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SHORT REPORT

Does Bedtime Music Listening Improve Subjective Sleep Quality and Next-Morning Well-Being in Young Adults? A Randomized Cross-Over Trial

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Previous research has found that young adults exhibit patterns of poor sleep and that poor sleep is associated with a host of negative psychological consequences. One potential intervention to improve sleep quality is listening to music at bedtime. Although there exist previous works investigating the efficacy of listening to music as a form of sleep aid, these works have been hindered by statistically weak designs, a lack of systematic investigation of critical characteristics of music that may affect its efficacy, and limited generalizability. In light of the limitations in the existing literature, a 15-day randomized cross-over trial was carried out with 62 young adults. Participants completed 5 nights of bedtime listening in each condition (happy music vs. sad music vs. pink noise, which acted as an active control condition) over 3 weeks. Upon awakening each morning, participants rated their subjective sleep quality, current stress, positive and negative affective states, and current life satisfaction. Frequentist and Bayesian multilevel modeling revealed that happy and sad music were both beneficial for subjective sleep quality and next-morning well-being, compared with the pink noise condition; potential nuances are discussed. The current study bears potential practical applications for health-care professionals and lay individuals.

Keywords: music listening intervention, sleep quality, well-being, randomized cross-over trial, daily diary

Previous research has found that young adults exhibit patterns of poor sleep (Owens et al., 2014) and that poor sleep is associated with a host of negative consequences, such as impaired cognitive functioning (Benitez & Gunstad, 2012) and an increase in anxiety and depressive symptoms (Gregory et al., 2011). In light of the prevalence and harmful impacts of poor sleep, there is a need to identify potential interventions to effectively improve sleep quality, thereby protecting young adults' sense of subjective well-being—that is, a person's cognitive and affective evaluations of his or her life (Diener, 1984; Diener et al., 2009). One potential intervention that has been proposed by the literature—and indeed self-reported as a sleep aid by young adults—is listening to music (Dickson & Schubert, 2020; Trahan et al., 2018) at bedtime.

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The use of music as a sleep aid has been empirically examined in various works. For example, de Niet et al. (2009) found from a meta-analysis of clinical studies that music-assisted relaxation improved sleep quality in patients with sleep complaints, whereas Wang et al.'s (2014) review of 10 randomized controlled trials found that music therapy significantly improved sleep quality in patients with acute and chronic sleep disorders. Most recently, Chen et al. (2021) conducted a meta-analysis of the effects of music therapy on sleep quality in older adults and found promising results from five randomized controlled trials. Various reasons have been proposed as to why or how listening to music can improve both objective and subjective sleep quality—through a systematic review of the existing literature on the use of music to aid in alleviating insomnia specifically, Dickson and Schubert (2020) identified six such mechanisms, including relaxation, distraction from stressful thoughts, and masking of unpleasant background noise.

Despite the number of previous works investigating the efficacy of listening to music as a form of sleep aid, these works have been limited in three main ways. First, most of these studies have drawn their conclusions based on pretest–posttest comparisons without a control group (Johnson, 2003; Mornhinweg & Voignier, 1995) or from comparisons with passive control conditions such as silence (Chan et al., 2010; Hernández-Ruiz, 2005; Lai & Good, 2006; c.f., Harmat et al., 2008). These less-than-ideal designs prevent conclusions from being drawn about the effects of music itself; instead, any changes in sleep quality can simply be attributed to natural changes over time (in designs without a control group) or to listening to sounds in general, and not music per se (in designs with passive controls).

Second, there is a need to identify critical factors that may influence the efficacy of such music listening interventions. Previous research on music and emotions more generally has found that listening to happy music and listening to sad music can have different impacts on affective states (Westermann et al., 1996). Accordingly, the valence of the music chosen may result in different effects on sleep quality and other well-being outcomes. Despite the strong body of work in the affective science area, the specific characteristics of music when used as a sleep aid have not been systematically investigated.

Third, there are limits on the generalizability of the past findings. Studies on music listening as a sleep aid have mostly focused on samples with clinical sleep disorders (Wang et al., 2014) or on older adults (Johnson, 2003; Lai & Good, 2006; Mornhinweg & Voignier, 1995). Thus, the efficacy of a music listening intervention in improving sleep quality in a more general, healthy young adult population remains uncertain.

