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***Stress and mood regulation using music in times of COVID-19 lockdown: an ecological
momentary assessment study***

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Abstract

Introduction: Music is a human universal that is frequently used as a means of stress reduction and mood improvement by individuals of all ages and cultures, particularly in times of crisis. However, ecologically valid research on stress- and mood-regulatory effects of music listening during the COVID-19 pandemic is lacking.

Objective: We investigated the effects of music listening on perceived stress and mood during the first lockdown using an ecological momentary assessment approach. Moreover, the modulating roles of chronic stress and qualitative aspects of music listening were examined.

Methods: A total of 711 adults residing in Austria and Italy reported their music-listening behavior and rated perceived stress and mood (valence, calmness, energetic arousal) five times per day across seven consecutive days during April and May, 2020.

Results: Music listening was prospectively associated with lower perceived stress and improved mood. For stress and energetic arousal in particular, music listening up- and downregulated levels towards a homeostatic balance. Individuals reporting higher chronic stress showed higher mood valence and energetic arousal after music listening. Characteristics of the music and the situation were differentially associated with stress and mood on the intra- and interindividual level.

Conclusions: The present findings suggest that music listening in daily life is a beneficial means to regulate stress and mood during psychologically demanding periods. Particularly individuals experiencing heightened momentary and/or chronic stress due to the challenges brought about by the pandemic might consider music as an easily accessible tool for the management of stress and mood in daily life.

Keywords: COVID-19; ecological momentary assessment; mood; music listening; stress

Introduction

The coronavirus disease 2019 (COVID-19) pandemic has changed the everyday life of many individuals worldwide. Starting in the spring of 2020, many countries implemented far-reaching lockdown measures, including strict social distancing and stay-at-home orders [1]. The resulting social and economic disruption was associated with stress, worries, and mental health problems in the general population [2–4]. This was aggravated by the fact that many leisure activities that were previously pursued to regulate stress and mood (e.g., meeting friends, attending cultural events) were banned due to the lockdown. Prolonged levels of heightened stress (i.e. chronic stress) and impaired mood have been shown to be major risk factors for mental and somatic disorders [5], specifically in the context of the COVID-19 pandemic [6–8].

Music listening qualifies as an easily accessible coping strategy during times of pandemic. Research conducted prior to the COVID-19 pandemic documented the capacity of music to modulate cognitive, affective, and neurobiological processes [9–12]. Moreover, historical evidence suggests that particularly in times of crisis and disasters, individuals across cultures turn to music to lift their mood and to increase feelings of social connectedness [13].

While most research on the beneficial effects of music on stress and mood is cross-sectional and/or lab-based in nature, ecological momentary assessment (EMA) methods enable the examination of dynamic microprocesses as they occur in the natural environment [14]. Initial EMA studies have revealed a complex interplay between characteristics of the listener, the situation, and the music, which interact in terms of stress and mood regulation [15–17]. Interestingly, previous studies suggest that the stress-reducing effects of music listening might be limited when individuals are confronted with intense and/or chronic stressors [16, 18, 19]. This challenges the assumption of beneficial effects of music in the context of a global stressor like a pandemic.

Taken together, increased levels of stress and impaired mood during COVID-19 lockdown constitute risk factors for detrimental health outcomes. Music listening qualifies as a helpful means of self-regulation during such times of crisis. However, the real-time and real-life stress-/mood-regulatory capacities of music listening remain to be investigated.

The present study

As part of a preregistered research project (<https://osf.io/rzqn6/>), we conducted an EMA study with over 700 individuals in two European countries, Austria and Italy, from April 1st to May 8th, 2020, when strict lockdown measures were first implemented in both countries (**online suppl. 1**).

We hypothesized that music listening would predict lower levels of perceived momentary stress and higher levels of mood (valence, energetic arousal, calmness). In order to unravel the dynamic regulatory properties of music listening, we took previous levels of perceived stress and mood into account and investigated time-delayed (as opposed to concurrent) effects of music listening on subsequent stress and mood. Furthermore, we examined whether perceived chronic stress moderated the effects of music listening, and expected to find a stronger beneficial effect in individuals experiencing lower levels of chronic stress [16].

Materials and Methods

Participants

The final sample comprised 711 participants ($M_{\text{age}} 31.6 \pm 11.6$ years, 69.9% female, 68.1% residing in Austria; see **Table 1**). To be eligible for inclusion, participants had to be fluent in German or Italian, at least 18 years old, and own an Android smartphone/tablet. Participants were reimbursed with 20€ and were given the opportunity to take part in a raffle to win 100€. Details on participant attrition and study compliance are reported in **online suppl. 2.1; 2.2**.

Table 1. Study sample characteristics and ecological momentary assessment data.

