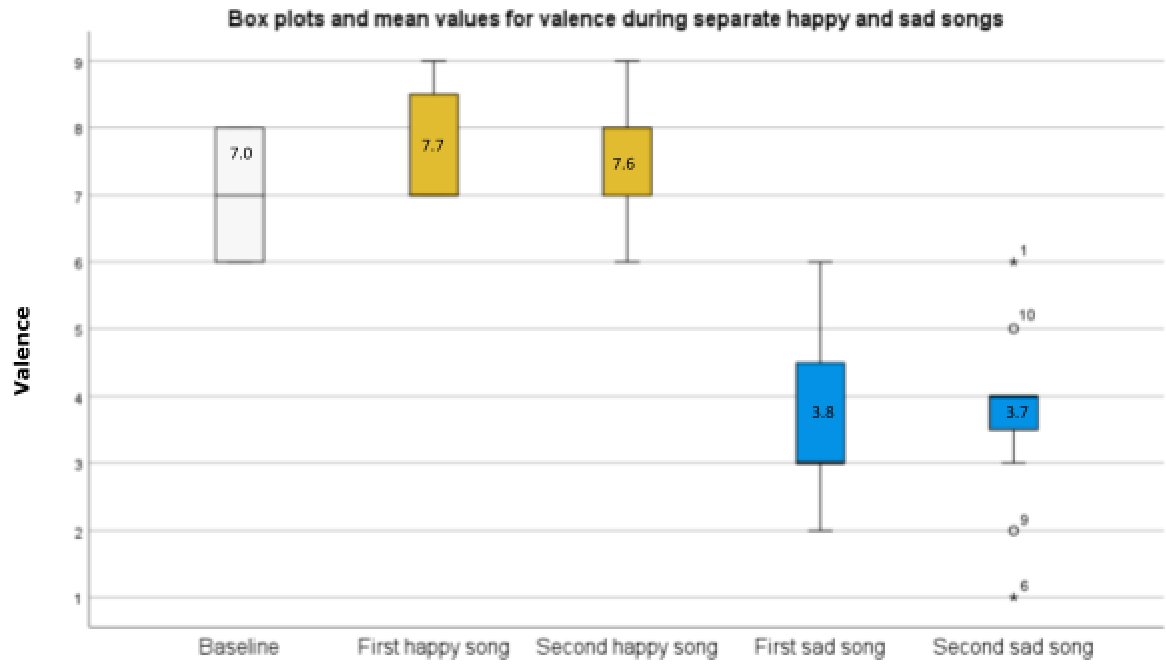


Figure 7. Box plots depicting mean emotional valence and its variation during no music listening, during the first and second happy song listening, and during the first and second sad song listening (N = 11).

Valence in calm and annoying songs

The repeated measures ANOVA for the calm and annoying songs and baseline also showed that there was a significant difference between the three, $F(4, 32) = 28.18$, $p < 0.001$.

The post hoc pairwise comparison with Bonferroni correction showed that there was a significant decrease in valence when comparing the first annoying song ($M = 4.33$, $SD = 1.80$) to baseline ($M = 6.78$, $SD = 0.67$), $p = 0.023$, and when comparing the second annoying song ($M = 4.22$, $SD = 1.72$) to baseline, $p = 0.029$. The post hoc pairwise comparison also showed that the first ($M = 7.67$, $SD = 0.71$) and second calm song ($M = 7.56$, $SD = 1.13$) valence scores both differed significantly from the valence scores during the first ($M = 4.33$, $SD = 1.80$) annoying song, $p = 0.007$ and $p = 0.015$, respectively. Both calm songs also differed from the second annoying song ($M = 3.73$, $SD = 1.35$), $p = 0.005$ and $p = 0.018$, consecutively. There were no significant differences between the valence during baseline (M

= 6.78, SD = 0.67) and during the first calm song (M = 7.67, SD = 0.71), p = 0.092. And, there was no significant difference between baseline valence and the second calm song valence (M = 7.56, SD = 1.13), p = 0.232.

These results suggest that annoying songs separately decrease valence, compared to when listening to no music. They also indicate that valence levels are higher during the listening to calm songs, compared to when listening to annoying songs. But, there is no significant effect of calm songs on valence compared to when someone is not listening to music. In figure 8, the separate valence scores for baseline and each calm and annoying song are depicted in a box plot.

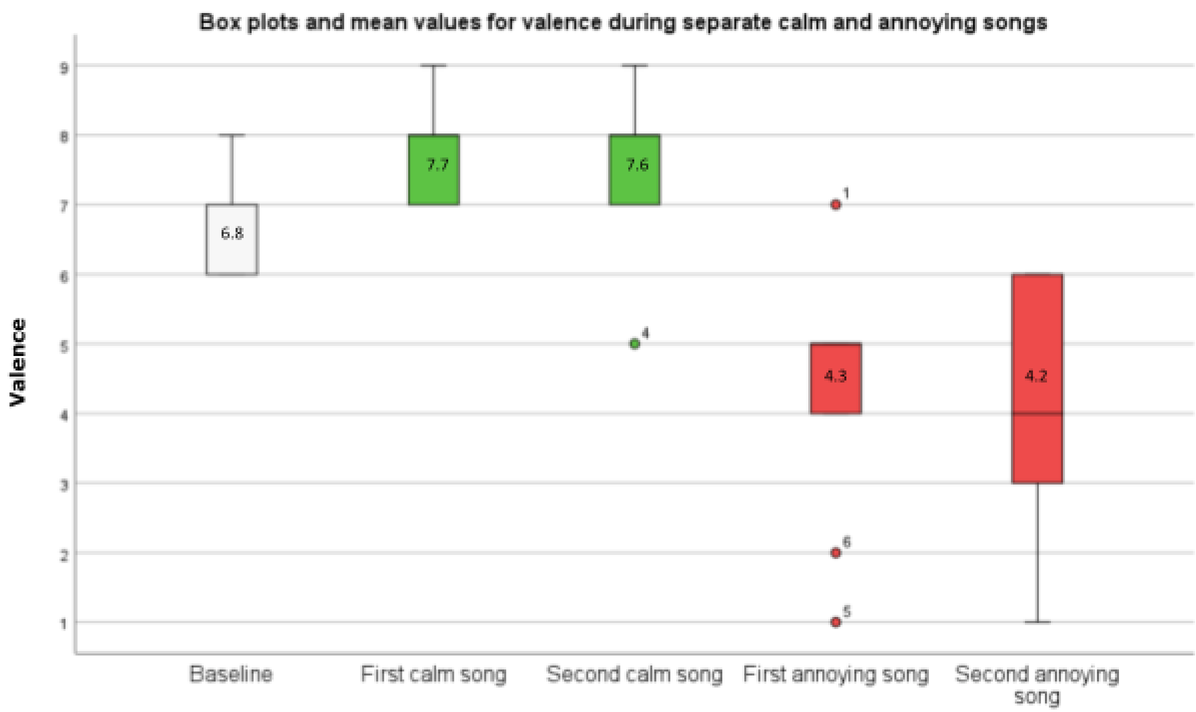


Figure 8. Box plots depicting mean emotional valence and its variation during no music listening, during the first and second calm song listening, and during the first and second annoying song listening (N = 9).

Effect sizes of music on valence

We conducted paired t-tests to examine effect sizes of each song compared to the baseline, this would indicate how strongly the songs affect valence levels. The effect sizes of significant and non significant effects are depicted in table 3. For the first sad song, effect sizes consisted of a Cohen's d of –2.16, 95% CI [–3.25, –1.04] or a Hedges' g of –2.00, 95%

CI [–3.06, –0.96]. For the second sad song, Cohen's d was –2.02, 95% CI [–3.06, –0.95] and Hedges' g –1.87, 95% CI [–2.83, –0.88].

For the first annoying song, the calculated Cohen's d was –1.47, 95% CI [–2.41, –0.49] and the Hedges' g –1.32, 95% CI [–2.17, –0.44]. The calculated effect on valence of the last annoying song compared to baseline consisted of a Cohen's d of –1.41, 95% CI [–2.33, –0.45] or a Hedges' g of –1.27, 95% CI [–2.11, –0.41].

As none of these confidence intervals contain the value 0, these results reinforce the suggestion that separate songs that are experienced as sad and annoying have significant effects on the valence dimension of someone's emotion. According to Cohen, these effects are very large when listening to sad and annoying songs.

	Effects on valence					
	Cohen's d			Hedges' g		
Song	Effect size	95% CI		Effect size	95% CI	
Happy song 1	0.804	0.104	1.475	0.742	0.096	1.361
Happy song 2	0.620	–0.042	1.256	0.572	–0.039	1.159
Sad song 1	**–2.163***	**–3.252**	**–1.044**	**–2.000***	**–3.062**	**–0.963**
Sad song 2	**–2.023***	**–3.062**	**–0.953**	**–1.866***	**–2.825**	**–0.880**
Calm song 1	1.14	0.27	1.97	1.03	0.24	1.78
Calm song 2	0.93	0.12	1.71	0.84	0.11	1.54
Annoying song 1	**–1.47***	**–2.41**	**–0.49**	**–1.32***	**–2.17**	**–0.44**
Annoying song 2	**–1.41***	**–2.33**	**–0.45**	**–1.27***	**–2.11**	**–0.41**

Table 3. The effect sizes and respective 95% confidence intervals for the effects of each song on valence, compared to baseline. The effect sizes are depicted in Cohen's d and in Hedges' g, as the latter may be a better estimate for sample sizes N < 20. The effect sizes of effects that were significant are marked with an asterisk (*).

Arousal in happy, sad, calm and annoying songs

Regarding arousal, the repeated measures ANOVA showed that the difference between baseline and each separate happy or sad song was not significant, $F(4, 40) = 2.97$, $p = 0.063$. As this was almost significant, we conducted a post hoc pairwise comparison with Bonferroni correction to find out which pairs were the closest to being significant. A non-significant difference between the baseline arousal ($M = 4.73$, $SD = 1.42$) and the second happy song ($M = 6.18$, $SD = 1.54$) was observed, $p = 0.457$. The difference between the second happy song ($M = 6.18$, $p = 1.54$) and the first sad song ($M = 4.27$, $SD = 1.56$) was also insignificant with a p-value of 0.388. Lastly, the pair closest to being significant consisted of the second happy song (M = 6.18, p = 1.54) and the second sad song (M = 5.09, SD = 0.94), p = 0.142. The first happy song (M = 5.45, SD = 1.75) did not significantly differ from any of the songs or baseline, p = 1.00. The mean arousal scores during each song can be seen in figure 9.

For calm and sad songs, no significant differences were found regarding arousal either (see figure 10). The repeated measures ANOVA indicated a non-significant difference, $F(4, 32) = 3.34$, $p = 0.059$. As this was almost significant as well, we conducted a post hoc pairwise comparison with Bonferroni correction to find out which pairs were the most close to being significant. This revealed a non-significant difference between the second calm song (M = 3.78, SD = 2.11) and the first annoying song (M = 6.22, SD = 1.30), p = 0.191; and a non-significant difference between the second calm song and the second annoying song (M = 6.11, SD = 1.62), p = 0.294. But, more interestingly, a significant difference for arousal between the second calm song (M = 3.78, SD = 2.11) and the first calm song (M = 4.78, SD = 2.33) was found, p = 0.028. This possible difference is discussed later in this subsection. There were no statistical differences for the music categories compared to no music (M = 4.89, SD = 1.05).

Even though these results are not significant, we depicted the mean arousal scores during the baseline compared to each song in figure 9 and figure 10. Calm songs seem to go together with low arousal levels (with the first song having a mean of 4.78 and the second song 3.78) and annoying songs seem to go together with high arousal levels (with means of 6.22 and 6.11), but these results are not significant. These results might indicate that calm songs do decrease arousal and annoying songs do increase arousal, when comparing them to each other. However, this needs to be researched further.

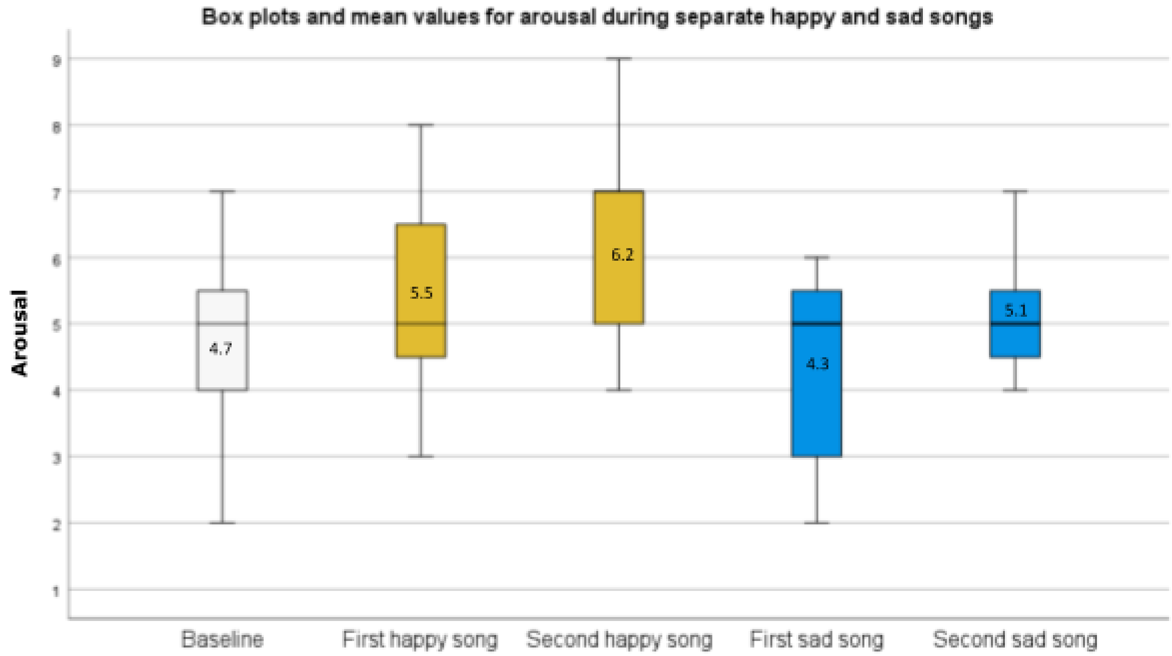


Figure 9. Box plots depicting mean emotional arousal and its variation during no music listening, during the first and second happy song listening, and during the first and second sad song listening (N = 11).