In light of the limitations in the existing literature, the current study aimed to experimentally test whether listening to happy music and sad music at bedtime could improve subjective sleep quality, in comparison with an active control condition, in a healthy young adult[1] sample. We hypothesized a priori that listening to music would result in improved sleep quality as compared with the active control condition. However, we had no a priori hypotheses regarding how the effects of sad and happy music on subjective sleep quality would differ, due to a lack of substantial previous literature examining such differences. In light of previous literature on interventions for subjective sleep quality as well as on day-to-day fluctuations in subjective sleep quality in healthy samples (Leppämäki et al., 2003; Simor et al., 2015), we operationalized subjective sleep quality in terms of sleep complaints as captured by the Groningen Sleep Quality Scale (Mulder Hajonides van der Meulen et al., 1980). In addition, the current study sought to extend the current literature on music as a sleep aid by exploring other subjective well-being outcomes—namely, positive affect, negative affect, and life satisfaction—upon next-day awakening. We additionally examined stress (a subset of negative affect) as an outcome due to the extensive amount of past work suggesting that music has beneficial effects on stress-related outcomes (for a review, see de Witte et al., 2020). Much research has suggested that music is able to decrease physiological arousal (as indicated by lower cortisol levels, heart rate, and blood pressure; de Witte et al., 2020) that is heightened when individuals are stressed. Nonetheless, only a limited body of research has examined the effects of bedtime music on next-morning stress levels. Thus, we examined stress as a well-being outcome as well to fill this gap in the existing literature.

Method

Participants and Recruitment

Recruitment was carried out over a predetermined period of 10 weeks, during which any individual who expressed interest in participating in a study on "listening and daily experiences" was invited to a briefing session. A total of 79 individuals originally expressed interest in the study, of which two individuals dropped out after completing the baseline measures but before commencing the trial. A 3-week randomized cross-over trial was then carried out with the sample of 77 young adults over 15 days. An additional 15 individuals dropped out of the study at various points during the trial period, leaving 62 participants in the final analytic sample (see Table 1 for sample characteristics). All 62 participants completed at least 12 days of the study, yielding 874 observations out of a possible total of 930 (62 participants $\times$ 15 days; 93.98% completion rate). All participants were recruited from a local university in Singapore and received course credit or SG$15 cash as remuneration. Participants were only eligible to take part in the trial if they were not already using any form of audio as a sleep aid. All participants gave informed consent and data collection was approved by the local institutional review board [IRB-21-009-A013-M1(321)].

Audio Stimuli

Happy music, sad music, and pink noise playlists were created by the authors for the purpose of the current study. Each 30-min playlist was assembled from 13 (happy condition), 10 (sad condition), or nine (pink noise condition) individual audio tracks. None of the 32 individual audio tracks contained lyrics or vocals. To reduce familiarity effects, the sequence of tracks within each playlist was reordered each day. Thus, although each playlist within each condition consisted of the same combination of pieces, there were five unique permutations of the pieces selected for each condition, resulting in a total of 15 playlists.

Music Tracks

Happy music tracks and sad music tracks were selected separately by Nadyanna M. Majeed, who has received formal training in both music and psychology, on the basis of sounding calm and relaxing. Tracks were selected from a pool of instrumental pieces provided by Epidemic Sound (https://www.epidemicsound.com/) through a commercial license. Literature on music perception and emotion has found major keys tend to be associated with happiness, whereas minor keys tend to be associated with sadness (Hunter et al., 2010; Kastner & Crowder, 1990; Parncutt, 2014). Thus, for the purposes of the current study, tracks written in any major key were eligible to be selected as "happy" tracks, whereas tracks written in any minor key were eligible to be selected as "sad" tracks. Following the selection of pieces, the remaining authors (all of whom have formal training in psychology, and half of whom additionally have some form of background in music) listened to the created "happy" (i.e., major key) and "sad" (i.e., minor key) playlists. No disagreements about the selection of pieces or categorization into "happy" and "sad" were raised during this process. The list of the music tracks used, and their corresponding keys, is shown in Table 2.

[1] We define young adults as those aged from 18 up till their early 30s, in line with other existing literature on sleep in young adults (Mellman et al., 2014).

Table 1
Summary of Sample Characteristics

Variable	*M*	*SD*	Range
Demographics			
Age	21.84	2.31	19–31
Sex (% female)	75.81%		
Ethnicity (% Chinese)	79.03%		
Monthly household income[a]	4.24	2.43	1–9
Subjective socioeconomic status[b]	5.95	1.19	3–9
Lifestyle[c]			
Sleep medication (% taking medication)	1.61%		
Caffeine consumption (% usually consume)	59.68%		
Musical experience			
Years of private lessons in music	4.02	4.50	0–16
Years of regular practice in music	3.53	4.53	0–14

Note. $N = 62$.
[a] Monthly household income was measured in SG$2,500 intervals, from 1 = *less than $2,500* to 10 = *more than or equal to $20,000.* [b] Subjective socioeconomic status was measured on a 10-point ladder scale (1 = *worst off in society*, 10 = *best off in society*) based on the MacArthur Scale of Subjective Status (Adler et al., 2000). [c] Participants were asked "Do you take any sleep medication?" and "Do you usually consume caffeine on a normal day?" and responded either *Yes* or *No* to each of the questions.

