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The stress-reducing effect of music listening varies depending on the social context

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ABSTRACT

Objective: Given that music listening often occurs in a social context, and given that social support can be associated with a stress-reducing effect, it was tested whether the mere presence of others while listening to music enhances the stress-reducing effect of listening to music.
Methods: A total of 53 participants responded to questions on stress, presence of others, and music listening five times per day (30 min after awakening, 1100 h, 1400 h, 1800 h, 2100 h) for seven consecutive days. After each assessment, participants were asked to collect a saliva sample for the later analysis of salivary cortisol (as a marker for the hypothalamic-pituitary-adrenal axis) and salivary alpha-amylase (as a marker for the autonomic nervous system).
Results: Hierarchical linear modeling revealed that music listening per se was not associated with a stress-reducing effect. However, listening to music in the presence of others led to decreased subjective stress levels, attenuated secretion of salivary cortisol, and higher activity of salivary alpha-amylase. When listening to music alone, music that was listened to for the reason of relaxation predicted lower subjective stress.
Conclusion: The stress-reducing effect of music listening in daily life varies depending on the presence of others. Music listening in the presence of others enhanced the stress-reducing effect of music listening independently of reasons for music listening. Solitary music listening was stress-reducing when relaxation was stated as the reason for music listening. Thus, in daily life, music listening can be used for stress reduction purposes, with the greatest success when it occurs in the presence of others or when it is deliberately listened to for the reason of relaxation.

1. Introduction

Music listening is a popular activity of daily life (North et al., 2004). As there is accumulating evidence that music listening in daily life is associated with beneficial effects for well-being and health, it is of utmost importance to study the effects of music listening in daily life, i.e. in a setting characterized by high ecological validity. Sloboda et al. (2001) were pioneers in this area of research in that they conducted the first ecological momentary assessment study which directly investigated participants and their music listening behaviors in their daily lives. In addition to descriptive data on situations in which music was listened to, Sloboda et al. (2001) were able to show that music listening in daily life was associated with beneficial effects on mood. This finding is in line with other studies set in daily life, which found that music listening was associated with the experience of positive emotions (Juslin et al., 2008; van Goethem and Sloboda, 2011). Furthermore, studies not only point towards beneficial effects for mood and well-being in healthy populations, but also towards favorable effects on various disease states (Batt-Rawden et al., 2005; Linnemann et al., 2015b; Särkämö et al., 2008).

However, the underlying psychophysiological mechanisms for these beneficial effects remain unclear. We hypothesize that beneficial effects of music listening on health are mediated by a psychophysiological stress reduction (Thoma and Nater, 2011). This is in line with evidence from recent neuroimaging studies. Music-evoked emotions are associated with activity in core emotion networks (Koelsch, 2014). Two brain structures that are involved in music-induced emotions are the hippocampus and the amygdala (Koelsch, 2014), which are both known to be involved in regulating the hypothalamic-pituitary-adrenal (HPA) axis (Tsigos

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and Chrousos, 2002). The HPA axis is one of the prominent stress systems in the body. An activation of this axis can be indirectly measured by the secretion of the hormone cortisol (Hellhammer et al., 2009). Indeed, music listening (in experimental contexts) has previously been linked to the secretion of cortisol, although the reported results are inconsistent (for an overview, see: Chanda and Levitin, 2013; Kreutz et al., 2012; Thoma and Nater, 2011). For example, studies investigating the effects of relaxing music on HPA axis activity either found reduced cortisol secretion or no effect (Chanda and Levitin, 2013). When studying the effects of stimulating music, both lower and higher cortisol secretion have been found (Chanda and Levitin, 2013). These inconsistencies might partly arise from heterogeneous methodologies, as the studies vary with regard to who had control over choice of music (self-selected versus experimenter-selected) and what kind of music was listened to (Chanda and Levitin, 2013). Another prominent stress-sensitive system in the body is the autonomic nervous system (ANS), which has also been implicated in mediating music-induced physiological changes (Hodges, 2011). Its activation can be indirectly measured by the secretion of the salivary enzyme alpha-amylase (Nater and Rohleder, 2009). Using this enzyme as an autonomic stress marker, subjects listening to music prior to stress have been shown to recover faster after exposure to a psychosocial stressor as compared to non-music control conditions (Thoma et al., 2013).

However, most of the findings examining mechanisms underlying the beneficial effects of music listening were gathered in experimental settings. The number of studies set in daily life is still limited. We were able to show that music listening in daily life affects psychophysiological stress as measured by salivary cortisol and salivary alpha-amylase (Linnemann et al., 2015a). In this study, different features of the music itself (e.g., valence and arousal of the music) but also nonmusical context factors (e.g., reasons for music listening) contributed to the stress-reducing effect of listening to music (Linnemann et al., 2015a). In particular, reasons for music listening predicted stress reduction. Listening to music for the reason of relaxation reduced both subjective and physiological parameters of stress in a sample of healthy participants (Linnemann et al., 2015a), and it increased control over pain in patients with fibromyalgia (Linnemann et al., 2015b).