	Overall N=711	Austria N = 484	Italy N = 227
Gender			
Female	497 (69.9%)	364 (75.2%)	133 (58.6%)
Male	214 (30.1%)	120 (24.8%)	94 (41.4%)
Age (years)	31.6 ± 11.6	33.2 ± 12.3	28.0 ± 8.9
range	18 – 80	18 – 76	18 – 80
Education level ^a			
Low	33 (4.6%)	30 (6.2%)	3 (1.3%)
Medium	259 (36.4%)	190 (39.3%)	69 (30.4%)
High	419 (58.9%)	264 (54.5%)	155 (68.3%)
Current working status ^b			
Full-/part-time home	223 (31.4%)	175 (36.2%)	48 (21.1%)
Full-/part-time away from home	117 (16.5%)	85 (17.6%)	32 (14.1%)
Full-time student	264 (31.7%)	162 (33.5%)	102 (44.9%)
Unemployed	66 (9.3%)	35 (7.2%)	31 (13.7%)
Perceived chronic stress ^c	18.7 ± 7.3	17.9 ± 7.2	20.5 ± 5.4
Depressive symptoms ^d	8.2 ± 5.2	7.8 ± 5.4	8.9 ± 4.7
<i>Ecological momentary assessment^e</i>			
Perceived stress	29.9 ± 25.8	25.9 ± 24.5	38.9 ± 26.4
Mood valence	63.5 ± 21.2	65.9 ± 21.0	58.1 ± 20.6
Energetic arousal	50.9 ± 23.0	51.4 ± 22.9	49.8 ± 23.2
Calmness	61.9 ± 22.3	64.4 ± 21.6	56.3 ± 22.7
Music-listening reports	4677 (24%)	3406 (25.2%)	1271 (21.2%)
range per person	0 – 32	0 – 32	0 – 21

Notes: Data are presented as n (%) or mean ± SD.

^abased on the International Standard Classification of Education (ISCED) 2011 (low: level 1 – 2, medium: level 3 – 4, high: level 5+).

^bmultiple answers were possible.

^cassessed via the Perceived Stress Scale (PSS-10) [20, 21], scale ranges from 0–40. Prepandemic norm values based on a representative German sample [21]: 13 ± 6.5; Values derived from a representative Austrian sample in April 2020 [2]: 16.0 ± 7.5.

^dassessed via the Patient Health Questionnaire (PHQ-9) [22], scale ranges from 0–27; values ≥5 indicate mild, ≥10 moderate levels of depression severity. Prepandemic norm values based on a representative German sample [37]: 2.9 ± 3.5; Values derived from a representative Austrian sample in April 2020 [2]: 6.2 ± 5.4.

^eaveraged across all observations and participants unless otherwise stated.

Procedure

Recruitment was undertaken via online posts. Interested participants received a link to download the app movisensXS (Movisens GmbH, Germany) for data collection. The EMA period lasted for seven consecutive days, with five data entries scheduled throughout the day (semi-randomly between 10:00-11:00, 11:00-14:00, 14:00-17:00, 17:00-20:00, self-initiated at bedtime; **online suppl. 2.3**). At the end of the EMA period, participants completed psychometric online questionnaires (Sosci Survey GmbH, Germany).

Psychometric questionnaires

The 10-item version of the Perceived Stress Scale (PSS-10) was administered to measure chronic stress over the past four weeks [20, 21]. The total score ranges from 0-40, with higher scores indicating higher chronic stress levels (Cronbach's α : 0.88 in this study). Information on depressive symptoms was assessed using a subscale of the Patient Health Questionnaire [22]. Habitual music-listening behavior was assessed using the Music Preference Questionnaire [23].

Ecological momentary assessment

Perceived stress was assessed using the item “*At the moment, I feel stressed*”, answered on a visual analogue scale (VAS) ranging from 0 (*not at all*) to 100 (*very much*) [24]. ***Mood*** was measured based on a validated mood scale [25] assessing the three basic mood dimensions *valence* (unwell-well; discontented-contented), *energetic arousal* (tired-awake; without energy-full of energy), and *calmness* (restless-calm; tense-relaxed). Participants indicated their momentary mood on VAS ranging from 0–100, with higher values indicating higher valence, energetic arousal, or calmness, respectively. ***Music listening*** was assessed using a single item [26], which reflected deliberate music listening preceding momentary reports of stress/mood and was coded as 0 (*no previous music listening*) or 1 (*previous music listening*). When participants indicated previous music listening, they were asked to state the perceived music characteristics on bipolar VAS (*valence*: 0(sad)-

100(happy); *arousal*: 0(calming)-100(energizing)) and the main reason for music listening (*relaxation, activation, distraction, reducing boredom*; selected=1, not selected=0) as qualitative aspects of music listening (**online suppl. 2.4; 2.5**).

