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Music-facilitated Relaxation in Adolescents:
Subjective and Physiological Responses

Gulnara Minkkinen[1], Josefiina Pajunen[1], Esa Ala-Ruona[1], Suvi Saarikallio [1*]

[1] Centre of Excellence in Music, Mind, Body & Brain, Department of Music, Art, and Culture Studies, University of Jyväskylä, Finland
* suvi.saarikallio@jyu.fi

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Abstract

Music is a common resource for adolescents, but relatively few studies have empirically investigated adolescents' use of music for relaxation. This study aimed to answer the following questions: (1) Does self-selected music promote relaxation (at both subjective and physiological levels) in adolescents? (2) How does the listening setting (the length of listening and the content of music selection) relate to the relaxation response? Twenty-six adolescents had a twenty-minute long individual relaxation session with self-chosen music over two consecutive years. Participants assessed their Valence, Arousal, and Tension pre and post sessions, and Heart Rate Variability (HRV) was recorded throughout the sessions. Music was reported by participants in a free form. Results showed a significant increase in Valence, decrease in Tension, and increase in the HRV, indicating a significant relaxation response for the music listening. This physiological response was reached within 5 minutes of listening. Participants with stronger relaxation response showed a stronger within-individual stability in responsiveness to music and tended to describe their music in greater detail than those with weaker relaxation response. This indicates that an in-depth personal relationship to music fosters music-facilitated relaxation. Music-facilitated relaxation is a cost-efficient and individually adaptable approach for stress reduction. Our findings provide support for the efficacy of music-facilitated relaxation for adolescents. While the definition of relaxation is explored, the concept of personal relationship to music deserves further examination in future research.

Keywords: music; music for relaxation; self-selected music; heart rate variability; music genre; personal relationship to music; music-facilitated relaxation

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Background

Music is often used for mood regulation, relaxation, and stress management both in everyday life situations and in clinical settings (e.g., Pelletier, 2004; Saarikallio & Erkkilä, 2007; Sloboda & O'Neill, 2001; van Goethem & Sloboda, 2011). Music plays an important role in adolescents' self-regulation, and adolescents actively use music for a variety of self-regulation purposes (Saarikallio & Erkkilä, 2007; Wells & Hakanen, 1991). This developmental stage is not only marked by a heightened interest in music listening, but the period between 15 and 25 years of age is also the peak time of onset of mental health problems (Papinczak et al., 2015). Capacity to adopt effective tools and patterns of self-regulation is therefore of critical relevance for youth development and mental wellbeing. One of the most common self-regulative processes that can be assisted with music is relaxation (van Goethem & Sloboda, 2011). However, while music listening has been identified as a common and important means for relaxation, we still don't comprehensively understand music-facilitated relaxation as an experience: how it progresses, how the subjective feelings and the physiological responses interact, and what is the role of self-selecting the music for the relaxation purpose. Furthermore, while adolescence is acknowledged as an important period for the self-regulatory use of music (Laiho, 2004; Miranda, 2012; Papinczak et al., 2015), especially for coping with stress (Miranda, 2019), most studies—particularly those using physiological measures—have been conducted with adults rather than adolescents.

Relaxation is often understood as a state of reduced arousal and tension (American Psychological Association, n.d.). The physiological side of relaxation is associated with the dominance of the parasympathetic branch of the autonomic nervous system over the sympathetic branch. One measure commonly used in relaxation research is Heart Rate Variability (HRV). HRV refers to the variability of the intervals between heartbeats or beat-to-beat variability, also known as RR intervals. It can index parasympathetic activity and therefore is often used as a physiological correlate of stress and relaxation states (Kim et al., 2018; Laborde et al., 2017; Pieper et al., 2007). HRV is generally considered to be a relatively non-invasive and reliable way of assessing the time course of the physiological change of the stress response in relation to baseline (e.g., Kim et al., 2018).

In their meta-analysis, de Witte et al. (2019) found that music has an effect on certain stress indicators on both physiological (heart rate, blood pressure and stress-related hormones) and psychological (state anxiety, nervousness, restlessness and feelings of worry) levels. However, the interplay between the physiological and subjective aspects of music-facilitated relaxation remains under-researched. While some research (Iwanaga & Moroki, 1999) has shown that the physiological outcomes were consistent with the subjective ones, Radstaak et al. (2014) suggest that a mismatch between physiological outcomes and subjective ratings is not uncommon. One reason for this discrepancy may be that the subjective experience of relaxation is not merely about calming down physically but may also contain feelings of revival and new energy. For instance, relaxation psychology researcher Smith (2007) describes 12 relaxation states that vary from sleepy to energetic and further divide into basic relaxation, core mindfulness, positive energy, and transcendence.

Music-related relaxation is also often linked with a wide range of emotional experiences. The effects of music on both physiological stress (Helsing et al., 2016; Kreutz et al., 2004) and the experience of emotions (Krumhansl, 1997; van der Zwaag et al., 2011) have been shown in various studies. Adolescents' subjective experiences of music-facilitated relaxation also appear to be closely related to emotional experiences. For instance, Saarikallio et al. (2017) qualitatively analysed 110 episode descriptions of adolescents' music listening for relaxation and suggested that affect is the core element of music-facilitated relaxation, with mood improvement and positive emotions typically being

perceived as outcomes of music-facilitated relaxation. The affective processing during music listening for relaxation purposes can consist of a variety of strategies, including distraction away from worries, processing of mental content, or affective merger with the emotional content of music (Saarikallio et al., 2017). Thus, music-facilitated relaxation appears to be a more complex process than mere arousal reduction, closely involving the subjective component of psychological and affective experiences. Yet, since the amount of research combining physiological measures with self-reports is limited, the current study seeks to better understand the interplay between these two aspects of relaxation.