As promising as these results might be, so far, most of the research on the stress-reducing effect of music listening focused on individuals listening to music in solitude. However, the social context is especially relevant, as music listening is thought to fulfill social functions (Boer and Abubakar, 2014; Hargreaves and North, 1999; Koelsch, 2013), and research addressing this factor is still in its infancy (Hargreaves and North, 1999). Furthermore, most of the studies concentrated on musical group activities (e.g. singing; Valentine and Evans, 2001), leaving the question of any beneficial effect of mere music listening unanswered. There is evidence from the literature that at least some of the beneficial effects of music listening are closely linked to its social functions. In a questionnaire study, Boer and Abubakar (2014) showed that listening to music with peers was positively associated with continuous measures of well-being and social cohesion. In an experimental study, in which participants were seated next to each other in rocking chairs and were asked to rock at a comfortable rate, Demos et al. (2012) found that those participants who synchronized their rate of rocking to music (as opposed to visual information) felt more connected to the other person. Studies set in daily life found that music listening in the presence of others evoked more positive emotions than music listening in solitude (Juslin et al., 2008). Consequently, there is evidence that in the presence of others, the beneficial effects of music on emotional well-being and social cohesion are enhanced, but little is known about whether this effect also translates into enhancing the stress-reducing effect of listening to music.

Empirical evidence on stress (beyond the scope of music listening) consistently shows that social support has a stress-buffering function (Cohen and Wills, 1985). Translating these findings to the stress-reducing effect of music listening, it seems quite reasonable to assume a relevant role of the social context of listening to music. Experimental studies investigating the social context of musical activities focus on synchronization between the actors (e.g., Mercadie et al., 2014), but the question arises whether the mere presence of others can yield beneficial effects as well. Although there is accumulating evidence from the stress literature that the presence of others affects stress levels (for a review, see: Seeman and McEwen, 1996), there is no evidence regarding whether this can be generalized to the stress-reducing effect of music listening. Furthermore, it does not seem to be the mere presence of others that is stress-reducing per se; rather, the familiarity of the people present may play a crucial role in this effect (Allen et al., 1991). Kissel (1965) showed that the stress-reducing effect of the presence of others is even more profound if friends are present in contrast to strangers. Kirschbaum et al. (1995) found that this effect might be sex-specific, with men benefitting more from partner support than women. According to Ditzen et al. (2007), the kind of support that is provided appears to be important, as supporters who performed a massage were more effective than supporters who provided verbal support. However, all of these results were mainly found in laboratory studies set in highly artificial surroundings with low ecological validity. The question arises whether listening to music in the presence of others can act as a source of support, and whether it enhances the stress-reducing effect of listening to music.

1.1. Research question

It is hypothesized that the presence of others while listening to music enhances the stress-reducing effect of listening to music (Hypothesis 1). This hypothesis is tested by means of an ambulatory assessment design encompassing both subjective stress as well as parameters of biological stress-responsive systems. Furthermore, it is hypothesized that the familiarity of the people present moderates this effect, with further attenuated stress levels when music is listened to in the presence of friends (Hypothesis 2). As listening to music for the reason of relaxation was found to be predictive of the stress-reducing effect of listening to music in previous studies, it was tested, in an exploratory manner, whether this stress-reducing effect of listening to music for the reason of relaxation varies depending on the presence of others.

2. Method

2.1. Participants

Participants were recruited from various sources, such as emails sent to university mailing lists and a notice on a bulletin board for psychological studies. A total of 53 healthy young subjects (32 female, 21 male) participated in the study. Participants' age ranged from 20 to 32 years with a mean of $\bar{x} = 23.32$ (SD = 3.08) years. All participants had a BMI < 30, were either non-smokers or smoked less than five cigarettes per week, did not consume drugs (no consumption of cannabis within the last two weeks, no consumption of any other psychotropic substances within the last four weeks), did not take any medication (except for hormonal contraceptives), and had no chronic somatic or psychiatric disease (according to self-reports based on the Patient Health Questionnaire (PHQ; Löwe et al., 2002)). They received either 40 Euro or course credit as reimbursement. The study has been approved by the local IRB.

2.2. Design

The study was designed as an ambulatory assessment study (Fahrenberg, 1996). Ambulatory assessment refers to studies set in daily life that encompass self-reports, behavior records, and/or physiological measurements (Fahrenberg et al., 2007). Examining participants repeatedly in their daily life while they are going about their daily routine allows recall bias to be minimized and ecological validity to be maximized (Shiffman et al., 2008). Therefore, it is possible to examine the dynamics of variables of interest in the participants' natural habitat (Shiffman et al., 2008; Smyth and Stone, 2003). At the same time, studies set in daily life bring challenges. As there is no random assignment to a condition, the possibility to draw causal conclusions is limited (Smyth and Stone, 2003). Furthermore, data quality is dependent on compliance, which cannot be as rigorously controlled for in daily life compared to laboratory settings (Smyth and Stone, 2003). Nevertheless, despite higher ecological validity and lower internal validity, Csikszentmihalyi and Larson (1987) provide evidence that the repeated assessment of mental states in daily life allows the fluctuations of psychological states to be captured close to the time of occurrence. To ensure the best possible reliability and validity of salivary stress markers obtained in the field, we took a two-pronged approach. First, we carefully instructed our participants on what to do and what not to do immediately before collection of samples and asked them to freeze the samples as soon as possible. Second, we assessed time of day, smoking, and food intake as sources of intraindividual variance.

