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Active and Passive Rhythmic Music Therapy Interventions Differentially Modulate Sympathetic Autonomic Nervous System Activity

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*Dysregulation of the autonomic nervous system (ANS) and the hypothalamic–pituitary–adrenal (HPA) axis has been implicated in psychiatric disorders. Music therapy (MT) has been shown to modulate heart-rate variability (HRV) and salivary stress markers, physiological markers of the ANS and HPA axes, respectively. Given the prominent role of arousal and stress physiology in many psychiatric disorders, MT has the potential to provide therapeutic benefits in psychiatry. Active MT requires patients to engage rhythmically with music; in contrast, passive MT requires patients to listen to music, eliminating the rhythmic movement seen in active MT. Yet, it remains unknown whether active or passive MT differentially modulates arousal and stress physiology. We contrasted the effects of active and passive MT experiences to examine the differential impact of rhythmic movement on the ANS and HPA axes in healthy participants. Individuals (*N = *16) participated in a crossover study of 40 min of an active MT and a passive MT intervention. HRV recordings and saliva samples were collected both before and after each intervention. The high-frequency component (HF) and the ratio of low-frequency to high-frequency components (LF/HF) were calculated as cardiac markers of parasympathetic and sympathetic ANS activation, respectively. Saliva samples were analyzed for alpha-amylase and cortisol, markers of the sympathetic ANS and HPA axes, respectively. Active MT and passive MT interventions differentially modulated LF/HF, where active MT decreased LF/HF and passive MT increased LF/HF. These results indicate that MT affects the ANS and suggests that differences in engagement between active MT and passive MT lead to a differential modulation of the sympathetic ANS.*

Keywords: *music therapy, quantitative evaluation, research design, mood*

Introduction

Music therapy (MT) is an engaging, multi-faceted, mind-body therapeutic treatment approach that is used to address a variety of physiological and neurological symptoms (Aldridge, 1996; Berger,

2002, 2016; Faulkner, 2017; Hanser, 2016; Schneck & Berger, 2006; Thaut, McIntosh, & Hoemberg, 2014; Tierney & Kraus, 2014). MT has developmental, rehabilitative, medical, and educational applications, and can be used to improve the quality of life for individuals with illnesses such as post-traumatic stress disorder, stroke, and depression (Aalbers et al., 2017; Landis-Shack, 2017; Sihvonen et al., 2017). Despite apparent clinical benefits, the mechanism of action underlying MT is not clearly understood. In addition, variables such as tempo, rhythm, clinical interaction, and musical content are often inconsistently controlled in many clinical and research practices (Aalbers et al., 2017; Leubner & Hinterberger, 2017). MT research that utilizes standardized treatment protocols with targeted mechanistic outcomes is needed to support the practice of MT and explain the therapeutic benefits that have been reported. In this study, we contrast two different MT treatment modalities—active MT and passive MT—to examine their effects on physiological systems and provide insight into whether different mechanisms may underlie each intervention.

Active MT includes music interventions that involve interactive engagement, playing, and creation of music by a patient with a clinician. In contrast, passive MT interventions involve patients listening to music, rather than actively participating with or producing it. Distinctions between these two types of MT interventions are often not made clear in the literature (Bringas et al., 2015; Doro, Neto, Cunha, & Doro, 2017; de la Rubia Orti et al., 2017). Some research has stressed a distinction between the two (Atiwannapat, Thaipisuttikul, Poopityastaporn, & Katekaew, 2016; Erkkila et al., 2011); yet, differences between active and passive interventions vary and comparative studies that isolate specific components of musical engagement have yet to be conducted.

Rhythm, a defining feature of music and hence MT, necessarily plays a differential role in active and passive MT intervention. In passive MT, the engagement of a patient is restricted to the rhythmic perception of music, whereas in active MT, both rhythmic perception and action are engaged as a patient coordinates motor actions with the perceived music. This process of integrating periodic input and output is termed *rhythmic movement* here, and has the potential to alter how MT interventions produce efficacy. Carefully controlled comparative studies would allow for

the isolation of component differences between active and passive MT interventions, specifically the presence of behavioral rhythmic movement with music.

Music-Induced Physiological Modulation

We argue that studying physiological systems in comparative MT intervention studies is critical to defining the component differences between interventions and how these differences impact physiology. Intervention components that modulate physiological systems can be translated into effective clinical MT interventions, allowing for the distillation of MT practice to crucial components with evidence-based biological targets, ultimately leading to an increase in the clinical efficacy of MT. Specifically, the autonomic nervous system (ANS) and hypothalamic–pituitary–adrenal (HPA) axis are useful physiological systems to examine in comparative MT research, as they index overall stress and arousal levels, are often altered in psychiatric disorders, and are easily assayed by noninvasive physiological markers.