In addition to understanding the interplay of subjective and physiological components of the relaxation experience itself, it is also relevant to understand the predictors of successful relaxation through music. In terms of the musical content, both self-selected (e.g., Labbé et al., 2007; Lingham & Theorell, 2009) and researcher-selected or standard relaxation music (e.g., Fallon et al., 2020; Lilley et al., 2014; Thoma et al., 2013) have been used in stress and relaxation research. Tan et al. (2012) conducted a set of studies to define relaxation music, including the selection of 30 pieces of relaxation music selected by music therapists. After that, the selected pieces were evaluated by another group of music therapists. The parameters for evaluation were the following: personal preference, perceived degree of relaxation, and familiarity. The analysis revealed that most of the 30 selected pieces of relaxation music had features such as slow tempo, small dynamic changes, moderately complex melody and relatively low rhythm complexity, were diatonic, and mostly instrumental (Tan et al., 2012). While some favour researcher-selected music (Pelletier, 2004), other researchers (Davis & Thaut, 1989; Yehuda, 2011) highlight the role of preference and familiarity for relaxation music. Labbé et al. (2007) point out that self-selected music gives participants a sense of control, which is an important factor for relaxation. Finally, self-selected music allows researchers to create more ecologically valid settings because the experimental situation in this case is closer to the everyday life situation of choosing music for self-regulation. In this study we chose to focus on self-selected music to explore what kind of music adolescents would choose for relaxation purposes.

In addition to the musical content and the self-selection of it, another factor that potentially plays a role in terms of the self-regulatory effect of music is the length of listening. Findings on this matter are somewhat inconsistent. Vigl et al. (2023) reported that 5-minute music listening episodes in a school setting were related to improvements in self-reported mood, concentration, and learning motivation among 15–19-year-olds. However, in a study specifically focusing on the timing aspects of music-facilitated relaxation, Linnemann et al. (2018) found that a minimum of 20 minutes of music listening was needed to show a decrease in stress.

Taken together, it can be argued that a variety of current literature supports the idea of music being a useful tool for relaxation. However, the use of music in both clinical therapy and in preventive and educational contexts would benefit from a more comprehensive understanding of the nuances of how music-facilitated relaxation occurs and how to best achieve the intended outcomes. These questions include clarifying the interplay of physiological and subjective levels of the relaxation experience and identifying appropriate predictors of the outcomes, such as the optimal length of music listening or the role of the content of personal music selections.

Aims and Research Questions

The current study aimed at providing new knowledge about music-facilitated relaxation in adolescents in terms of a) clarifying the interplay between the physiological and self-reported responses, b) identifying the required length of listening, and c) gaining new

insight about the type of music that adolescents choose for relaxation. The research questions were as follows:

RQ1. Does self-selected music listening increase adolescents' subjective ratings of relaxation (as measured by changes in Valence, Arousal, and Tension)?
RQ2. Does self-selected music listening increase adolescents' physiological indicators of relaxation (as measured by HRV parameters)?
RQ3. If an HRV response is observed, what is the length of music listening required for the response?
RQ4. Do the subjective ratings (of Valence, Arousal, and Tension) correlate with the HRV parameters?
RQ5. How is the content of self-selected music (genres, specificity) related to the relaxation responses?

Based on previous research, we expected that listening to self-selected relaxing music would result in an increase of both self-reported (RQ1) and physiological indicators of relaxation (RQ2). More specifically, higher ratings of Valence and lower ratings of Arousal and Tension were expected to be observed after the music listening. Based on previous research done by Linnemann et al. (2018), we further expected that HRV parameters would reach their peak values at the 20-minute timepoint (RQ3). We expected that the physiological responses and the subjective ratings would align (i.e., increased HRV would positively correlate with increased Valence and decreased Arousal and Tension) (RQ4). Investigation of RQ5 was kept exploratory. In order to validate the consistency of our results, the study was repeated with the same participants after a period of one year.

Method

Research Team and Positionality

We are a team of a professor in music therapy, a professor in music education, and two graduate students—one in music therapy and the other in music education. The research was conducted within a research unit that places a strong emphasis on empirical, quantitative methods and music psychology approaches. At the same time, all members of the team have experience in clinical and/or educational practice. The current study stems from our interest in combining subjective and physiological measures to study the effects of music and to reflect on the relevance of these findings for practice, particularly in work with young people across music education and music therapy contexts.

Recruitment and Participants

The study focused on individuals in mid-adolescence, a life period that holds relevance for the development of coping skills and increased vulnerability for the onset of mental health problems (Papinczak et al., 2015). Adolescents (N = 26, 18 females, 8 male) living in Central Finland area took part in the study in 2012 and in 2013 (later referred to as Year 1 and Year 2). Recruitment was conducted in collaboration with local schools to reach the whole age group as comprehensively as possible, not only those students who might be interested in music. The study was introduced during a school day and an opportunity to participate was offered to all. Volunteers as well as their guardians were thereafter contacted for more detailed informed consent, prior to any data collection. Participants' guardians provided consent in a written form. Volunteering participants were thereafter invited to take part in the study, which took place at the University on a separate day. The Human Sciences Ethics Committee of the University of Jyväskylä approved the study.

The current study was conducted as part of a larger longitudinal research project on music in adolescence. Those participants who took part in the specific measures of the current study in both years were included ($N = 30$). To determine eligibility for HRV analysis, participants reported on smoking, alcohol use, medication intake, and known heart conditions. Participants who reported smoking during the measurement day ($n = 1$) or taking cardioactive medication ($n = 3$) were removed from the sample. None reported having heart conditions. The final sample, after applying exclusion criteria mentioned above, consisted of the following: $N = 26$ (18 female, 8 male), with all participants being 15 years old in Year 1 and 16 years old in Year 2.

Procedure and Design

A within-subject design was used in the form of an individual music-facilitated relaxation session. At the start of the procedure, participants were given the HRV monitors and instructions. They were then seated on a sofa in a quiet room, and the researcher exited, allowing them to complete the relaxation task on their own. Participants were asked to listen to the music they had chosen for supporting their relaxation. They could use their own device and headphones on a comfortable volume level; if a personal device was unavailable a player and headphones were provided. Duration of the relaxation session was 20 minutes. Participants reported their subjective Valence, Arousal, and Tension scores before and after the relaxation session. A year later, the procedure was repeated with the same participants to test the consistency of the results.

Musical Stimulus Material

Participants were instructed to bring their own relaxation music to the experiment. They were asked to freely report the type of music they had chosen. Some participants reported artists and pieces in detail, while others reported only genres or just a general description of the music (e.g., “Relaxing music,” participant 3 in Year 1). In our analysis we concentrated on the genre and the level of detail of the music description. When possible, genre descriptions provided by the participants were used. If participants didn’t provide their own genre descriptions, genres were identified based on artist or piece and cross-validated by two researchers from the group. The level of detail was assessed in terms of whether the participant reported the name of the piece(s), the name of the artist(s), genre(s), or only provided a more generic description such as “relaxing music.”