2.3. Procedure

Participants were screened for eligibility criteria via a telephone-based interview. In the case of eligibility, participants were invited to an introductory session during which they received standardized information about the study, gave informed consent, and were familiarized with handling a pre-programmed iPod touch®. All participants received a study manual in which all items occurring in this study were explained in detail. Furthermore, all participants completed one trial assessment in the presence of the study staff in order to ensure that all items were properly understood. Participants were asked to carry the iPod touch® with them for the following seven consecutive days. Each day, they were asked to complete six assessments. The first assessment was triggered by the participants themselves immediately after awakening. As this assessment did not include any items on music listening, it will not be considered further. Subsequent assessments were triggered by the pre-programmed iPod touch® 30 min after the first assessment and at 1100 h, 1400 h, 1800 h, and 2100 h. Additionally, participants were asked to collect a saliva sample at each assessment.

2.4. Measures

2.4.1. Stress

Stress was assessed using indicators for both the experience of subjective stress and for physiological markers of stress.

2.4.1.1. Subjective stress levels. Momentary subjective stress levels were measured using the item 'At this moment, I feel stressed', which could be answered on a 5-point Likert scale ranging from 0 to 4. Low scores indicate low levels of stress and high scores indicate high levels of stress, respectively.

2.4.1.2. Physiological markers of stress. Salivary cortisol (sCort) and salivary alpha-amylase (sAA) were concomitantly measured. Participants were asked to collect whole saliva using the SaliCap® system (IBL, Hamburg, Germany). sCort levels were measured using a commercially available enzyme-linked immunoassay (IBL, Hamburg, Germany). sAA activity was measured using a kinetic colorimetric test and reagents obtained from Roche (Fa. Roche Diagnostics, Mannheim, Germany). Inter- and intraassay variance was below 10.00% for both sAA and sCort.

2.4.2. Presence of others (while listening to music)

If music listening had occurred since the last assessment, participants had to indicate retrospectively whether they were alone, in the presence of friends, or in the presence of acquaintances while listening to music. All participants were given a standardized definition of 'presence of others while listening to music'. In line with the description provided in the study manual, participants were asked to refer to music listening in the presence of others whenever other people were around when they were listening to music. They were asked to state the mere presence of others while listening to music independently of interacting with others. Based on Juslin et al. (2008), who showed that the options 'being alone', 'being with a partner or close friend', and 'being with several friends or acquaintances' accounted for 75% of the situations captured in their ambulatory assessment study, we decided to use these three response options.

Additionally, participants were asked to state whether other people were present when the actual assessment was triggered. This information was assessed as a control variable in order to rule out that changes in stress were due to the mere presence of others at the moment the assessment was triggered. This is in line with the known association between the presence of others and stress (Seeman and McEwen, 1996). Therefore, by controlling for the presence of others when the assessment was triggered, we were able to examine whether the presence of others while listening to music affects stress in addition to the mere presence of others when the actual assessment was triggered and in addition to the effect of music listening.

2.4.3. Items on music listening

At each assessment, participants indicated whether they had listened to music since the last assessment. If they had done so, additional items on music listening followed. Based on the current evidence on the stress-reducing effect of music listening, participants were asked to complete items regarding the characteristics of the music by indicating the perceived valence of the music (visual analogue scale (VAS) ranging from sad (0) to happy (100)) (Sandstrom and Russo, 2010) and the perceived arousal of the music (VAS ranging from 0 (relaxing) to 100 (energizing)) (Khalfa et al., 2003). Subsequently, they indicated liking for the music on a scale ranging from 0 (not at all) to 100 (very much) (Stratton and Zalanowski, 1984) and were asked whether they had control over choice of music (yes/no) (Chanda and Levitin, 2013), and whether they had listened to music deliberately (Linnemann et al., 2015a). Then, reasons for music listening were assessed (Linnemann et al., 2015a) with participants choosing their main reason for music listening from among 'relaxation', 'activation', 'distraction', and 'reducing boredom'. Finally, participants had to indicate the source of music listening (MP3 player, television/radio, stereo equipment, live music, public speaker) (Juslin et al., 2008). All participants received standardized instructions concerning these options. They were provided with a manual in which all items were described in detail and each response option was carefully described.

2.5. Data analysis

Analyses are based on hierarchical linear modeling (HLM) (Raudenbush et al., 2004). Hypothesis testing was conducted in accordance with Woltman et al. (2012). The interpretation of interactions was conducted as recommended by Preacher et al. (2006).

P-values of ≤ 0.05 were considered significant. Unstandardized coefficients (UC) and standard errors are presented.

Using HLM, both unconditional and conditional models were specified. The unconditional model only included the outcome variable (subjective stress, sCort, or sAA, respectively) and control variables (gender, BMI, presence of others at the moment the assessment was triggered, control over choice of music (self-selected vs. not self-selected), liking for music, valence, arousal, reasons for music listening). The conditional model was specified by adding the variable of interest, that is, the presence of others while listening to music and the interaction of 'presence of others when the assessment was triggered × presence of others while listening to music'. Level-1 comprised variables that were assessed repeatedly, whereas level-2 (individual level) comprised trait variables that were assessed only once. Thus, at level-1, the intercept was modeled as a function of presence of others at the moment the assessment was triggered (γ_{10}), control over choice of music (γ_{20}), liking for music (γ_{30}), perceived valence of the music (γ_{40}), perceived arousal of the music (γ_{50}), relaxation (γ_{60}), activation (γ_{70}), distraction (γ_{80}), reducing boredom (γ_{90}), presence of others while listening to music (γ_{100}), interaction 'presence of others when the assessment was triggered × presence of others while listening to music' (γ_{110}). At the individual level (level-2), the intercept (β_0) was modeled as a function of gender (γ_{01}) and a residual component (u_0). In analyses concerning physiological markers of stress, body mass index (BMI) was additionally entered at the individual level due to its known association with HPA axis regulation (Champaneri et al., 2013).