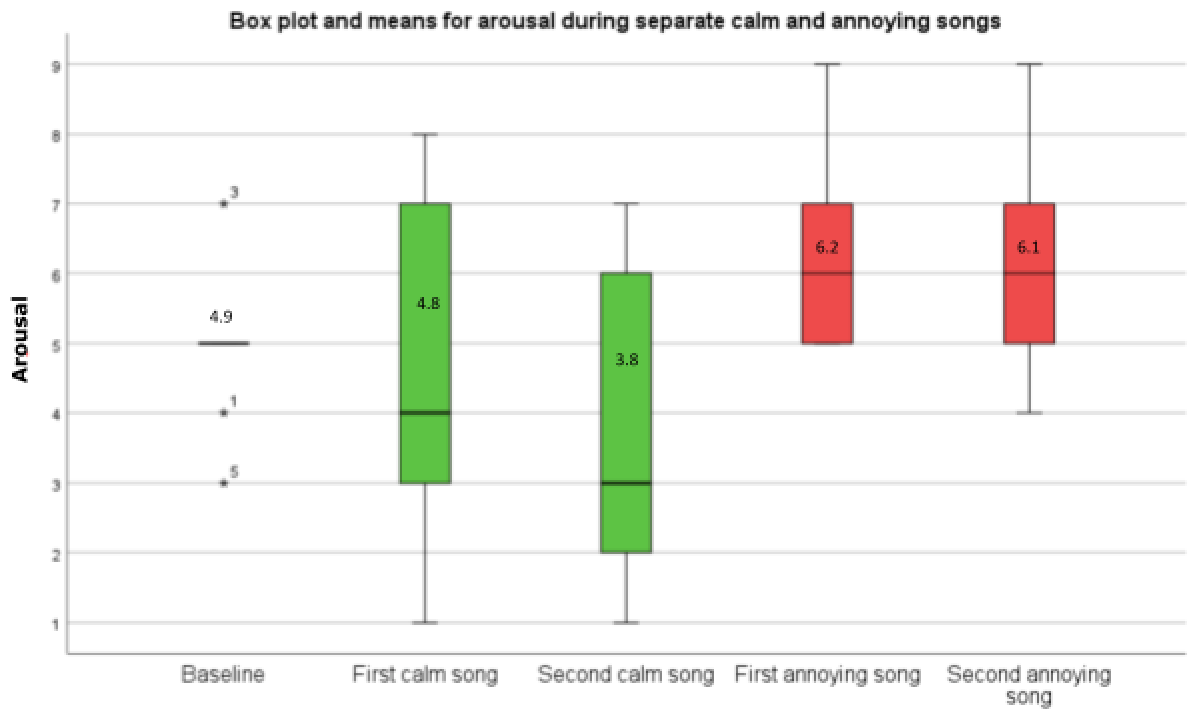


Figure 10. Box plots depicting mean emotional arousal and its variation during no music listening, during the first and second calm song listening, and during the first and second annoying song listening (N = 9).

Effect of quantity of listened songs

Possibly, each separate song has a different effect on valence or arousal. These results can give insight into whether the quantity of songs belonging to each emotionally charged music category influences this effect. Both happy and both calm songs had no statistical effect on valence, compared to baseline. The first and second sad songs both had a statistical effect and these effects were similar in size, as are the means of both songs. The same is true for the first and second annoying songs.

As stated before, there were no significant differences for each song compared to each other and compared to the baseline, when regarding arousal. However, the means between each first and second song do seem to differ, when looking at the box plots. Arousal seems higher after listening to the second happy song, compared to the first. The same effect is seen for the second sad song, compared to the first. The found pairwise comparison difference in arousal for the first and second calm song also indicates that there may be a decrease in arousal when listening to the second song, compared to the first song. Only for annoying songs, there seems to be no difference in effect on arousal between the first and second song.

The results suggest that there is no effect on valence caused by the quantity of happy or calm songs, as there was no effect of these songs at all. Even if the songs had an effect on valence, the means of both happy songs are similar, as are the means of the calm songs – suggesting that there would be no effect of the quantity of songs on valence. These results also suggest that while sad and annoying songs do have an effect on valence, the quantity that one listens to these songs is not relevant either. However, for arousal, there seems to be a non-significant effect caused by the quantity of songs. For happy and sad songs, arousal may increase after listening to more songs of the same emotionally charged category. For calm songs, arousal may decrease after listening to more calm songs.

Emotion differences between first and second songs

In the above section, we analyzed differences in arousal and valence between each separate song and baseline. However, it is also interesting to look at the effects of the averaged values of both songs of each emotionally charged music category. Separate songs give insight into whether it matters how many songs you play of a certain emotionally charged category, to obtain a certain effect. However, in light of the research question, we also want to know the effects of a certain emotionally charged music category in general.

In order to be able to average the effects of each music category, we need to know whether the songs within a category themselves differed significantly. If these do not differ or only in the slightest, we can average the effects of both songs as they have statistical similar effects. With this reason in mind, we conducted paired t-tests to test whether there were significant differences between each song within an emotional music category.

As can be seen in table 4, there were no significant differences between first and second song valence. There were also no significant differences between first and second song arousal, except for between the first and second calm song. In line with the findings above, the first calm song generated a reported mean arousal of 4.78 ($SD = 2.33$), whereas participants indicated a mean arousal of 3.78 while listening to the second calm song ($SD = 2.11$). With a mean difference of –1 there seems to be a highly significant decrease in arousal when listening to the second calm song compared to the first song, $t(8) = –4.42$; $p = 0.003$. These results are visible in table 5. The effect size of this difference was very large with a Cohen's d of –1.41, 95% CI [–2.34, –0.45] and a Hedges' g of –1.28, 95% CI [–2.11, –0.41]. This difference may be due to the discussed fact that the quantity of calm songs that one listens to, has an influence on the arousal level. Future research could build on these findings by letting participants listen to more songs of each emotionally charged category.

	Valence differences between songs: happy–happy, sad–sad, calm–calm and annoying–annoying						
	Songs	Mean values	St. dev.	Mean difference	t	One-sided p	Two-sided p
Happy	First happy song	7.73	0.905	−0.09	−0.559 (df 10)	0.294	0.588
	Second happy song	7.64	0.924				
Sad	First sad song	3.82	1.328	−0.09	−0.177 (df 10)	0.431	0.863
	Second sad song	3.73	1.348				
Calm	First calm song	7.67	0.707	−0.11	−0.286 (df 8)	0.391	0.782
	Second calm song	7.56	1.13				
Annoying	First annoying song	4.33	1.803	−0.11	−0.217 (df 8)	0.417	0.834
	Second annoying song	4.22	1.716				

Table 4. Valence means during each first and second song and the differences between each first and second song. The results of each corresponding paired t-test are depicted in the three outer right columns.

	Arousal differences between songs: happy–happy, sad–sad, calm–calm and annoying–annoying						
	Songs	Mean values	St. dev.	Mean difference	t	One-sided p	Two-sided p
Happy	First happy song	5.45	1.753	0.73	1.31	0.111	0.221
	Second happy song	6.18	1.537				
Sad	First sad song	4.27	1.555	0.82	1.58	0.073	0.146
	Second sad song	5.09	0.944				
Calm	First calm song	**4.78**	**2.333**	**−1.00**	**−4.24**	**0.001***	**0.003***
	Second calm song	**3.78**	**2.108**				
Annoying	First annoying song	6.22	1.302	−0.11	−0.26	0.400	0.799
	Second annoying song	6.11	1.616				

Table 5. Arousal means during each first and second song and the differences between each first and second song. The results of each corresponding paired t-test are depicted in the three outer right columns. The values marked with an asterisk (*) indicate that there was a significant difference.

Averaged effects of emotionally charged music on emotional dimensions

As only the songs of the calm music category differed significantly, we proceeded to analyze averaged arousal and valence values for each music category. However, as the two calm songs did significantly differ in arousal, conclusions about this category should be drawn with caution.

Repeated measures ANOVAs were performed to compare the effect of music condition on valence and arousal. Valence and arousal scores during no music listening (baseline) and during happy and sad music were compared to each other. The same counts for calm and annoying music. In figures 11 to 14, we visualized valence and arousal scores during baseline compared to music. The figures marked with an asterisk (*) indicate that the differences between each condition (baseline and the emotionally charged music categories) within the plot are significant.

Averaged music effects on valence

The repeated measures ANOVA for valence determined a statistically significant difference in valence between at least two of the three music conditions (baseline, happy and sad music), $F(2, 20) = 67.35$, $p < 0.001$. A post hoc pairwise comparison (Bonferroni correction) showed a non-significant increase in valence between the happy music and no music ($M = 7.68$, $SD = 0.87$; and $M = 7.00$, $SD = 0.89$, respectively), $p = 0.106$. The comparison did show a significant decrease in valence for the sad music ($M = 3.77$, $SD = 1.03$) compared to no music ($M = 7.00$, $SD = 0.89$), $p < 0.001$. Lastly, there was also a significant decrease in valence for the sad music ($M = 3.77$, $SD = 1.03$), in comparison with the happy music ($M = 7.68$, $SD = 0.87$), $p < 0.001$. We can conclude that these results indicate a significantly differing effect of happy, sad and no music listening on valence.

For the calm and annoying music conditions, repeated measures ANOVA showed a statistically significant difference in valence for at least two of the three music conditions (baseline, calm and annoying music), $F(2, 16) = 28.26$, $p <0.001$. The post hoc pairwise comparison with Bonferroni correction determined a significant increase in valence during calm music ($M = 7.61$, $SD = 0.74$), compared to no music ($M = 6.78$, $SD = 0.67$), $p = 0.006$. It also showed a significant decrease in valence for annoying music ($M = 4.28$, $SD = 1.58$), compared to calm music ($M = 7.61$, $SD = 0.74$), $p = 0.004$. Furthermore, there was a significant difference in valence between calm (M = 7.61, SD = 0.74) and annoying music (M = 4.28, SD = 1.58), p = 0.001. These results indicate that calm, annoying and no music listening all have significant effects on valence.

Averaged music effects on arousal

Another repeated measures ANOVA did not show a statistically significant difference in arousal between the music conditions of the baseline–happy–sad condition, F(2, 20) = 3.32, p = 0.057. The post hoc pairwise comparison (Bonferroni correction) showed a non–significant increase in arousal for happy music (M = 5.82, SD = 1.37) compared to no music (M = 4.73, SD = 1.42), p = 0.178. There was a non–significant difference between sad music (M = 4.86, SD = 0.96) and no music (M = 4.73, SD = 1.42), p = 1.000. Lastly, there was also a non–significant difference between sad (M = 4.68, SD = 0.96) and happy music (M = 5.82, SD = 1.37), p = 0.195. This suggests that there is no significant effect whatsoever of music condition on arousal for happy and sad music.

The last repeated measures ANOVA showed that there was not a statistically significant difference in arousal for calm, annoying and no music listening, F(2, 16) = 2.71, p = 0.097. The post hoc comparison (Bonferroni) showed a non-significant difference in arousal between no music (M = 4.89, SD = 1.05) and calm music (M = 4.28, SD = 2.20), p = 1.000. There was also no significant increase in arousal for annoying music (M = 6.17, SD = 1.32) compared to no music (M = 4.89, SD = 1.05), p = 0.357. Lastly, there was no significant difference between annoying music (M = 6.17, SD = 1.31) and calm music (M = 4.28, SD = 1.32), p = 0.187. These results suggest that also for calm and annoying music, there is no significant effect for (no) music listening on arousal.

Even though these results are not significant, arousal seems to increase during happy and annoying music and to decrease during sad and calm music, see figures 13 and 14.

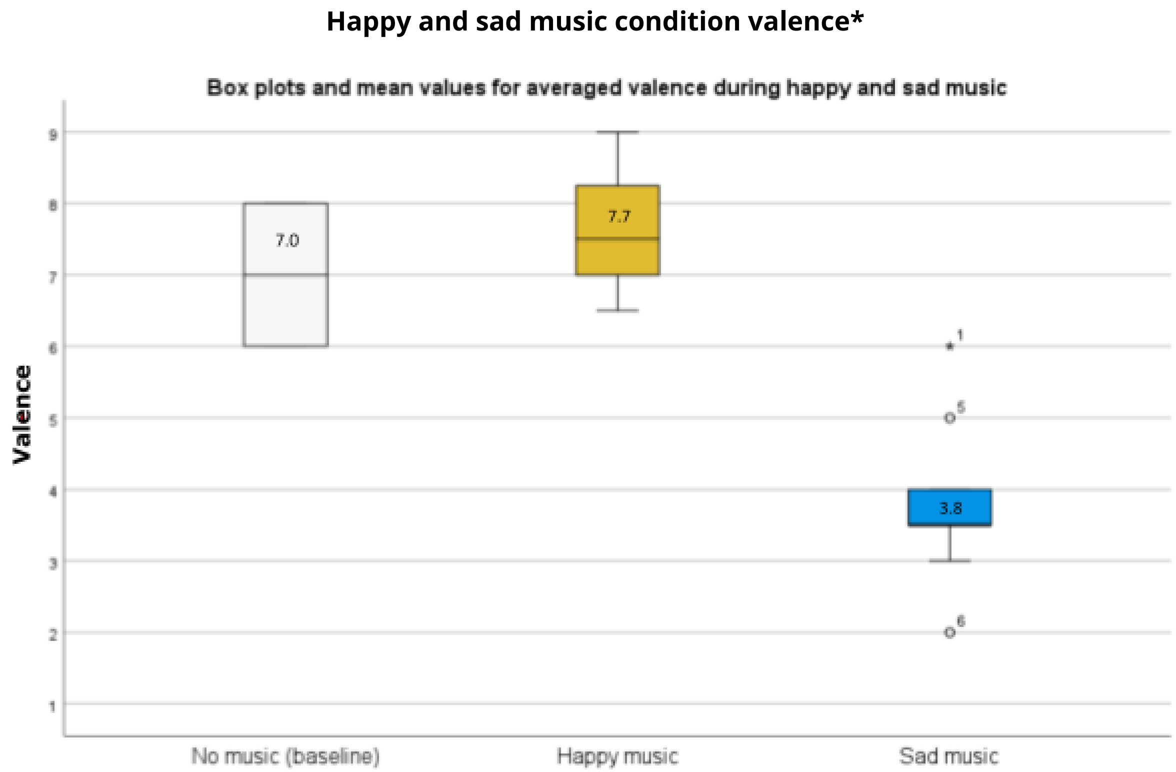


Figure 11. Box plots depicting averaged emotional valence and its variation during no music listening, during happy music listening, and during sad music listening (N = 11).