Pink Noise Tracks

Pink noise—which is often described to sound similar to rustling leaves, steady rain, or wind (Nunez, 2019)—was used as the active control stimuli due to prior research suggesting that pink noise is effective as a sleeping aid and invokes a sleep deepening effect for individuals (Suzuki et al., 1991). Although white and brown noises are also often used as sleeping aids (Nunez, 2019), white noise has been found to have a sleep shallowing effect (Suzuki et al., 1991), and little research has examined the efficacy of brown noise as a sleeping aid. As such, in the light of existing empirical research, pink noise was chosen as the stimuli for the active control condition.

The nine pink noise tracks were selected by Verity Y. Q. Lua. The selected tracks were limited to frequencies ranging from 32 Hz to 200 Hz to ensure that the changes in pitch would not be too jarring, considering sudden sound changes may be disruptive for sleep (Fry, 2021). In addition, lower frequencies were used due to prior work suggesting that the lower frequencies in pink noise make pink noise more soothing and less harsh to the ears compared with other noises such as white noise (Boynton, 2020; Burch, 2020).

Procedure and Measures

At baseline, participants provided data on their demographics, use of sleep medication and caffeine consumption, and musical experience (Table 1). Participants then commenced the trial proper 1 to 4 days later, such that all participants started the trial on the same day of the week. All participants completed all three conditions (happy music, sad music, and pink noise [active control] conditions), in a randomized order (Figure 1). During the trial, participants were first assigned to one of the three conditions and asked to listen to 30-min audio tracks for five consecutive nights. After which, all participants underwent a 2-day washout period before commencing the next condition. This cycle repeated twice more (without repeating conditions) until the participants completed all three conditions. Audio was administered online via participants' own smartphones, and participants were instructed to begin playing the audio at a "comfortable but audible volume"[2] only when they were ready to close their eyes and go to sleep.

Participants were briefed thoroughly on the procedure of the experiment and the importance of compliance with the instructions. Participants were given the freedom to drop out without penalty should they feel they were unable to comply. Every night during the trial, participants received a Qualtrics survey link via email through which they could complete a short nightly check-in. Only participants who completed the night check-in were given the link to the audio for that night. Subsequently, only participants who completed the night check-in were provided with the link to the morning survey. We also ensured that we only retained the morning check-in data from participants who had completed the night check-in the previous night.

The use of a cross-over or within-subjects design allowed us to rule out stable individual differences as a potential confound, increasing the power of the current study (Bolger et al., 2012; Maxwell & Delaney, 2004), thereby allowing us to obtain a clearer understanding of the effects of a music intervention on daily sleep and next-morning subjective well-being. In addition, the randomization of the order of the conditions allowed us to rule out order effects as a potential confound. Furthermore, the current design where participants were tracked in a more natural setting (as opposed to a lab setting) allowed for a high degree of ecological validity.

Upon waking up each morning, participants completed a short online diary in which they rated their sleep quality and current well-being. In line with previous studies examining day-to-day variations in subjective sleep quality (Leppämäki et al., 2003; Simor et al., 2015), sleep quality was assessed using the 15-item Groningen Sleep Quality Scale (Mulder Hajonides van der Meulen et al., 1980), which assessed participants' general subjective sleep quality, whether they had trouble falling asleep, and whether they felt unrested when they woke up, among other concerns or complaints (Meijman et al., 1990). The scale displayed good internal reliability across all 15 days in the current study (α = [.81, .89]) and was scored such that higher values indicated poorer subjective sleep quality.

As additional outcomes, participants rated their current stress ("How stressed do you feel now?," 0 = *no stress*, 10 = *extreme stress*), positive and negative affective states (α_{positive} = [.94, .97], α_{negative} = [.84, .94]; 18-item affect scale; Conner & Silvia, 2015), and current life satisfaction ("Taking all things together, how satisfied are you with your life as a whole now?," 1 = *very dissatisfied*, 5 = *very satisfied*) each morning. Table 3 shows a summary of the average levels of each outcome across all participants for each condition.

Analytic Plan

We used multilevel modeling to examine the within-persons effects of bedtime listening to happy music and sad music (vs. pink noise; dummy-coded with the pink noise condition acting as the reference category) on sleep quality and the other well-being outcomes. In analyzing repeated measures data, multilevel

[2] As previous research has suggested that individuals differ significantly in their sensitivity to noise and audio (Florentine et al., 2011), we did not specify a fixed volume at which participants should play the audio tracks.