A representative formula is depicted here:

Unconditional model:

$$\textit{Subjective stress}_{ij} = \gamma_{00} + \gamma_{01}{}^{*}\textit{gender}_j + \gamma_{10}{}^{*}\textit{presence of others at the moment the assessment was triggered} + \gamma_{20}{}^{*}\textit{control over choice of music}_{ij} + \gamma_{30}{}^{*}\textit{liking for music}_{ij} + \gamma_{40}{}^{*}\textit{valence}_{ij} + \gamma_{50}{}^{*}\textit{arousal}_{ij}\ \gamma_{60}{}^{*}\textit{relaxation}_{ij} + \gamma_{70}{}^{*}\textit{activation}_{ij} + \gamma_{80}{}^{*}\textit{distraction}_{ij} + \gamma_{90}{}^{*}\textit{reducing boredom}_{ij} + u_{0j} + r_{ij}$$

Conditional model:

$$\textit{Subjective stress}_{ij} = \gamma_{00} + \gamma_{01}{}^{*}\textit{gender}_j + \gamma_{10}{}^{*}\textit{presence of others at the moment the assessment was triggered}_j + \gamma_{20}{}^{*}\textit{control over choice of music}_{ij} + \gamma_{30}{}^{*}\textit{liking for music}_{ij} + \gamma_{40}{}^{*}\textit{valence}_{ij} + \gamma_{50}{}^{*}\textit{arousal}_{ij}\ \gamma_{60}{}^{*}\textit{relaxation}_{ij} + \gamma_{70}{}^{*}\textit{activation}_{ij} + \gamma_{80}{}^{*}\textit{distraction}_{ij} + \gamma_{90}{}^{*}\textit{reducing boredom}_{ij} + \gamma_{100}{}^{*}\textit{presence of others while listening to music} + \gamma_{110}{}^{*}\textit{interaction}_{ij} + u_{0j} + r_{ij}$$

The comparison between these models was undertaken by means of χ^2-square statistics, which compares the reduction in deviance as a measure of model fit. As an indicator of explained variance, pseudo-R^2 is reported, calculated in accordance with the formula (σ^2(unconditional growth model)−σ^2(subsequent model))/σ^2(unconditional growth model) (Singer and Willett, 2003).

As subjective stress reports ($UC = -0.06$, $t(1623) = -2.692$, $p = 0.007$), the secretion of sCort ($UC = -0.37$, $t(1623) = -28.413$, $p \leq 0.001$), and the activity of sAA ($UC = 0.22$, $t(1623) = 11.566$, $p < 0.001$) varied throughout the day, all analyses concerning music listening (yes/no) and stress controlled for time of day on level-1. However, for the sake of consistency with previous studies (Linnemann et al., 2015a), a time predictor was not entered into analyses in which only music listening episodes were included. As music listening was most often reported during the afternoon/evening ($UC = 0.06$, $t(1878) = 7.984$, $p \leq 0.001$), it can be assumed that the influence of diurnal variations was kept to a minimum in these analyses. Biological data were checked for normality using the Kolmogorov-Smirnov test. Both sCort ($D(2082) = 6.099$, $p \leq 0.001$) and sAA ($D(2058) = 7.561$, $p \leq 0.001$) significantly differed from a normal distribution and were therefore logarithmized using the formula ln (x) + 10.

3. Results

Music listening was reported at 38.5% of the total time points (so-called music episodes). Music was listened to in the presence of others in 35.0% of these music episodes. When listening to music in the presence of others, music was more often listened to in the presence of friends (64.3%) than acquaintances (35.7%). Furthermore, music listening behavior differed depending on the presence of others when listening to music. When listening to music alone, liking for music was higher and music was significantly more often listened to deliberately and self-chosen, and the reasons were more often relaxation or reducing boredom. When listening to music in the presence of others, the valence of the music was rated as more positive. Moreover, the source of the music varied depending on the presence of others, with music being listened to more often using an MP3 player or television/radio when listening to music alone. By contrast, when listening to music in the presence of others, live music or music at a public place was most often listened to. An overview of all music listening items and the exact inferential statistics can be found in Table 1.

The mean stress level experienced over the whole assessment duration was $\bar{x} = 1.25 \pm 1.01$. When listening to music alone, the mean stress level was $\bar{x} = 1.27 \pm 1.02$, whereas when listening to music in the presence of others, the mean stress level was $\bar{x} = 1.04 \pm 1.01$. This difference was significant ($t = 2.717$, df = 652, $p = 0.007$). At 47.5% of the total time points, participants reported being in the presence of others when the assessment was triggered.

3.1. The presence of others while listening to music enhances the stress-reducing effect of listening to music (Hypothesis 1)

Mere music listening was not associated with any parameters of stress (subjective stress levels: $UC = -0.05$, $t(1622) = -1.100$, $p = 0.271$; sCort: $UC = -0.02$, $t(1622) = -0.660$, $p = 0.509$; sAA: $UC = 0.03$, $t(1622) = 0.738$, $p = 0.461$). However, when considering the presence of others, the following pattern of results emerged (see Table 2): neither the presence of others when the assessment was triggered nor the presence of others while listening to music were associated with subjective stress reports. However, the 'presence of others when the assessment was triggered x presence of others while listening to music' interaction was significant with 2.23% of variance explained in subjective stress ($\chi^2 = 59.85$; $df = 13$; $p \leq 0.001$). This interaction term may be interpreted in the sense that subjective stress was lowest when both circumstances were met, that is being in the presence of others when the assessment was triggered and having listened to music in the presence of others ($\gamma_{1|1} = -0.462$, $t(582) = -2.863$, $p = 0.004$) (see Fig. 1).