Subjective Outcome Measures

Participants were asked to report their current state before and after the relaxation session by rating three parameters using a nine-point Likert scale. The core affect dimensions of Valence and Arousal (Feldman Barrett & Russell, 1998) were complemented with an additional third dimension of Tension (vs relaxation), to capture the affective content of the subjective relaxation experience. One-question self-report ratings using a nine-point Likert scale were chosen for each of these dimensions to keep the response process brief and unintrusive, thus capturing the adolescents’ immediate responses. The question was formulated as, “How are you feeling at the moment?” The parameters rated were Valence (1 – Unpleasant, 9 – Pleasant), Arousal (1 – Sleepy, 9 – Energetic), and Tension (1 – Tense, 9 – Relaxed, so higher scores indicated *lower* Tension).

HRV Data Sources

HRV was measured continuously throughout the procedure day at the university (9am–3pm). Measures were conducted using the heart rate monitors “Bodyguard” and ECG

electrodes. The heart rate monitors and the software were produced by Firstbeat Technologies Oy. These monitors were chosen because they are suitable for long-term measurements and comfortable to wear. Kubios HRV Standard 3.4.3 software (2020) was used to analyse the HRV data. For this study, the time points of analysis were the following: the 5-minute-long baseline measurement (participants were seated) prior to the relaxation session and the 20-minute-long procedure measurement. For the analysis, we divided the 20-minute procedure measurement into 5-minute timepoints (5 minutes, 10 minutes, 15 minutes and 20 minutes). This allowed us to see how the physiological response to the music-facilitated relaxation changed throughout the procedure.

HRV Parameters

HRV is commonly used in stress and relaxation research as an indicator of the autonomic nervous system (ANS) state. Two branches of the ANS—sympathetic (SNS) and parasympathetic (PNS)—regulate our stress responses and relaxation states. Dominance of the sympathetic branch is associated with stress, while parasympathetic activity indicates recovery. HRV can be assessed through different parameters: time-domain parameters, frequency-domain parameters, non-linear indices and complex parameters that consist of a combination of different parameters.

In this research we analysed a Parasympathetic Nervous System Index (PNS Index): a complex parameter that indicates the degree of dominance of PNS activity over SNS and is calculated in Kubios software. Parasympathetic activity decreases heart rate and increases HRV due to enhanced respiratory sinus arrhythmia (RSA) components and decreases the ratio between lower and higher frequency oscillations in the HRV time series (Kubios, n.d.). The parameter consists of the Mean RR (to capture decrease in heart rate), Root Mean Square of Successive RR interval Differences (RMSSD, to detect beat-to-beat changes and changes in RSA) and Poincaré plot index SD1 in normalised units (as a correlate for the low and high frequency ratio).

As advised in Laborde et al. (2017), in addition to the complex parameter (PNS Index) we also reported a more traditional time-domain parameter: RMSSD. The RMSSD is the time-domain HRV parameter that reflects vagal tone (Kim et al., 2018; Laborde et al., 2017). Vagal tone is an internal biological process that reflects the activity of the vagus nerve, which is strongly associated with parasympathetic activity in general and, thus, with recovery processes. This time-domain parameter was chosen because it is more influenced by PNS activity than the Standard Deviation of Normal-to-Normal (SDNN) intervals (Heathers, 2014; Shaffer & Ginsberg, 2017). We used the natural logarithm transformation of the RMSSD (lnRMSSD) as it is advised to correct for non-normality in the data (Laborde et al., 2017).

Analysing the PNS Index allowed us to get a more comprehensive picture of the participants' parasympathetic activity, and including a more traditional parameter such as lnRMSSD helped us to build connections to the previous research in the field. In both parameters higher scores indicate stronger relaxation response. Artifacts (caused for instance by movement or poor sensor contact, not by true physiological changes) were removed using the Kubios at the stage of pre-processing. Subsequently, detrending was performed using the smoothness priors method ($\lambda = 500$) to remove low-frequency components and achieve stationarity of the time series.

Analyses

We first tested whether the participants' self-reported Valence, Arousal, and Tension differed before and after the relaxation session (RQ1). The self-report data were not normally distributed, so the Wilcoxon signed-rank test for dependent samples was used.

We then tested whether there was a difference between baseline and procedure in HRV (as measured via PNS Index and lnRMSSD), using a paired sample *t*-test (RQ2). Next, we aimed to identify the required length of music listening for the relaxation response (RQ3), by testing differences in mean HRV responses across the time points (the Baseline and the four Procedure time points), using Repeated Measures ANOVA and subsequent pairwise comparisons with Bonferroni correction. To test the relationship between the subjective ratings and the physiological measures (RQ4), we calculated changes in all measures and conducted a Spearman rank-order correlation. Lastly, we explored the role of the music choice for the relaxation response (RQ5). For this, we divided participants into two physiological response groups, based on their PNS Index changes:

> *Group 1: Strongest HRV response to music* (five participants with the highest difference in PNS Index between baseline and music listening)
> *Group 2: Weakest HRV response to music* (five participants with the lowest difference between baseline and music listening in PNS Index).

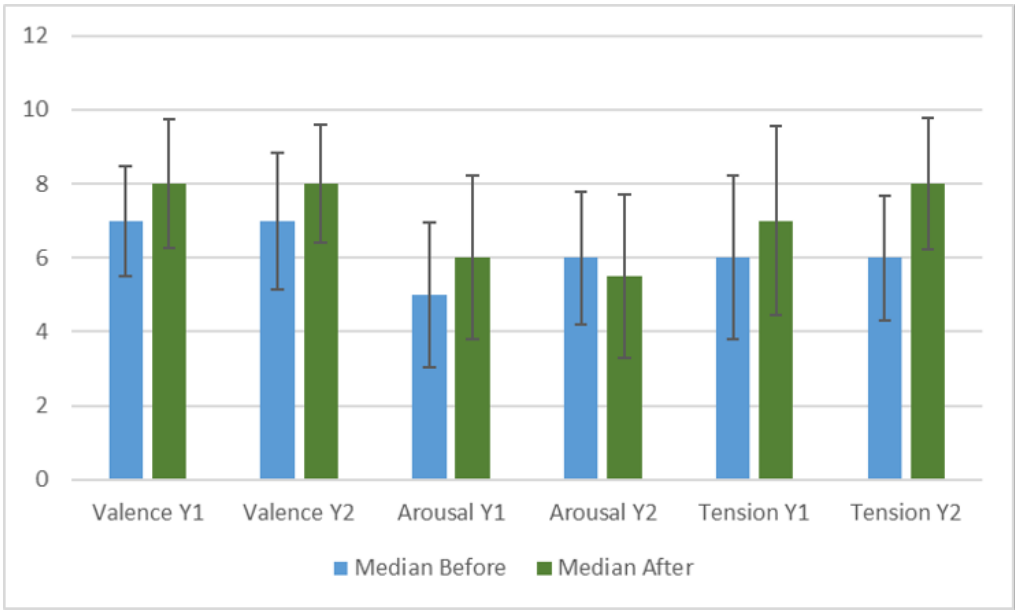
PNS Index was selected as the indicator, because as a complex parameter it is assumed to contain less random variation that might be present in individual parameters. We then explored potential differences between these two physiological response groups in terms of their genre choices and the level of detail of their music descriptions.