Table 2
List of Music Tracks Used in the Current Study

Happy track name (artist)	Key	Sad track name (artist)	Key
Before the War (Lama House)	C major	Awake (Megan Wofford)	E minor
Beginning (Megan Wofford)	G major	Declaration (Johannes Bornlof)	C minor
Breakfast on the Balcony (Franz Gordon)	G major	Empathy (Gavin Luke)	E minor
Evening Waltz (Helmut Shenker)	D major	Exile (Lo Mimieux)	C minor
Flirting at the Masquerade (Franz Gordon)	A major	Les Feuilles Jaunes (Franz Gordon)	A minor
For Jack (Arden Forest)	D major	Misericorde (Lo Mimieux)	D minor
Kiriume (Arden Forest)	G major	Nod (Lo Mimieux)	D minor
My Gift (Megan Wofford)	D major	Solace (Gavin Luke)	G minor
Onthou (Ever So Blue)	C major	The French Library (Franz Gordon)	C minor
Pollux (S.A. Karl)	C major	Togetherless (Franz Gordon)	A minor
Progress (Ever So Blue)	C major		
Rain (Valter Nowak)	B major		
Remembering (Ever So Blue)	E major		

Note. Tracks on the left were used in the happy music condition, whereas tracks on the right were used in the sad music condition.

modeling is superior to more traditional general linear models (e.g., analysis of variance) as multilevel modeling takes into account the nonindependence of data within participants while maximizing information gained from multiple available data points per participant (Field & Wright, 2011). In line with recommendations by Westfall et al. (2014), the value of each outcome was modeled as a function of three components of the intercept—the overall intercept value (fixed parameter γ_{00}), the deviation of the intercept for each *participant i* (random parameter μ_{0i}), and the deviation of the intercept for each playlist p (random parameter μ_{0p})—as well as the overall effect of listening to happy music (fixed parameter γ_{10}) and to sad music (fixed parameter γ_{20}) at bedtime and their corresponding deviations for each *participant i* (random parameters μ_{1i} and μ_{2i}). Thus, the general equation for each outcome was as follows, where the parameters of interest are γ_{10} and γ_{20}:

$$\begin{aligned}(\text{Outcome})_{dpi} = {} & (\gamma_{00} + \mu_{0i} + \mu_{0p}) \\ & + (\gamma_{10} + \mu_{1i})(\text{Happy music})_{dpi} \\ & + (\gamma_{20} + \mu_{2i})(\text{Sad music})_{dpi} + \varepsilon_{dpi}\end{aligned}$$

In the equation, the residual term ε_{dpi} refers to the deviation of the value of the outcome—for each participant–playlist combination at each observation—which is not captured by the predictors included in the model. Given the multiple random components in the general model, simplifications to the model were then made as the original model failed to converge and/or faced singular fit issues. Namely, the random slope components μ_{1i} and μ_{2i} and the random intercept by playlist component μ_{0p} were dropped (i.e., it was assumed that $\mu_{1i} = 0$, $\mu_{2i} = 0$, and $\mu_{0p} = 0$).[3] Thus, the final analytic model was as follows:

$$\begin{aligned}&(\text{Outcome})_{di} \\ &= (\gamma_{00} + \mu_{0i}) + \gamma_{10}(\text{Happy music})_{di} + \gamma_{20}(\text{Sad music})_{di} + \varepsilon_{di}\end{aligned}$$

We made use of both frequentist and Bayesian methods for model estimation. In the frequentist framework, effects are considered statistically significant if $p < .05$. In the Bayesian framework, Bayes factors are computed, where $BF_{10} < 1$ indicates support for the null hypothesis that there is no effect, and $BF_{10} > 1$ indicates support for the alternative hypothesis that there is an effect. In addition, we statistically examined whether the effects of happy music and sad music on each outcome were meaningfully different by swapping the reference category from pink noise to happy music, thereby allowing us to obtain a p value[4] for the effect of sad music in comparison with happy music.

Lastly, we conducted exploratory multilevel mediation analyses to test if subjective sleep quality served as a mediator of the effect of bedtime listening to happy music (vs. pink noise) on next-morning well-being, and similarly for sad music (vs. pink noise). Specifically, we were interested in the indirect effect of listening to music on the various well-being outcomes through subjective sleep quality (i.e., music → subjective sleep quality → next-morning well-being).