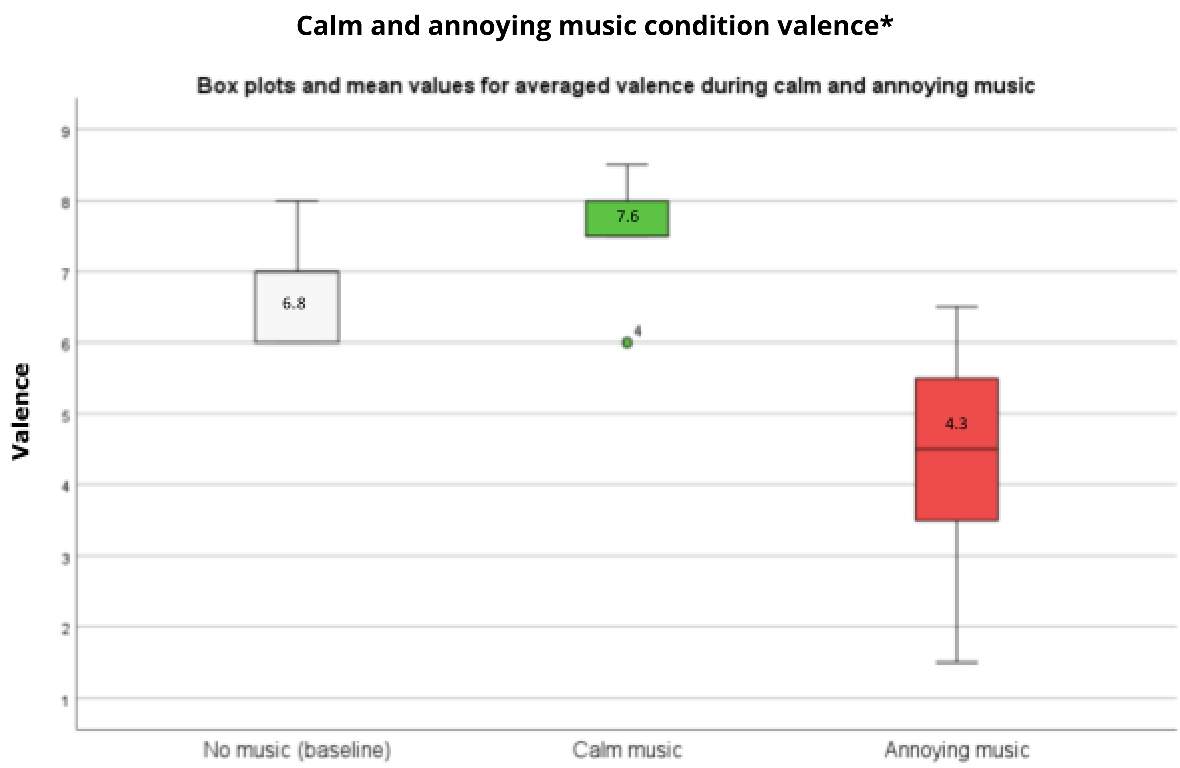


Figure 12. Box plots depicting averaged emotional valence and its variation during no music listening, during calm music listening, and during annoying music listening (N = 9).

Happy and sad music condition arousal

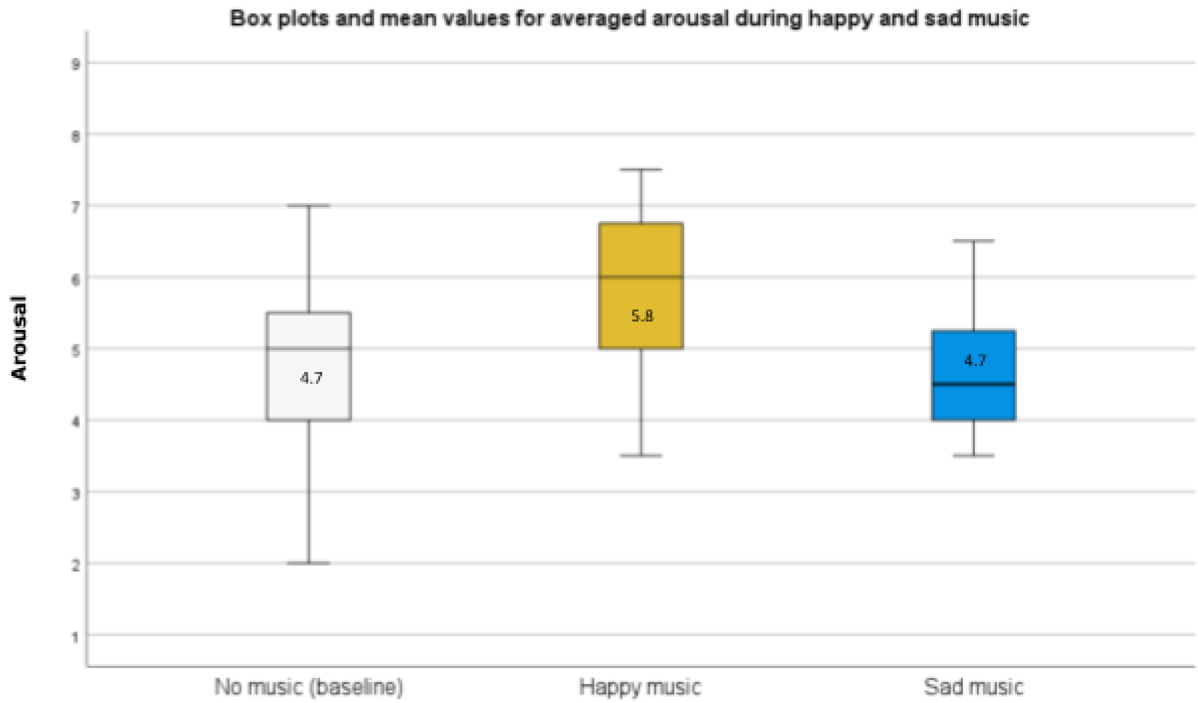


Figure 13. Box plots depicting averaged emotional arousal and its variation during no music listening, during happy music listening, and during sad music listening (N = 11).

Calm and annoying music condition arousal

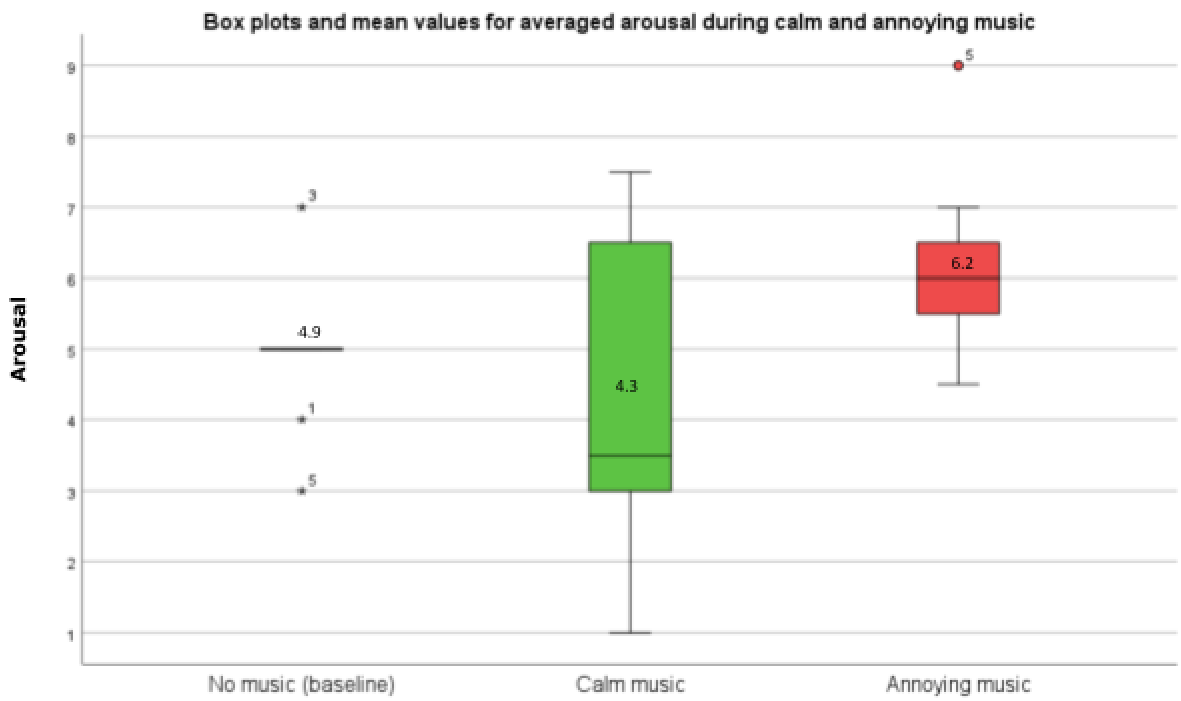


Figure 14. Box plots depicting averaged emotional arousal and its variation during no music listening, during calm music listening, and during annoying music listening (N = 9).

In figure 15 we can see the averaged values of each category in a dimensional graph depicting valence on the x-axis and arousal on the y-axis, similar to the circumplex model by Russell (1980). When comparing this figure to the model by Russell (figure 1), the four music categories seem to fit the quadrant 'locations' of the emotions in the model quite well. This fit is better for valence than for arousal, as all music categories have fallen out more towards the middle of the arousal-axis compared to the original model by Russell (1980).

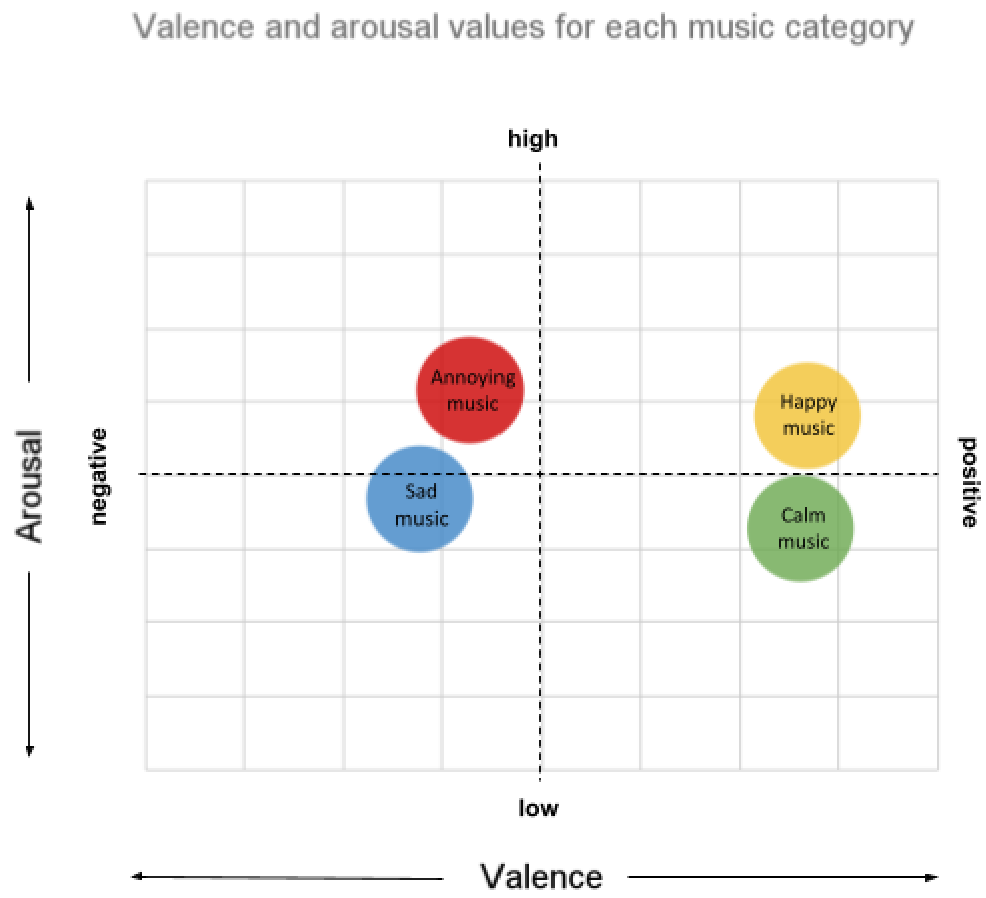


Figure 15. The circumplex model, with the measured dimensional arousal and valence scores of the four emotionally charged music categories. The x-axis represents valence, where the most negative valence score is to the left side and the most positive score to the right. The y-axis represents arousal. The most active score is on the top of the graph and the most passive score on the bottom.

Effect of emotion elicitation order on emotional dimensions

We can also look at the effects of the order of the music conditions on the emotions. Participants in each condition group (happy and sad, calm and annoying) were randomized to either start listening to two songs of one emotionally charged music category, followed by the songs of the other category, or vice versa. For example, a particular participant was offered the sad songs first, and after those the happy songs. Independent t-tests were performed to test whether there were significant differences for valence and arousal when comparing music order conditions.

For the average valence during the happy music, the happy–sad order ($M = 7.9$, $SD = 0.89$) did not differ significantly from the sad–happy other ($M = 7.5$, $SD = 0.89$), $t(9) = 0.73$, $p = 0.479$. For the average valence during sad music, both orders did not differ significantly from each other either, with a mean happy–sad valence of $M = 4.3$ ($SD = 1.20$) and a sad–happy valence of $M = 3.3$ ($SD = 0.68$), $t(9) = 1.679$, $p = 0.127$. For the average arousal during happy music, the orders did not differ significantly from each other as well, ($M = 5.8$, $SD = 1.44$; $M = 5.8$, $SD = 1.44$), $t(9) = -0.04$ $p = 0.97$. For the average arousal during sad music, there was also no significant difference between the happy–sad order ($M = 5.0$, $SD = 1.17$) and the sad–happy orders ($M = 4.42$, $SD = 0.74$), $t(9) = 1.01$, $p = 0.339$.

Furthermore, for the average valence during calm music, there was no significant difference between the calm–annoying order ($M = 7.60$, $SD = 0.22$) and the annoying–calm order ($M = 7.63$, $SD = 1.18$), $t(7) = 0.04$, $p = 0.969$. For the annoying music, valence also did not differ significantly between the different order groups, with consecutive means of 3.7 for the calm–annoying order ($SD = 1.79$) and 5 for the annoying–calm order ($SD = 1.08$), $t(7) = 1.27$, $p = 0.245$. However, arousal levels during the calm music were significantly higher for the participants who first listened to calm music and then annoying music ($M = 5.6$, $SD = 1.95$), compared to participants who first listened to annoying music, and then to calm music ($M = 2.6$, $SD = 1.11$), $t(7) = -2.7$, $p = 0.031$. For annoying music, there was no significant effect of the order on arousal: the calm–annoying order arousal ($M = 6.3$, $SD = 1.75$) was not significantly different from the annoying–calm order arousal ($M = 6.0$, $SD = 0.71$) during calm music.

These results suggest that valence levels of all the music types did not differ when certain music was played first or second. Furthermore, they suggest that arousal levels only differ depending on when calm music is played: before or after annoying music. Participants who first listened to annoying music, and then to calm, had lower arousal scores compared to the participants who listened in the other order. This could suggest that listening to calm music after being aroused by annoying music, has a stronger (relative) positive effect on relaxation than when listening to calm music in general.

Even though there are few significant order effects, there seems to be a non-significant tendency in order effects for valence during the happy and sad music condition, based on the means. The differences between each order condition are visualized in figures 16 and 17 Listening to happy music first seems to have a lingering positive effect on the valence level during the sad music that comes after (figure 17). And vice versa, after first listening to sad music, the valence during the happy music is lower (figure 16). This seems to suggest that happy and sad music have an extended effect on valence levels during the other music category. It could be interesting to further investigate these order effects in future research with a bigger sample size.

