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# Natural Sounds vs. Favorite Music: Which Is the More Restorative Indoor Leisure Activity When Listened to Repeatedly?

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## ABSTRACT

This longitudinal online field study compared the restorative effects of two indoor leisure activities: repeated listening to natural sounds and favorite music, considering individuals' music-related mood-regulation strategies. Sixty-nine university students participated in a 14-day online field experiment with a crossover design. Subjects listened to natural sounds for 10min every day for 1 week and to favorite music in the other week. The effects of these sounds on the subjects' self-reported daily restorative experience and weekly perceived stress were measured by questionnaires. The analyses based on linear mixed-effects models showed that, when listened to repeatedly, natural sounds became more and more restorative than music for those with no music-related mood-regulation strategies, while these two sound types were equally restorative among subjects who had such strategies. This suggests the superiority of natural sounds over music. People who spend time in stressful indoor spaces can benefit from this easy-to-use, cost-free indoor leisure activity when unable to visit natural surroundings.

## ARTICLE HISTORY

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## KEYWORDS

Favorite music; indoor leisure activity; longitudinal experiment; natural sounds; restorative effect


## SUBJECT CLASSIFICATIONS

Health and well-being; nature-based recreation; psychological well-being; restorative environment; recreation activity

## Introduction

Two types of prevalent leisure activities/recreations are reportedly conducive to benefits for mental/physical health and well-being: contact with nature (Hakoköngäs & Puhakka, 2023; Harmon & Kyle, 2022; Hartig et al., 1991; Korpela & Kinnunen, 2010; Pasanen et al., 2018; Subiza-Pérez et al., 2022; Wöran & Arnberger, 2012) and listening to music (Harmon & Arpajian, 2020; Helsing et al., 2016; Huang et al., 2010; Siedliecki & Good, 2006). An example of the health benefits of such activities is restorative effect. This refers to renewing or reestablishing depleted adaptive resources or capacities (Hartig, 2004), and this effect has been contextualized with two main theories: attention restoration theory (ART) (Kaplan & Kaplan, 1989) and stress recovery theory (SRT) (Ulrich, 1983; Ulrich et al., 1991). ART suggests that the ability to concentrate (i.e.

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directed attention resources) may be restored by exposure to natural environments (Ohly et al., 2016). SRT postulates that a positive initial affective and physiological response, frequently deriving from unthreatening natural stimuli, should reduce stress-related feelings and taxing physiological mobilization (Ulrich, 1983; Ulrich et al., 1991).

A promising yet still relatively uncommon approach to studying the restorative effects of nature, in comparison to those of other leisure activities such as listening to music, would involve engaging in indoor recreations that offer indirect contact with nature. People can enjoy such effects of nature even when their contact with nature is not direct, e.g. by seeing a picture of natural landscape (Ulrich, 1981) or listening to natural sounds (Alvarsson et al., 2010; Annerstedt et al., 2013; Cerwén et al., 2016; Medvedev et al., 2015; Ratcliffe et al., 2013; Suko et al., 2019, 2022). Compared to direct contact with nature (e.g. nature walk), indirect contact with restorative nature, and also listening to music, may be more beneficial to two types of people: city dwellers without ready access to greenery and people confined to hospital, in prison, or during future pandemics like COVID-19. Given that more than half of the world's population lives in cities (United Nations, Department of Economics and Social Affairs, Population Division, 2019) and urban population growth may result in the loss of urban green spaces as nodes of citizens' contact with nature (Home et al., 2012), enhancing our understanding of the restorative effects of indirect contact with nature is imperative.

An example of restorative indirect contact with nature is listening to (pre-recorded) natural sounds indoors. Such activities reportedly facilitate physiological restoration (Alvarsson et al., 2010; Liu et al., 2019; Medvedev et al., 2015; Suko et al., 2022), increase the perceived restorativeness of the place where people listened to them (Suko et al., 2019), and promote psychological restoration (Goel & Etwaroo, 2006; Ma & Shu, 2018; Suko et al., 2022). Pleasant or preferred natural sounds are associated with better recovery from stress (Aletta et al., 2018; Ma & Shu, 2018), and birdsong and the sounds of water have been reported to be particularly restorative (Cerwén, 2016; Fang et al., 2021; Liu et al., 2019; Ratcliffe et al., 2013, 2020). However, guaranteeing the benefits of natural sounds necessitates gauging their effects with those of a more prevalent, allegedly restorative auditory stimulus: music.

Many scholars have studied music in relation to leisure and the multifaceted psychological benefits of this relationship. Lashua et al. (2014) contextualized music within leisure and tourism, stating that the invention of recording technology, radio broadcasting, and amplification techniques in the twentieth century ushered in the habit of music listening during journeys, e.g. traveling with iPods, and hearing *Muzak* in hotel lifts (note: *Muzak* refers to quiet, unobtrusive, and continuous background music played in public spaces for relaxation). Pate and Johnson (2013) described the meaning of listening to music from the phenomenological viewpoint, suggesting that music can assure a listener of not being alone in feeling a particular way, denoting a relationality between her/himself, a particular community of artists, and humanity in general. Kumm (2013) reported the potential of songwriting as a therapeutic and transformative leisure activity. Harmon and Scott (2017) emphasized the important role of music scene participation in extending aspects of fans' identity and affiliation. The psychological benefits of music have also been reported such that participating in group music-making activities provides older citizens with social, cognitive, emotional, and health benefits

(Hallam & Creech, 2016; Varvarigou et al., 2012). This stream of research paved the way theoretically for a relatively new research topic: the restorative effects (i.e. an example of the psychological benefits) of listening to music as an indoor leisure activity.

A recent meta-analysis suggests that listening to music is a useful resource for alleviating anxiety in a range of settings, in both clinical and nonclinical groups (Harney et al., 2023). Regarding existing studies on the restorative effects of music, researchers' opinions on the most restorative type of music seem to be converging on two: self-selected (or favorite) music or classical music. Some studies suggest that preferred, self-selected, or familiar music may be a better means of stress alleviation (Helsing et al., 2016; Jiang et al., 2016; Pereira et al., 2011). On the other hand, other studies report that classical music, which experimenters chose for an experiment, was more relaxing than jazz or pop (Chafin et al., 2004), than rock music (Burns et al., 2002), than self-preferred music (Pelletier, 2004). There is also a study reporting a non-significant difference between the effects of researcher-selected music and those of subject-preferred music (Siedliecki & Good, 2006). Overall, either classical music or self-selected music is claimed to be the most restorative type of music.