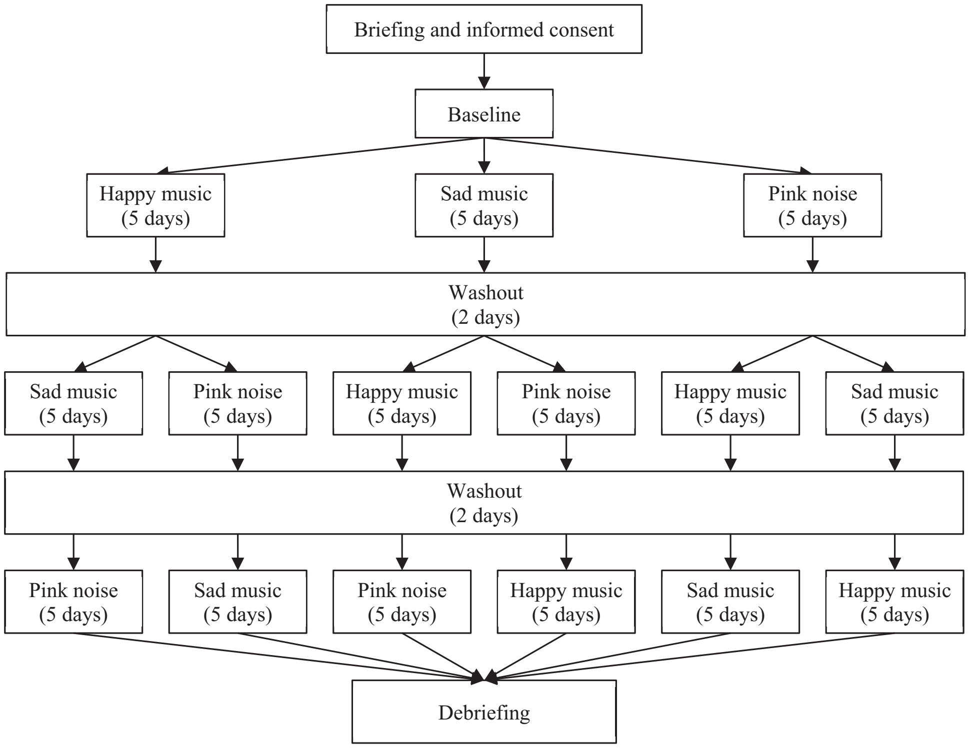
Transparency and Openness

The relevant materials, data, and code required to reproduce our analyses have been made publicly available on ResearchBox (#293; https://researchbox.org/293). All analyses were conducted in R Version 3.6.3 (R Core Team, 2020) using various packages. Frequentist multilevel modeling was performed using *lme4* Version 1.1-26 (Bates et al., 2015) with maximum likelihood estimation and default optimization methods, and significance testing was carried out by *lmerTest* Version 3.1-3 (Kuznetsova et al., 2017). Bayesian multilevel modeling was performed using *brms* Version 2.16.1 (Bürkner, 2017, 2018) with 10,000 iterations per model. In line with recommendations by Lorah (2018), effect sizes were calculated in the form of standardized coefficients for fixed effects using *effectsize* Version 0.4.5 via the *pseudo* method (Ben-Shachar et al., 2020), and in the form of intraclass correlation coefficients for random effects using *merTools* Version 0.5.2 (Knowles & Frederick, 2020). Multilevel mediation was conducted using a

[3] Results from the maximal models (i.e., where the most complex model possible was run for each outcome regardless of whether the model was valid for other outcomes) are available upon request.

[4] Due to the extremely high amount of computational resources needed to run Bayesian analyses, we did not conduct Bayesian analyses when comparing the effects of happy music and sad music.

Figure 1
Experimental Flow



Note. Participants were randomly assigned (via a computer randomizer) to each condition such that each participant completed every condition once. Participants were not aware of the order in which they would go through each condition. Participants did not listen to any audio during the 2-day washout period between conditions to reduce carry-over effects.

frequentist bootstrapping approach using *mlma* Version 6.1-1 (Yu & Li, 2020, 2021).

Results

A full summary of the fixed effects results from multilevel modeling is available in Table 4, whereas a summary of the random effects can be obtained online from ResearchBox (#293; https://researchbox.org/293).

Subjective Sleep Quality

We first examined whether participants' daily sleep quality differed according to whether they listened to sad music, happy music, or pink noise at bedtime. We found from frequentist analysis that listening to happy music significantly improved subjective sleep quality ($\gamma_{10} = -.61$, $SE = .24$, $\beta = -.10$ [$-.17$, $-.02$], $p = .013$) compared with the pink noise condition, with strong evidence for the same observation from Bayesian analysis ($BF_{10} = 13.12$). We similarly found from frequentist analysis that compared with the pink noise condition, sad music significantly improved subjective sleep quality ($\gamma_{20} = -.72$, $SE = .24$, $\beta = -.12$ [$-.19$, $.04$], $p = .003$) compared with the pink noise condition, with very strong evidence for the same observation from Bayesian analysis ($BF_{10} = 50.37$). The patterns were such that participants reported better sleep quality during the weeks where they were assigned to listen to happy music or sad music at bedtime, compared with when they were assigned to listen to pink noise.[5] The difference between the effects of happy music and sad music was nonsignificant ($p = .636$), suggesting that the magnitude of the effect of music on subjective sleep quality did not vary by the mood of music.