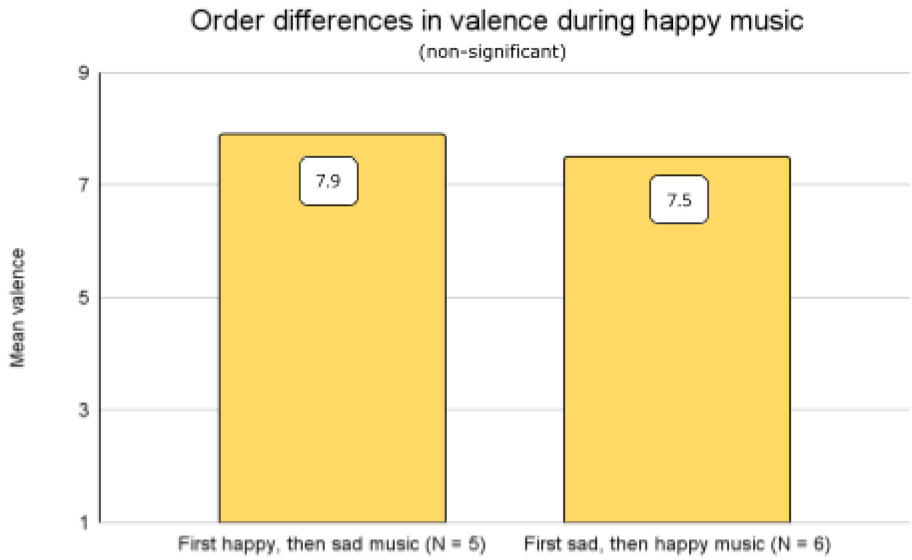


Figure 16. Mean valence scores during happy music listening for the two different orders. On the left is the mean valence during happy music when happy music was played before sad music. On the right is the mean valence during happy music when happy music was played after sad music. The differences were non-significant.

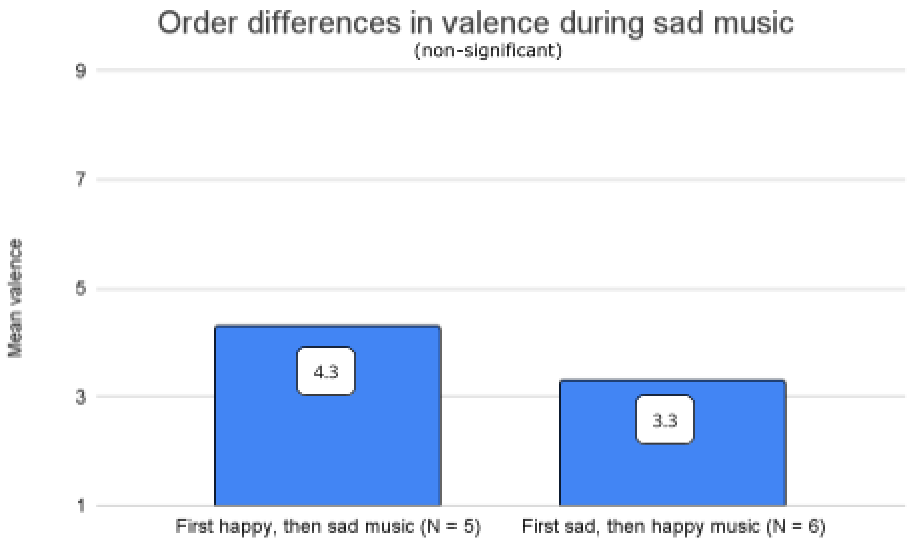


Figure 17. Mean valence scores during sad music listening for the two different orders. On the left is the mean valence during sad music when sad music was played after happy music. On the right is the mean valence during sad music when sad music was played before sad music. The differences were non-significant.

Discussion – arousal and valence

In this subsection, we examined the relation between self-selected emotionally charged music and their arousal and valence levels. We investigated the differences for each separate song and between each music category. As we wanted to look into the effects of music in general and not only separate songs, we regarded this step as essential.

There were significant differences between the separate songs regarding valence. Happy songs had a higher valence than sad songs. Sad songs caused lower valence levels when compared to no music listening and happy song listening. Calm songs caused a significantly higher valence than annoying songs, and annoying songs caused a significantly lower valence than no music listening.

Similar but slightly different effects were seen when we averaged the values of the first and second song of each music category. The sad music caused lower valence levels compared to no music listening and to happy music listening. Happy music increased valence levels compared to sad music listening. Calm music caused valence to increase, compared to no music and annoying music. Annoying music has the opposite effect: it decreases valence, compared to no music and calm music. Thus, when looking at calm music in general compared to the effect of separated calm songs, calm music does increase valence compared to no music listening. Only for the averaged happy music compared to when no music is played there was no significant effect. This could mean that happy songs only increase valence when played after or before sad music and not when listening to happy music after not listening to any music. However, when looking at the means, there does seem to be a slightly higher valence during the happy songs compared to baseline. This suggests that there may be a difference after all, but that this experiment did not uncover a statistically significant difference. This may be due to the small sample size. To examine whether happy music does truly increase valence levels compared to when no music is played, further research must be conducted.

Furthermore, the analysis uncovered that there is no effect on valence caused by the quantity of happy or calm songs, as there was no effect of these songs at all. Even if the separate songs had an effect on valence, the means of both happy songs are similar, as are the means of the calm songs – suggesting that there would be no effect of the quantity of songs on valence. These results also suggest that while sad and annoying songs do have an effect on valence, the quantity that one listens to these songs is not relevant either. There were also no effects of music category order on valence.

For arousal, the results are less fitting. For the separate song values and for the averaged values, no significant effects were found for all the types of emotionally charged music. However, arousal levels during the calm music were significantly higher for the participants who first listened to calm music and then annoying music ($M = 5.6$, $SD = 1.95$), compared to participants who first listened to annoying music, and then to calm music. Order of the calm and annoying music does matter in the experienced arousal during calm music.

Furthermore, there did seem to be a tendency that calm and sad songs decrease arousal and happy and annoying songs increase arousal compared to baseline, but these results were not significant. A possible explanation for this could be that people found the questionnaire regarding arousal to be more confusing than the one regarding valence, and as a result we can see a fence-sitting effect, where people do not choose the more extreme values. Together with the small sample size, this could lead to reveal non-significant results when in reality the effects may be existent.

Lastly, there is a non-significant effect tendency visible in the data of the separate songs: the effect that some emotionally charged songs have on arousal seems to strengthen over time.

For example, the second happy song has a higher arousal than the first second song. And, the second calm song has a lower arousal than the first calm song. This could indicate that one's level of arousal is dependent on how many songs with a certain associated emotion you play. However, to truly find out if this may be the case, further research is necessary.

These results suggest that each emotionally charged music category fits into the expected valence dimension of the circumplex model of emotion, as expected. For arousal, it seems to be fitting as well, but not significantly.

In conclusion, music that an individual associates with happy emotions causes them to experience more positive emotions than when listening to sad music. Music that one associates with sad emotions causes them to experience more negative emotions than when listening to no music or happy music. This is an interesting finding when comparing it to Chapter 2, subsection 2.2, "Music and emotion". Existing literature found that sad music often increases valence levels, possibly due to the difference between music-induced emotions and real-life emotions. The fact that, in this experiment, sad music did decrease valence levels, may indicate that when one selects their own sad music, the emotional associations may cause them to feel more "real-life" sadness than when one has to listen to sad music selected by others.

Furthermore, music that someone associates with calm music makes them experience more positive emotions than when listening to no music or to annoying music. When someone finds music annoying, they have more negative emotions than when not listening to music or to calm music. The order in which the music is played does not significantly influence the valence. Music may not influence the arousal level of one's emotional state. But, listening to calm music after being aroused by annoying music, decreases arousal more strongly than when listening to calm music first. This gives reason to further research the order effects of music on arousal.

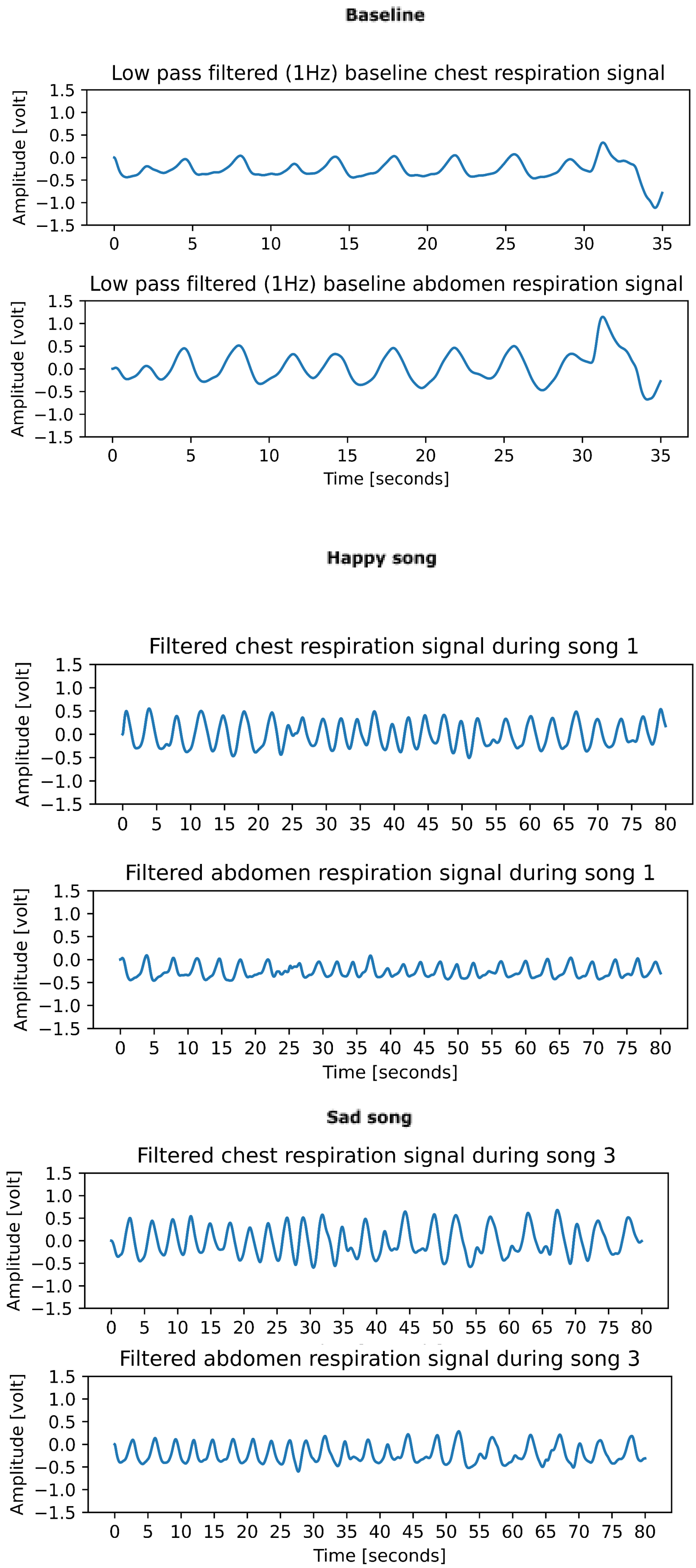
Subsection 4.2 – Respiration features

In this subsection, we will discuss the effects of emotionally charged music on the measured respiration features. To start, we will first visualize some examples of our participants' respiration patterns during no music listening (baseline) and music listening. A random participant's respiration pattern is chosen, visible in figure 18 (18A–C). In table 6, we notated the corresponding respiration features of this participant.

For this participant, all songs seem to have shorter respiration cycles, and thus a bigger respiration frequency, than during baseline. The chest respiration seems to be more sensitive to the effects of different songs compared to the abdominal respiration, as the abdominal signal seems to have a similar number of respiration cycles and amplitude for each song. For the chest respiration, the sad songs seem to have a higher amplitude and also more amplitude variability, compared to the happy songs.

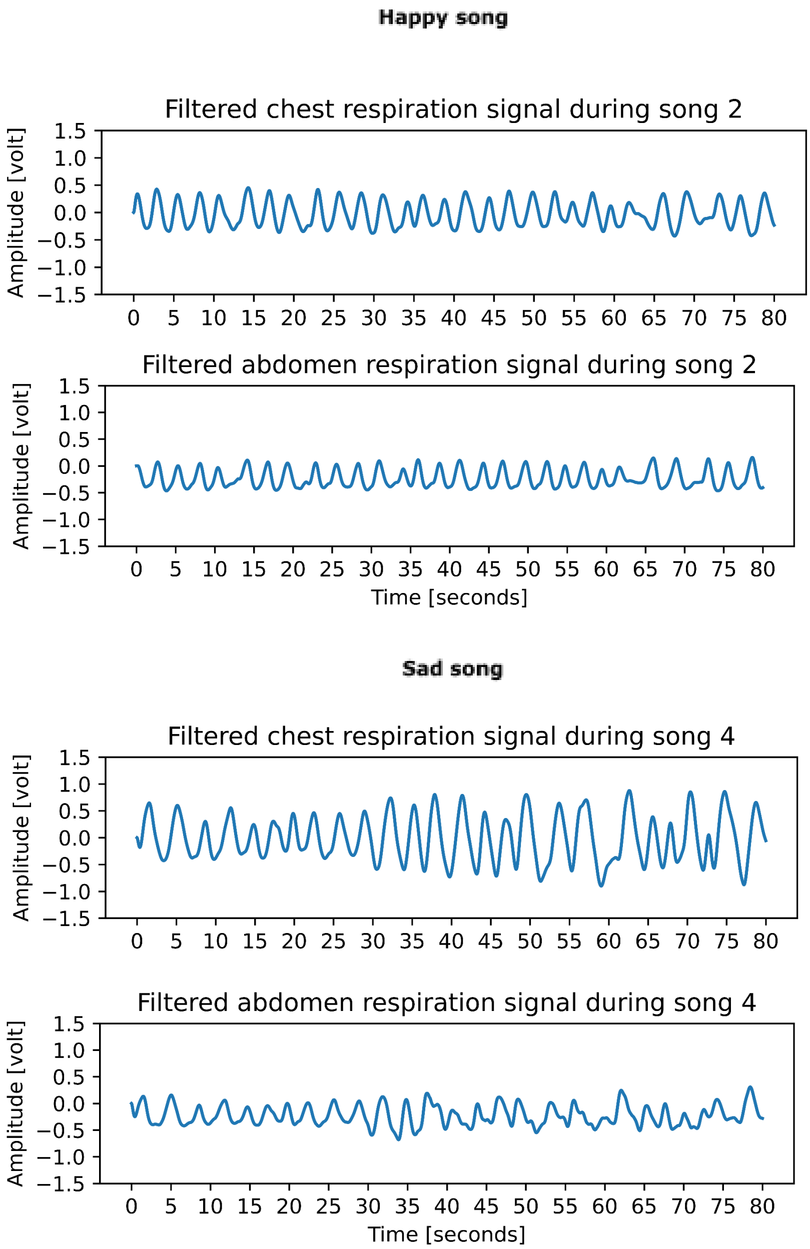
These are interesting findings and give an idea of possible respirational changes when one is listening to music. However, to explore whether these are incidental results or truly statistically significant, we need to look at the respiration data of all participants. For this purpose, we followed a similar analysis process for the respiration features as for the dimensional emotion values.