Empirical research comparing the restorative effects of natural sounds with those of music has recently been reported. For example, Largo-Wight and colleagues conducted a one-off experiment in an office or waiting room-like environment comparing the effects of natural sounds, classical music, and silence, and found that only natural sounds had a significant effect on alleviating muscle tension, pulse rate, and self-reported stress (Largo-Wight et al., 2016). Their study is pioneering, given that most studies so far have investigated separately the effects of natural sounds and music in different contexts.

Nevertheless, there are still two research gaps to be bridged. Firstly, research comparing the effects of natural sounds and music when listened to repeatedly in a real-life setting is lacking. Secondly, an important individual factor that can affect people's restorative experience through listening to natural sounds or music has not been considered yet: the extent to which each person uses music as a means of mood regulation. Saarikallio classified people's mood-regulation strategies while listening to music into seven categories: entertainment (E), revival (R), strong sensation (SS), diversion (Div), discharge (Dis), mental work (MW), and solace (S) (Saarikallio, 2008, 2012). The level of such strategies may differ from person to person, and as far as we know, no study has considered it in assessing the effects of natural sounds and music.

Particularly, the level of people's mood-regulation strategies should be taken into account because such strategies may affect the extent to which listening to natural sounds or music changes people's moods or restorative experiences. The research so far has considered the ability for emotion regulation through music (hereinafter we call it "the MMR ability," where MMR refers to music for mood regulation) to be an independent variable or a covariate in predicting outcome variables, such as the skill of positive solitude (Bachman et al., 2022). Although there has been hardly any research predicting the restorative effects of natural sounds (vs. music) as a function of the MMR ability, existing studies have reported that the MMR ability was positively correlated with other independent variables, for example, playing a musical instrument and daily exposure to music (Bachman et al., 2022), and *emotional agreement with music* and the weekly amount of listening to music (Saarikallio et al., 2013). This suggests that, before listening to music in an experiment, people with a greater MMR

ability (as a trait score) may already have cultivated a stronger connection with music than those with a less MMR ability, which may result in the former being more able than the latter to derive benefits from listening to music. This leads to the assumption that categorizing participants by the level of their MMR ability would be reasonable in comparing the restorative effects of natural sounds with those of music.

To bridge these research gaps, this study aimed to answer the following research questions: (RQ1) In general, is listening to either natural sounds or music restorative? (RQ2) Are natural sounds more restorative than favorite music? (RQ3) Does the longitudinal restorative effect differ between natural sounds and music? (RQ4) Do the answers to RQs1–3 differ depending on people's levels of music-related mood-regulation strategies? Here, we focused on "favorite music (i.e. self-selected music)" as opposed to "classical music," assuming that not everyone necessarily likes listening to classical music in their daily routine. Our research hypotheses were as follows:

- RH1 (for RQ1): At least natural sounds are restorative (vs. baseline).
- RH2 (for RQ2): If both natural sounds and music are restorative (vs. baseline), the restorative effect of natural sounds is greater than that of music.
- RH3 (for RQ3): When listened to repeatedly, natural sounds provide a greater daily increase in the restorative experience than music.
- RH4 (for RQ4): Natural sounds are restorative regardless of people's levels of music-related mood-regulation strategies, while the restorative effect of music is constrained by people's levels of music-related mood-regulation strategies (i.e. only people with higher levels can be restored through listening to music).

## Method

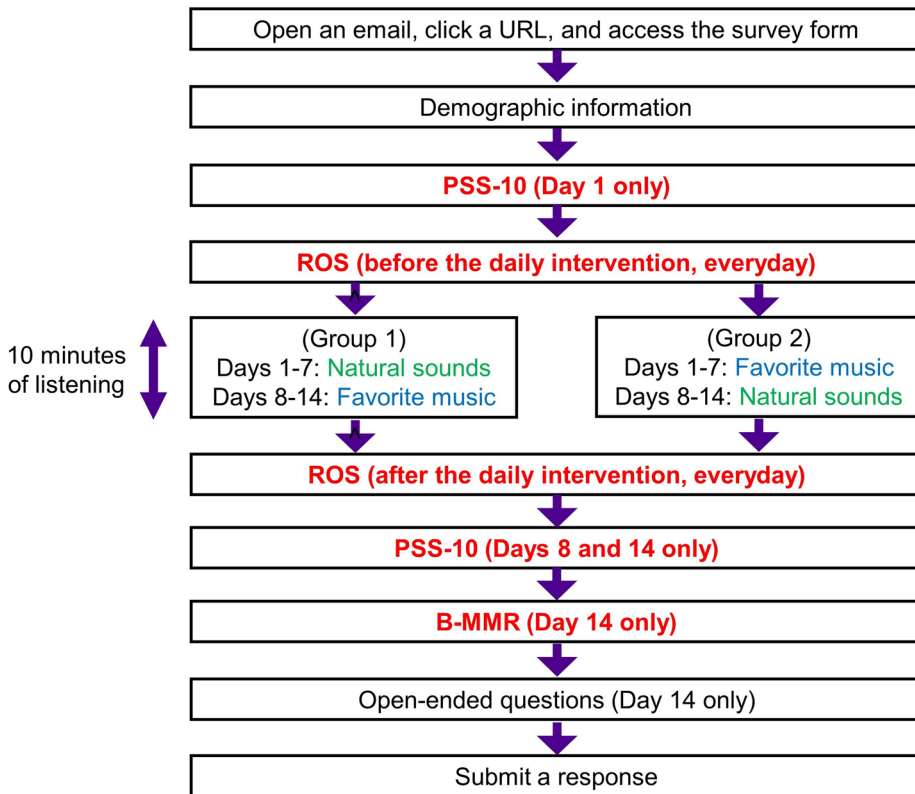
### *Experimental design*

We chose a crossover design, where half of the subjects listened to natural sounds (i.e. experimental condition) in the first week, and then favorite music (i.e. control condition) in the second week, while the other half were subjected to the same conditions but in reverse order. Hereinafter, we call the former group "Group 1" and the latter "Group 2." Each subject was randomly assigned to one of these groups, and repeated the process illustrated in [Figure 1](#) for 14 consecutive days.

### *Data collection*

Data collection was conducted at the University of Tokyo (UTokyo) in Japan and Tampere University (TAU) in Finland during the spring semester 2021. This study was reviewed and approved by the Ethics Review Committee of UTokyo (the approval number is 21–44). This study was not reviewed by the committee of TAU because, according to TAU's ethics review guidelines, this study—using informed consent—required no review by this university. However, we followed their guidelines in conducting this research.