Next-Morning Well-Being

Compared with the pink noise condition, both happy and sad music were beneficial in improving all four of the next-morning well-being outcomes ($|\beta| \geq .10$, $ps \leq .012$, $BF_{10}s \geq 2.07$; Table 4). No significant differences were found when comparing happy music to sad music ($ps \geq .125$). Specifically, listening to music at bedtime helped to reduce next-morning stress, reduce

[5] We conducted similar analyses after the removal of participants currently taking sleep medication and found the same pattern of results. We also repeated the analyses with the inclusion of a Condition × Musical Experience interaction term, where we operationalized each participant's musical experience as the mean of the number of years of private lessons in music and the number of years of regular practice in music. Musical experience did not moderate the effect of listening to happy or sad music on subjective sleep quality. We thank an anonymous reviewer for suggesting these analyses.

Table 3
Average Sleep Quality and Next-Morning Well-Being by Condition

Outcome	Happy music		Sad music		Pink noise	
	M	*SD*	*M*	*SD*	*M*	*SD*
Average sleep quality[a]	3.65	2.07	3.51	2.11	4.26	2.26
Average stress	4.56	2.48	4.59	2.62	4.94	2.56
Average positive affect	2.40	0.80	2.36	0.84	2.14	0.78
Average negative affect	1.43	0.49	1.49	0.59	1.57	0.63
Average life satisfaction	3.42	0.71	3.37	0.72	3.26	0.76

Note. $N = 62$. Values were computed by first calculating an average for each outcome for each condition per participant, such that there were 62 data points per condition.
[a] Higher values denote poorer sleep quality.

next-morning negative affect, increase next-morning positive affect, and increase next-morning life satisfaction.[6] These findings remained consistent even after applying a Hommel correction to the frequentist results ($p_{\text{Hommel}}\text{s} \leq .012$), which is appropriate for adjusting for multiple comparisons across different outcomes (Vickerstaff et al., 2019).

Exploratory Mediation Analyses

As an exploratory analysis, we examined whether subjective sleep quality would mediate the relationship between sad and happy music on next-morning well-being. We found that sleep quality did not mediate the relationship between sad music and next-morning well-being, nor did the relationship between happy music and next-morning well-being (all 95% CIs included 0; Table 5). These results suggest that the effects of sad and happy music on next-morning well-being occur independently of the effects of music on sleep.

Discussion

The current 15-day randomized cross-over trial contributes to an understudied area of research by shedding light on the efficacy of music listening interventions in improving sleep quality and next-morning well-being in young adults. The use of an active control condition—compared with weaker control conditions used in many previous studies, such as an equivalent duration of silence or even no specific activity at all (Chan et al., 2010; Hernández-Ruiz, 2005; Lai & Good, 2006)—implies that the benefits of music listening found in the current study are not due to simply listening to sounds in general but are specifically due to listening to music. In addition, the use of a randomized cross-over design allowed us to rule out stable individual differences and natural changes over time as potential confounds.

The Impact of Music on Sleep Quality

We found consistent evidence from frequentist and Bayesian perspectives that subjective sleep quality improved after listening to happy music and sad music compared with listening to pink noise, with no difference between the two types of music. Although the current study does not examine the mechanisms behind this relationship, we posit that the stress-reducing effects of music on individuals' physiological and psychological outcomes (de Witte et al., 2020) may be a possible explanation for the current findings. Considering that several other studies have evidenced that stress can lead to longer sleep latency, interrupted sleep, and nightmares among other things (Åkerstedt et al., 2007; Kim & Dimsdale, 2007; Schredl, 2003), we believe that music may improve sleep quality by reducing individuals' stress levels right or while falling asleep, thereby enhancing individuals' sleep quality.

In the current study, we found a small effect of music listening on subjective sleep quality in a healthy young adult sample. Comparatively, a recent up-to-date meta-analysis by Chen et al. (2021) examining the effects of mindfulness-based stress reduction (MBSR) for sleep among insomnia patients found that MBSR has a medium effect on subjective sleep quality. Although our observed effect size may not be as large as that found by Chen et al. (2021), it may be possible the difference observed is partially due to the difference in baseline subjective sleep quality between insomnia patients and the current sample of young adults, and not merely indicative that music is less effective than MBSR for sleep. In addition, the strength of using music interventions for sleep lies in the fact that it is a cost-effective and convenient intervention for individuals. This may be particularly beneficial for individuals with low motivation or low ability to comply with other interventions such as the MBSR.