Results

Subjective Ratings: Self-reported Valence, Arousal, and Tension

Figure 1 demonstrates participants' median ratings of Valence, Arousal, and Tension before and after the relaxation session in both years. Significant differences were observed in Valence and Tension between the pre- and post-session ratings for both years. No significant differences in Arousal were found (Table 1), with some participants even reporting an increase in their Arousal after the relaxation session. The results thus align with our expectations in terms of Valence and Tension, but not of Arousal. Differences between Year 1 (Y1) and Year 2 (Y2) were insignificant.

Figure 1. Median Valence, Arousal, and Tension Before and After the relaxation session in Year 1 (Y1) and in Year 2 (Y2).



Note. Higher Tension score means *lower* Tension.

Table 1 : Results of Wilcoxon S-R test for self-reports of Valence, Tension and Arousal.

Valence	Year 1	After (*Mdn* = 8, *M* = 7.54) > Before (*Mdn* = 7, *M* = 6.96), *p* = .023, *Z* = -2.28
	Year 2	After (*Mdn* = 8, *M* = 7.54) > Before (*Mdn* = 7, *M* = 6.35), *p* = .002, *Z* = -3.16
Tension	Year 1	After (*Mdn* = 7, *M* = 6.35) > Before (*Mdn* = 6, *M* = 5.65), *p* = .014, *Z* = -2.46
	Year 2	After (*Mdn* = 8, *M* = 7.35) > Before (*Mdn* = 6, *M* = 5.96), *p* = .001, *Z* = -3.38
Arousal	Year 1	After (*Mdn* = 6, *M* = 5.5) > Before (*Mdn* = 5, *M* = 5.23), *p* = .621, *Z* = -0.49
	Year 2	After (*Mdn* = 5.5, *M* = 5.58) > Before (*Mdn* = 6, *M* = 5.42), *p* = .819, *Z* = -0.23

The Heart Rate Variability (HRV) Results

Significant differences were observed between Baseline and Procedure measurements of both PNS Index and lnRMSSD. Table 2 presents the results as well as Means and Standard Deviations (SD) for both parameters for both years. Figures 2 and 3 illustrate the mean scores of Baseline and Procedure of the PNS Index and lnRMSSD across both years. Both parameters were significantly higher in the Procedure points than in the Baseline, indicating a relaxation effect during the music listening. Large SD is typical for the HRV data due to the individual differences in HRV responses.

Table 2 : Results of *t*-test for the HRV Parameters.

PNS Index	Year 1	Procedure (*M* = -0.04, *SD* = 1.15) > Baseline (*M* = -0.63, *SD* = 0.87); *t*(25) = -3.92, *p* = .001, Cohen's *d* = 0.77
	Year 2	Procedure (*M* = -0.05, *SD* = 1.12) > Baseline (*M* = -0.77, *SD* = 1.05); *t*(25) = -5.82, *p* < .001, Cohen's *d* = 0.63
lnRMSSD	Year 1	Procedure (*M* = 3.99, *SD* = 0.42) > Baseline (*M* = 3.83, *SD* = 0.42); *t*(25) = -2.86, *p* = .008, Cohen's *d* = 0.28
	Year 2	Procedure (*M* = 3.99, *SD* = 0.47) > Baseline (*M* = 3.86, *SD* = 0.55); *t*(25) = -2.36, *p* = .027, Cohen's *d* = 0.3

Figure 2. Mean Baseline and Procedure of PNS Index in Year 1 and Year 2.

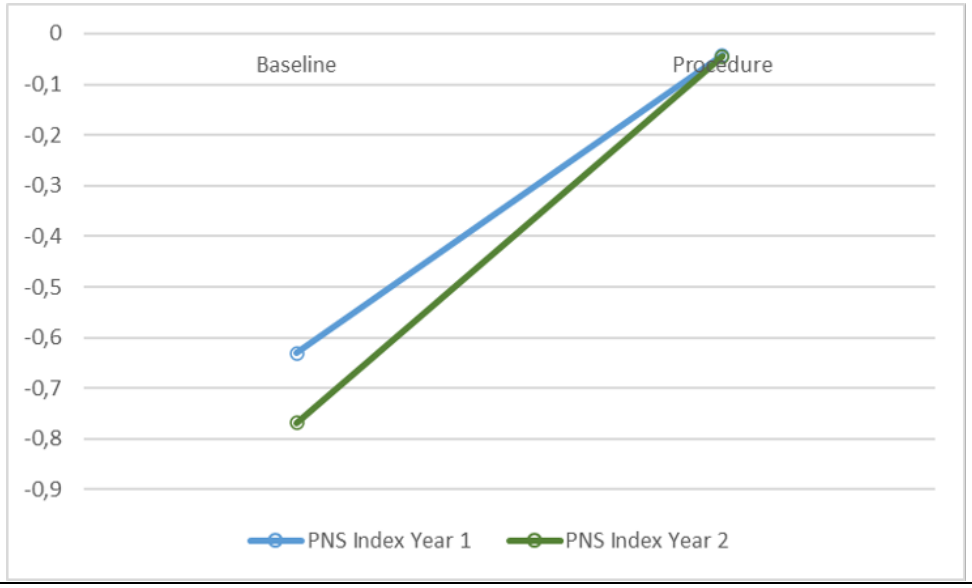
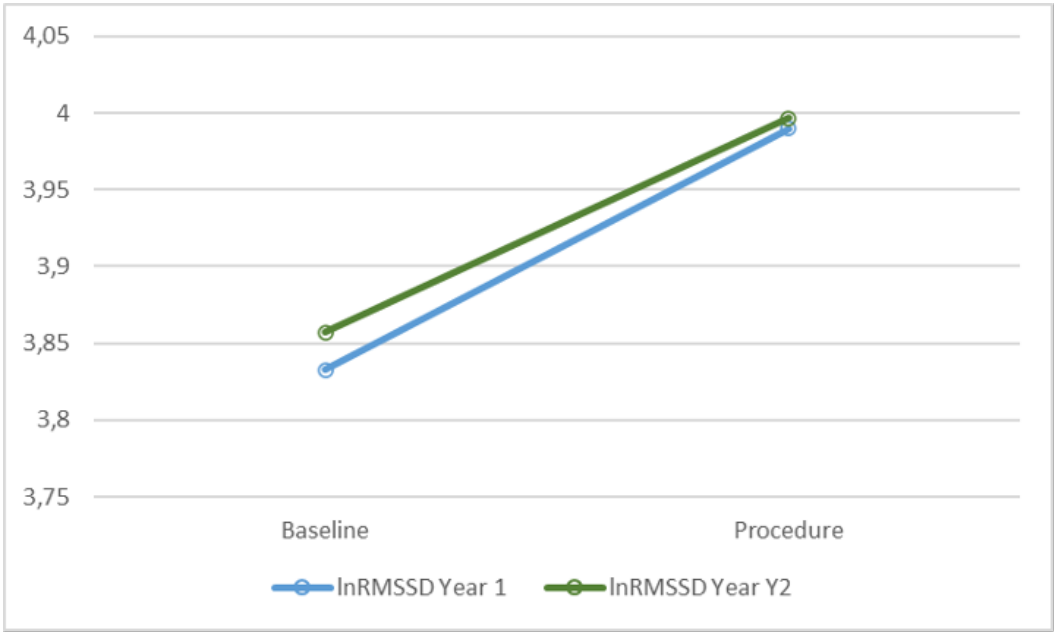