Figure 18.



A. Baseline respiration pattern of participant. In the upper plot, the chest respiration is depicted. In the lower plot, the abdomen respiration is depicted.

B. Respiration pattern of participant during the **first** happy song and during the **first** sad song. The two upper plots depict chest and abdomen respiration for the **first** happy song, consecutively.
In the two lower plots, the chest and abdomen respirations for the **first** sad song are depicted, consecutively.



C. Respiration pattern of participant during the **second** happy song and during the **second** sad song. The two upper plots depict chest and abdomen respiration for the **second** happy song, consecutively. In the two lower plots, the chest and abdomen respirations for the **second** sad song are depicted, consecutively.

Figure 18. Respiration pattern for one of the participants. Figure 18A depicts the baseline respiration pattern. Figure 18B shows the respiration pattern for the first happy song and the first sad song, to be able to compare both emotionally charged music categories. Figure 18C shows the respiration pattern during the second happy and sad song.

Chest			Abdomen		
Respiration pattern	Depth (volt)	Frequency (breaths/minute)	Respiration pattern	Depth (volt)	Frequency (breaths/minute)
Baseline chest	0.44	15.6	Baseline abdomen	0.71	17.8
First happy song chest	0.65	19.8	First happy song abdomen	0.32	19.9
First sad song chest	0.81	18.3	First sad song abdomen	0.50	18.3
Second happy song chest	0.57	22.1	Second happy song abdomen	0.41	22.1
Second sad song chest	1.01	19.4	Second sad song abdomen	0.43	19.5

Table 6. Respiration depth and frequency corresponding to the chest respiration pattern (left) and the abdominal respiration pattern (right) of figure 18.

Effect of separate emotionally charged songs on respiration features

In the following section the results of the analysis of slope, depth, peak to peak distance, respiration frequency and respiration regularity will be laid out. Repeated measures ANOVAs were conducted to compare differences between respiration features during each song and during the baseline. For example, the chest slope was compared for the baseline, the first happy song, the second happy song, the first sad song and the second sad song. We grouped the ANOVA results of each chest and abdominal respiration feature for the happy–sad condition and for the calm–annoying condition in appendix 2, tables 1–4.

Slope

Compared to baseline, there were no significant differences in chest respiration slope during any of the happy and sad songs. Neither were there significant differences in the abdominal respiration slope during these songs compared to baseline and each other. The same lack of significant findings can be seen in participants' respiration slope during the calm and annoying songs. These results indicate that separate emotionally charged songs have no effect on the respiration slope.

Depth

For abdominal and chest respiration depth, there were also no significant differences during the happy, sad, calm and annoying songs compared to each other and to baseline. This suggests that separate emotionally charged songs have no effect on the respiration depth.

Peak to peak distance

There were no significant differences in the peak to peak distance during chest or abdominal respiration. Nevertheless, regarding the chest respiration peak to peak distance, the repeated measures ANOVA showed that there was an almost significant difference between baseline, the happy songs and the sad songs, $F(4, 40) = 3.03$, $p = 0.059$. A post hoc pairwise comparison with Bonferroni correction showed that none of the combinations were statistically significant. Most of the pair differences had a significance of $p = 1.000$, with a few exceptions. For example, the difference between the chest peak to peak distance during no music ($M = 4.41$, $SD = 0.79$) and the second happy song ($M = 3.57$, $SD = 0.62$) had a p-value of 0.202. The difference between no music and the first sad song ($M = 3.68$, $SD = 0.66$) was also insignificant with a p-value of 0.357. And lastly, the difference between the second sad song and no music had a p-value of 0.496. These results suggest that happy nor sad songs have an effect on the peak to peak distance. However, as there was an almost significant difference in the ANOVA, further research must be done to truly rule out these effects.

For this reason, paired t-tests were conducted to compare the means of chest peak to peak distances of the baseline and each separate song. For the second happy song, the mean peak to peak distance in chest respiration was significantly lower ($M = 3.57$, $SD = 0.62$) than during baseline ($M = 4.41$, $SD = 0.79$), $t(10) = -2.76$, $p = 0.01$. Furthermore, a similar significant effect can be seen for chest respiration during the first and second sad songs. The mean peak to peak distance during the first sad song ($M = 3.68$, $SD = 0.66$) is significantly lower than during baseline, $t(10) = -2.43$, $p = 0.02$, and the same counts for the second sad song ($M = 3.71$, $SD = 0.73$), $t(10) = -2.23$, $p = 0.03$. These results, together with the ANOVA results, indicate that there probably is an effect of separate happy and sad songs on chest respiration peak to peak distance.

Frequency

There were no significant differences in the chest or abdominal frequency during the songs compared to baseline and each other. This indicates that separate emotionally charged songs have no effect on the respiration frequency.

Regularity

For the happy and sad music songs, the repeated measures ANOVA again showed that there were no significant differences in respiration peak to peak distance variation for chest or abdominal respiration. For the calm and annoying music conditions, there was no statistically significant difference in peak to peak distance variation either. These results indicate that emotionally charged songs do not (separately) influence the regularity of chest or abdominal respiration.

Thus, none of the respiration features showed significant differences for the separate emotionally charged songs. This would indicate that separate song listening has no effect on respiration at all. However, we can also examine the averaged effect of songs on respiration. Before we do this, we will analyze differences in respiration features between first and second songs.

Respiration features differences between first and second songs

Even though the above results can be insightful in the (lack of) effects of separate songs on respiration features, they are not conclusive as we had to deal with a small sample size for both the happy and sad and calm and annoying music conditions. For this reason, as for valence and arousal, it is interesting to look at the differences between both songs of each music category. If each mean feature value is similar during the first and second song, we could look at the average of each music condition and compare these to each other. Furthermore, analyzing the differences between the first and second songs can create insight into the effects of listening to multiple songs of the same music category. With this in mind, we conducted paired t-tests to compare the respiration feature means during both songs of each music-emotion category.

For the happy songs, there are no significant differences for each respiration feature during the second song compared to the first song. For the sad songs, however, there is one significant difference. The peak to peak distance for abdominal respiration during the second sad song ($M = 1.29$, $SD = 1.08$) is significantly higher with a mean difference of 0.18 seconds compared to the first song ($M = 1.10$, $SD = 1.07$), $t(10) = 3.54$, $p = 0.005$. The effect size consisted of a Cohen's d of 1.07, 95% CI [0.30, 1.80] or a Hedges' g of 0.99, 95% CI [0.28, 1.66].

For the calm songs, there are no significant differences. For the annoying songs there is one significant difference – for the abdominal respiration depth – but only when we consider the one-sided p-value (p = 0.035). We have no reasonable argument to do so, as we have no reason to suspect a difference in depth in a specific direction to occur between a first and a second song, so we should consider the two-sided p-value (p = 0.070).

The means and results of the paired t-tests for the first and second song of the sad music category are depicted in table 7. As there were no significant differences for the other three music categories, we organized the corresponding means and results of the paired t-tests for each first and second song into three tables in appendix 2, tables 5–7.

	Sad songs respiration variables	Mean values	Mean difference	t(10)	One-sided p	Two-sided p
Slope (volt per seconds)	Song 1 **chest** slope	0.34	0.02	0.71	0.248	0.496
	song 2 **chest** slope	0.36				
	Song 1 **abdomen** slope	0.34	0.06	1.27	0.116	0.232
	Song 2 **abdomen** slope	0.40				
Depth (volt)	Song 1 **chest** depth	0.58	0.07	1.72	0.058	0.117
	Song 2 **chest** depth	0.66				
	Song 1 **abdomen** depth	0.65	0.10	1.17	0.135	0.269
	Song 2 **abdomen** depth	0.76				
Peak to peak distance (seconds)	Song 1 **chest** peak to peak distance	3.68	0.04	0.19	0.427	0.854
	Song 2 **chest** peak to peak distance	3.72				
	Song 1 **abdomen** peak to peak distance	**1.10**	**0.18**	**3.54**	**0.003***	**0.005***
	Song 2 **abdomen** peak to peak distance	**1.28**				
Respiration frequency (breaths/minute)	Song 1 **chest** frequency	17.84	−0.48	−0.73	0.204	0.480
	Song 2 **chest** frequency	17.36				
	Song 1 **abdomen** frequency	17.90	−1.65	−1.42	0.094	0.187
	Song 2 **abdomen** frequency	16.25				
Respiration variation in peak to peak distance	Song 1 **chest** variation	0.85	−0.14	−1.56	0.075	0.150
	Song 2 **chest** variation	0.71				
	Song 1 **abdomen** variation	1.69	−0.82	−1.41	0.095	0.189
	Song 2 **abdomen** variation	0.88				

Table 7. The mean differences in respirational features for each first sad song compared to the second sad song. The results of the corresponding paired t-test are depicted in the three outer right columns.

We can conclude that there is solely one relevant significant difference between first and second songs: for abdominal peak to peak distance of the sad songs. As the rest of the respiration features do not differ significantly between each of the two songs, we will proceed to use the averages of each feature to further interpret the results. However, we should proceed with caution as we should consider possible missed significant results due to the small sample size and we should consider the significant effects found in above results.

Averaged effects of emotionally charged music on respiration features

We used the averaged respiration features to look at the overall effect of music on respiration features, as we did for valence and arousal. The average effect of multiple songs on respiration features may be different than the effect of separate songs.

We performed repeated measures ANOVAs to compare the effect of emotionally charged music on the respiration features. Of all the respiration features, there was only one statistically significant difference: between at least two of the mean chest respiration peak to peak distances during the happy–sad condition, $F(2, 20) = 39.75$, $p > 0.001$. With a post hoc pairwise comparison of the LSD type, it became clear that there was a significantly higher peak to peak chest respiration distance for no music ($M = 4.41$, $SD = 0.79$) compared to sad music ($M = 3.70$, $SD = 0.61$), $p = 0.033$. This suggests that breathing cycles become shorter when listening to sad music, compared to no music listening. There was no significant difference between no music and happy music ($M = 3.70$, $SD = 0.64$), $p = 0.062$, nor between sad and happy music, $p = 0.982$. In figure 19, the differences between peak to peak distance of chest respiration for the happy–sad condition are depicted.

In table 8, we can see the averaged chest and abdomen respiration features during happy, sad music and no music listening and the results of the corresponding repeated measures ANOVA. The non-significant differences between the averaged respiration features during the other three music categories are summarized in appendix 2, table 8.

There are few significant differences, and this may be due to the small sample size. As a result, it may be interesting to look at non-significant tendencies in the results to provide a framework of possible results for further research. For example, the slope for abdomen and chest respiration appears to increase in happy, sad, calm and annoying music when comparing it to no music listening. And, chest respiration depth seems to decrease for happy music compared to sad and no music listening. Abdominal respirational depth seems to increase for sad songs compared to no music and happy music.

	Average respiration features (happy and sad music condition)	Mean values	St. dev	F (df 2, 20)	p
Slope (volt per seconds)	Chest slope during baseline	0.28	0.12	0.54	0.508
	Chest slope during happy music	0.31	0.18		
	Chest slope during sad music	0.35	0.19		
	Abdominal slope during baseline	0.28	0.12	1.20	0.304
	Abdominal slope during happy music	0.31	0.14		
	Abdominal slope during sad music	0.37	0.19		
Depth (volt)	Chest depth during baseline	0.64	0.29	0.30	0.744
	Chest depth during happy music	0.54	0.29		
	Chest depth during sad music	0.62	0.30		
	Abdominal depth during baseline	0.54	0.23	1.48	0.252
	Abdominal depth during happy music	0.52	0.24		
	Abdominal depth during sad music	0.71	0.42		
Peak to peak distance (seconds)	Chest peak to peak distance during baseline	**4.41**	**0.79**	**4.50**	**0.024***
	Chest peak to peak distance during happy music	**3.70**	**0.64**		
	Chest peak to peak distance during sad music	**3.70**	**0.61**		
	Abdominal peak to peak distance during baseline	1.27	1.76	0.28	0.630
	Abdominal peak to peak distance during happy music	1.48	2.53		
	Abdominal peak to peak distance during sad music	1.19	1.07		
Respiration frequency (breaths/minute)	Chest frequency during baseline	16.19	2.00	1.83	0.186
	Chest frequency during happy music	17.51	2.54		
	Chest frequency during sad music	17.60	2.52		
	Abdominal frequency during baseline	15.92	4.32	0.85	0.441
	Abdominal frequency during happy music	17.21	2.87		
	Abdominal frequency during sad music	17.07	2.74		
Respiration peak to peak variation (seconds)	Chest respiration variation during baseline	0.98	0.73	0.40	0.677
	Chest respiration variation during happy music	1.01	0.78		
	Chest respiration variation during sad music	0.78	0.45		
	Abdominal respiration variation during baseline	1.95	3.38	0.34	0.582
	Abdominal respiration variation during happy music	1.35	0.92		
	Abdominal respiration variation during sad music	1.29	0.92		

Table 8. The mean differences in averaged respirational features (chest and abdomen) for no music listening (baseline), compared to happy and sad music listening. The results of the corresponding repeated measures ANOVA are depicted in the two outer right columns.

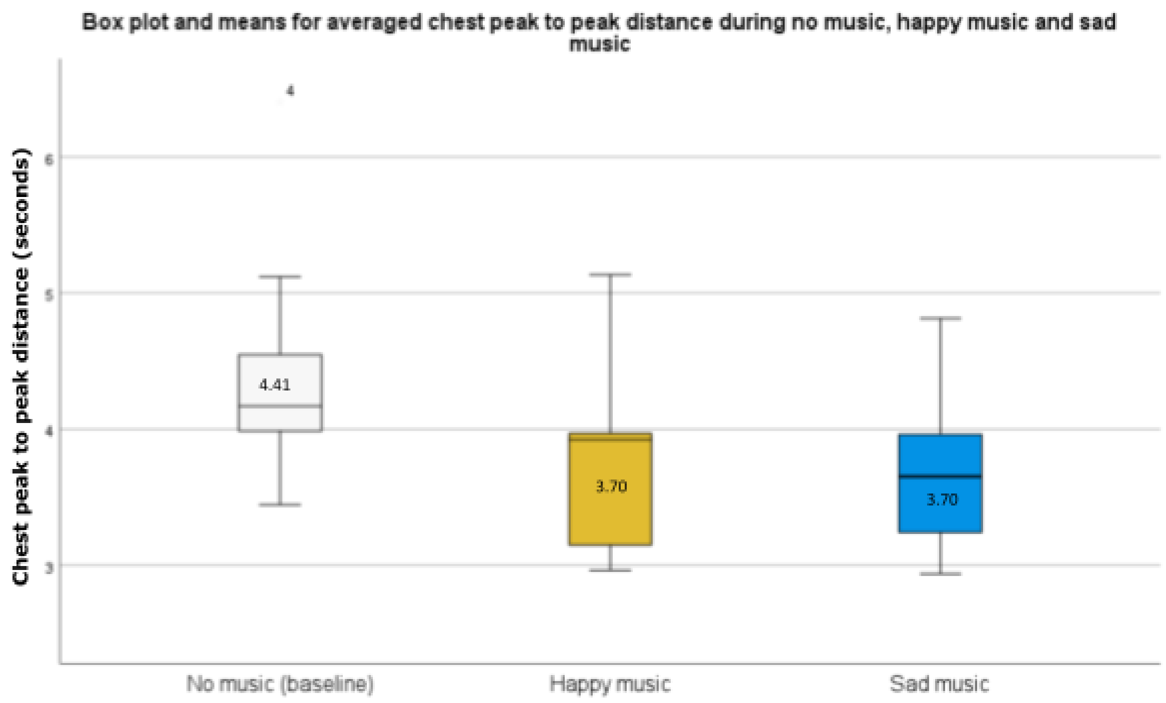


Figure 19. Box plots depicting averaged chest peak to peak distance and its variation during no music listening, during happy music listening, and during sad music listening (N = 11).