Future works should seek to expand the assessment of sleep quality used in the current study. The current work, and indeed most of the existing literature on this topic, has made use of self-report or subjective measures of sleep quality, neglecting to examine if these results replicate with objective measures of sleep quality. Previous works have found that subjective and objective measures of sleep quality do not necessarily correspond with each other (O'Donnell et al., 2009), thereby highlighting the need for future work to examine objective sleep quality for a more holistic assessment. In addition, sleep onset latency is another sleep-related factor that should be considered in future works. Although there is reason to believe that participants fell asleep within the duration of each 30-min playlist (Allen et al., 2018), it is possible that some participants remained awake after the end of the playlist,

[6] Like for subjective sleep quality, we conducted similar analyses for each of the well-being outcomes after the removal of participants currently taking sleep medication, and found that the results described here remained consistent. We also repeated the analyses with the inclusion of a Condition × Musical Experience interaction term, where we operationalized each participant's musical experience as the mean of the number of years of private lessons in music and the number of years of regular practice in music. Generally, musical experience moderated the effect of listening to happy or sad music on the three affective outcomes—providing an interesting starting point for future research—but did not moderate the effect on life satisfaction. We thank an anonymous reviewer for suggesting these analyses.

Table 4
Fixed Effects on Subjective Sleep Quality and Well-Being Outcomes

	Happy music (vs. Pink noise)						Sad music (vs. Pink noise)					
Outcome	β	95% CI	γ_{10}	*SE*	*p*	BF_{10}	β	95% CI	γ_{20}	*SE*	*p*	BF_{10}
Sleep quality	−.10	[−0.17, −0.02]	−0.61	0.24	.013	13.12	−.12	[−0.19, −0.04]	−0.72	0.24	.003	50.37
Stress	−.12	[−0.19, −0.04]	−0.40	0.13	.002	35.09	−.10	[−0.18, −0.03]	−0.34	0.13	.009	9.76
Negative affect	−.15	[−0.23, −0.08]	−0.14	0.03	<.001	219.71	−.10	[−0.17, −0.02]	−0.09	0.03	.012	2.07
Positive affect	.23	[0.15, 0.30]	0.27	0.04	<.001	>1000	.20	[0.12, 0.27]	0.23	0.04	<.001	>1000
Life satisfaction	.17	[0.10, 0.25]	0.17	0.04	<.001	>1000	.11	[0.04, 0.19]	0.11	0.04	.003	7.35

Note. $N_{\text{participants}} = 62$, $N_{\text{observations}} = 874$. β = effect size or standardized slope coefficient; 95% CI = 95% confidence interval of β; γ_{10} and γ_{20} = unstandardized slope coefficients of happy music and sad music, respectively; *SE* = standard error of γ_{10} or γ_{20}; BF_{10} = Bayes factor indicating the likelihood of the alternative hypothesis compared with the null hypothesis. Conditions were dummy-coded such that the pink noise condition served as the reference category (i.e., happy = 1, pink noise = 0 for the first dummy variable; sad = 1, pink noise = 0 for the second dummy variable). The estimates of the random effects can be obtained from ResearchBox (#293; https://researchbox.org/293).

which could potentially reduce the benefits of listening to music. On the other hand, it is also possible that participants fell asleep after only a short duration of listening to music, and if so, this would provide preliminary evidence for some form of subconscious or physiological mechanism in the relationship between music listening and the various outcomes described here. However, as the current study did not measure sleep onset latency, these questions remain to be answered.

The Impact of Music on Next-Morning Well-Being

In addition to our main findings on subjective sleep quality, we observed lower levels of stress, lower levels of negative affect, higher levels of positive affect, and higher levels of life satisfaction the morning after listening to music, regardless of whether the music was happy or sad in mood. Of note, findings from our mediation analyses suggest that the improvements in next-morning well-being in the current study are driven by lasting effects of listening to music at bedtime, and not due to indirect effects brought about by improvements in subjective sleep quality. Given that these findings are both novel and unexpected, examining the mechanisms behind these findings is beyond the scope of the current work. Further research is warranted to fully appreciate the mechanisms behind these findings.

The (Lack of Differences) Between Happy and Sad Music

Apart from investigating the efficacy of listening to music in improving subjective sleep quality and various well-being outcomes, the current study also aimed to provide a more fine-grained examination of the potential differences between listening to happy music and listening to sad music (Westermann et al., 1996). We found that there were no significant differences between the effects of happy music and the effects of sad music on any of the five outcomes assessed in the current study, suggesting that music can improve subjective sleep quality and next-morning well-being regardless of the mood of the music.