Figure 3. Mean Baseline and Procedure of lnRMSSD in Year 1 and Year 2.



No significant differences between the years were found. As expected, the results for both analysed parameters align.

HRV Across the Relaxation Session

A Repeated Measures ANOVA was conducted to detect possible significant changes, with two factors: Time (the Baseline and the four Procedure time points) and Year. For both HRV parameters, the main effect of Time was significant:

The PNS Index: $F\ (2.25, 56.35) = 14.23, p < 0.001$, Partial $\eta 2 = 0.36$
lnRMSSD: $F\ (2.39, 59.77) = 4.49, p = 0.011$, Partial $\eta 2 = 0.15$

Pairwise comparison for the PNS Index revealed significant differences between the Baseline and all Procedure timepoints in both years, but no significant difference among the Procedure time points themselves (see Table 3). For the lnRMSSD, significant differences were found between the following timepoints in Year 1: Baseline and 5-minutes as well as 5-minutes and 20-minutes. In Year 2, significantly different timepoints were observed in the following: between 10-minutes and 15-minutes as well as between 10-minutes and 20-minutes (see Table 3). No significant difference was found between the two years.

Table 3. Pairwise Comparison of HRV Parameters.

PNS Index					
Year	Time (1)	Time (2)	Mean Difference (1-2)	Std. Error	*p*
1	Baseline	5-minute	-0.56	0.15	0.007
		10-minute	-0.6	0.19	0.043
		15-minute	-0.55	0.15	0.011
		20-minute	-0.52	0.16	0.033
2	Baseline	5-minute	-0.53	0.13	0.004
		10-minute	-0.87	0.14	<0.001
		15-minute	-0.71	0.15	0.001
		20-minute	-0.61	0.16	0.007

lnRMSSD					
Year	Time (1)	Time (2)	Mean Difference (1-2)	Std. Error	*p*
1	Baseline	5-minute	-0.23	0.06	0.006
	5-minute	20-minute	0.16	0.05	0.034
2	10-minute	15-minute	0.1	0.03	0.026
		20-minute	0.13	0.04	0.022

Figures 4 and 5 demonstrate the changes in the PNS Index and lnRMSSD throughout the music-facilitated relaxation sessions respectively.

Figure 4. Estimated Marginal Means for PNS Index.

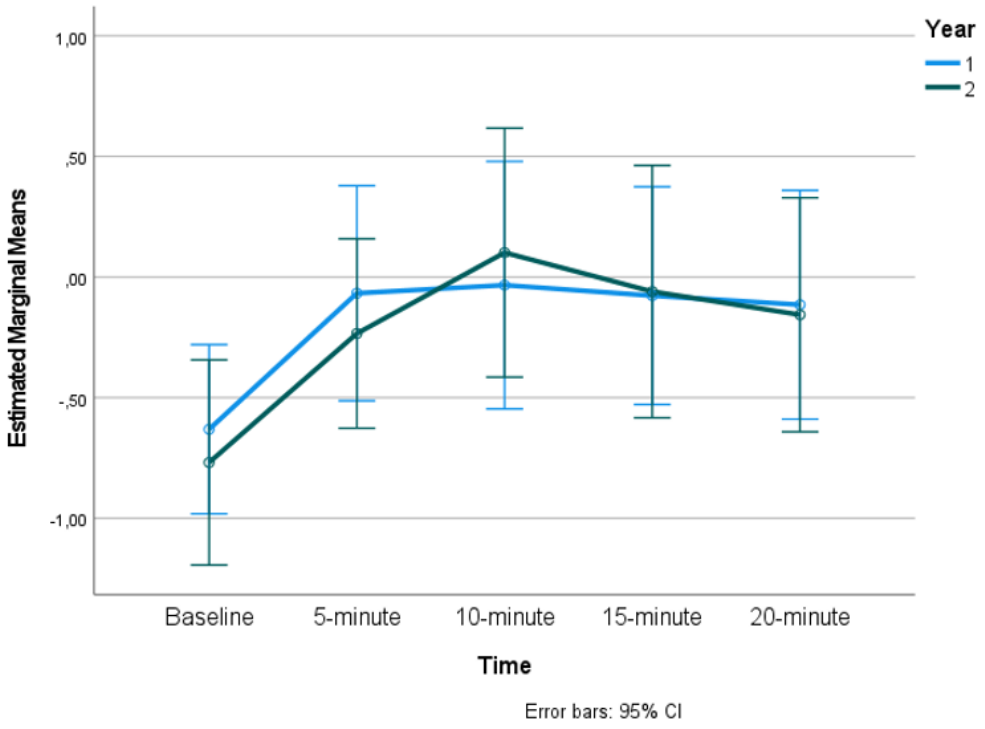
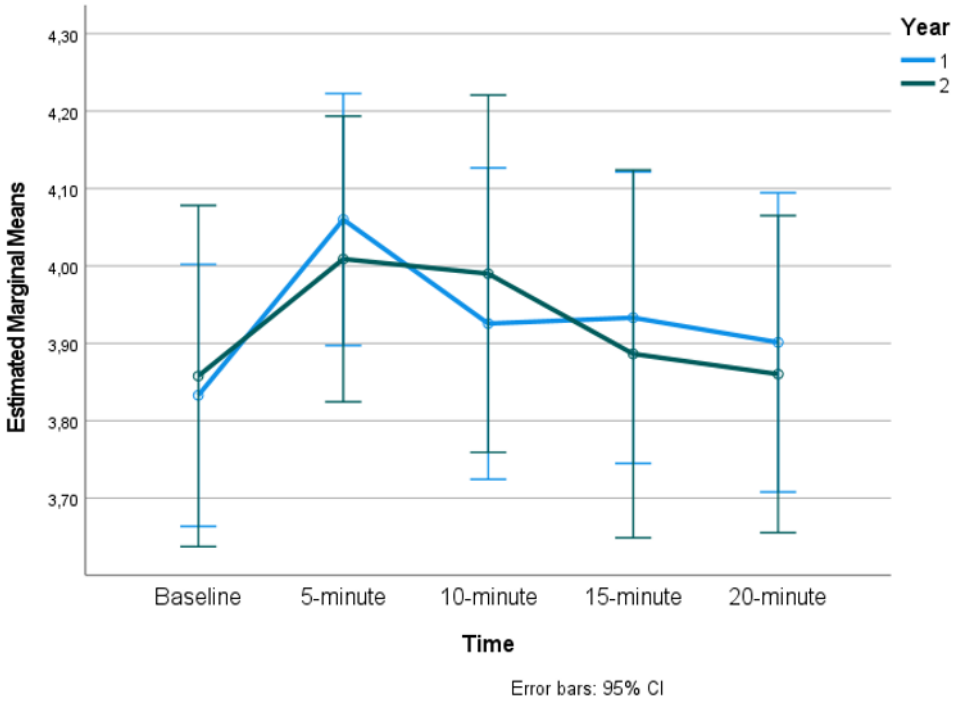