The ANS is a system that is devoted to regulating arousal and maintaining physiological homeostasis; it is comprised of two distinct systems—parasympathetic and sympathetic. Both systems are tonically active and regulate overall arousal. The sympathetic ANS predominates during high arousal "fight or flight" responses, while the parasympathetic ANS predominates during a relaxed resting state (Chen et al., 2017; Jangpangi, Bandhu, Kataria, & Gandhi, 2016). A variety of psychiatric disorders, including depression and generalized anxiety, are characterized by an imbalance in ANS activity, where individuals exhibit elevated sympathetic ANS activity, and reduced parasympathetic activity, indicating a state of pathologically elevated arousal (Alvares, Quintana, Hickie, & Guastella, 2016).

The HPA axis is a system that mediates the stress response. It primarily produces the hormone cortisol in response to stressful events. Individuals with psychiatric illnesses such as depression and generalized anxiety are known to have hyperactive HPA axes, and consequently elevated levels of cortisol (Pariante & Lightman, 2008). Sympathetic ANS activity can also lead to the activation of the HPA axis, linking the physiological responses of stress and arousal (Ulrich-Lai & Herman, 2009).

Previous work has demonstrated that music can modulate heart-rate variability (HRV) parameters known to be physiological markers of the ANS (Koelsch & Jancke, 2015). HRV measures have been frequently used as noninvasive and convenient measures of ANS activation (Billman, Huikuri, Sacha, & Trimmel, 2015; Chen et al., 2017). The high-frequency component power (HF) of the frequency domain HRV has been associated with parasympathetic ANS activation (Shaffer & Ginsberg, 2017). In contrast, the ratio of the low-frequency component to the high-frequency component power (LF/HF) can be extracted and has been associated with sympathetic ANS activation (Shaffer & Ginsberg, 2017). MT interventions that attempt to reduce pathological stress and arousal would ideally reduce LF/HF and increase HF, indicating a reduction in sympathetic and enhancement of parasympathetic ANS activation, respectively.

MT interventions have also been suggested to modulate salivary markers of the ANS and HPA axes (Thoma et al., 2013). Salivary α-amylase is a marker of stress response that has been associated with sympathetic ANS activation (Nater et al., 2005), while another salivary stress response marker, cortisol, is associated with HPA-axis activation (Pariante & Lightman, 2008). MT interventions that attempt to reduce pathological stress and arousal would ideally reduce salivary cortisol and α-amylase levels, indicating a reduction in HPA axis and sympathetic ANS activation, respectively. Thoma and colleagues (2013) had participants listen to relaxing music, rippling water, or nothing at all before taking a stress test. The cortisol response to the stressor was significantly different between all three conditions, and salivary α-amylase returned to baseline after the stress test more quickly when participants had listened to music, rather than simply resting, demonstrating the ability of music to modulate salivary stress markers.

Purpose

In this study, we compared the ability of active MT and passive MT interventions to modulate physiological markers—cortisol, α-amylase, HF, and LF/HF—in healthy adults. Both interventions were designed with the goal of reducing physiological stress and arousal, making them representative of a clinical intervention that would be pertinent for psychiatric populations where these

physiological systems are dysregulated. The effects of MT in psychiatric populations have been previously studied, but our experimental isolation of different mechanisms of MT is novel. The two interventions had parallel structures and protocols such that rhythmic movement with music was the primary difference between the active MT and passive MT intervention. Other potential differences, such as the amount of interpersonal interaction between participant and clinician, did exist between the two protocols. However, these differences are essential components of the interventions that we contrasted and are necessary to keep each protocol relevant to clinical practice. The manipulation of behavioral rhythmic movement between our two protocols and their subsequent comparison is unrelated to the typical clinical practice of MT and represents an experimental manipulation. We hypothesized that a single-session active MT—in comparison to passive MT—would preferentially increases parasympathetic ANS activation, decreases sympathetic ANS activation, and decreases activation of HPA axis. An additional exploratory objective was to see whether the interventions impacted mood and if changes in mood correlated with changes in ANS activity. This study ultimately allows us to examine how the presence of rhythmic movement with music impacts the modulation of physiological systems within the context of a clinical MT intervention.