However, we note that the categorization of music into "happy" and "sad" was done by the research team on the objective basis of what key each piece was written in, and not according to participants' subjective perceptions. Although it is relatively well-established that major keys tend to be associated with happiness and minor keys tend with sadness (Hunter et al., 2010; Kastner & Crowder, 1990; Parncutt, 2014), some research has suggested that it is the listener's subjective perception of a piece of music rather than the objective characteristics of a musical piece that determines the effect of music on affect (see literature on emotional contagion, Davies, 2013; Juslin & Västfjäll, 2008). In addition, other critical objective (e.g., tempo) and subjective (e.g., perceptions of arousal) characteristics could also be determinants of whether a piece of music is considered "happy" or "sad". Thus, although the current study suggests that the choice of major versus minor keys does not affect the magnitude of the music–sleep effect, it remains plausible that other objective factors and listeners' subjective perceptions of music as happy or sad could affect the efficacy of listening to music as a sleep aid. This nuance, although out of the scope of the current work, provides an interesting and important direction for future research to explore.

Limitations and Future Directions

The current study is not without limitations, which future research should seek to address. First, although there is theoretical reason to posit that our findings evidence the positive effect of

Table 5
Results of Multilevel Mediation Analyses

	Happy music (vs. pink noise)		Sad music (vs. pink noise)	
Outcome	Indirect effect	95% CI	Indirect effect	95% CI
Stress	.0,010	[−0.0,093, 0.0,113]	.0,014	[−0.0,101, 0.0,128]
Negative affect	.0,001	[−0.0,033, 0.0,036]	.0,002	[−0.0,022, 0.0,025]
Positive affect	−.0,003	[−0.0,042, 0.0,036]	−.0,002	[−0.0,037, 0.0,032]
Life satisfaction	−.0,001	[−0.0,040, 0.0,038]	−.0,002	[−0.0,028, 0.0,024]

Note. Values refer to the indirect effect of happy or sad music (vs. pink noise) onto each outcome through sleep quality.

bedtime music listening on subjective sleep quality and other outcomes, there is a possibility that the results in the current study are due to *negative* effects due to the pink noise condition, rather than positive effects due to the two music conditions. Future research can address this by measuring the outcomes of interest at baseline. Thus, comparisons against baseline levels can reveal if pink noise has impairing effects, or if music has beneficial effects, or both. Future studies may also benefit from having both an active control and a passive control as an alternative way to empirically test if findings are driven by the impairing effects of the active control condition. Second, participant familiarity with and liking of the various music tracks were not examined. Future research should examine if these factors can affect the efficacy of music as a sleep aid. Last, the current study was conducted on a sample of young adults. Future studies would benefit from expanding these findings to a sample with a wider age range to ascertain the replicability of these effects to those outside the age group currently studied.

As a final note, we highlight potential considerations that future works should take into account when considering trade-offs in the design of similar studies. First, future works should aim to minimize the attrition inherent in longitudinal designs such as in the current study. As trials in this area inherently require participants to commit to a longitudinal study (one-time interventions are not efficacious; for a review on the minimum duration required for music-based interventions for sleep, see Tang et al., 2021), ways to increase participant motivation and compliance—without introducing potential confounds—should be explored.

Second, future works should consider the trade-off between internal and ecological validity when designing their studies. Although the current study achieved high ecological validity due to its natural setting in participants' day-to-day lives, this comes at the cost of potentially lower internal validity due to threats of day-to-day confounds such as daily positive or negative events that may influence the outcomes of interest in the current study (Majeed et al., 2021).

Third, the nature of within-subjects designs implies that participants cannot be completely blind, thus raising concerns about demand characteristics or participant reactivity. Although the current study made use of vague information (e.g., informing participants that we were interested in listening to audio, and not music specifically) and a placebo control condition in an attempt to assuage these concerns, these concerns cannot be completely prevented. Future studies that aim to examine this topic using a between-subjects design to address this concern should be aware of the corresponding trade-off in statistical power, and the inability of between-subjects designs to elucidate within-subjects patterns, which may not necessarily correspond (Charness et al., 2012).

Conclusion

The findings of the current study suggest that found that music-listening at bedtime is effective in improving subjective sleep quality, and may even have lasting effects on next-morning well-being. The findings of the current study bear potential practical applications; given that music listening is relatively cheap and easy-to-implement, health-care professionals and lay individuals alike can use music listening as a cost-effective and convenient intervention for improving subjective sleep quality and other daily well-being outcomes. Future research should extend this work to other age groups, so as to examine the usefulness of music interventions across the life span. In addition, future research should consider other aspects of the music selected, beyond mood, to identify critical characteristics that must be considered when designing interventions.

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