Concerning the secretion of sCort the following results emerged: both the presence of others when the assessment was triggered as well as the presence of others while listening to music were associated with lower secretion of sCort. The presence of others while listening to music additionally explained 2.25% of variance in sCort ($\chi^2 = 70.91$; $df = 14$; $p \leq 0.001$).

Concerning the activity of sAA, the presence of others while listening to music was associated with higher activity of sAA, whereas there was no such effect for the presence of others when the assessment was triggered. Furthermore, the presence of others while listening to music additionally explained 2.91% of variance in the activity of sAA ($\chi^2 = 70.57$; $df = 14$; $p \leq 0.001$)

With regard to the control variables, music that was listened to for the reason of relaxation was associated with lower subjective stress levels, whereas music that was listened to for the reason of

Table 1
Statistics on music listening items.

	All music episodes		Listening to music alone		Listening to music in the presence of others		χ^2 square statistics[1]
	n	%	n	%	n	%	p value
Music listening (0/1)[2]	649	38.5	422	65.0	227	35.0	–
Deliberate music listening (0/1)[2]	340	52.4	250	73.5	90	26.5	<0.001
control over choice of music (0/1)[3]	362	55.8	301	83.1	61	16.9	<0.001
Reason relaxation (0/1)[2]	136	21.0	106	77.9	30	22.1	<0.001
Reason activation (0/1)[2]	167	25.7	111	66.5	56	33.5	0.339
Reason distraction (0/1)[2]	108	16.6	75	69.4	33	30.6	0.161
Reason reducing boredom (0/1)[2]	38	5.9	31	81.6	7	18.4	0.017
Source: MP3 Player (0/1)[2]	120	18.5	103	86.6	16	13.4	<0.001
Source: TV/radio (0/1)[2]	218	33.6	118	54.1	100	45.9	<0.001
Source: stereo (0/1)[2]	272	41.9	181	66.5	91	33.5	0.218
Source: Live Music (0/1)[2]	5	0.8	0	0.0	5	100.0	0.015
Source: Public Place (0/1)[2]	15	2.3	4	26.7	11	73.3	0.003
	Mean	SD	Mean	SD	Mean	SD	t-statistic[4]
Liking for music (0–100)[5]	74.99	20.67	77.71	18.65	69.55	23.30	<0.001
Valence (0–100)[6]	64.58	21.31	61.99	21.87	68.74	19.60	<0.001
Arousal (0–100)[7]	63.15	23.45	61.99	22.79	64.89	24.16	0.129

Note: [1]analyses are based on contingency tables comparing the frequency of music listening in the presence of others to the frequency of music listening alone, [2](0/1): 0 = no, 1 = yes (note: the frequency of 'yes' is depicted), [3]0 = not self-selected, 1 = self-selected (note: the frequency of self-selected music is depicted), [4]analyses are based on hierarchical linear modeling testing whether the presence of others while listening to music explains variance in liking for music, valence, and arousal, respectively, [5]VAS ranging from 0 (not at all) to 100 (entirely), [6]VAS ranging from 0 (sad) to 100 (happy), [7]VAS ranging from 0 (relaxing) to 100 (energizing).

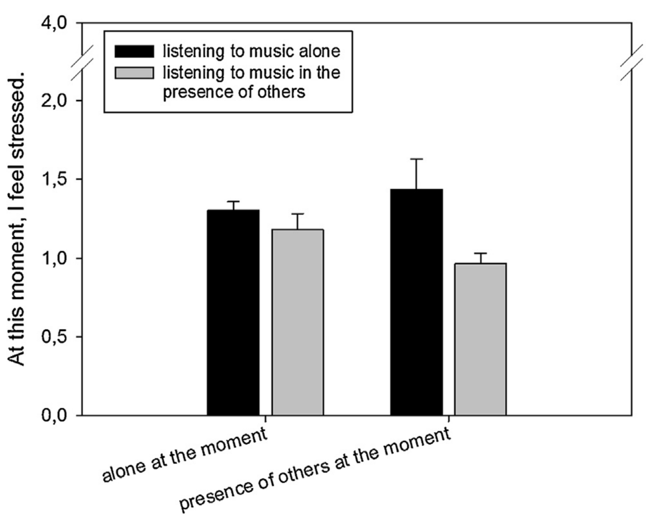

Fig 1. Mean stress level as a function of presence of the others at the moment of assessment (0/1) and presence of others while listening to music (0/1).

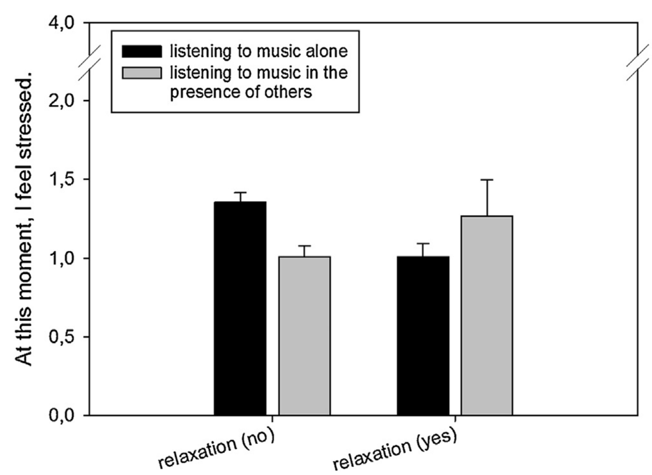

Fig. 2. Mean stress level as a function of relaxation (0/1) and presence of others while listening to music (0/1).

activation was associated with higher sCort secretion. Music that was low in arousal was associated with lower sAA activity. Control over choice of music was associated with sCort secretion, with music that was self-chosen being associated with lower sCort secretion. At the same time, liking for music was associated with higher sCort secretion (see Table 1 for details).