Methods

Participants

Sixteen healthy adults (12 females, all right handed) participated in two 60-min experimental intervention sessions and were compensated $20 for participating, receiving $10 upon the completion of each session. Participant ages were within the range of 18 to 34 years and all individuals had command of the English language. Participants had no history of neurological or cardiovascular illness and were not taking medications for cardiovascular or neurological disorders. Musical experience was not controlled for because MT interventions are not targeted for specific participant expertise. All participants were recruited from the Chapel Hill area and provided written and informed consent before participating. The study was conducted in the University of North Carolina at

Chapel Hill (UNC-CH) Medical School in a room provided by the Program on Integrative Medicine. The UNC-CH Institutional Review Board approved this study and all methods were performed in accordance with relevant guidelines and regulations. This study was registered on clinicaltrials.gov (NCT03362944).

The research described was conducted to determine whether our previously untested active MT and passive MT interventions could produce differential impacts on physiology. For this reason, we did not calculate a sample size beforehand as the effects of our intervention on physiology were previously unknown. We had to restrict the number of included participants to a small sample size due to limited funding resources. The data obtained from this study can be used to inform future large-scale clinical trials that involve our active and passive MT interventions.

Interventions

In this cross-over designed study, 16 participants underwent a single-session active MT intervention and a single-session passive MT intervention. Both intervention sessions were intended to reduce physiological stress and arousal. Participants were randomized into two balanced groups with respect to session order. Half of the participants underwent the active MT intervention followed by the passive MT intervention, while the other half underwent the passive MT intervention followed by the active MT intervention. This resulted in a total of 16 active MT and 16 passive MT intervention sessions, where each participant experienced both active MT and passive MT once. All intervention sessions were separated by a washout period of at least 1 week to avoid any carryover effects.

The active MT intervention consisted of 40 min of the following rhythmic musical activities in the following order: clinician-guided recorder blowing (10 min), hand-clapping exercises (5 min), improvisational expressive music making on a self-selected variety of available instruments (20 min), and a concluding reflection period during which participants listened to live improvised music performed by the clinician (5 min) (Figure 1). This intervention was designed to reduce stress and arousal through a sequence of relaxation, followed by engagement, and concluding with relaxation during clinician-guided music making. Participants started with breathing exercises to engage their core muscles and respiratory

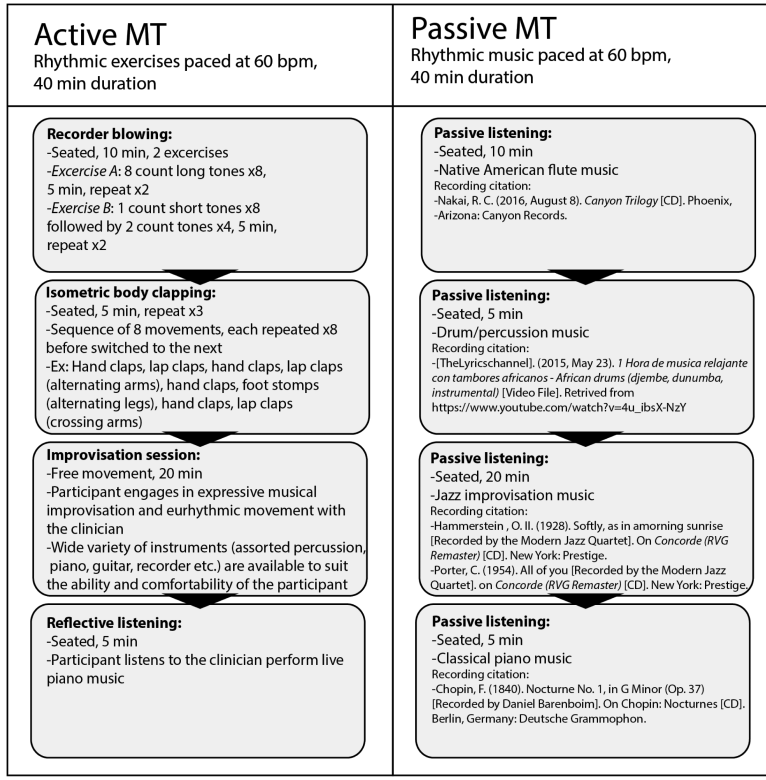

Figure 1.
A comparative view of active MT and passive MT interventions.

system. Seated isometric clapping was then done to engage the extremities of the participant. Improvisation then provided the participant with the ability to engage with instruments and music making of their choosing for much of the rest of the session. Through these selected exercises, the intervention systematically guides the participant through a large range of motion and then encourages the participant to entrain and move in the manner that feels most comfortable through improvisatory engagement with music. Finally, the participant is instructed to relax and reflect upon their experience during the reflective listening, facilitating a final relaxed physiological state with low stress and arousal. All sections of the active MT intervention involve rhythmic movement processes,

with the exception of the reflective listening. This section is intentionally designed to have no rhythmic movement to relax the participant into a calm physiological state upon the conclusion of the intervention. All activities were paced to a constant 60 bpm pulse. This choice in pulse was motivated by previous clinical experience and the hypothesis that tempos slower that physiological heart rate may enhance parasympathetic and suppress sympathetic ANS activation. A wide selection of instruments (piano, guitar, recorder, and assorted percussion including drums, auxiliary, and pitched metallophones) was available for the improvisational segment of the active MT session to meet the ability, comfort, curiosity, and interests of each participant. A board-certified music therapist was present and conducted all of the active MT intervention sessions.