Participation in this online experiment at home, which was a premise of our study, was ensured as much as possible in three ways. Firstly, before the experiment started,



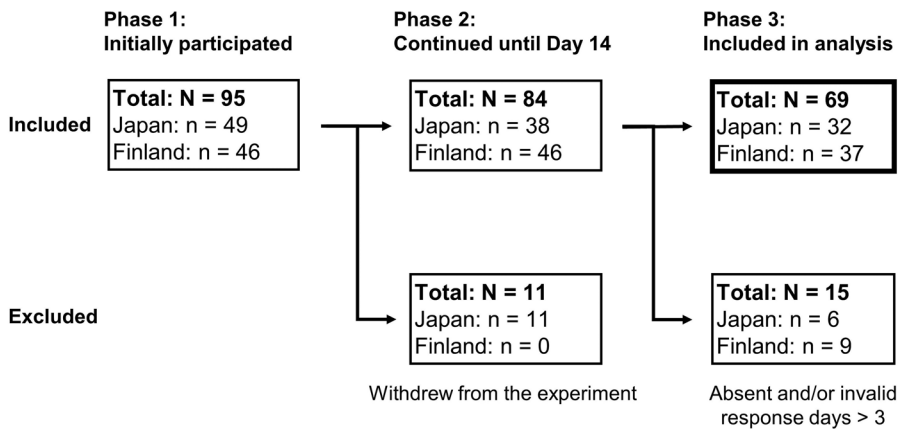
**Figure 1.** Experimental protocol.

the subjects were informed three times (in the recruitment message, in the information sheet, and on the informed consent form) that the purpose of the experiment was to investigate the effects of listening to natural sounds or music *at home*. Secondly, the COVID-19 pandemic during the above-mentioned experimental period in both countries caused people to stay home, avoiding unnecessary outings. Thirdly, the two universities in principle substituted distance learning for contact teaching during this period, requiring the students to be at home to attend classes on weekdays. We assume these three factors ensured that listening to music did indeed take place at home.

### **Subjects, sample size and exclusion criteria**

Our analyses included 69 university students from the two countries (mean age = 26.8 years, female students accounted for 74%, 37 out of the 69 students were from Finland), who were screened through the data exclusion process described in Figure 2. Hereinafter we give them a Subject ID 1–69.

The attributes of the Japanese subjects differed from those of the Finnish subjects in two ways: the means whereby they were recruited and the types of compensation for participation. The Japanese students were recruited through a mailing list for students at the Graduate School of Frontier Sciences at UTokyo and our invitation letter stated that participants completing the whole process of the experiment would receive



**Figure 2.** Exclusion criteria.

*Note.* Regarding the 15 subjects excluded in Phase 3, being invalid means at least one of the following conditions being met: (1) the duration of a subject's response time for the survey, which had been automatically measured by the online survey form, was less than 10 minutes on Days 1–13 or less than 15 minutes on Day 14 (note: the experiment on the final day took longer than on the other days because of the B-MMR and other open-ended questions.); (2) a subject listened to natural sounds as her/his "favorite music" in the week when she/he was supposed to listen to music.

5,000 JPY (corresponding to 38 EUR or 48 USD, according to the exchange rate at the time) in vouchers for purchasing books, which was the remuneration equivalent to five hours of research/teaching assistant work. In Finland, we contacted students taking an introductory psychology course at TAU, promising to give five hours of course credits to those who completed the entire process of the experiment.

### **Intervention type**

Natural sounds were played to subjects in Group 1 in the first week and to those in Group 2 in the second week. Conversely, favorite music was played to subjects in Group 1 in the second week and to those in Group 2 in the first week. The subjects were asked to use their own headphones while listening and to measure 10 min by themselves when starting listening (i.e. when opening the listening section of the online survey form).

### **Natural sounds**

The subjects were provided with two 10-minute sound clips embedded in the listening-to-natural-sound section of the online survey form: birdsong in Japan or birdsong in Finland. Both were recorded in a forest and contained a mixture of several bird species' chirping sounds. The former clip was extracted from the Cyberforest database (Saito et al., 2015), while the latter was recorded by the first author of this article. The subjects were allowed to change sound clips and adjust the audio volume at any time during the 10-minute intervention period.

### **Favorite music**

The subjects used their own devices (e.g. PC or smartphone) and their preferred platforms (e.g. Spotify, YouTube, and/or CDs) to listen to music. They were allowed

to listen to any genre of music, and they could also change songs/pieces and adjust the audio volume at any time during the 10-minute period.

## **Measures**

We used three established questionnaires: the Restoration Outcome Scale (ROS) (Korpela et al., 2008, 2010), the 10-item version of the Perceived Stress Scale (PSS-10) (Cohen, 1988; Cohen et al., 1983, 1994), and the Brief Music in Mood Regulation Scale (B-MMR) (Saarikallio, 2008, 2012). The first two are state measures, while the last one is a trait measure. The ROS was filled out twice a day; before and after a 10-minute intervention. The PSS-10 was measured on Days 1, 8, and 14, and each of these was intended to assess subjects' perceived stress during the week before the experiment started, during the first week, and during the second week respectively. The B-MMR was answered only once, at the end of the experiment on Day 14.

### ***Restoration outcome scale (ROS)***

The Restoration Outcome Scale (ROS) provides a measure of general restorative experiences based on six items rated on a seven-point Likert scale (1 = not at all, 7 = completely) (Korpela et al., 2008, 2010). This scale was developed in accordance with the previous measures and findings of restorative outcomes (Hartig et al., 1998; Kaplan et al., 1993; Staats et al., 2003). In this study, we used the state measure version (e.g. "1. I feel calm"). Participants in Finland filled out the English version of the ROS, while those in Japan answered the Japanese version (Fujisawa & Takayama, 2014).

### ***10-item version of perceived stress scale (PSS-10)***

The Perceived Stress Scale (PSS) is the most widely used psychological instrument for measuring the perception of stress, i.e. the degree to which situations in one's life are appraised as stressful (Cohen, 1988; Cohen et al., 1983, 1994). Our present study employed the 10-item version of PSS (PSS-10) (Cohen, 1988; Cohen et al., 1994). Each item of the PSS-10 was rated on a five-point Likert scale (0 = Never, 1 = Almost Never, 2 = Sometimes, 3 = Fairly Often, 4 = Very Often). The original PSS-10 was based on the one-month time frame, but we employed the 1-week time frame. Items 1, 2, 3, 6, 9, and 10 are negatively stated (e.g. 1. In the last week, how often have you been upset because of something that happened unexpectedly?), while items 4, 5, 7, and 8 are positively stated (e.g. 4. In the last week, how often have you felt confident about your ability to handle your personal problems?). Therefore, the scores for the latter four items were reversed in the analysis. Participants in Finland filled out the English version of the PSS-10, while those in Japan answered the Japanese version (Sumi, 2006).