Figure 5. Estimated Marginal Means for lnRMSSD.



As shown in the results, there are common trends in both parameters, and the results indicate a relaxation response to music listening. However, against our expectation, the most relaxing state was achieved as early as the 5-minute time point, rather than at the 20-minute time point. Also, the PNS Index results are more consistent than lnRMSSD, with Baseline values significantly differing from all other timepoints in both years. This pattern is partially supported by the lnRMSSD results, in which the Baseline significantly differs from the 5-minute time point in Year 1.

Relationship between Subjective Ratings and Physiological Measures

A significant positive correlation was found between the change in Valence and both HRV parameters in Year 1:

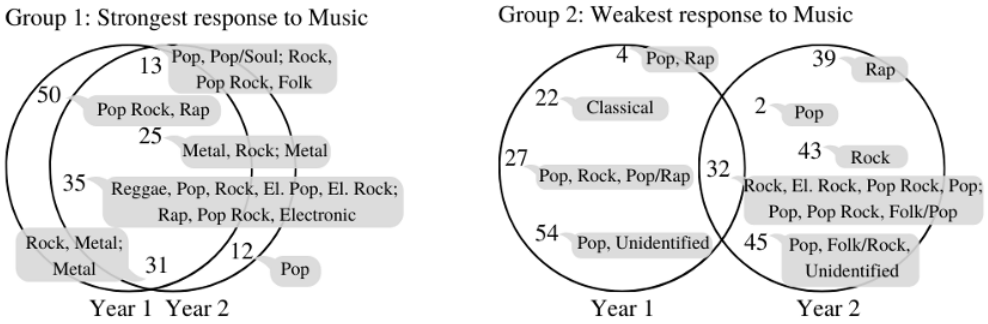
$$\text{PNS Index: } \rho = 0.48,\ p = 0.013;\ \text{lnRMSSD: } \rho = 0.44,\ p = 0.025$$

This indicates that the change in participants' subjective rating of Valence aligned with the change in the HRV in Year 1. However, no correlations were observed between the HRV parameters and the Tension and Arousal ratings in either year, and also not for Valence in Year 2. The findings point towards a linkage between physiological relaxation and positive Valence change.

Music and the Relaxation Responses

Figure 6 shows the participant numbers of those participants who were allocated to Group 1 (Strongest HRV response to music) and Group 2 (Weakest HRV response to music) in Years 1 and 2. Circles represent Year 1 and Year 2, and the numbers indicate participant IDs. Participants in circle intersections were included in the same physiological response group in both years. The figure additionally lists the genre selections of each participant.

Figure 6. The yearly overlap of participants in the two physiological response groups with their genre selections.



There was a difference in within-individual stability across Years 1 and 2 when comparing Groups 1 and 2. In Group 1 (Strongest HRV response to music) a relatively large proportion of the same individuals were allocated to this group in both Years 1 and 2, while in Group 2 (Weakest HRV response to music), only one individual remained the same across Years 1 and 2. This indicates some within-individual stability in strong physiological responsiveness to music.

Most popular genres were pop, rock, rap, pop rock and unidentified (which refers to the cases when only general description was provided, e.g., "Relaxing music"). The whole list of genres can be found in the Appendix (Table A1). In terms of genres, differences across the physiological response groups were minor, with pop and rock dominating in all groups.

As for the level of detail in responses, the adolescents widely differed in terms of how elaborately and specifically they articulated their music choice. Many participants

reported both artists and pieces (9 in Year 1 and 8 in Year 2) or at least the artists (10 in Year 1 and 12 in Year 2), while some participants reported only genres (4 in Year 1 and 4 in Year 2) or only provided general descriptions (3 in Year 1 and 1 in Year 2). Furthermore, clear differences between the physiological response groups were observed in the level of detail. Participants from Group 1 (Strongest HRV response to music) provided more detailed descriptions: all provided at least one piece (5 participants) or at least 1 artist (5 participants). Meanwhile, participants from Group 2 (Weakest HRV response to music) described the music in a more generic manner: 4 participants reported a genre, 3 reported at least one artist and 3 reported at least one piece.