Statistical analyses

We computed multilevel models (observations (level 1) within individuals (level 2)) using RStudio 4.1.2 [27] with the packages *lme4* [28] and *interactions* [29]. The effect of music listening was analyzed on each outcome separately, taking into account lower-level interactions with previous stress/mood levels (i.e. reported at the measurement time point preceding the outcome) and cross-level interactions with chronic stress. Country of residence was included in all models, along with further covariates (**online suppl. 2.5**). We report Cohen's *d* as a measure of effect size, calculated using the R package *EMAtools* [30].

Results

Table 1 displays sample characteristics and EMA reports. Details on habitual and daily life music behavior and descriptive within-/between-person statistics for outcome variables are reported in **online suppl. 3.1-3.3**.

Perceived stress

Having listened to music predicted lower perceived stress ($b=-0.88$, $SE=0.44$, $p=.045$, $d=0.04$). A significant '*music listening*previous stress level*' interaction ($b=-0.08$, $SE=0.02$, $p=.002$, $d=0.06$) emerged, indicating that this effect varied as a function of previous stress. This interaction was probed using the Johnson-Neyman test, which revealed that music listening up- and downregulated momentary stress in the opposite direction to previous stress levels (shown in **Fig. 1A**, **online suppl 3.4**).

Mood

Music listening predicted higher subsequent mood valence ($b=1.85$, $SE=0.37$, $p<.001$, $d=0.09$) and calmness ($b=1.42$, $SE=0.39$, $p<.001$, $d=0.07$), irrespective of previous levels ($ps\geq.15$). Furthermore, music listening predicted higher energetic arousal ($b=2.19$, $SE=0.42$,

$p<.001$, $d=0.09$). A significant interaction effect ($b=-0.10$, $SE=0.02$, $p<.001$, $d=0.08$) emerged, indicating that this effect varied as a function of previous energetic arousal. The Johnson-Neyman test revealed that music up- and downregulated energetic arousal in the opposite direction to previous energetic arousal levels (shown in **Fig. 1B**, **online suppl. 3.4**).

Figure 1. Music listening up/downregulated levels of stress and energetic arousal depending on previous levels of stress/energetic arousal. Positive values on the x-axis indicate that music listening occurred, negative values indicate that music listening did not occur. pmc, person-mean centered.

(A) Momentary perceived stress as a function of music listening at various levels of previous stress. Music listening downregulated perceived stress when participants reported above-average stress levels at the previous data entry ($p<.05$). When participants reported very low stress levels (≤ -2.1 SDs) at the previous data entry, music listening upregulated perceived stress ($p<.05$). **(B)** Momentary energetic arousal as a function of music listening at various levels of previous energetic arousal. Music listening upregulated energetic arousal when participants reported average and below-average energetic arousal at the previous data entry ($p<.05$). When participants reported very high energetic arousal ($\geq +2.9$ SDs) at the previous data entry, music listening downregulated energetic arousal ($p<.05$).

Chronic stress as a moderator

Chronic stress moderated the relationship between music listening and mood valence ($b=0.13$, $SE=0.05$, $p=.01$, $d=0.21$). A comparable effect was found for energetic arousal ($b=0.16$, $SE=0.06$, $p=.007$, $d=0.26$). Johnson-Neyman tests revealed that music listening predicted higher mood valence and energetic arousal starting at PSS values >12.6 and >10.9 , respectively. The effects of music listening on perceived momentary stress and calmness were not moderated by chronic stress ($ps \geq 0.22$).

Qualitative aspects of music listening

Listening to *happier music* (relative to a person's average reports) predicted lower perceived stress, higher mood valence, and higher calmness. A significant *music valence*previous mood valence* interaction revealed that listening to happier music particularly at below-average mood valence predicted higher subsequent mood valence. Moreover, listening to more *energizing music* (relative to a person's average reports) predicted higher energetic arousal. Having listened to music for the reason of *distraction* predicted higher perceived stress, irrespective of previous stress levels ($p=.63$). A *distraction*previous mood valence* interaction showed that listening to music for *distraction* at above-average values of mood valence predicted lower mood valence at the subsequent time point. No other interactions with previous outcome levels were significant ($ps \geq .12$). Besides these within-person effects (shown in **Fig. 2**, bottom part), several between-person effects for *musical valence*, and the reasons *relaxation* and *activation* (shown in **Fig. 2**, upper part) emerged.

Figure 2. Significant within-person (“momentary level”) and between-person (“Person level”) associations (with regression coefficients and Cohen’s d values) between music characteristics/reasons for music listening and outcome variables (perceived stress, mood valence, energetic arousal, calmness). * $p < .05$, ** $p < .01$, *** $p < .001$.