3.2. *The familiarity of the people present moderates this stress-reducing effect, with further attenuated stress levels when music is listened to in the presence of friends (Hypothesis 2)*

The familiarity of the people present (friends versus acquaintances) did not further enhance the stress-reducing effect of listening to music in the presence of others (subjective stress levels: $UC = -0.31$, $t(171) = -0.847$, $p = 0.987$; sCort: $UC = 0.02$, $t(171) = 0.064$, $p = 0.949$; sAA: $UC = 0.06$, $t(171) = 0.212$, $p = 0.832$). However, only N = 44 participants were entered into these analyses as nine participants always listened to music alone.

3.3. *Exploratory analysis: does the stress-reducing effect of listening to music for the reason of relaxation vary depending on the presence of others?*

As expected, music listening for the reason of relaxation predicted lower subjective stress levels (see Table 2). It was therefore tested, in an exploratory manner, whether the stress-reducing effect of listening to music for the reason of relaxation varies depending on the presence of others. For this purpose, an interaction term 'relaxation as reason for music listening × presence of others while listening to music' was added to the conditional model. This interaction was significant ($UC = 0.42$, $t(585) = 2.049$, $p = 0.041$). When listening to music alone, subjective stress levels were lowest when music was listened to for the reason of relaxation ($\gamma_{1|0} = -0.3852$, $t(601) = -3.7347$, $p \le 0.001$), whereas when listening to music in the presence of others, there was no effect of reasons for music listening on subjective stress levels ($\gamma_{1|1} = 0.103$, $t(601) = 0.580$, $p = 0.562$) (Fig. 2).

Table 2
Hierarchical linear models predicting repeatedly assessed momentary subjective stress levels, salivary cortisol (sCort) secretion as well as salivary alpha-amylase (sAA) activity by presence of others while listening to music using restricted maximum likelihood.

	subjective stress levels predicted by presence of others while listening to music		sCort secretion predicted by presence of others while listening to music		sAA activity predicted by presence of others while listening to music	
Fixed Effects	Unstandardized Coefficients	SE (df), *p*	Unstandardized Coefficients	SE (df), *p*	Unstandardized Coefficients	SE (df), *p*
Intercept Level-2	1.73	0.23 (51), *≤0.001*	12.19	0.18 (50), *≤0.001*	13.89	0.19 (50), *≤0.001*
Gender	0.04	0.17 (51), *0.831*	0.12	0.12 (50), *0.308*	−0.03	0.16 (50), *0.875*
BMI[1]			−0.02	0.02 (50), *0.338*	0.04	0.03 (50), *0.198*
Presence of others (0/1)[2]	−0.09	0.10 (582), *0.362*	−0.29	0.08 (582), *≤0.001*	0.14	0.08 (582), *0.085*
Presence of others while listening to music (0/1)[3]	0.14	0.16 (582), *0.378*	−0.28	0.13 (582), *0.030*	0.32	0.13 (582), *0.011*
Interaction term[4]	−0.37	0.19 (582), *0.050*	0.14	0.15 (582), *0.342*	−0.20	0.14 (582), *0.164*
Valence (0–100)[5]	−0.00	0.00 (582), *0.060*	−0.00	0.00 (582), *0.890*	−0.00	0.00 (582), *0.424*
Arousal (0–100)[6]	0.00	0.00 (582), *0.392*	−0.00	0.00 (582), *0.487*	0.00	0.00 (582), *0.043*
Control over choice of music (0/1)[7]	0.04	0.10 (582), *0.665*	−0.19	0.08 (582), *0.014*	0.03	0.07 (582), *0.667*
Liking for music (0–100)[8]	−0.00	0.00 (582), *0.189*	0.00	0.00 (582), *0.014*	0.00	0.00 (582), *0.214*
Reason relaxation (0/1)[9]	−0.25	0.11 (582), *0.025*	−0.09	0.09 (582), *0.319*	0.07	0.09 (582), *0.399*
Reason activation (0/1)[9]	−0.07	0.11 (582), *0.493*	0.29	0.08 (582), *≤0.001*	0.01	0.08 (582), *0.903*
Reason distraction (0/1)[9]	0.15	0.12 (582), *0.223*	0.00	0.09 (582), *0.967*	0.01	0.09 (582), *0.930*
Reason reducing boredom (0/1)[9]	−0.12	0.17 (582), *0.478*	−0.10	0.14 (582), *0.473*	−0.01	0.13 (582), *0.930*

Random Effects	Variance Component	SD (df), *p*	Variance Component	SD (df), *p*	Variance Component	SD (df), *p*
Intercept Level-1	0.29	0.54 (51), *≤0.001*	0.12	0.35 (50), *≤0.001*	0.28	0.53 (50), *≤0.001*
Residual	0.73	0.85	0.46	0.68	0.43	0.66

Note: [1]BMI was only entered into analyses predicting sCort and sAA, [2]presence of others at the moment the assessment was triggered, [3](0/1): 0 = listening to music alone, 1 = listening to music in the presence of others, [4]Interaction term 'presence of others at the moment the assessment was triggered × presence of others while listening to music', [5]VAS ranging from 0 (sad) to 100 (happy), [6]VAS ranging from 0 (relaxing) to 100 (energizing), [7]0 = not self-chosen, 1 = self-chosen, [8]VAS ranging from 0 (not at all) to 100 (very much), [9]0 = no, 1 = yes.