The passive MT intervention consisted of 40 min of passive music listening, during which participants listened to clinician-selected rhythmic musical excerpts matched in style, timbre, length, and tempo to the active MT intervention (Figure 1). This sequence of matched musical excerpts was intended to mirror the physiological excitement and relaxation induced by the active MT intervention, giving the passive MT intervention the same goal of reducing physiological stress and arousal, while not emphasizing the role of rhythmic movement (i.e., not moving to the music). The tempo of all musical selections was adjusted using Garageband (v10.2.0) audio-editing software (Apple, Cupertino, California) so that they were all paced at a constant pulse of 60 bpm. All participants listened to the same material. Participants were seated 4 feet in front of a stereo speaker system and asked to relax and enjoy the 40 min of audio. Audio was presented at 60 decibels. Sessions were conducted by a researcher who was trained by a board-certified music therapist to administer passive MT.

Experimental Measures

HRV and salivary markers were assessed both pre- and post-session for each participant at each experimental session. HRV was assayed through 5-min heart rate recordings taken on a first-beat heart rate monitor (Jyvaskyla, Finland). Each 5-min recording was analyzed for high-frequency power (HF) and ratio of low-frequency to high-frequency power (LF/HF) HRV components in Kubios (Kuopio, Finland). Salivary cortisol and α-amylase were

collected through an oral collection swab that was held under the participants tongue for 2 min. Samples were immediately refrigerated and shipped in bulk to Salimetrics (Carlsbad, California) for analysis after the completion of data collection.

In addition to collecting primary physiological measures described above, other exploratory measures were collected to examine potential effects of approach motivation, musical experience, handedness, and mood. The BIS/BAS (Carver & White, 1994), Goldsmiths Musical Sophistication Index (Müllensiefen, Gingras, Musil, & Stewart, 2014), and a handedness questionnaire (Oldfield, 1971) were administered at the beginning of the initial experimental session. The Profile of Mood States (POMS) questionnaire (Grove, 1992) was administered pre- and post-sessions for both. Qualitative observational notes were recorded by an experimenter for the duration of each intervention session.

Procedure

Participants were asked not to eat or drink anything within an hour before participation in an experimental session, as foods or beverages consumed immediately before each visit had the potential to impact the salivary markers that were collected. Upon arrival, participants provided informed consent and completed the initial battery of questionnaires. Salivary markers were assayed, followed by HRV. During all 5-min HRV recordings, participants were given unrelated reading material to occupy them and control behavior for the duration of the recording.

The 40-min intervention session—either Active MT or Passive MT—was then administered. In the active MT intervention session, the first recorder blowing exercise was completed two times, followed by two repetitions of the second recorder blowing exercise. The isometric clapping exercise was completed three times, followed by the improvisation. The improvisation lasted 20 min on average and was adjusted in length based on the amount of time it took to complete the previous exercises so that total intervention time was 40 min. This was followed by 5-min of reflective listening of the clinician playing the piano or guitar. In the passive MT intervention, participants were seated and listened to 40 min of music matched in style and timbre to the components of the active MT intervention.

Upon completion of the 40-min intervention, a 5-min HRV recording was taken and saliva samples were collected. The POMS was then re-administered. In the second session, participants underwent the same procedure, only they experienced the intervention that they had previously not undergone in the first session. All initial questionnaires other than the POMS were omitted from the second session.

Data Analysis

Data were analyzed using custom MATLAB (Mathworks, Inc., Natick, MA, R2016a) and R scripts (R Core Team, 2013). Statistical analyses and figures were generated using custom R scripts using "ggplot2," "ggpubr," and "stats" packages. All physiological measures were normalized through a log-transformation of the data.