Notes. A temporal precedence between music listening and outcomes is considered on the momentary level (but not on the person level). On the “momentary level”, musical valence and musical arousal predicted lower perceived stress and higher mood (see arrows with coefficients). Furthermore, distraction predicted higher perceived stress (see arrows with coefficients). Dashed lines show interaction effects with previous *mood valence* with corresponding coefficients. On the “person level”, individuals who listened to *happier* music as well as those who listened to music for *relaxation* or *activation* more frequently than others reported lower levels of stress and higher levels of mood (see arrows with coefficients).

Discussion

To the best of our knowledge, this is the first study to investigate the stress- and mood-regulatory effects of music listening in daily life during COVID-19 lockdown restrictions using an ecologically valid method in an exceptionally large sample. Our findings suggest that

music listening is a beneficial tool for stress and mood regulation during lockdown, corroborating previous cross-sectional findings [31–34]. Importantly, we showed that the magnitude and direction of stress/mood changes in daily life varied according to preceding psychological states, chronic stress, and qualitative aspects of music listening.

We found evidence that music seems to regulate perceived stress and energetic arousal towards a neutral state or balance [15]. Interestingly, this “homeostasis” effect was not found for mood valence or calmness, suggesting that music listening improves these independently of previous states, while arousal-related psychological states are up/downregulated depending on previous arousal levels. In this regard, our findings are broadly in line with a pre-pandemic EMA study [35] and can be explained by mood management theory, suggesting that in general, individuals choose music with the aim of creating an optimal balance of arousal while increasing hedonic valence [36].

Contrary to our expectations, individuals reporting higher chronic stress benefitted most from music listening in terms of higher mood valence and energetic arousal, while the stress-regulatory effect of music listening remained unaffected by chronic stress level of the listener. Previous studies conducted in the context of a stressful student exam period [16] and an experimental psychosocial stress paradigm [18] suggested that the stress-reducing effects of music might be limited under heightened stress. However, these stressful encounters may not be comparable to a pandemic-like situation. Thus, our findings provide evidence for beneficial effects of music listening particularly for individuals perceiving heightened chronic stress during the psychologically challenging circumstances of lockdown. Future research should examine whether this finding can be generalized to other long-term stressors.

Finally, we found differential effects of qualitative aspects of music listening on the within- and between-person level. *Happier* music predicted lower stress and improved mood on the momentary level, and individuals who generally listened to *happier* music as well as

those who listened to music more frequently for *relaxation* and *activation* reported lower stress and higher mood than others. Strikingly, listening to music for *distraction* predicted higher stress. This was also reported in a previous EMA study and supports the notion that distraction by music might be helpful in moments of acute stress but not chronic stress [16]. It is important to note that this effect was only found on the momentary level and not on the person level, indicating that individuals with a greater tendency to listen to music for distraction do not display higher stress levels overall.

Our findings need to be interpreted in light of several limitations. First, we recruited a convenience sample, which is not representative of the general population. Second, effect sizes tended to be small, although these may nevertheless indicate clinically relevant findings due to the low cost and easy availability of music in daily life. Third, as this study was observational in nature, additional confounders cannot be ruled out. We considered a temporal precedence of up to several hours between reports of music listening and the measurement of outcome variables and included a comprehensive set of covariates. These are necessary, but not sufficient, requirements to determine causality.

Despite these limitations, the present findings improve our understanding of stress and mood regulation using music during COVID-19-related lockdowns. Our study revealed that psychological states and person- and music-related characteristics modulate the beneficial effects of music listening. In particular, individuals experiencing heightened momentary and/or chronic stress may benefit from engaging in music listening. These findings can be highly informative for the development of tailored ecological momentary interventions that deliver music to foster resilience in times of crisis.

Statements

Acknowledgement

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Statement of Ethics

All study procedures were conducted in accordance with the World Medical Association Declaration of Helsinki and its later amendments. All participants provided electronic consent at the beginning of the study and were informed that they could discontinue study participation at any time. The local Ethics Review Board of the University of Vienna approved the study (#00543).

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

All authors contributed to the conception and design of the study. AF, EP, AS, GP, and PF were involved in the acquisition of the data. AF performed the statistical analyses and drafted

the first version of the manuscript. All authors revised the manuscript, provided their approval for the final version and agreed to be accountable for all aspects of the work.

Data Availability Statement

The data and the corresponding R-code for the statistical analyses that support the findings of this study are openly available on the Open Science Framework at <https://osf.io/q3uz9/>.

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Online Supplementary Material for the preprint article:

Stress and mood regulation using music in times of COVID-19 lockdown: an ecological momentary assessment study

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1. Online Supplementary Material Part A: Study background and hypotheses

The present study is part of a larger research project entitled “The COVID-19 crisis, stress, mood, and behavior: an ecological momentary assessment study” with the overall aim to examine risk and resilience factors during and after the COVID-19 pandemic from a daily life perspective (see <https://osf.io/gsvdf> for the preregistered methods and hypotheses).