Participants were also grouped according to their subjective responses on Valence, Arousal, and Tension (increase, decrease or no change in each of the three parameters). However, no differences could be observed in the genre selections or level of detail between these groups. Common genres such as Pop, Rock and Rap were present across all groups.

These findings suggest that the way a person relates to music might be one of the factors that play a role in the effectiveness of music-facilitated relaxation: more refined descriptions may indicate a more in-depth relationship with music (greater personal investment, attention, and awareness allocated to the music choice) which seems to promote the relaxing impact of music. Moreover, there appears to be some within-individual stability across time in those who demonstrate the strong physiological response and elaborate music choice descriptions. No conclusion about the possible relationship between the genres of music and relaxation could be drawn.

Discussion

This study aimed to increase understanding of adolescents' physiological and subjective responses to self-chosen relaxation music. Firstly, the results confirmed that self-selected music listening impacts both subjective ratings and physiological indicators of relaxation. Physiologically, participants were consistently more relaxed during the music listening procedure as compared to the baseline: significant differences in both HRV parameters were found in both years. In terms of self-report ratings, the results were slightly more nuanced. Music-facilitated relaxation helped participants to improve Valence and reduce Tension in both years. However, no significant changes in Arousal were found, with some participants even reporting an increase in Arousal. The role of Arousal will be further discussed in later paragraphs. Secondly, the results offered new information concerning the relatedness of the physiological responses and the subjective ratings. A positive correlation between Valence change and both HRV parameters was found in Year 1, while no correlations were observed between the HRV parameters and ratings for Tension and Arousal. Such a pronounced role of Valence change highlights the relevance of the personally-experienced positive affect for the relaxation experience. Thirdly, the results showed that the time required for the relaxation response was much shorter than the expected 20 minutes. Indeed, there was a common trend in both parameters: there was an increase in relaxation level by either 5-, 10- or 15-minute timepoint as compared to the Baseline, followed by a decrease by the 20-minute timepoint, which indicates that only 5 minutes are required for the desired physiological response. This observation is also discussed in further paragraphs. Finally, the exploration about the role of music choice revealed some novel insights: we observed within-individual stability across Year 1 and Year 2 particularly in those adolescents who demonstrated strong physiological relaxation response to music. This response appeared to be related not to genre choice but to the level of detail and elaborateness of the music choice descriptions. This issue is also further

discussed in the following paragraphs. Finally, it is important to note that all of our findings were largely consistent across Year 1 and 2, demonstrating the reliability of results.

The Importance of Emotion and Ambiguity of Arousal for the Relaxation Experience

Our results indicate that the positive emotions assessed by Valence and negative emotions assessed by Tension seem to play an important role in music-facilitated relaxation. It may be that music-facilitated relaxation is psychologically mood-improving and Tension-reducing yet reviving and for some even energising. This finding is in line with the notion from Saarikallio et al. (2017) that affect is a core element in music-facilitated relaxation. The combination of increase in positive emotions and energy and decrease in Tension aligns with the regulatory strategy Revival, described in Saarikallio & Erkkilä (2007).

Meanwhile, the ambiguous Arousal scores might be explained from several viewpoints: the understanding of arousal, individual differences, understanding of relaxation as a psychological experience, and the role of preferred music. Firstly, this relates to the broader conceptual understanding of arousal. Thayer (1989) suggested two dimensions of arousal: tense (continuum from calmness to anxiety) and energetic (a continuum from tiredness to energy). In the current study, subjective Arousal was measured with a nine-point Likert scale from sleepy to energetic, so using the framework suggested by Thayer it was measuring the energetic dimension of Arousal. The tense dimension of Arousal was represented with the Tension scale, and participants reported feeling significantly less tense after the music listening. The reason may also lie in the individual differences: Kuppens (2008) conducted an experience sampling study on the relationship between valence and arousal and found out that pleasant or unpleasant feelings are typically associated with high arousal for some people, but with low arousal for others, and people differ in whether arousal is usually appraised pleasant or unpleasant. We can therefore expect that someone who generally perceives low arousal to be unpleasant would try to achieve more energetic states in the self-regulation task because such states are experienced as more pleasant and associated with joy, while low arousal states are more associated with sadness rather than relaxation.

This discussion further involves the understanding of relaxation as a psychological concept. As mentioned earlier, Smith (2007) describes 12 types of relaxation states that vary from sleepy to energetic. Based on our results, we can conclude that music-facilitated relaxation with preferred music can sometimes fall into the category of "Positive energy," which includes relaxation states such as Joyful and Optimistic and does not necessarily involve low Arousal.

Another factor that may have affected the ambiguous Arousal ratings is the self-selected nature of the music. Research has shown that preferred music is associated with increased subjective Arousal (Radstaak et al., 2014; Salimpoor et al., 2009; Schafer & Sedlmeier, 2011). This aligns with Lingham and Theorell's (2009) conclusion that even if the music is classified as relaxing, it can still increase arousal due to its familiarity and personal preference.

Findings about the Optimal Length of Music-facilitated Relaxation

The results concerning the time required for a desired HRV response were contrary to our expectations. The desired response was achieved after only 5 minutes, which was notably faster than the expected 20 minutes, based on the work by Linnemann et al. (2018). One possible reason for this might be developmental: in Linnemann et al. (2018) the participants were adults aged 18–34, while the participants of the current study were adolescents aged 15–16 years old. The age group of our participants corresponds to the

study by Vigl et al. (2023), which demonstrated self-reported mood changes in 15–19-year-olds using only a 5-minute listening session. It can thus be suggested that the reaction times to music listening are faster for adolescents than for adults. An optional explanation relates to the setting: participants knew the length of the listening session, so they were likely to expect the researcher to enter the room towards the end of the session. More research is needed to confirm the optimal length of music-facilitated relaxation across different settings, ranging from daily life to clinical contexts. However, our findings support the idea that adolescents may physiologically benefit even from relatively short music-listening moments.

What about the Music?