### ***Brief music in mood regulation scale (B-MMR)***

The B-MMR questionnaire is a trait measure intended to assess people's use of seven different music-related mood-regulation strategies: entertainment (E), revival (R), strong sensation (SS), diversion (Div), discharge (Dis), mental work (MW), and solace (S) (Saarikallio, 2012). B-MMR comprises 21 items rated on a 5-point Likert scale ranging

from strongly disagree to strongly agree, and each set of three items (i.e. Q1–3, Q4–6, and so on) corresponds to each of the above-mentioned seven categories. Participants in Finland filled out the English version of the B-MMR, while those in Japan answered the Japanese version (Shoda et al., 2019).

We re-coded the B-MMR summary score, i.e. the average score across the 21 items, into a two-level categorical variable (1=low level of using music for mood regulation, 2=high level of using music for mood regulation); separate statistical analyses were carried out for these two categories. Here, we re-coded it to two categories as opposed to three or more categories to ensure that each separate statistical test would include a sufficient sample size. As we found that participants' B-MMR summary scores in this study were normally distributed, we used the mean B-MMR summary score (as opposed to the median score) across all 69 participants, which was 3.38, as the threshold to recode each subject's score into "low" or "high." Hereinafter, we call this re-coded variable "the B-MMR level".

### **Statistical analyses**

We made fitting models using the linear mixed-effects models (LMMs) (Fitzmaurice et al., 2011). We first split the sample ( $N=69$ ) into two sub-samples, based on the B-MMR level: low ( $n=30$ ) or high ( $n=39$ ). Then we built an LMM separately for each questionnaire (i.e. ROS or PSS-10) in each sub-sample. In the LMMs, model effects are divided into fixed and random effects, assuming that random effects and random errors are independent and follow the normal distribution. The marginal significance of the fixed effect coefficients of interest and the 95% confidence intervals were based on the restricted maximum likelihood estimator and large sample theory. We used the "lme4" package (Bates et al., 2015) in R Statistical Software version 4.3.1 (R Core Team, 2022).

In the LMM predicting ROS in each sub-sample, the fixed effects were the day (1–7 in each week; Day 1, i.e. the intercept, was the reference level), sound type (natural sounds or music; "music" was the reference level), and timing (before or after the daily intervention; "before" was the reference level). The random effect was the subject ID (1–69). The ROS summary score was considered a continuous variable because it is based on symmetric seven-point Likert scale variables. The day was considered a continuous variable ranging from 1 to 7. The sound type and timing were categorical variables.

In the LMM predicting the PSS-10 summary score in each sub-sample, the fixed effect was the weekly sound type (1=baseline, 2=after the natural-sounds week, 3=after the music week; "baseline" was the reference level). The random effect was the subject ID (1–69). The PSS-10 summary score was considered a continuous variable because it is based on symmetric five-point Likert scale variables. The weekly sound type was a categorical variable.

Prior to the main analyses, we conducted preliminary tests and confirmed that there was no carryover effect (or order effect) on the ROS and PSS-10 scores between Groups 1 (natural sounds first) and 2 (music first). Therefore, we conducted our main analyses merging the data of these groups. The preliminary tests are detailed in the [Supplementary Material](#).

**Table 1.** Linear hypothesis tests for RHs 1–3 for ROS score.

F-test no.	RH	F-test	B-MMR level	Sound type
1.1	1	Overall restorative effect (vs. baseline) of each sound type	Low	Natural sounds
1.2				Music
1.3			High	Natural sounds
1.4				Music
2.1	2	Natural sounds vs. music (overall restorative effect)	Low	n/a
2.2			High	n/a
3.1	3	Natural sounds vs. music (daily increase in restorative experience)	Low	n/a
3.2			High	n/a

Note. Each of RHs 1–3 was tested separately in each of the B-MMR level samples (low and high).  
RH: research hypothesis.

### Hypothesis tests

Regarding the ROS score, Research Hypotheses (RH) 1 (at least natural sounds are restorative compared to the baseline), 2 (the restorative effect of natural sounds is greater than that of music), and 3 (natural sounds provide a greater daily increase in the restorative experience than music) were examined through several linear hypothesis tests using F-statistics. Here, a linear hypothesis test is to assess the significance of a particular linear combination of the LMM parameter estimates of the fixed effects. Table 1 shows the eight linear hypothesis tests (i.e. F-tests) conducted. The “car” package (Fox & Weisberg, 2018) was used for the linear hypothesis tests. The details of the formulae and hypotheses for the respective tests are provided in the [Supplementary Material](#).

For the PSS-10 score, RH1 (at least natural sounds are restorative compared to baseline) was tested using the LMM parameter estimates because the LMMs for the PSS-10 had only one fixed effect (i.e. the weekly sound type) without any interaction terms, thereby yielding results directly corresponding to RH1. The PSS-10 score was assessed in two steps. Step 1: In the LMMs, if the fixed effects of natural sounds (vs. baseline) and that of music (vs. baseline) are significant, these sound types are restorative, which provides an answer to RH1. Step 2: If both natural sounds and music are found to be restorative (vs. baseline) in Step 1, a post-hoc paired t-test will be conducted to compare the restorative effect of natural sounds with that of music, thereby testing RH2 (the restorative effect of natural sounds is greater than that of music). It should be noted that RH3 (natural sounds achieve a greater daily increase in the restorative experience than music) concerns the ROS only, and is therefore not relevant to the PSS-10.

For both ROS and PSS-10 scores, RH4 (natural sounds are restorative for all the subjects, but music is only restorative for the high B-MMR sample) was tested by comparing the results of the former RHs (i.e. RHs 1–3 for ROS, RHs 1–2 for PSS-10) between the low and high B-MMR samples.

### Effect size

The effect size in this study was the sum of the LMM parameter estimates for the fixed effects involved in specific linear combinations; we did not use eta squared. This

**Table 2.** Parameter estimates for the LMM predicting the ROS (low B-MMR sample).

Effect	Term	Estimate	SE	Statistic	95% CI (low)	95% CI (high)
Fixed	(Intercept)	4.15	0.17	24.46	3.82	4.48
	Day	0.01	0.03	0.41	-0.04	0.06
	<b>Natural sounds</b>	<b>-0.50</b>	<b>0.16</b>	<b>-3.10</b>	<b>-0.82</b>	<b>-0.18</b>
	<b>After</b>	<b>0.40</b>	<b>0.16</b>	<b>2.47</b>	<b>0.08</b>	<b>0.72</b>
	<b>Day*natural sounds</b>	<b>0.11</b>	<b>0.04</b>	<b>2.95</b>	<b>0.04</b>	<b>0.18</b>
	Day*after	-0.00	0.04	-0.06	-0.07	0.07
	Natural sounds*after	0.22	0.23	0.94	-0.24	0.68
	Day*natural sounds*after	-0.05	0.05	-0.97	-0.15	0.05
Random	Random intercept (subject ID)	0.69				
	Correlation (subject ID, day)	-0.67				
	Random slope (subject ID, day)	0.05				
	Residual variability (observation)	0.73				

Note. Bold face indicates significance (95% CIs do not cross zero). After=after the daily intervention.