Strict lockdown measures were implemented in both countries in which we recruited participants, i.e., Austria and Italy, during the the data collection period (April 1st to May 8th 2020). See <https://osf.io/374qn/> for an overview on restrictions in place during data collection.

At the time of preregistration, we planned to conduct another wave of measurement under ‘normal’ conditions for comparison purposes (i.e., lockdown vs. ‘normal’). However, the pandemic was still ongoing at the date of writing and unpredictability with regard to the future development of the pandemic characterized the majority of the year of 2021 in Austria and Italy. Therefore, we decided to analyze the data from the first lockdown and publish the research results in order to make it available to the scientific community. Consequently, in the present study, we could investigate only part of the preregistered hypotheses. Hypothesis testing can be considered confirmatory in these cases; whilst our examination regarding the moderating role of chronic stress is considered exploratory in nature.

2. Online Supplementary Material Part B: Procedure and Methods

2.1 Participant attrition and data cleaning

A total of 2,014 links (for coupling the EMA app and start participation in the study) were sent to individuals that contacted the research team via email and showed initial interest in the study. Of those, 1,211 downloaded the app, provided informed consent to participate, and started at least one data entry. During data cleaning, 260 subjects needed to be excluded since they did not provide a sufficient amount of data (e.g., due to technical problems or loss of

interest), so that data from 951 individuals remained with at least 18 (out of 35) observations (including missings).

Of these 951 participants, 198 individuals were excluded ($n=2$ did not provide sociodemographic information, $n=19$ were under the age of 18 years, $n=57$ reported residing in countries other than Austria or Italy, $n=119$ did not provide data on chronic stress, and $n=1$ reported being of diverse gender and needed to be excluded from the present analyses as these include gender as covariate. Moreover, current guidelines emphasize the need to consider thresholds of compliance for multilevel analyses. A low compliance rate can be associated with a systematic bias in the data and estimates for lagged effects tend to be less reliable (Trull & Ebner-Priemer, 2020). Given the lack of a designated threshold in the literature, we decided for a 50% completion rate, which has been applied in other studies (see for example Doerr et al., 2015; Mewes et al., 2021). Forty-two individuals were excluded following this criterion. Consequently, 711 participants remained as the final sample in the present study.

2.2 Missing data and study compliance

In the final sample ($N=711$), a total of 24,885 observations were expected according to the EMA protocol (5 observations*7 days*711 subjects). Of these, 5,244 (21.1%) were missing (i.e., signal not responded to/bedtime data entry not initiated), resulting in an overall satisfactory compliance rate of 78.9%. Thus, a participant provided on average 28 data entries (range: 18 – 35 per participant). Furthermore, we discarded 70 (0.3%) data entries due to implausibility indicating potential incompliance with the study protocol (bedtime entry after 6:00 o'clock the next day, response 1 hour after the prompt signal, response duration ≥ 20 min), increasing the number of missing data to a total of 5,313 (21.4%). On 86 (0.3%) observations, data entries were incomplete. Response latency (i.e., amount of time elapsed from prompt signal to answering the prompt) averaged 2 min 56 sec (± 6 min 27 sec). Response duration (i.e., amount of time elapsed from starting to finishing the answer) averaged 2 min 40 sec (± 1 min 36 sec).

To test whether compliance was related to demographic aspects or other study variables, we conducted a multilevel logistic regression analysis in which *missing occurrence* (1=data entry missing, 0=data entry not missing) was modelled as outcome variable. Earlier *measurement time point* during the day ($OR = 0.95, p < .001$), and later *study day* during the EMA period ($OR = 1.13, p < .001$) were significantly associated with a higher probability of missing occurrence, indicating lower compliance earlier the day and as the study progressed. Moreover, younger individuals ($OR = 0.99, p < .001$) and individuals residing in Italy ($OR =$

1.23, $p=.002$) showed a higher probability of missing occurrence. In contrast, *day of week* (weekend vs. weekday), *gender*, *chronic stress*, and *depressive symptoms* were unrelated to missing occurrence ($ps \geq 0.10$). *Time of day*, *age*, and *country of residence* were included as covariates in all statistical analyses (see 2.5 for details). *Study day* was only significantly associated with *energetic arousal* (i.e., individuals seemed to report higher energetic arousal towards the end of the study period). Since inclusion of *study day* did not markedly alter the final result pattern (data not shown), we decided to refrain from including *study day* as a covariate in the analyses for reasons of parsimony.