Furthermore, chest and abdominal frequency seem higher during sad and happy music, compared to no music listening. Calm music seems to decrease respiration frequency for both chest and abdominal respiration. Even though only the peak to peak chest distance during sad music was significantly shorter compared to baseline, the peak to peak chest distance during happy music had the same mean and almost the same standard deviation as during sad music. This suggests that happy music probably has a similar effect on respiration rate as sad music. Lastly, the variation in abdominal respiration peak to peak distance seems to decrease when listening to happy and sad music, compared to baseline. This would indicate that breathing becomes more regular when listening to happy and sad music, compared to listening to no music. Future research could build on this framework of possible effects by examining them in a greater sample size.

Effect of emotion elicitation order on respiration features

For the respiration features we also examined order effects of the different music categories. Multiple independent t-tests were performed to compare the effect of the different orders of music categories on the averaged respiration features. No t-test revealed a significant difference between the orders. For the sake of brevity and clarity, we grouped the results and their t- and p-values in appendix 2, tables 9–12. These results suggest that there is no effect of music order on respiration features for happy, sad, calm or annoying music.

Discussion – respiration features

In this subsection, we analyzed the effects of emotionally charged music on the respiration features. For none of the separate songs we saw significant differences in breathing features. Additional t-tests revealed that the peak to peak chest distance may be shorter during separate sad songs, and during the second happy song. Moreover, abdominal peak to peak distance may depend on the quantity of sad songs that one listens to, as the second sad song caused a significantly longer peak to peak distance than the first sad song. In future research, a higher quantity of songs and a greater sample size could reveal more significant effects of separate songs on peak to peak distances and thus on respiration rate.

However, when looking at the averaged effects, it became clear that peak to peak chest distance does become significantly shorter when listening to sad music, compared to no music listening. For happy music, the almost significant results showed that it is possible that peak to peak distance for chest respiration also decreases. These results suggest that respiration rate increases when listening to sad and happy music. This could mean that when listening to happy and sad music, the respiration becomes more active. This is in line with the non-significant tendency that the frequency of chest and abdomen respiration increased during the averaged happy music category. However, these results were not significant. This could be due to the small sample size and thus needs further research.

In conclusion, the results suggest that music experienced as sad increases one's respiration rate. Furthermore, music that is experienced as happy, may increase respiration rate too. These conclusions are in line with the existing literature discussed in Chapter 2. The order of the played music does not influence the differences.

However, the effects of music-experienced emotions on slope and depth are unclear, and the role of calm and annoying music on respiration features stays unsettled as well.

Subsection 4.3 – Predicting emotional dimensions with respiration features

Another way to test whether respiration features are influenced by emotions, is to reason the other way around: by testing if we can predict one's emotions with given respiration features. This prediction will reflect if there are (high) correlations between respiration features and one's emotions, which will not indicate a causal relationship but it can still provide added information on top of the previous analyses. It can show how changes in respiration features go together with increases or decreases in valence or arousal. This will shed light on whether the effects of music on respiration depend on elicited emotions as a mediator. For instance, if a high respiration frequency is strongly positively correlated with valence, this would suggest that music that elicits emotions with a high valence level possibly causes the respiration rate to increase. As the linear regression can only reveal correlations and not causations, the results should be carefully interpreted in the context of the results from subsections 4.1 and 4.2.

To attempt to predict changes in the emotional dimensions valence and arousal with respiration features, we conducted linear regression for both valence and arousal. In this prediction, we only consider changes in these values with respect to their baseline values, and not absolute values. This is due to the fact that absolute values are bound to a person. The variable names in the regression equation are thus understood to mean the change of this variable.

In order to predict changes in valence and arousal, we added all values of each feature together to form a general feature variable (e.g. valence, arousal, chest slope, et cetera). These variables were normalized by subtracting the baseline value from the value during the song. Afterwards, they were standardized to Z-scores. For the linear regression, valence and arousal were respectively considered as outcome values. All respiration features were considered predictor variables for both models.

Valence

After fitting the respiration data for valence, we can see a R square value of 0.163. This would mean that our model explains 16.3% of the variance in valence. However, when ANOVA is performed, we could see that this R-square was not significant ($F = 1.35$, $p = 0.223$).

If the model would be significant, we could predict the change in valence dimension of a song compared to baseline by its respiration features with the following regression equation:

$$
\begin{aligned}
Valence \ = \ & 2.00 \cdot 10^{-11} + 0.30 \cdot chest\ slope - 0.25 \cdot chest\ depth \\
& - 0.69 \cdot chest\ peak\ to\ peak\ distance - 0.93 \cdot chest\ frequency \\
& + 0.14 \cdot chest\ peak\ to\ peak\ variation + 0.33 \cdot abdominal\ slope \\
& - 0.51 \cdot abdominal\ depth + 0.20 \cdot abdominal\ peak\ to\ peak\ distance \\
& + 0.22 \cdot abdominal\ frequency + 0.13 \cdot abdominal\ peak\ to\ peak\ variation.
\end{aligned}
$$

To predict valence properly, one would need to use standardized Z-scores of the respiration features, and subtract the corresponding baseline value. However, in this case, the prediction result would just be a speculative estimate, as the R square change and the F-value change of the regression were not significant. Even if this were not the case, by further inspection of the relevant coefficients contributing to this model it became clear that only the chest frequency had a significant coefficient of –0.926, t(79) = –2.56, p = 0.013. As only chest frequency was a significant predictor for valence, a possible better fitting model would be reflected by the following regression equation:

$$
Valence = 2.00 \cdot 10^{-11} - 0.93 \cdot chest\ frequency.
$$

But this model would still not be statistically significant, according to the ANOVA, F(79) = 1.03, p = 0.314.

Arousal

For arousal the R Square value was 0.089. This would indicate that our model explains 8.9% of the variance in arousal. However, the ANOVA for the regression model shows a non-significant change of R square (F = 0.68, p = 0.741).

If the model would be significant, we could predict the arousal dimension of a song by its respiration features with the following regression equation:

$$
\begin{aligned}
Arousal \ = \ & 3.69 \cdot 10^{-11} + 0.06 \cdot chest\ slope + 0.13 \cdot chest\ depth \\
& - 0.13 \cdot chest\ peak\ to\ peak\ distance + 0.05 \cdot chest\ frequency \\
& - 0.17 \cdot chest\ peak\ to\ peak\ variation - 0.28 \cdot abdomen\ slope \\
& + 0.24 \cdot abdominal\ depth + 0.10 \cdot abdominal\ peak\ to\ peak\ distance \\
& + 0.09 \cdot abdominal\ frequency + 0.13\ abdominal\ peak\ to\ peak\ variation.
\end{aligned}
$$

Again, to use this regression equation, one needs to fill in standardized Z-scores of the respiration features. If this model would be statistically significant, we can look at the relevant coefficients contributing to the model more specifically. However, none of the features were a significant predictor for changes in arousal.

The valence prediction variables and their coefficients are visible in table 9 and for arousal in table 10.

Valence prediction model			
Respiration feature change (Z-scores)	Standardized Coefficients Beta	t	p-value
Slope chest	0.30	0.97	0.338
Slope abdomen	0.33	0.97	0.336
Depth chest	–0.25	–0.80	0.428
Depth abdomen	–0.51	–1.53	0.131
Peak to peak distance chest	–0.69	–1.76	0.082
Peak to peak distance abdomen	0.20	1.51	0.136
Frequency chest	**–0.93**	**–2.56**	**0.013***
Frequency abdomen	0.22	1.38	0.171
Peak to peak variation chest	0.14	0.96	0.340
Peak to peak variation abdomen	0.13	0.76	0.450

Table 9. Coefficients of the predictor variables (standardized respiration features) that belong in the valence predicting model, their corresponding t-value, p-value and part correlations. The part correlations reflect the relative contribution of each predictor variable.

Arousal prediction model			
Respiration feature change (Z-scores)	Standardized Coefficients Beta	t	p-value
Slope chest	0.06	0.17	0.865
Slope abdomen	–0.28	–0.79	0.432
Depth chest	0.13	0.39	0.695
Depth abdomen	0.24	0.70	0.489
Peak to peak distance chest	–0.13	–0.32	0.750
Peak to peak distance abdomen	0.10	0.76	0.453
Frequency chest	0.05	0.14	0.893
Frequency abdomen	0.09	0.54	0.594
Peak to peak variation chest	–0.17	–1.11	0.271
Peak to peak variation abdomen	0.13	0.75	0.454

Table 10. Coefficients of the predictor variables (standardized respiration features) that belong in the arousal predicting model, their corresponding t-value, p-value and part correlations. The part correlations reflect the relative contribution of each predictor variable.

These results suggest that respiration rate would be negatively correlated with valence, if the model itself would be significant. This is contradictory to the finding that happy and sad music both increase the respiration rate. To check if there truly could be a linear correlation between changes in valence and changes in respiration frequency, a Pearson correlation coefficient was computed. There was no significant correlation between the two variables, $r(78) = -0.11$, $p = 0.314$. In the discussion, parallels between these results and the effect of music on emotions and respiration features will be further discussed.

Discussion – predicting emotions with respiration features

In this subsection we attempted to construct a predictive model for changes in emotions with given respiration features. Both models for arousal and valence explained very little of the variance and were not significant.

However, if these models were significant, chest frequency would be most strongly negatively correlated with valence. This could suggest that valence is negatively influenced by chest frequency: as chest frequency increases, valence decreases and vice versa. This is partly in line with existing literature and the previous analyses, as emotions with a low valence level go together with an increase in respiration rate. However, happiness, which has a low valence, also tends to increase respiration rate, according to existing literature and the experiment results.

If the model for arousal were significant, arousal would have the strongest positive relation with the abdominal depth and the strongest negative relation with abdominal slope. This suggests that when abdominal respiration depth increases, arousal increases. And as abdominal respiration depth decreases, arousal also decreases. This does seem to be partly in line with existing literature, as emotions with high arousal show an increase in respiration depth, where emotions with low to medium arousal show variable effects or decreases in depth. The negative relation with the abdominal slope suggests that when abdominal respiration slope increases, arousal decreases. This would mean that faster inhalation goes together with lower arousal levels. Further research must be conducted to examine these correlations.

The discrepancy between the valence model and the analyzed effects is probably due to the non-significance of the model and because the relationship between valence and respiration rate is not linear. Therefore, it is statistically more sensible to consider the results of the analyzed effects to be more relevant than the results of the linear regression analysis. Both models mainly serve as an example of a way to set up prediction models if the results would be significant, for example, when a larger sample size is at play.

Furthermore, the lack of high correlations and the low predictive power could suggest that changes in emotions are not highly predictable when only considering respiration features as predictors. Respiration features may help in predicting emotions, for example when programming an AI to recognize emotions, but we need more predictive factors to accurately deduct which emotion is at play.

Chapter 5: General conclusion and discussion

In this thesis, we explored the following main research question: To what extent does self-selected emotionally charged music influence one’s respiration and emotional states?

In Chapter 2, existing literature revealed that music has an influential effect on one’s emotions and respiration. Existing research mainly used music that was associated with certain emotions on the basis of general assumptions or by assessment of the researchers themselves. Or, they assessed the effects of internal aspects of music (e.g. tempo, key). The literature showed that the effect of music on emotions is influenced by how we measure an emotion: the effect is stronger when measuring dimensional values of emotions (e.g., arousal and valence), compared to when a categorical emotion (e.g, anger) is measured. In the existing literature, it became clear that – amongst others – happy, angry and sad music all tend to increase one’s respiration rate. Calm music decreases one’s respiration rate. Happy and calm music have a positive effect on valence levels, whereas sad and annoying music have a negative effect. Thus, there seems to be no linear relationship between valence and respiration rate. Respiration rate may have more to do with arousal. The results on respiration depth are more ambiguous, as the respiration depths seem quite variable for different emotions.

To expand the results found in literature, we conducted an experiment where we specifically asked participants to select their own music, based on which emotions they normally experience during these songs. This was based on the assumption that every person experiences different associative emotions when listening to a song, even if this song is intended to convey a specific emotion. Furthermore, we measured respiration features and experienced arousal and valence levels during these songs.

The results showed that self-selected emotionally charged music does influence one’s emotional state by strongly influencing experienced valence levels during music listening. Music that one regards as happy or calm, increases valence levels. And, sad and annoying music decreases one’s valence level.

Furthermore, self-selected emotionally charged music has an effect on respiration. The results confirmed the finding that one has a relatively high respiration rate when listening to happy music. Sad music probably has the same effect, but this needs further research. This confirms the fact that valence is not linearly correlated to respiration rate: respiration rate seems to increase whenever “intense” emotions are at play, regardless of how positive these emotions are experienced. This suggests that arousal may be more important in influencing the respiration rate. Or it could mean that there may be a separate dimension at play, which indicates the intensity of an experienced emotion. Lastly, it could also mean that music in general heightens respiration rate, regardless of the induced emotions. Unfortunately, the results did not fill in the missing gaps regarding the effect of music on arousal, the connection between arousal and respiration rate, or the one regarding the ambiguous effects of music on respiration depth. This does not necessarily mean that music has no influence on arousal or respiration depth. Explanations as to why there is a lack of conclusive findings are discussed below.

Lastly, linear regression between the dimensional values and respiration features revealed that chest respiration may be correlated with valence. However, the found relationship is linear, which is not in line with the rest of the results. Whether elicited emotions are truly the mediator in the effect of music on respiration is thus yet to be uncovered. As stated above, the literature and tendencies in the results point to the influence of arousal on respiration rate, which may play an important part in this mediating effect. However, it is clear that emotionally charged music separately has an effect on the experienced positivity of emotions and on at least one respiration feature.

Even though this thesis was designed with a keen eye on safeguarding validity and reliability, it has a few limitations. The most obvious and largest limitation is the small sample size. With eleven participants for the happy and sad condition and nine participants for the calm and annoying condition, both groups had too small a statistical power to produce statistically strong results. This may have resulted in the lack of significant effects and correlations in the participant sample, whereas these results may exist in the population sample. Or, it could be the other way around: results seen in this participant sample, may not exist in the population sample. This is why this thesis may serve a purpose as a possible pilot study for future research.