4. Discussion

This study was designed to test the hypothesis that the presence of others enhances the stress-reducing effect of music listening in daily life. Overall, music listening per se was not associated with a stress-reducing effect. However, listening to music in the presence of others was associated with decreased subjective stress levels, attenuated secretion of sCort, and higher sAA activity. These effects were not due to the mere presence of others when the assessment was triggered, as music listening in the presence of others additionally explained variance in subjective stress levels, secretion of sCort and sAA activity. Furthermore, these effects were independent of the familiarity of the people present and of the reasons for music listening. Reasons for music listening, in particular relaxation, only predicted successful stress reduction when music listening in solitude was reported.

4.1. Is the mere presence of others while listening to music stress-reducing?

Music listening in the presence of others reduced subjective stress levels as well as the secretion of sCort. This extends the idea of the stress-buffering hypothesis of social support (Cohen and Wills, 1985). Here, it was shown that even the mere presence of others while listening to music is associated with stress-reducing effects. Participants in this study were not instructed to engage in any social activity that might lead to receiving social support while listening to music, but still a stress-reducing effect was found. As Boer and Abubakar (2014) found that listening to music in the presence of peers was associated with increased feelings of social cohesion, it might be speculated that the mere presence of others while listening to music could lead to feelings of social cohesion without specific social support interventions. Moreover, the stress-reducing effect of listening to music in the presence of others exceeded the stress-reducing effect of the mere presence of others. This is in line with findings from Pearce et al. (2015), who compared singing to a non-singing control condition (craft, creative writing) and showed that singing has beneficial effects that are specific to music and that exceed the effect of the social group context.

Interestingly, the familiarity of the people present while listening to music did not moderate this relationship. As familiarity was an important factor identified in experimental studies on the stress-reducing effect of presence of others (Kissel, 1965), our results suggest that when listening to music with others, familiarity does not affect the stress-reducing effect of listening to music in the presence of others. It is likely that in the context of music listening with others, different aspects, such as similar music preferences, are more important than the familiarity per se. However, this finding has to be interpreted with caution, as most of the music was listened to in the presence of friends. Therefore, our findings need to be corroborated in a more heterogeneous sample of music listening episodes.

4.2. Potential mechanisms underlying the stress-reducing effect of listening to music in the presence of others

With respect to specific characteristics of social encounters that may be stress-reducing in a given situation, the literature is inconsistent. Most of the studies suggest that it is not the mere presence of others that is stress-reducing, but rather that the effects of the presence of others vary depending on familiarity (Allen et al., 1991; Kissel, 1965), sex (Kirschbaum et al., 1995), and kind of social support (Ditzen et al., 2007). In the present study, the mere presence of others while listening to music was associated with a reduction in stress.

Most interestingly, music listening in the presence of others differentially affected physiological markers of stress. Whereas music listening in the presence of others decreased HPA axis activity, it increased ANS activity. Relating these findings to the existing literature, a quite heterogeneous picture emerges: Egermann et al. (2011) found in an experimental study that music listening was more arousing (as measured by skin conductance levels) when it was listened to alone compared to in a group. Liljeström et al. (2013) found no difference in heart rate and skin conductance levels when listening to music either alone or with a close friend or partner. At first glance, these findings contradict the results of the present study. Nevertheless, it is possible to reconcile the findings. Egermann et al. (2011) and Liljeström et al. (2013) examined music listening in *experimental settings*, whereas here, we studied music listening in *daily life*. Music listening might fulfill different functions depending on whether others are present while listening to music. When listening to music alone, the music seems to be in the focus of attention, whereas when listening to music in the presence of others, music might act more as a background activity. This might explain why participants in this study reported less deliberate music listening when listening to music in the presence of others (as opposed to solitary music listening). This attributes to music rather indirect effects on health, suggesting that it may facilitate social contact and social connectedness without being the focus of attention. Such a suggestion is in line with findings on background music and well-being. For example, Ghaderi et al. (2009) found that cortisol was decreased if athletes listened to relaxing background music while exercising, mirroring our finding of lower subjective stress levels and lower sCort secretion when listening to music in the presence of others. Higher activity of sAA after listening to music in the presence of others might be explained by the arousal of the music that was listened to – even though the simultaneous observation of attenuated sCort secretion and heightened sAA activity might initially appear contradictory. Nevertheless, a recent study also found that music listening differentially affected sCort secretion and sAA activity (Linnemann et al., 2015a). The perceived arousal of the music influenced sAA activity, with energizing music increasing sAA activity and relaxing music decreasing sAA activity, respectively. Interestingly, in descriptive terms, the participants in this study rated the music they listened to in the presence of others as more arousing than the music that they listened to in solitude (see Table 1). Therefore, higher sAA activity when listening to music in the presence of others might be explained by the perceived arousal of the music.