2.3 Details on the EMA protocol

The EMA sampling design involved four signal-contingent data entries that were scheduled semi-randomly between 10:00 and 11:00, between 11:00 and 14:00, between 14:00 and 17:00, and between 17:00 and 20:00, respectively. The app signaled participants via an alarm to respond to the respective data entry. A temporal distance of at least 1h 29min was determined to separate two subsequent prompts. Furthermore, participants had the option to postpone signaled data entries for a maximum delay time of 30 minutes. An additional data entry needed to be self-initiated before going to bed.

Participants received a short manual via email at the beginning of the study, informing them about the sampling protocol. Participants were asked to not change their daily routines due to study participation. Furthermore, the manual included a definition of ‘deliberate music listening’ along with several examples (see 2.4 for details) to standardize reporting among participants. The definition could also be retrieved within the app during study participation.

2.4 Details on the assessment of music listening in daily life

The assessment of music-listening behavior during the EMA period was conducted in line with recommendations provided by Linnemann et al. (2017). At each data entry, participants were inquired to report whether they were deliberately listening to music at the moment of responding (‘yes’/‘no’) or whether they had been listening to music since the last data entry (since waking up for the first prompt of the day).

Deliberate or active music listening was defined as situations in which music listening was the main activity that participants were engaged in, or an accompanying activity with music being in the focus of attention. This definition excluded background music which was not listened to actively as well as music making (e.g., playing an instrument). Upon reports of current or previous music listening, additional questions were asked considering qualitative

aspects of music listening: perceived music characteristics (valence, arousal) and reasons for music listening. *Musical valence* and *arousal* were assessed on Visual analogue scales (VAS), ranging from sad (0) to happy (100) and from calming (0) to energizing (100), respectively. Concerning reasons for music listening, participants were requested to select their main reason for music listening from *relaxation*, *activation*, *distraction*, *reducing boredom*. Only one reason could be selected per response. In cases in which no reason applied, this could be indicated, too.

2.5 Details on the analytical approach

In order to examine time-delayed (rather than concurrent) effects of music listening on perceived stress and mood, we ensured that music listening always temporarily preceded the outcome assessments. Therefore, we lagged reports of current music listening and combined these with reports of music listening since the last data entry into a single binary variable (0= ‘no previous music listening’; 1= ‘previous music listening’). In addition, reports of momentary perceived stress/mood were also lagged to the subsequent measurement time point to be able to include the value of the outcome at the previous data entry as a covariate/moderator (‘previous stress/mood’; see below). As lagging of variables is typically related to loss of data, the total sum of $n=4.677$ (current and past) music listening reports was reduced to $n=4.063$ reports that were included in the statistical analyses.

Sixty-nine out of the 711 participants did not report any music listening episode. Data from these individuals is included in analyses investigating the effects of music listening per se on momentary stress/mood, but can not be included in analyses concerning qualitative aspects of music listening (music characteristics, reasons for music listening) as predictors, as information on these aspects were only provided in case of reported music listening.

In all multilevel models, we controlled for a set of covariates. Selection of covariates was based on theoretical and empirical considerations. On level 2 (person level), *gender* (female=0, male=1), *age*, and *depressive symptoms*, and *country of residence* (Austria=0, Italy=1) were included as covariates. On level 1 (observation level), we controlled for *time of day* (centered on 10:00 o’clock) in order to detrend diurnal fluctuations of the outcome variables. Furthermore, *weekday* (weekday=0, weekend/holiday=1) and *current activity* (work/study/other=0, leisure=1) were included as covariates.

Multilevel modeling was conducted in a three-step approach in line with state-of-the art recommendations (Aguinis et al., 2013; Bolger & Laurenceau, 2013; Finch et al., 2019; Hox et al., 2018). Although the main focus of the present analyses is on within-person effects, we

additionally included the person means of the focal predictors on level 2 in all models in order to examine within- and between-person effects of music listening (aspects) concurrently.

First, we tested the main effect of *previous music listening* on the outcome variable (perceived stress, mood valence, energetic arousal, calmness, respectively) while also including the covariates mentioned above. In addition, we included the lag-1 serial autocorrelation of the outcome as a covariate in this first modeling step in order to control for the level of the outcome at the previous measurement time point (Hamaker & Grasman, 2014; Kuppens et al., 2010). An exemplary equation is outlined below (exemplary equation 1.).

In the second step, we included a lower-level interaction term between *previous music listening* and the level of the outcome at the previous measurement time point. This allowed us to examine the regulatory properties of music listening, e.g., whether the effect of music listening on subsequent perceived stress varied as a function of the level of stress reported at the previous time point. An exemplary equation is outlined below (exemplary equation 2.).

In the final step, we investigated whether the effect of *previous music listening* on the respective outcome was moderated by *chronic stress levels* via inclusion of a cross-level interaction term. An exemplary equation is outlined below (exemplary equation 3.).