**Table 3.** Parameter estimates for the LMM predicting the ROS (high B-MMR sample).

Effect	Term	Estimate	SE	Statistic	95% CI (low)	95% CI (high)
Fixed	(Intercept)	4.05	0.13	30.62	3.79	4.31
	<b>Day</b>	<b>0.08</b>	<b>0.02</b>	<b>3.26</b>	<b>0.03</b>	<b>0.12</b>
	Natural sounds	0.03	0.13	0.25	-0.22	0.29
	<b>After</b>	<b>0.70</b>	<b>0.13</b>	<b>5.38</b>	<b>0.45</b>	<b>0.96</b>
	Day*natural sounds	-0.04	0.03	-1.29	-0.09	0.02
	Day*after	-0.04	0.03	-1.21	-0.09	0.02
	Natural sounds*after	0.04	0.19	0.22	-0.32	0.41
	Day*natural sounds*after	0.01	0.04	0.32	-0.07	0.10
Random	Random intercept (subject ID)	0.59				
	Correlation (subject ID, day)	-0.39				
	Random slope (subject ID, day)	0.07				
	Residual variability (observation)	0.68				

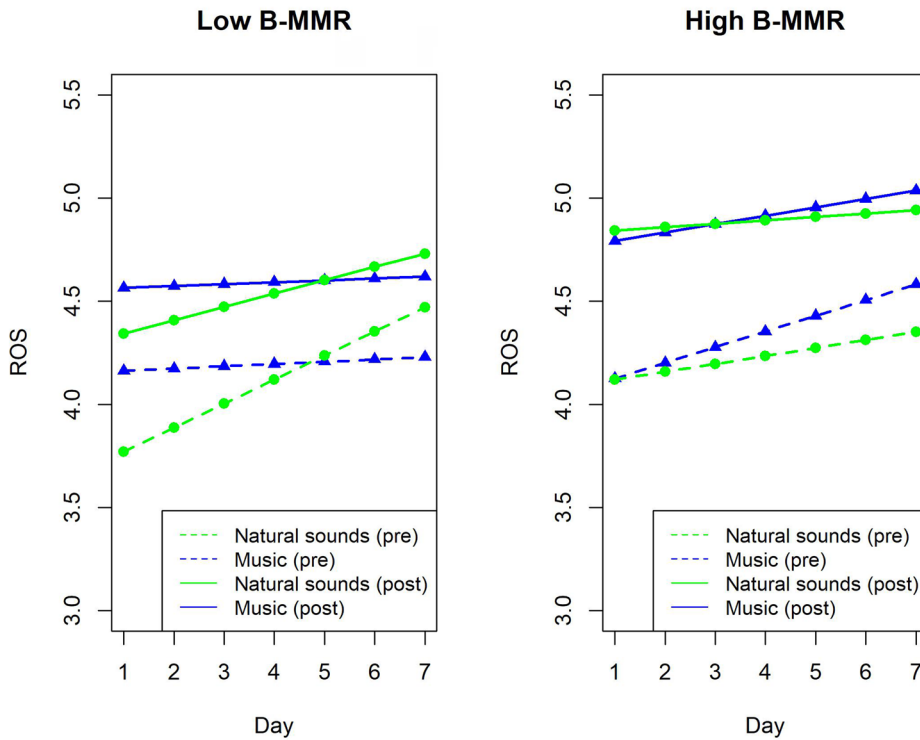
Note. Bold face indicates significance (95% CIs do not cross zero). After=after the daily intervention.

enables the effect sizes of all the linear hypothesis tests (i.e. F-tests) in this study to be compared against each other. The details of the formulae for each linear combination are shown in the [Supplementary Material](#).

## Results

### *Restorative outcome (ROS)*

The parameter estimates for the LMM predicting the ROS in the low and high B-MMR samples are shown in [Tables 2](#) and [3](#), respectively. Our RHs were examined by the linear hypothesis tests as opposed to the statistical significance of each fixed effect in these tables because the fixed effect terms of the rows in these tables do not coincide with our research interest. Our interest lies in testing the specific linear combinations



**Figure 3.** ROS score predicted by the LMMs.

of these terms, which correspond to the F-tests described in the Methods section (the detailed formulae are shown in the [Supplementary Material](#)). The ROS score predicted by these LMMs is illustrated in [Figure 3](#).

#### **Low B-MMR level**

F-test 1.1 showed that, in general, natural sounds significantly increased the ROS score,  $F(1, 611) = 38.50$ ,  $p < .001$ , the sum of the parameter estimates (i.e. the effect size) = 0.82. F-test 1.2 showed that music also significantly increased the ROS score,  $F(1, 609) = 10.82$ ,  $p = .001$ , the sum of the parameter estimates (i.e. the effect size) = 0.43. These results indicate that both natural sounds and music were restorative in general, supporting RH1. In addition, F-test 2.1 showed that the restorative effect of natural sounds was significantly greater than that of music,  $F(1, 732) = 4.54$ ,  $p = .033$ , the sum of the parameter estimates = 0.39, supporting RH2. Furthermore, F-test 3.1 showed that the daily increase in the ROS in the natural-sounds week was significantly greater than that in the music week,  $F(1, 735) = 9.62$ ,  $p = .002$ , the sum of the parameter estimates = 0.081, thereby supporting RH3.

#### **High B-MMR level**

F-test 1.3 showed that, in general, natural sounds significantly increased the ROS score,  $F(1, 658) = 53.26$ ,  $p < .001$ , the sum of the parameter estimates = 0.79. F-test 1.4 showed that music also significantly increased the ROS score,  $F(1, 654) = 58.10$ ,  $p < .001$ , the sum of the parameter estimates = 0.83. These results indicate that both natural sounds and music

were in general restorative, thereby supporting RH1. F-test 2.2 showed that the restorative effect of natural sounds was found not to be significantly different from that of music,  $F(1, 970) = 0.04$ ,  $p = .83$ , the sum of the parameter estimates =  $-0.030$ , hence RH2 was rejected. Likewise, F-test 3.2 showed that the daily increase in the ROS in the natural-sounds week was found not to be significantly different from that in the music week,  $F(1, 973) = 2.17$ ,  $p = .14$ , the sum of the parameter estimates =  $-0.031$ , thus RH3 was rejected.