Secondly, there are some points for improvement regarding the experiment design. For example, during the debriefing, some participants reflected that they felt uneasy and even nervous during parts of the experiment because they had to speak to a camera. This tension may have still been influencing the participants’ experienced emotions during the songs. This may have increased or flattened out the results. This is especially a possibility for arousal, as it may be increased by nervosity. In future research, it may be better to split the experiment into two experiments or two sessions: in the first experiment there is a focus on the arousal and valence questionnaires and on the respiration features, and in the second participants get interviewed and (audio) recorded when they talk about the emotions they experienced during the songs.

Furthermore, the participants may have been influenced by the fact that they knew which songs they had entered for each emotional music category. For instance, when they knew they selected a certain happy song, they may have felt social conformity to fill in that they indeed felt positive emotions when listening to this song. This effect could be strengthened by the fact that most participants knew the researcher conducting the experiment, making them want to provide “nice” results. Additionally, results of the questionnaires may be affected because participants had to recollect the emotions they experienced during listening a small period afterwards. This could cause recall bias: an inaccurate recollection of events or experiences. In the future, it would be better to have a double-blind experiment and find a solution for this recall bias, but this was not yet possible due to lack of time and (other) resources.

Next to these limitations of the experiment design, we will discuss a limitation of the data analysis. The respiration signal had to be filtered and smoothed to calculate its respiration features. For the purpose of statistical reliability, the respiration signals of each participant were smoothed in the same manner, albeit based on a value relative to their individual maximum respiration values. This may have caused some respiration features to not be completely statistically valid. Additionally, as the sample size was small, the normality distribution of the data may be compromised. However, because of the small sample size, testing for normality is also of low statistical value. If the data were not distributed normally, it would have been better to conduct different statistical tests. However, we chose not to do this because this thesis was meant as a pilot study and a showcase of how statistical analysis should be done in case the sample size was bigger.

Lastly, we should consider respiration features that were not included in this thesis. For example, a well researched parameter for respiration is the inspiration–expiration ratio. For the sake of brevity, this respiration feature was not part of the scope of this thesis. However, as current literature shows no conclusive results on the effects of music on this ratio, it could be interesting to research in the future with regard to emotionally charged music. It could also be relevant to look at long term effects of music on respiration features and emotions.

In spite of the limitations, the results of this thesis thus partly confirm the findings in the literature. More importantly, they show that there are effects of music when participants themselves choose emotionally charged songs. This indicates that the effect of music on emotions and respiration may depend on individual associations with music. Future research could build further on these findings by examining the role that these associative emotions play in influencing emotions and respiration, on the one hand, and the role of internal aspects of songs on the other hand. For example, participants could listen to their own emotionally charged music, but also the emotionally charged music of other participants. In this research, long-term effects of music on emotion and respiration could be measured over longer periods of time. Lastly, more emotional dimensions than arousal and valence should be considered to uncover the mediating role of emotions in the effects of music on respiration.

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Appendices

Appendix 1. Selected songs.

	Artist(s)	Title
Happy music	Parcels	Lightenup
	Vampire Weekend feat. Steve Lacy	Sunflower
	Dua Lipa	Pretty please
	Jack Garratt	Mara
	Tame Impala	Let it happen
	Tender	Smoke
	Lionel Richie	All night long (all night)
	A$AP Rocky	Sundress
	Thijs Boontje	Dansen met jou
	Froukje	Niets tussen
	Doja Cat feat. SZA	Kiss me more
	The Strokes	The adults are talking
	Saint Motel	My type
	Lizzo	Good as hell
	Unknown Mortal Orchestra	Multi Love
	Don Omar	Dile
	Scotty McCreery	Damn straight
	Drake White	Giants
	Post Malone feat. Swae Lee	Sunflower
	Myd	The sun
	Davina Michelle	No angel
	Antoon	Hotelschool

Table 1. All the songs (artist and title) that were selected by participants to represent happiness. For each participant (N = 11), two of the self-reported songs that made them feel happy (before the experiment) were selected and presented in this table.

	Artist(s)	Title
Sad music	Tom Odell	Sense
	Mandolin Orange	Wildfire
	Bryce Xavier	Fall in love again
	Kina	Are you still with him
	Archive	Again
	Michael Kiwanuka	Cold little heart
	XXXTENTATION	Jocelyn
	Coldplay	Fix you
	Labrinth	Jealous
	Frances	Grow
	Emma Louise	Wish you well
	Khruangbin feat. Leon Bridges	Chocolate hills
	Foals	Mountain at my gates
	Kendrick Lamar	Sing about me, I'm dying of thirst
	Lord Huron	The night we met
	The Lumineers	Sleep on the floor
	Tenille Townes	Villain in me
	Ashley Campbell	Remembering
	Goldband	Alles kapot
	Sampha	(No one knows me) like the piano
	Birdy	Skinny love
	Nick en Simon	Onvrijwillig vrij

Table 2. All the songs (artist and title) that were selected by participants to represent sadness. For each participant (N = 11), two of the self-reported songs that made them feel sad (before the experiment) were selected and presented in this table.

	Artist(s)	Title
Calm music	Hiroshi Yoshimura	Green
	Frédéric Chopin	Nocturne in E flat Major, Op. 9, No. 2
	Jack Johnson	Banana pancakes
	Natalia Lafourcade feat. Jorge Drexler	Para qué sufrir
	fun.	Be calm
	Danny Vera	Roller Coaster
	Snatam Kaur	Mul mantra
	Ben Howard	Only love
	Elvis Presley	Suspicious minds
	Ludovico Einaudi	Fly
	Ben Howard	Depth over distance
	Spinvis	Bagagedrager
	Gradient Descent	Ani's song
	First Aid Kit	My silver lining
	JNR Choi	To the moon
	V.I.C.	A teen
	A$AP Rocky	L$D
	Childish Gambino	Redbone

Table 3. All the songs (artist and title) that were selected by participants to represent calmness. For each participant (N = 9), two of the self-reported songs that made them feel calm (before the experiment) were selected and presented in this table.

	Artist(s)	Title
Annoying music	Antoon	Leuk
	Kraantje Pappie	Liefde in de lucht
	Olivia Rodrigo	Good 4 u
	Snollebollekes	Links Rechts
	LMFAO	Party rock anthem
	Doja Cat	Say so
	Mart Hoogkamer	Ik ga zwemmen
	Baauer	Harlem shake
	Hornbach	Advertisement tune (on loop)
	Kruidvat	Advertisement tune (on loop)
	Aqua	Barbie Girl
	Rebecca Black	Friday
	The Chemical Brothers	The devil is in the details
	Xiao Ke	Beijing welcomes you
	Lang leve de liefde	Intro song
	Bol.com	Advertisement tune (on loop)
	Rihanna	Work
	Slipknot	Duality

Table 4. All the songs (artist and title) that were selected by participants to represent annoyance. For each participant (N = 9), two of the self-reported songs that made them feel annoyed (before the experiment) were selected and presented in this table.

Appendix 2. Tables

Chest respiration	Respiration features (happy and sad songs)	Mean values	St. dev	F (df 4, 40)	p
Slope (volt per seconds)	Chest slope during baseline	0.28	0.12	0.55	0.569
	Chest slope during happy song 1	0.31	0.17		
	Chest slope during happy song 2	0.32	0.21		
	Chest slope during sad song 1	0.34	0.18		
	Chest slope during sad song 2	0.36	0.22		
Depth (volt)	Chest depth during baseline	0.64	0.29	0.72	0.492
	Chest depth during happy song 1	0.54	0.29		
	Chest depth during happy song 2	0.50	0.29		
	Chest depth during sad song 1	0.59	0.31		
	Chest depth during sad song 2	0.66	0.31		
Peak to peak distance (seconds)	Chest peak to peak distance during baseline	4.41	0.79	3.03	0.059
	Chest peak to peak distance during happy song 1	3.82	0.83		
	Chest peak to peak distance during happy song 2	3.57	0.62		
	Chest peak to peak distance during sad song 1	3.68	0.66		
	Chest peak to peak distance during sad song 2	3.72	0.73		
Respiration frequency (breaths/minute)	Chest frequency during baseline	16.19	2.00	1.25	0.305
	Chest frequency during happy song 1	17.11	2.82		
	Chest frequency during happy song 2	17.90	2.97		
	Chest frequency during sad song 1	17.84	2.61		
	Chest frequency during sad song 2	17.36	2.87		
Respiration regularity (seconds)	Chest regularity during baseline	0.98	0.73	0.54	0.566
	Chest regularity during happy song 1	1.00	0.81		
	Chest regularity during happy song 2	1.02	0.81		
	Chest regularity during sad song 1	0.71	0.44		
	Chest regularity during sad song 2	0.85	0.50		

Table 1. Mean chest respiration features during the baseline, during the first and second happy song, and during the first and second sad song (happy–sad condition). The results of the corresponding repeated measures ANOVA are depicted in the two outer right columns.

Abdominal respiration	Respiration features (happy and sad songs)	Mean values	St. dev	F (df 4, 40)	p
Slope (volt per seconds)	Abdomen slope during baseline	0.28	0.12	1.04	0.374
	Abdomen slope during happy song 1	0.31	0.24		
	Abdomen slope during happy song 2	0.31	0.12		
	Abdomen slope during sad song 1	0.34	0.17		
	Abdomen slope during sad song 2	0.40	0.23		
Depth (volt)	Abdomen depth during baseline	0.54	0.23	1.54	0.209
	Abdomen depth during happy song 1	0.54	0.36		
	Abdomen depth during happy song 2	0.51	0.19		
	Abdomen depth during sad song 1	0.65	0.40		
	Abdomen depth during sad song 2	0.76	0.48		
Peak to peak distance (seconds)	Abdomen peak to peak distance during baseline	1.27	1.76	0.79	0.400
	Abdomen peak to peak distance during happy song 1	0.96	1.05		
	Abdomen peak to peak distance during happy song 2	1.99	4.16		
	Abdomen peak to peak distance during sad song 1	1.11	1.07		
	Abdomen peak to peak distance during sad song 2	1.28	1.08		
Respiration frequency (breaths/minute)	Abdomen frequency during baseline	15.92	4.32	0.15	0.709
	Abdomen frequency during happy song 1	17.48	2.83		
	Abdomen frequency during happy song 2	16.95	5.25		
	Abdomen frequency during sad song 1	17.90	2.47		
	Abdomen frequency during sad song 2	16.25	4.06		
Respiration regularity (seconds)	Abdomen regularity during baseline	1.95	3.38	0.56	0.554
	Abdomen regularity during happy song 1	1.12	0.78		
	Abdomen regularity during happy song 2	1.57	1.87		
	Abdomen regularity during sad song 1	0.88	0.56		
	Abdomen regularity during sad song 2	1.69	1.75		

Table 2. Mean abdominal respiration features during the baseline, during the first and second happy song, and during the first and second sad song (happy–sad condition). The results of the corresponding repeated measures ANOVA are depicted in the two outer right columns.

Chest respiration	Respiration features (calm and annoying songs)	Mean values	St. dev	F (df 4, 40)	p
Slope (volt per seconds)	Chest slope during baseline	0.31	0.15	0.73	0.451
	Chest slope during calm song 1	0.34	0.11		
	Chest slope during calm song 2	0.35	0.11		
	Chest slope during annoying song 1	0.34	0.11		
	Chest slope during annoying song 2	0.38	0.11		
Depth (volt)	Chest depth during baseline	0.65	0.38	0.37	0.647
	Chest depth during calm song 1	0.61	0.22		
	Chest depth during calm song 2	0.68	0.22		
	Chest depth during annoying song 1	0.57	0.15		
	Chest depth during annoying song 2	0.67	0.22		
Peak to peak distance (seconds)	Chest peak to peak distance during baseline	4.20	0.76	1.25	0.313
	Chest peak to peak distance during calm song 1	4.09	1.05		
	Chest peak to peak distance during calm song 2	4.54	1.55		
	Chest peak to peak distance during annoying song 1	4.01	0.96		
	Chest peak to peak distance during annoying song 2	3.93	0.89		
Respiration frequency (breaths/minute)	Chest frequency during baseline	16.51	3.19	0.81	0.466
	Chest frequency during calm song 1	16.66	3.63		
	Chest frequency during calm song 2	15.30	4.40		
	Chest frequency during annoying song 1	16.60	3.29		
	Chest frequency during annoying song 2	16.71	3.07		
Respiration regularity (seconds)	Chest regularity during baseline	1.05	0.55	0.51	0.619
	Chest regularity during calm song 1	0.95	1.15		
	Chest regularity during calm song 2	0.68	0.31		
	Chest regularity during annoying song 1	1.01	0.88		
	Chest regularity during annoying song 2	0.88	0.50		

Table 3. Mean chest respiration features during the baseline, during the first and second calm song, and during the first and second annoying song (calm–annoying condition). The results of the corresponding repeated measures ANOVA are depicted in the two outer right columns.

Abdominal respiration	Respiration features (calm and annoying songs)	Mean values	St. dev	F (df 4, 40)	p
Slope (volt per seconds)	Abdomen slope during baseline	0.27	0.11	1.65	0.232
	Abdomen slope during calm song 1	0.34	0.13		
	Abdomen slope during calm song 2	0.29	0.16		
	Abdomen slope during annoying song 1	0.37	0.12		
	Abdomen slope during annoying song 2	0.29	0.15		
Depth (volt)	Abdomen depth during baseline	0.56	0.19	2.72	0.107
	Abdomen depth during calm song 1	0.65	0.16		
	Abdomen depth during calm song 2	0.57	0.22		
	Abdomen depth during annoying song 1	0.74	0.29		
	Abdomen depth during annoying song 2	0.51	0.24		
Peak to peak distance (seconds)	Abdomen peak to peak distance during baseline	2.03	1.67	0.30	0.744
	Abdomen peak to peak distance during calm song 1	2.16	1.83		
	Abdomen peak to peak distance during calm song 2	2.14	1.80		
	Abdomen peak to peak distance during annoying song 1	2.05	1.47		
	Abdomen peak to peak distance during annoying song 2	2.03	1.73		
Respiration frequency (breaths/minute)	Abdomen frequency during baseline	15.86	2.92	0.26	0.707
	Abdomen frequency during calm song 1	15.26	3.48		
	Abdomen frequency during calm song 2	15.58	3.18		
	Abdomen frequency during annoying song 1	16.02	3.62		
	Abdomen frequency during annoying song 2	16.02	2.80		
Respiration regularity (seconds)	Abdomen regularity during baseline	0.76	0.50	0.19	0.956
	Abdomen regularity during calm song 1	0.95	0.58		
	Abdomen regularity during calm song 2	0.96	0.54		
	Abdomen regularity during annoying song 1	1.30	1.01		
	Abdomen regularity during annoying song 2	1.24	0.68		

Table 4. Mean abdomen respiration features during the baseline, during the first and second calm song, and during the first and second annoying song. The results of the corresponding repeated measures ANOVA are depicted in the two outer right columns.