Many mechanisms by which musical group activities fulfill social functions have been discussed (Keeler et al., 2015; Koelsch, 2013; Kreutz, 2014; Tarr et al., 2014). Tarr et al. (2014) highlight two mechanisms by which musical group activities lead to positive emotional responses and social bonding – two factors that are known to have stress-reducing properties. Interestingly, these authors distinguish the effects of musical group activities from those of passive music listening. However, passive music listening can be a group activity was well. For example, Särkämö et al. (2014) showed in dementia patients that both music making and music listening in groups have similar, positive effects on cognitive, emotional, and social functioning. Therefore, it might not be necessary to distinguish music listening from music making in this context, and mechanisms regarding musical group activities might accordingly apply for music listening in the presence of others as well. The first mechanism highlighted by Tarr et al. (2014) is called 'self-other merging', meaning that when engaging in musical group activities, people (involuntarily and spontaneously) synchronize with each other, which in turn leads to social bonding. Musical features such as tempo can facilitate the synchronization of movements, which can create a feeling of togetherness and bonding. Relating this to findings from stress research, feelings of social connectedness are associated with lower subjective stress levels as well as reduced HPA axis activity (Sladek and Doane, 2015).

The second mechanism by which musical group activities fulfill social functions relates to the release of endocrine hormones, especially endorphins (Tarr et al., 2014). Passive music listening has been shown to activate endorphins, especially if musical activities occur in groups. The release of endorphins is closely linked to the experience of positive emotions as well as to attenuated levels of cortisol (Taylor et al., 1983) and higher alpha-amylase activity (Ortu et al., 2015). Furthermore, there is evidence that music listening in daily life leads to more positive emotions when it occurs in the presence of others (Juslin et al., 2008). This might explain why listening to music in the presence of others decreased HPA axis activity, as positive music-induced emotions in particular have been shown to decrease HPA axis activity (Suda et al., 2008). Consequently, music-induced physiological changes and involuntary synchronization might explain why listening to music in the presence of others has stress-reducing effects in terms of subjective stress levels and HPA activity, and at the same time arousing effects in terms of ANS activity.

In line with a previous study (Linnemann et al., 2015a), music that was listened to for the reason of relaxation reduced subjective stress levels. However, this was only the case when listening to music alone, and not when listening to music in the presence of others. Different mechanisms might underlie the stress-reducing effect of listening to music depending on the social context of the listening situation. When listening to music in the presence of others, music listening seems to be a background activity, and beneficial effects occur independently of specific reasons for music listening. However, when listening to music alone, the reverse seems to be true: Only music that is deliberately listened to for the reason of relaxation is associated with attenuated stress levels. In these cases, the stress-reducing effect seems to be more closely linked to the music itself (as reasons for music listening are important) than to the presence of others while listening to music.

4.3. Limitations

Although this is a study with high ecological validity, encompassing both subjective and physiological markers of stress, certain limitations have to be discussed. First, we do not know *when* music listening took place relative to the assessment of stress markers. Especially as both sAA and sCort underlie different temporal dynamics, it cannot be ruled out that music listening occurred up to four hours before the assessment of stress. However, as we examined 53 participants for the duration of seven days with five daily assessments, we gathered a total 1855 observations with 35 observations per participant. This high number of observations per participant makes it highly unlikely that music listening (in contrast to other activities that might have occurred in-between) was not associated with stress. Furthermore, we only assessed whether participants were alone or in the presence of friends or acquaintances while listening to music, but did not ask about the quality of social interactions. Therefore, we cannot know whether the presence of others was perceived as positive or negative. Third, the proportion of music listening episodes in the presence of acquaintances was relatively small, as most of the music listening occurred in the presence of friends.

4.4. Future directions

Future research should further characterize the nature of the stress-reducing effect of listening to music in the presence of others. By means of event-based schedules, the temporal dynamics underlying the effects of music listening on stress markers should be examined. Furthermore, future studies should assess whether participants listened to music together with others when listening to music in the presence of others. Moreover, the quality of interaction should be assessed in order to shed further light on the possible mediating role played by the social context in the stress-reducing effect of listening to music. Concerning the physiological markers assessed in this study, it would be interesting to examine the role of the neuropeptide oxytocin in future studies. Most of the studies so far examined oxytocin in the context of music making, for example in the context of group singing (e.g., Grape et al., 2003; Kreutz, 2014). However, future studies should assess oxytocin-related mechanisms in the context of music listening in the mere presence of others in order to further understand the social functions of music listening in daily life. Finally, to ultimately test hypotheses on health-beneficial effects of music listening mediated by a reduction in psychobiological stress, the assessment of immune system markers is warranted (Fancourt et al., 2016).

4.5. Conclusion

Our findings suggest that music listening has stress-reducing effects in daily life – especially when it occurs in the presence of others. This opens important avenues for music listening as a means for health promotion in daily life. Especially as stress has been related to a number of negative health outcomes, music listening in the presence of others might beneficially affect psychosocial well-being as well as (physical) health by means of stress reduction. As opposed to clinical interventions, mere music listening in daily life is easily accessible, popular, and cost-effective. Consequently, these findings should be translated into promoting music listening as health behavior in daily life. It should be recommended to engage in music listening for stress reduction purposes – either in the presence of others or deliberately for the reason of relaxation when listening to music alone.

Conflict of interest

The authors declare no financial interest related to the study.

Contributors

All authors contributed to the study design. Testing and data collection was performed by AL. All authors contributed to the data analysis and interpretation. AL and UMN drafted the manuscript, and JS provided critical revisions. All authors approved the final version of the manuscript for submission.

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