### *Comparison of the results in the low and high B-MMR samples*

Lastly, RQ4 (Do the answers to RQs1–3 differ depending on people’s levels of music-related mood-regulation strategies?) was answered by summarizing the results of RHs 1–3 in both B-MMR samples. In the low B-MMR sample, both natural sounds and music were restorative in general (RH1 supported), with the former having a greater restorative effect (RH2 supported), and natural sounds provided a greater daily increase in the restorative experience than music when listened to repeatedly (RH3 supported). In the high B-MMR sample, both natural sounds and music were restorative in general (RH1 supported), but there was no significant difference between natural sounds and music (RH2 rejected). Nor was any significant difference found between natural sounds and music in terms of the daily change in the restorative effect in the high B-MMR sample (RH3 rejected). These results support RH4.

### *Weekly perceived stress (PSS-10)*

The parameter estimates for the LMMs predicting the PSS-10 score in the low and high B-MMR samples are shown in Tables 4 and 5, respectively. Figure 4 illustrates the observed PSS-10 score. A decrease in the PSS-10 score suggests restorative effect. Firstly, RH1 (at least natural sounds are restorative, compared to the baseline) was tested by the LMM parameter estimates. In the low B-MMR sub-sample ( $n = 30$ ), only

**Table 4.** Parameter estimates for the LMM predicting the PSS-10 (low B-MMR sample).

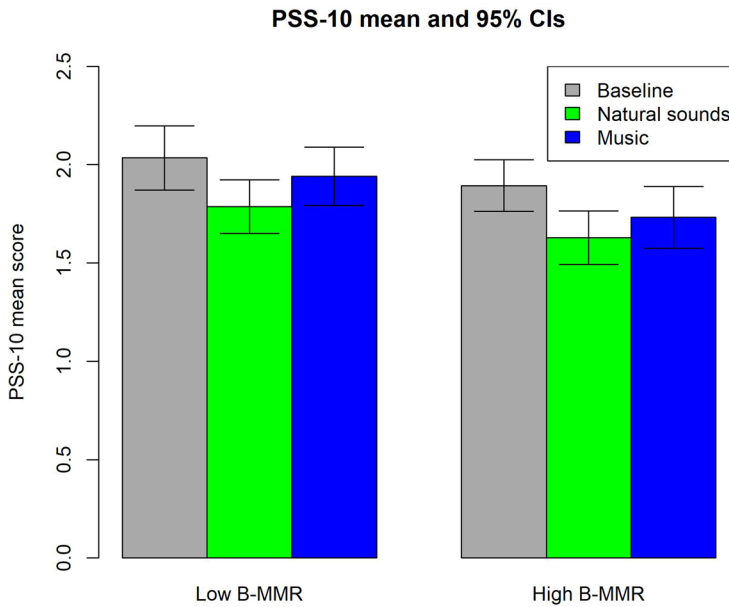
Effect	Term	Estimate	SE	Statistic	95% CI (low)	95% CI (high)
Fixed	(Intercept)	2.03	0.10	21.31	1.85	2.22
	<b>Natural sounds</b>	<b>-0.26</b>	<b>0.06</b>	<b>-4.00</b>	<b>-0.38</b>	<b>-0.13</b>
	Music	-0.09	0.06	-1.47	-0.22	0.03
Random	Random intercept (subject ID)	0.46				
	Residual variability (observation)	0.35				

Note. Bold face indicates significance (95% CIs do not cross zero).

**Table 5.** Parameter estimates for the LMM predicting the PSS-10 (high B-MMR sample).

Effect	Term	Estimate	SE	Statistic	95% CI (low)	95% CI (high)
Fixed	(Intercept)	1.89	0.09	20.15	1.71	2.08
	<b>Natural sounds</b>	<b>-0.26</b>	<b>0.05</b>	<b>-4.82</b>	<b>-0.37</b>	<b>-0.16</b>
	<b>Music</b>	<b>-0.16</b>	<b>0.05</b>	<b>-2.95</b>	<b>-0.27</b>	<b>-0.05</b>
Random	Random intercept (subject ID)	0.53				
	Residual variability (observation)	0.34				

Note. Bold face indicates significance (95% CIs do not cross zero).



**Figure 4.** Observed PSS-10 score and 95% CIs.

natural sounds significantly decreased the PSS-10 score compared to the baseline by 0.26 (i.e. increased by  $-0.26$ ), 95% CI  $[-0.38, -0.13]$ . By contrast, in the high B-MMR sub-sample ( $n=39$ ), both natural sounds and music significantly decreased the PSS-10 score compared to the baseline: natural sounds by 0.26, 95% CI  $[-0.37, -0.16]$ ; music by 0.16, 95% CI  $[-0.27, -0.05]$ . Therefore, RH1 was supported in both low and high B-MMR samples. Then we further tested RH2 (the restorative effect of natural sounds is greater than that of music) for the high B-MMR sample only; in the low B-MMR sample, the results of RH1 preclude testing RH2.

RH2 was tested by a post-hoc, paired t-test in the high B-MMR sub-sample. The test compared the PSS-10 score for the natural-sounds week to the score for the music week. The paired t-test was based on pairwise deletions. The test showed that there was no significant difference in the PSS-10 score between the natural-sounds week and the music week,  $t(38) = 1.28$ ,  $p = .21$ , thereby rejecting RH2. Here, the Bonferroni correction was not applied because we performed only one t-test for the “natural sounds vs. music” comparison; the LMM parameter estimates had already shown significant differences between baseline and the natural-sounds week and between baseline and the music week. To summarize, natural sounds were restorative, i.e. lowered perceived stress in both B-MMR samples, while music was only restorative among the high B-MMR sub-sample, thereby supporting RH4.

## Discussion

Regarding the self-reported restorative experience (ROS), our RH1 was supported in both low and high B-MMR samples such that, compared to the baseline (i.e. the first time point), both natural sounds and music were restorative. The effect sizes (i.e. sums

of specific linear combinations of parameter estimates) were almost the same among the natural sounds in the low B-MMR sample (0.82), the natural sounds in the high B-MMR sample (0.79), and music in the high B-MMR sample (0.83), while only the effect size for music in the low B-MMR sample (0.43) was smaller than them. This suggests that the restorative effect of music was suppressed in the low B-MMR sample. This apparent suppression was found to be significant according to F-test 2.1; the superiority of the restorative effect of natural sounds over that of music, corresponding to an increase in the ROS score of  $0.82 - 0.43 = 0.39$ , was found significant. In addition, F-test 3.1 showed that, in the low B-MMR sample, the daily restorative experience through listening to natural sounds (vs. music) increased by 0.081 every day, suggesting that seven days of listening to natural sounds (vs. music) would further increase the ROS score by  $0.081 \times (7 - 1) = 0.49$ . In this context, the daily increase corresponds to the average steepness of the two slopes (i.e., pre- and post-intervention scores) for each sound type within each B-MMR sub-sample shown in [Figure 3](#). This 0.49 increase can be interpreted as a weekly accumulated surplus of the effect of natural sounds over that of music, corresponding to 60% of the restorative effect of listening to natural sounds on a one-off occasion in the low B-MMR sample (i.e. 0.82, F-test 1.1).