The same three-step approach was applied when examining music characteristics (with *musical valence* and *musical arousal* entered simultaneously as predictors) and reasons for music listening (with *relaxation*, *activation*, *distraction*, and *reducing boredom* entered simultaneously as predictors).

Continuous level-2 variables were grand-mean centered (by subtracting the overall sample mean from the individual's value), while binary level-2 variables (*gender*, *country of residence*) remained uncentered in order to facilitate interpretation of the results. Except for *time of day* and *weekday*, all level-1 variables were person-mean centered in order to disentangle within- from between-person effects (Enders & Tofighi, 2007).

All models included random intercepts while random slopes were added only if they improved model fit and did not result convergence issues (Matuschek et al., 2017). This was generally the case for *time of day* (i.e., the diurnal trend of the respective outcome variable varied between individuals). When examining cross-level interactions with *chronic stress*, we included a random slope for the focal predictor(s) as recommended by Aguinis et al. (2013). We used restricted maximum likelihood for model estimation. Significant interactions were probed via the Johnson-Neyman test, which provides regions of significance at all levels of the moderator (Bauer & Curran, 2005).

Exemplary equations with momentary perceived stress as outcome variable:

1. The main effect of music listening on perceived stress:

$$\begin{aligned} stress_{ti} = & \gamma_{00} + \gamma_{01}gender + \gamma_{02}ageGMC + \gamma_{03}pssGMC + \gamma_{04}phq9GMC + \\ & + \gamma_{05}country + \gamma_{06}MprevPM + \gamma_{10}Mprevpmc + \gamma_{20}stresspmc_{ti-1} + \\ & + \gamma_{30}time + \gamma_{40}leisurepmc + \gamma_{50}wewd + u_{0i} + u_{3i}time + r_{ti} \end{aligned}$$

2. The moderating role of previous stress level (lower level interaction):

$$\begin{aligned} stress_{ti} = & \gamma_{00} + \gamma_{01}gender + \gamma_{02}ageGMC + \gamma_{03}pssGMC + \gamma_{04}phq9GMC + \\ & + \gamma_{05}country + \gamma_{06}MprevPM + \gamma_{10}Mprevpmc + \gamma_{20}stresspmc_{ti-1} + \\ & + \gamma_{30}time + \gamma_{40}leisurepmc + \gamma_{50}wewd + \gamma_{60}Mprevpmc * stresspmc_{ti-1} + \\ & + u_{0i} + u_{3i}time + r_{ti} \end{aligned}$$

3. The moderating role of chronic stress (cross-level interaction):

$$\begin{aligned} stress_{ti} = & \gamma_{00} + \gamma_{01}gender + \gamma_{02}ageGMC + \gamma_{03}pssGMC + \gamma_{04}phq9GMC + \\ & + \gamma_{05}country + \gamma_{06}MprevPM + \gamma_{10}Mprevpmc + \gamma_{20}stresspmc_{ti-1} + \\ & + \gamma_{30}time + \gamma_{40}leisurepmc + \gamma_{50}wewd + \gamma_{60}Mprevpmc * stresspmc_{ti-1} + \\ & + \gamma_{13}Mprevpmc * pssGMC + u_{0i} + u_{1i}Mprevpmc + u_{3i}time + r_{ti} \end{aligned}$$

Variable key

Level-2 variables

- gender: female = 0, male = 1
- ageGMC: age, grand-mean centered
- pssGMC: chronic stress, grand-mean centered
- phq9GMC: depressive symptoms, grand-mean centered
- country (of residence): Austria = 0, Italy = 1
- MprevPM: person mean of the level-1 predictor ‘previous music listening’

Level-1 variables

- Mprevpmc: previous music listening, 0 = did not occur, 1 = occurred, person-mean centered
- stresspmc_{ti-1}: lag-1 serial autocorrelation (i.e. stress level reported at the previous time point), person-mean centered
- time: time indicator (hours passed since 10:00 o’clock)
- leisurepmc: work/study/other = 0, leisure = 1, person-mean centered
- wewd: weekday = 0, weekend/holiday = 1

3. Online Supplementary Material Part C: Results

3.1 Details on habitual music listening behavior

Habitual music listening behavior was assessed at the final online survey via a shortened version of the Music Preference Questionnaire (revised version; Nater et al., 2005) with a focus on main reasons and occasions for music listening, current active music making, and importance of music in life. Participants indicated the habitual frequency of listening to music for various reasons and occasions on Likert scales ranging from 1 ('never') to 5 ('very often') as well as importance of music in life on a Likert scale ranging from 1 ('not at all important') to 5 ('very important').