In this study, the participants were asked to bring in their preferred relaxation music. The variety of genres chosen by the participants was wide and included 20 different genres and genre combinations. The most popular genres were Pop and Rock. When participants were divided into two groups based on the strength of their HRV response to music, only minor differences were observed as regards to which genres were selected. However, there was a difference between the groups in terms of within-individual stability and the level of detail of their music descriptions: participants from Group 1 (Strongest HRV response to music) reported their self-selected music in a more detailed manner, e.g., reporting artist and piece, not only describing the music as “Relaxing music” or “Radio.” In Group 1 most participants were mostly the same across Year 1 and 2, while in Group 2 only one participant was the same in both years. This suggests that the way participants responded to and related to music stayed consistent within the period of one year, especially for those participants who showed stronger relaxation responses. This within-individual stability in strong responsiveness to music might be connected to the way one relates to music: a personal relationship to music develops gradually, so it is not likely to change drastically within one year. These findings lead us to the assumption that the way a person relates to the music might be connected to their responsiveness to it. This resonates with the current understanding of what musical sophistication is: it is not merely a matter of being a musician versus non-musician, but it also encompasses the personal relationship with the music one chooses to listen to in daily life and the personal agency of being an “expert” in using musical material (Cogo-Moreira & Lamont, 2017; Lamont et al., 2016).

Limitations and Suggestions for Future Research

The sample size of the current study is small, so our conclusions are not necessarily generalisable. Participants in the current study were 15–16-year-old boys and girls living in Finland. Thus, we cannot claim that the same conclusions are directly applicable for an adult or a non-Finnish population. Also, the data are more representative of girls (18 out of 26) than boys.

An obvious limitation of the current study is that the data were collected in 2012 and 2013, so we can assume that the music genre list would look a bit different if the data were collected in more recent years. However, we believe that the main findings of the study are still relevant today. Genre did not emerge as a major factor. Meanwhile, the main findings (e.g., the relevance of emotions for subjective responding, the ambivalent nature of arousal, the speed of physical response, and the importance of personal musical relationship), are likely to be phenomena that still exist and provide valuable insights into how adolescents respond to music.

A clear limitation of the study was that we did not collect information about the music choices and personal music experiences of the adolescents beyond the artist, genre, and the overall level of detail. The way our participants reported the music (they could choose

the level of detail) allowed us to analyse the level of detail in their reports and thus find that the tendency for more detailed music reports is linked to stronger physiological relaxation. However, while this very finding emphasizes the importance of the personal relationship with music in achieving the relaxation response, it also creates further questions, which are beyond the scope of the current study. We did not ask the adolescents about the reasons behind their choices, the meaning the music held for them, which elements of the music (e.g., beat, mood, lyrics) resonated with them, or the contexts in which they discovered it. Future research could benefit from a more in-depth analysis that would give greater voice to participants and elaborate the various nuances that are involved in the concept of a relationship with music.

Another challenge relates to the ecological validity of laboratory research. In the current study we used HRV as a physiological measure of relaxation. It is commonly used in stress and relaxation research, however, there are also challenges related to it: HRV is methodologically sensitive to a high number of individual factors affecting the measurement result. HRV experiments should therefore be conducted in a controlled environment, which we appropriately chose to do. However, we simultaneously acknowledge that a laboratory context may lack some ecological validity. Future research could investigate the possibilities of collecting physiological data in adolescents' real-life contexts.

Future research could also include stress induction activities to observe the relaxation effects more clearly. On the other hand, this approach would include only one type of relaxation—relaxation as recovery from stress—while other possible types and goals of relaxation would remain under-researched.

Concluding Thoughts

The current study provided new knowledge about the nature and explanatory factors of music-facilitated relaxation during mid-adolescence. Adolescents are impacted by music both physiologically and experientially, and the physiological response of relaxation can be reached already after 5 minutes of listening. The relaxation experience appears to occur strongly on the emotional front. There may also be some within-individual consistency in strong physiological responding to music, and this tendency seems to relate to the elaborateness of personal music choice. The concept of music-facilitated relaxation may be more complex than what is commonly considered, particularly in relation to the arousal dimension. This creates a need for further research to carefully consider how to conceptualise and operationalize music-facilitated relaxation. We also hope that our findings enhance the discussion about the role of personal relationship(s) to music. The phenomenon of personal relationship to music deserves thorough examination and consideration from the viewpoints of both theory and practical application in music-based interventions. Further research that utilises a combination of physiological and self-report measures, as well as in-depth investigation of personal meanings is needed to achieve a comprehensive knowledge of musical experiences.

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Research Data

The data is of sensitive nature and contains health-related information. Data sharing consent was not asked at the point of data collection. Specific anonymised parts of the data can be provided upon a special request.

Conflicts of Interest

The Authors declare that there is no conflict of interest.

About the Authors

Gulnara Minkkinen, MA, graduated with a Master of Arts from the University of Jyväskylä in 2018 majoring in Music Therapy. She was a PhD researcher at the University of Jyväskylä 2021-2024.

Josefiina Pajunen, MA, is a music educator and a musician. She is currently working as a music teacher teaching general music to adolescents in Finnish middle and upper-secondary schools. She holds her Master's Degree in Music Education from the University of Jyväskylä and also holds a Bachelor of Cultural Studies (Music) from the JAMK University of Applied Sciences.

Esa Ala-Ruona, PhD, is an Associate Professor of Music Therapy at the Centre of Excellence in Music, Mind, Body and Brain, University of Jyväskylä, Finland. He is a music therapist and integrative psychotherapist (advanced level) working as a researcher, clinical teacher, and supervisor at the JYU Music Therapy Clinic for Research and Training. His research interests are in music therapy assessment and evaluation, and in studying therapeutic interaction, meaning making and clinical processes in multimodal music therapy. His special expertise lies on creating therapy and training models, as well as clinical practice of integrative music psychotherapy, and vibroacoustic therapy.

Suvi Saarikallio, PhD, is a Professor of Music Education at the University of Jyväskylä, Finland. Saarikallio is the PI for the Centre of Excellence in Music, Mind, Body and Brain and leads an ERC-funded project MUSICONNECT on music for youth empowerment. Saarikallio studies music in relation to emotions, identity, youth development, and mental health and actively publishes across the fields of music psychology, music education, and music therapy. She is the acting President of ESCOM and the European commissioner for the ISME Research Commission.

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Appendix

Table A1 : The List of Music Genres Reported by the Participants

	Year 1	Year 2	Total
Pop	14	13	27
Rock	7	6	13
Pop Rock	5	6	11
Rap	5	5	10
Unidentified	4	2	6
Metal	3	3	6
Electronic Pop	2	2	4
Rop/R&B	2	1	3
Reggae	2	0	2
Electronic Rock	2	0	2
Classical	1	1	2
Pop/Rap	1	1	2
Folk	0	2	2
Electronic	1	0	1
Ambient	1	0	1
Rap/Rock	1	0	1
Jazz	0	1	1
Folk Rock	0	1	1
Folk Pop	0	1	1
Rock/Metal	0	1	1