	Happy songs respiration values	Mean values	Mean difference	t(10)	One-sided p	Two-sided p
Slope (volt per seconds)	Song 1 **chest** slope	0.31	0.01	0.28	0.391	0.782
	song 2 **chest** slope	0.32				
	Song 1 **abdomen** slope	0.31	−0.01	−0.07	0.473	0.945
	Song 2 **abdomen** slope	0.31				
Depth (volt)	Song 1 **chest** depth	0.54	−0.04	−0.58	0.286	0.572
	Song 2 **chest** depth	0.50				
	Song 1 **abdomen** depth	0.54	−0.03	−0.31	0.381	0.763
	Song 2 **abdomen** depth	0.51				
Peak to peak distance (seconds)	Song 1 **chest** peak to peak distance	3.82	−0.26	−1.18	0.133	0.265
	Song 2 **chest** peak to peak distance	3.57				
	Song 1 **abdomen** peak to peak distance	0.96	1.03	1.02	0.165	0.331
	Song 2 **abdomen** peak to peak distance	1.99				
Respiration frequency (breaths/minute)	Song 1 **chest** frequency	17.11	0.79	0.95	0.183	0.366
	Song 2 **chest** frequency	17.90				
	Song 1 **abdomen** frequency	17.48	−0.53	−0.28	0.391	0.783
	Song 2 **abdomen** frequency	16.95				
Respiration variation in peak to peak distance	Song 1 **chest** variation	1.00	0.01	0.11	0.456	0.912
	Song 2 **chest** variation	1.02				
	Song 1 **abdomen** variation	1.12	0.45	0.69	0.254	0.508
	Song 2 **abdomen** variation	1.57				

Table 5. The mean differences in respirational features for each first happy song compared to the second happy song. The results of the corresponding paired t-test are depicted in the three outer right columns.

	Calm songs respiration values	Mean values	Mean difference	t(8)	One-sided p	Two-sided p
Slope (volt per seconds)	Song 1 **chest** slope	0.34	0.01	0.40	0.350	0.699
	song 2 **chest** slope	0.35				
	Song 1 **abdomen** slope	0.34	−0.05	−0.95	0.185	0.371
	Song 2 **abdomen** slope	0.29				
Depth (volt)	Song 1 **chest** depth	0.61	0.07	1.38	0.102	0.204
	Song 2 **chest** depth	0.68				
	Song 1 **abdomen** depth	0.65	−0.08	−0.99	0.174	0.349
	Song 2 **abdomen** depth	0.57				
Peak to peak distance (seconds)	Song 1 **chest** peak to peak distance	4.09	0.45	1.13	0.145	0.291
	Song 2 **chest** peak to peak distance	4.54				
	Song 1 **abdomen** peak to peak distance	2.16	−0.02	−0.28	0.392	0.784
	Song 2 **abdomen** peak to peak distance	2.14				
Respiration frequency (breaths/minute)	Song 1 **chest** frequency	16.66	−1.36	−1.35	0.106	0.213
	Song 2 **chest** frequency	15.30				
	Song 1 **abdomen** frequency	15.26	0.33	1.36	0.105	0.210
	Song 2 **abdomen** frequency	15.58				
Respiration variation in peak to peak distance	Song 1 **chest** variation	0.95	−0.28	−0.72	0.246	0.491
	Song 2 **chest** variation	0.68				
	Song 1 **abdomen** variation	0.97	0.02	0.18	0.342	0.865
	Song 2 **abdomen** variation	0.95				

Table 6. The mean differences in respirational features for each first calm song compared to the second calm song. The results of the corresponding paired t-test are depicted in the three outer right columns.

	Annoying songs respiration variables	Mean values	Mean difference	t(8)	One-sided p	Two-sided p
Slope (volt per seconds)	Song 1 **chest** slope	0.34	0.04	1.84	0.051	0.103
	song 2 **chest** slope	0.38				
	Song 1 **abdomen** slope	0.37	–0.08	–1.45	0.092	0.184
	Song 2 **abdomen** slope	0.29				
Depth (volt)	Song 1 **chest** depth	0.57	0.11	1.18	0.136	0.271
	Song 2 **chest** depth	0.68				
	Song 1 **abdomen** depth	**0.74**	**–0.23**	**–2.09**	**0.035***	**0.070**
	Song 2 **abdomen** depth	**0.51**				
Peak to peak distance (seconds)	Song 1 **chest** peak to peak distance	4.00	–0.08	–0.77	0.233	0.466
	Song 2 **chest** peak to peak distance	3.93				
	Song 1 **abdomen** peak to peak distance	2.05	–0.02	–0.13	0.450	0.009
	Song 2 **abdomen** peak to peak distance	2.03				
Respiration frequency (breaths/minute)	Song 1 **chest** frequency	16.60	0.11	0.22	0.417	0.835
	Song 2 **chest** frequency	16.71				
	Song 1 **abdomen** frequency	16.02	0.003	0.007	0.497	0.995
	Song 2 **abdomen** frequency	16.02				
Respiration variation in peak to peak distance	Song 1 **chest** variation	1.01	–0.70	–0.57	0.292	0.584
	Song 2 **chest** variation	0.88				
	Song 1 **abdomen** variation	1.30	0.74	–0.25	0.404	0.809
	Song 2 **abdomen** variation	1.24				

Table 7. The mean differences in respirational features for each first annoying song compared to the second annoying song. The results of the corresponding paired t-test are depicted in the three outer right columns.

	Average respiration features (calm and annoying music condition)	Mean values	St. dev	F (df 2, 16)	p
Slope (volt per seconds)	Chest slope during baseline	0.31	0.15	0.56	0.478
	Chest slope during calm music	0.35	0.10		
	Chest slope during annoying music	0.36	0.10		
	Abdominal slope during baseline	0.27	0.11	2.14	0.177
	Abdominal slope during calm music	0.32	0.12		
	Abdominal slope during annoying music	0.33	0.11		
Depth (volt)	Chest depth during baseline	0.65	0.38	0.03	0.894
	Chest depth during calm music	0.65	0.21		
	Chest depth during annoying music	0.62	0.13		
	Abdominal depth during baseline	0.56	0.19	1.32	0.295
	Abdominal depth during calm music	0.61	0.15		
	Abdominal depth during annoying music	0.62	0.20		
Peak to peak distance (seconds)	Chest peak to peak distance during baseline	4.20	0.76	0.93	0.414
	Chest peak to peak distance during calm music	4.32	1.19		
	Chest peak to peak distance during annoying music	3.97	0.91		
	Abdominal peak to peak distance during baseline	2.03	1.67	0.31	0.739
	Abdominal peak to peak distance during calm music	2.15	1.81		
	Abdominal peak to peak distance during annoying music	2.04	1.59		
Respiration frequency (breaths/minute)	Chest frequency during baseline	16.51	3.19	0.29	0.645
	Chest frequency during calm music	15.98	3.74		
	Chest frequency during annoying music	16.66	3.10		
	Abdominal frequency during baseline	15.86	2.92	0.16	0.730
	Abdominal frequency during calm music	15.42	3.31		
	Abdominal frequency during annoying music	16.02	3.16		
Respiration peak to peak distance variation (seconds)	Chest respiration variation during baseline	1.05	0.55	0.71	0.505
	Chest respiration variation during calm music	0.81	0.62		
	Chest respiration variation during annoying music	0.94	0.63		
	Abdominal respiration variation during baseline	0.76	0.50	2.19	0.144
	Abdominal respiration variation during calm music	0.96	0.53		
	Abdominal respiration variation during annoying music	1.27	0.78		

Table 8. The mean differences in averaged respirational features (chest and abdomen) for no music listening (baseline), compared to calm and annoying music listening. The results of the corresponding repeated measures ANOVA are depicted in the two outer right columns.

		Respiration feature	Condition	N	Mean	Std. Deviation	t(9)	p
Happy music	Slope	Slope chest respiration during happy music	Happy–sad	5	0.37	0.20	0.97	0.356
			Sad–happy	6	0.26	0.16		
		Slope abdomen respiration during happy music	Happy–sad	5	0.31	0.12	0.08	0.940
			Sad–happy	6	0.31	0.17		
	Depth	Depth chest respiration during happy music	Happy–sad	5	0.70	0.33	1.74	0.115
			Sad–happy	6	0.42	0.20		
		Depth abdomen respiration during happy music	Happy–sad	5	0.56	0.20	0.52	0.617
			Sad–happy	6	0.49	0.28		
	Peak to peak distance	Peak to peak distance in chest respiration during happy music	Happy–sad	5	3.42	0.51	-1.38	0.201
			Sad–happy	6	3.93	0.69		
		Peak to peak distance in abdomen respiration during happy music	Happy–sad	5	0.56	0.20	-1.22	0.277
			Sad–happy	6	2.24	3.36		
	Frequency	Frequency chest respiration during happy music	Happy–sad	5	18.55	2.49	1.28	0.232
			Sad–happy	6	16.64	2.45		
		Frequency abdomen respiration during happy music	Happy–sad	5	17.51	2.14	0.30	0.769
			Sad–happy	6	16.96	3.56		
	Peak to peak distance variation	Variation chest respiration during happy music	Happy–sad	5	0.65	0.26	-1.47	0.175
			Sad–happy	6	1.31	0.97		
		Variation abdomen respiration during happy music	Happy–sad	5	1.14	0.70	-0.66	0.527
			Sad–happy	6	1.52	1.11		

Table 9. Differences between respiration features for each music listening order during happy music listening.

		Respiration feature	Condition	N	Mean	Std. Deviation	t(9)	p
Sad music	Slope	Slope chest respiration during sad music	Happy–sad	5	0.41	0.20	0.94	0.372
			Sad–happy	6	0.30	0.19		
		Slope abdomen respiration during sad music	Happy–sad	5	0.38	0.16	0.11	0.918
			Sad–happy	6	0.37	0.22		
	Depth	Depth chest respiration during sad music	Happy–sad	5	0.71	0.27	0.87	0.408
			Sad–happy	6	0.55	0.33		
		Depth abdomen respiration during sad music	Happy–sad	5	0.69	0.33	-0.12	0.908
			Sad–happy	6	0.72	0.51		
	Peak to peak distance	Peak to peak distance in chest respiration during sad music	Happy–sad	5	3.44	0.46	-1.34	0.214
			Sad–happy	6	3.92	0.67		
		Peak to peak distance in abdomen respiration during sad music	Happy–sad	5	0.69	0.33	-1.66	0.15
			Sad–happy	6	1.61	1.32		
	Frequency	Frequency chest respiration during sad music	Happy–sad	5	18.39	2.11	0.95	0.369
			Sad–happy	6	16.94	2.82		
		Frequency abdomen respiration during sad music	Happy–sad	5	16.92	2.35	-0.16	0.878
			Sad–happy	6	17.20	3.25		
	Peak to peak distance variation	Variation chest respiration during sad music	Happy–sad	5	0.57	0.18	-1.49	0.171
			Sad–happy	6	0.95	0.54		
		Variation abdomen respiration during sad music	Happy–sad	5	1.22	0.94	-0.20	0.843
			Sad–happy	6	1.34	0.90		

Table 10. Differences between respiration features for each music listening order during sad music listening.

		Respiration feature	Condition	N	Mean	Std. Deviation	t(7)	p
Calm music	Slope	Slope chest respiration during calm music	Annoying–Calm	4	0.36	0.05	0.20	0.846
			Calm–Annoying	5	0.34	0.14		
		Slope abdomen respiration during calm music	Annoying–Calm	4	0.32	0.13	-0.02	0.983
			Calm–Annoying	5	0.32	0.13		
	Depth	Depth chest respiration during calm music	Annoying–Calm	4	0.62	0.06	-0.37	0.72
			Calm–Annoying	5	0.67	0.28		
		Depth abdomen respiration during calm music	Annoying–Calm	4	0.65	0.17	0.74	0.484
			Calm–Annoying	5	0.58	0.13		
	Peak to peak distance	Peak to peak distance in chest respiration during calm music	Annoying–Calm	4	4.25	1.43	-0.15	0.989
			Calm–Annoying	5	4.37	1.12		
		Peak to peak distance in abdomen respiration during calm music	Annoying–Calm	4	1.64	1.97	-0.73	0.492
			Calm–Annoying	5	2.55	1.79		
	Frequency	Frequency chest respiration during calm music	Annoying–Calm	4	15.96	4.33	-0.01	0.887
			Calm–Annoying	5	16.00	3.73		
		Frequency abdomen respiration during calm music	Annoying–Calm	4	14.33	4.23	-0.87	0.415
			Calm–Annoying	5	16.29	2.53		
	Peak to peak distance variation	Variation chest respiration during calm music	Annoying–Calm	4	0.52	0.16	-1.37	0.212
			Calm–Annoying	5	1.05	0.76		
		Variation abdomen respiration during calm music	Annoying–Calm	4	1.08	0.71	0.61	0.561
			Calm–Annoying	5	0.85	0.40		

Table 11. Differences between respiration features for each music listening order during calm music listening.

		Respiration feature	Condition	N	Mean	Std. Deviation	t(7)	p
Annoying music	Slope	Slope chest respiration during annoying music	Annoying–Calm	4	0.38	0.03	0.57	0.588
			Calm–Annoying	5	0.34	0.14		
		Slope abdomen respiration during annoying music	Annoying–Calm	4	0.34	0.10	0.30	0.771
			Calm–Annoying	5	0.32	0.13		
	Depth	Depth chest respiration during annoying music	Annoying–Calm	4	0.67	0.05	1.15	0.305
			Calm–Annoying	5	0.58	0.16		
		Depth abdomen respiration during annoying music	Annoying–Calm	4	0.73	0.16	1.62	0.148
			Calm–Annoying	5	0.53	0.20		
	Peak to peak distance	Peak to peak distance in chest respiration during annoying music	Annoying–Calm	4	4.15	1.32	0.52	0.622
			Calm–Annoying	5	3.82	0.54		
		Peak to peak distance in abdomen respiration during annoying music	Annoying–Calm	4	1.66	1.75	-0.62	0.556
			Calm–Annoying	5	2.35	1.59		
	Frequency	Frequency chest respiration during annoying music	Annoying–Calm	4	16.39	4.11	−2.13	0.838
			Calm–Annoying	5	16.86	2.53		
		Frequency abdomen respiration during annoying music	Annoying–Calm	4	14.47	3.86	-1.39	0.208
			Calm–Annoying	5	17.26	2.11		
	Peak to peak distance variation	Variation chest respiration during annoying music	Annoying–Calm	4	0.58	0.18	-1.76	0.12
			Calm–Annoying	5	1.24	0.72		
		Variation abdomen respiration during annoying music	Annoying–Calm	4	1.29	1.02	0.05	0.96
			Calm–Annoying	5	1.26	0.66		

Table 12. Differences between respiration features for each music listening order during annoying music listening.