[Figure 3](#) also shows that, for those subjects who did not use music for mood regulation (i.e. the low B-MMR sample), the distance between the pre-listening ROS score for natural sounds (broken green line) and the post-listening score for natural sounds (solid green line) diminished over time, while music did not provide such an effect. The steeper slope of the pre-listening score in the natural-sounds week can be attributed to the positive expectations/effects of listening to natural sounds on earlier days persisting on later days, even before the scheduled daily listening. The gentler slope of the post-listening score may be due to the experimental “diminishing returns” effect; the well-being-related benefit people derive from any activity or stimulus decreases after achieving a satisfactory level (Abbas et al., 2024; Luo et al., 2022). Conversely, the subjects who used music for mood regulation (i.e. the high B-MMR sample) did not show any statistically significant differences between the effect of natural sounds and that of music, although both significantly increased the restorative experience (ROS) in general. This may be due to the experimental ceiling effect; the people in the high B-MMR sample may have already been able to maximally enjoy the restorative effects of both natural sounds and music from the beginning of the seven-day experiment. Thus, there may have been no room for further increase even though these subjects’ scores did not reach the high end of the Likert scale (e.g. 6 or 7). Taken together, these findings suggest that natural sounds are indeed restorative for both types of people, i.e. those who do not use music for mood regulation (low B-MMR) and those who use it (high B-MMR), and the effect of natural sounds on the former group may further increase over time, while music is only restorative for the latter.

The effect size (i.e. the sum of the parameter estimates for each linear combination, which is comparable to the change scores in other studies) for the ROS score in this study can be gauged against those in the literature. Takayama et al. (2014) reported that viewing a forest landscape increased Japanese male university students’ ROS score by 0.60–0.70. Tyrväinen et al. (2014) revealed that a 15-min viewing of a forest landscape increased participants’ (mostly middle-aged women in Finland) ROS score by 0.40, and a subsequent 15-min walk in the forest further increased the ROS score by

0.16; therefore, the total increase after the viewing and walking was 0.56. Hyvönen et al. (2023) reported that a 12-week nature-based treatment increased the ROS score of participants diagnosed with depression by 0.71 (pre: 3.30, post: 4.01), and that the score further increased by 0.12 after a three-month follow-up period. Ojala et al. (2019) showed that a 15-min viewing of a forest landscape increased middle-aged women's ROS score by 0.43, and a subsequent 30-min guided walk in the forest further increased the ROS score by 0.10; therefore, the total increase was 0.53. Suko et al. (2022) reported that surgeons' ROS score increased by 0.97 through listening to natural sounds for 10 min after performing a surgical operation (note that a  $6.96 - 1.17 = 5.79$  increase in the ROS sum score reported by Suko et al., 2022, was divided by 6). Although the samples in these studies were not similar to our present sample, these findings suggest that the restorative effects of listening to natural sounds or music in our study, which correspond to approximately 0.80 of the increase in the ROS score, are as much as the restorative effect of viewing a natural landscape combined with a nature walk.

The changes in the weekly perceived stress (PSS-10) are in line with the changes in the restorative experience (ROS) insofar as natural sounds significantly reduced the PSS-10 score in both low and high B-MMR samples (note that a decrease in the PSS-10 suggests greater restoration) but music significantly reduced the PSS-10 score only in the high B-MMR sample. However, unlike the case of the ROS, the PSS-10 effect size (i.e. the LMM parameter estimate for the fixed effect) for natural sounds (-0.26) in the high B-MMR sample was slightly greater than that for music (-0.16) in the same sample. To summarize, natural sounds may be more effective means than music of reducing weekly perceived stress.

### ***Theoretical implications and future perspectives***

This longitudinal online field study showed that natural sounds were restorative for both types of participants, those who did or did not use music for mood regulation. By contrast, music was found to be less restorative than natural sounds for those who did not use music for mood regulation, albeit it was as restorative as natural sounds for those who used music for mood regulation. This findings indicate that the restorative effects of these sound types on a one-off listening occasion in a laboratory setting, which was reported by Largo-Wight et al. (2016), remain valid when listened to repeatedly in our daily lives. In addition, the cumulative surplus of the effect in the low B-MMR sample on the daily restorative experience (ROS) of natural sounds (vs. music) may be related to the "positive feedback" loop: the self-reported restorative effects of natural sounds may have strengthened spontaneously when listened to repeatedly due to accumulating positive expectations. Given that expectations may be based on personal experience and influence our affective responding and forecasting (Hoorens, 2012), we can assume that, on later days of the week-long experimental period, the expectation of being able to listen to pleasant natural sounds later may have already increased the restorative experience before the scheduled daily listening. At the same time, the attenuation of the daily restorative effect of natural sounds in the low B-MMR sample suggests the diminishing returns effect, i.e. the benefit of a one-shot listening may decrease over time when the exposure is repeated.

As far as we know, this study is the first to indicate the possibility of the positive feedback loop and the diminishing returns of the restorative effect of natural sounds. Detailed analyses of these phenomena would be a subject for future research.

Our findings also give insights into the existing literature on leisure studies, especially regarding the multifaceted psychological benefits of music, in two aspects: passive experience and active engagement. Regarding the former, we found that natural sounds were restorative regardless of listeners' skills in mood regulation through music, suggesting that such sounds can be regarded as a variant of *Muzak* due to their unobtrusive and relaxing characteristics. This naturally-derived "Muzak" can be a subject of future research on the roles that music plays in tourism, given that music can passively permeate journeys through, for instance, impromptu street entertainment, the sounds of car radios, and the Muzak of hotel lifts (Lashua et al., 2014). Regarding the latter (i.e. active engagement), since songwriting and group music-making activities are reported to have therapeutic and well-being effects (Hallam & Creech, 2016; Kumm, 2013; Varvarigou et al., 2012), incorporating natural sounds into such engagements, possibly by having participants record natural sounds and mix these sounds with songs or music, would also be restorative, encouraging further research. This idea also aligns with Bernie Krause's concept of likening the components of natural sounds (e.g. animal sounds, the sounds of natural forces) to the instrumental parts of music (Krause & Payne, 2016).