Participants rated music as rather important in their life (3.9 ± 1.1 ; range: 1 – 5). *Activation* (3.7 ± 1.3), *for the music* (3.5 ± 1.4), and *relaxation* (3.3 ± 1.2) were stated the most frequent reasons to engage in music listening, followed by *distraction* (3.1 ± 1.4), *to evoke feelings* (3.0 ± 1.4), *to intensify feelings* (3.0 ± 1.4), *to reduce boredom* (2.7 ± 1.4), *to work better* (2.5 ± 1.4), *to reduce loneliness* (2.7 ± 1.4), and *to reduce aggression* (1.8 ± 1.2). The main occasions for music listening were *as background activity while engaged in another task* (4.0 ± 1.2), *when being alone* (3.4 ± 1.2), and *when being with friends* (2.4 ± 1.2). Moreover, 27.7% ($n=197$) of the participants indicated being currently musically active (of those, 23.6% reported playing an instrument and 4.2% reported being member of a choir).

3.2 Details on music-listening behavior in everyday life

Overall, participants reported a total of 4,677 (24.0%) music listening episodes. On 1,713 (8.8%) observations, participants listened to music at the moment of the data assessment and on 2,964 (15.2%) observations, participants reported music listening since the last data entry. Music listening occurred most frequently in the afternoon/evening: 17.9% of all music episodes occurred in the morning before/at the first measurement time point (10:00-11:00), 19.0% occurred around noon (11:00-14:00), 21.1% occurred in the afternoon (14:00-17:00), 21.3% occurred in the evening (17:00-20:00), and 20.8% occurred before/when going to bed.

With regard to qualitative aspects of music listening, perceived *music valence* was rated rather happy (65.8 ± 23.1) and perceived *musical arousal* was rated rather energizing (61.3 ± 27.6). *Activation* was stated the most common main reason for music listening (31.6%), followed by *relaxation* (26.6%), *other reasons* (16.2%), *distraction* (14.9%), and *reducing boredom* (10.5%). Descriptively, while *activation* was indicated the most common reason for music listening at all signaled time points during the day, *relaxation* was indicated most frequently at bedtime.

3.3 Descriptive statistics for outcome variables

Table 1. Intraclass correlation coefficients (ICC), means, standard deviations (SD) and correlations regarding perceived stress and mood dimensions.

<i>Measure</i>	<i>ICC</i>	<i>M</i>	<i>SD_{within}</i>	<i>SD_{between}</i>	1	2	3	4
1. Perceived stress	0.46	29.91	18.89	17.51	1	−0.71***	−0.42***	−0.79***
2. Mood valence	0.45	63.47	15.67	14.14	−0.47***	1	0.66***	0.91***
3. Energetic arousal	0.19	50.89	20.77	9.92	0.01	0.32***	1	0.58***
4. Calmness	0.46	61.92	16.35	15.05	−0.57***	0.70***	0.10***	1

Notes. The correlation matrix shows Pearson correlation coefficients within participants (N=711) below the diagonal and between participants above the diagonal.

* $p < .05$, ** $p < .01$, *** $p < .001$.

3.4 Details on lower-level interactions for perceived stress and energetic arousal

The Johnson Neyman test for probing interactions summarizes the association between music listening and outcome across all levels of the moderator (Bauer & Curran, 2005). Johnson Neyman tests for the interactions *music listening*previous stress level* and *music listening*previous energetic arousal* showed that the direction and magnitude of the association between music listening and the outcome (momentary perceived stress/momentary energetic arousal) varied as a function of the moderator (previous stress level/energetic arousal).

In particular, based on person-mean centered values (i.e., the mean was subtracted from the value of the observation per person to disentangle between from within-person effects; Enders & Tofighi, 2007), the slope of music listening was positive when previous stress levels took any value between -82.94 (lowest person-mean centered value in the dataset) and -40.32, indicating that music listening predicted higher perceived stress ($p < .05$); whereas the slope of music listening was negative when previous stress levels took any value between 1.60 and 89.21 (highest person-mean centered value in the dataset), indicating music listening predicted lower perceived stress ($p < .05$). When previous stress levels took any value between -40.32 and 1.60, the association between music listening and subsequent stress levels was not significant ($p \geq .05$).

Regarding energetic arousal, based on person-mean centered values, the slope of music listening was positive when previous energetic arousal took any value between -60.48 (lowest

person-mean centered value in the dataset) and 17.77, indicating that music listening predicted higher energetic arousal ($p < .05$); whereas the slope of music listening was negative when previous energetic arousal took any value between 56.48 and 68.09 (highest person-mean centered value in the dataset), indicating that music listening predicted lower energetic arousal ($p < .05$). When previous energetic arousal levels took any value between 17.77 and 56.48, the association between music listening and subsequent energetic arousal was not significant ($p \geq .05$).

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