Furthermore, the juxtaposition of natural sounds with favorite music in our present study has prompted a new research question: What would be the natural-sounds counterpart of the *extended leisure experiences (ELEs)* of fan participation in the music scene? Here, ELEs refer to activities that leisure participants engage in following the completion of a primary leisure activity (Scott & Harmon, 2016). Harmon and Scott (2017) revealed that ELEs, such as listening to and discussing past concerts with other music fans, provided a foundation from which fans embody their experiences and create opportunities to extend aspects of their identity and affiliation through music. Although natural sounds do not have any personification (i.e. artists or stars) around which like-minded fans flock together, people may nevertheless engage with similar ELEs in relation to natural sounds, possibly by recollecting their experiences in the same favorite places (e.g. forests, urban parks) associated with the sounds. Indeed, a study reported that recalling prior experiences in favorite (natural) places was related to imagination-based restorative experience (Ratcliffe & Korpela, 2016). Specifically, such ELEs could be facilitated by using smartphone apps that allow people to mark their favorite natural places, comment on the sounds there, and discuss them with other participants later. Such apps can be developed based on similar GPS-based apps used in previous studies on the relationship between momentary happiness/well-being and individuals' immediate environment (De Vries et al., 2021; MacKerron & Mourato, 2013). Taken together, it would be worth comparing the ELEs in music and in natural sounds with regard to psychological restoration in future research.

### **Practical implications**

Our findings suggest that natural sounds may be a more versatile (or efficient) means of restoration indoors than music. Primary examples of such situations include the healthcare setting, such as healthcare facility lobbies or waiting rooms (Rehn & Schuster,

2017) and medical professionals' rest space (Suko et al., 2022). Considering that not everyone uses music for mood regulation and not even every individual using music for that purpose necessarily has similar musical tastes, it would be more effective to play natural sounds in such places. In addition, listening to natural sounds could serve as a means of respite during long working hours indoors. Considering that people are working more from home and they are less capable of disconnecting from work due to technology blurring the work-nonwork boundaries (Meier et al., 2021), this recreational activity merits special attention.

### **Limitations**

This study has several limitations. Firstly, we provided only two options of natural sounds, both consisting of birdsong recorded in the late spring or summer. Adding water sounds or the sound of wind in trees, which are also claimed to be restorative (Cerwén, 2016; Fang et al., 2021; Liu et al., 2019), may further increase the restorative effect of natural sounds in future experiments. Nevertheless, it could also be argued that limiting our present study to birdsong may have succeeded in controlling for potential confounding factors inherent in different types of natural sounds. Future research can include various types of natural sounds while controlling for any confounding factors. It would also be important to study the restorative sounds of blue spaces, given that until recently research on the health benefits of nature has focused primarily on greenspaces (Nicolosi et al., 2021).

Secondly, this study did not have any clear control conditions. To gauge the restorative effects of natural sounds and music more accurately, it may be necessary to add a prevalent but non-restorative daily activity and a non-intervention control (i.e. subjects only fill out questionnaires). However, it may not be feasible to have participants experience all these conditions in a crossover design. Therefore, future research can employ a parallel-groups design with a larger sample size, thereby comparing the effects of these interventions. Including both self-reported measures and physiological indicators will also enable future research to assess the restorative effects more precisely.

Thirdly, the timings of filling out the PSS-10 (weekly perceived stress) and B-MMR (people's levels of using music for mood regulation) questionnaires could have been better. The second measurement point for the PSS-10 was at the end of the experiment on Day 8, and therefore the 10-min listening on that day might have affected the subjects' responses to this questionnaire, albeit they were asked to assess their perceived stress during the previous week. Likewise, the B-MMR, which is a trait measure, was filled out at the end of Day 14. This may have slightly "contaminated" the scores with what the subjects had experienced during these 14 days. Although we assume that our crossover design should have counterbalanced these confounding effects to a sufficient extent, future studies can implement a PSS-like questionnaire at the end of Day 7 or at the beginning of Day 8, and a B-MMR-like questionnaire at the beginning of the entire experimental process.

Fourthly, although we instructed the subjects to participate in the whole experiment at home as opposed to public indoor spaces, there may nevertheless have been some confounding factors deriving from the variability within such spaces. For example, we

did not ask the subjects whether they lived in a private studio, a shared flat, or at their parents' house, or whether they had a small baby. In some cases, activities of flatmate(s) or co-inhabitant(s) may have interfered with the interventions of our experiment. A solution to address this issue in future research would be to include the type of residence as a covariate in the analysis.

Lastly, our research design could not preclude the possibility that the accumulation of the benefits of listening to natural sounds can be ascribed to a self-fulfilling prophecy. Considering that expectations or beliefs may affect behaviors in such a way that they make themselves come true (Constant et al., 2019; Hoorens, 2012; Kruglanski et al., 2020), the subjects may have unconsciously sought every reason to report higher and higher scores when filling out the ROS questionnaire as the day progressed, expecting (or believing) that listening to natural sounds would be beneficial. To control for this confounding factor, future research can, for example, have participants listen repeatedly to the same natural sound but with three different explanations: telling them that there is already scientific evidence of this sound being (1) restorative or (2) stressful, or (3) not providing any information. Comparing the effects of these explanations on the participants' self-reported restorative experience in a longitudinal experiment will reveal whether the cumulative restorative effect of natural sounds, which was found at the weekly level in our present study, is attributed to the sound *per se* or the self-fulfilling prophecy.

## Conclusion

In a longitudinal online field experiment, this study compared the restorative effect of listening to natural sounds with that of listening to favorite music, both of which are restorative indoor leisure activities. Subjects' ways of using music as a means of mood regulation were also considered. The results showed that people who were more likely to use music for mood regulation (i.e. high B-MMR score) improved their self-reported restorative experience and reduced their weekly perceived stress through listening to both natural sounds and music to the same extent. Conversely, the restorative effects of natural sounds were greater than those of music for those who were less likely to use music for mood regulation (i.e. low B-MMR score). Likewise, the accumulation of the daily restorative effect of natural sounds (vs. music) over the course of a week occurred only in the low B-MMR sample. These findings indicate that natural sounds are restorative for a wider range of people than music. This implication makes such sounds a better means of restoration in public spaces with people who are not necessarily music lovers. People who spend time in stressful indoor spaces can benefit from this easy-to-use, cost-free indoor recreation when unable to visit natural surroundings to seek restoration.

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