Differences in pre-session, baseline values were calculated across condition (active MT vs. passive MT) and session (first session vs. second session), with paired sample *t*-tests, and across sequence (active MT first session vs. active MT second session, passive MT first session vs. passive MT second session), with two-sample *t*-tests. The pre-registered outcomes for this study (NCT03362944) consisted of the change pre- to post-session for active MT and passive MT for all physiological measures (primary outcomes) and the difference in post-session values for active MT and passive MT for all physiological measures (secondary outcomes). Since a difference in normalized pre-session measures was found for condition in one of the markers, we restricted our subsequent analyses to examining the change pre- to post-session (primary outcomes) and did not examine differences in post-session values (secondary outcomes), as absolute differences in post-session values may be mediated by baseline pre-session values, while relative changes pre- to post-session can still be accurately quantified regardless of baseline differences.

The change between normalized pre- and post-session measures was calculated for all markers (cortisol, α-amylase, HF, LF/HF, as well the POMS questionnaire results) in both the active MT and passive MT interventions. Physiological and mood questionnaire measurements were statistically analyzed with an ANOVA that assessed the significance of intervention condition (active MT vs. passive MT), session (first vs. second) and sequence (a session by

condition interaction). If a session by condition interaction was significant (an effect for sequence), then results were reported by session. If there was no session by condition interaction, then a main effect for condition was looked for. Main effects of condition from the ANOVA were reported. If a main effect of condition was not found, then exploratory paired sample *t*-tests were used to compare normalized pre- and post-session values for both active MT and passive MT intervention conditions separately. Exploratory correlations were conducted on the POMS questionnaire data with HRV and saliva marker outcomes. Bonferroni correction was used to control for Type I error and adjust *p*-values of statistical tests run on the questionnaire data. The datasets generated and analyzed in this study are available from the corresponding author.

Results

Distribution of Physiological Markers

Table 1 depicts the mean and SD of raw pre- and post-session values for both active MT and passive MT intervention conditions. Distribution plots of individual participant data can be found in Supplementary Figure 1.

Pre-session Values Are Consistent Across Session and Condition

To ensure that pre-session differences did not influence our findings, the normalized pre-session values for each physiological marker (cortisol, α-amylase, HF, LF/HF) were compared with paired sample *t*-tests across sessions (first session vs. second session), condition (active MT vs. passive MT), and with two-sample *t*-tests across sequence (active MT first session vs. active MT second session, passive MT first session vs. passive MT second session). A significant difference in LF/HF was found for the comparison across condition (paired sample *t*-test, $p = .02$; all other *p*-values >.10). For this reason, we restricted our analyses to the changes in physiological markers pre- to post-session (preregistered primary outcomes), and did not examine differences in post-session physiological markers (preregistered secondary outcomes), as absolute differences in post-session values may be influenced by differences in pre-session values. In all other instances, pre-session values were comparable across session, condition, and sequence. Despite the lack of statistically significant

Table 1

Descriptive Statistics of Physiological and Questionnaire Data

Physiological Marker	Mean	SD	Median	IQR
Cortisol (μg/dL) (N = 16)				
Active pre	0.2280	0.1560	0.2125	0.1253
Active post	0.1784	0.0884	0.1588	0.1208
Passive pre	0.2013	0.0835	0.1885	0.1167
Passive post	0.1839	0.0902	0.1685	0.1073
α-Amylase (U/mL) (N = 16)				
Active pre	94.04	67.43	76.92	105.5
Active post	75.02	62.87	56.83	72.98
Passive pre	61.24	66.27	45.02	27.06
Passive post	57.31	45.31	44.61	53.63
HF (N = 16)				
Active pre	6267	1437	820.1	2040
Active post	1862	1723	1309	1963
Passive pre	1200	1190	813.8	1178
Passive post	1220	877.0	1018	1302
LF/HF (N = 16)				
Active pre	2.266	2.071	1.428	2.210
Active post	1.344	1.141	1.035	0.9980
Passive pre	1.397	1.288	1.015	1.673
Passive post	1.753	1.459	1.100	1.444
POMS TMD (N = 16)				
Active pre	90.31	8.546	92.00	12.25
Active post	93.13	14.81	89.50	8.75
Passive pre	83.69	7.905	82.00	11.75
Passive post	90.69	7.364	90.50	8.5

differences seen, we highlight the fact that the SD of our normalized measures (Table 1) is generally large relative to the means. Higher SDs mean that larger sample sizes would be needed to have sufficient statistical power to detect condition effects, provided that all characteristics of the data remained unchanged (such as the effect size of interest, Type I error, and power).

LF/HF: Interventions Oppositely Modulate ANS

The change in normalized LF/HF pre- to post-sessions was assessed with a 2 × 2 ANOVA with factors session (within-participant, first session, second session) and condition (within-participant, active MT, passive MT), revealing a main effect for condition ($F(1, 27) = 8.206$, $p = .00783$, $\eta p^2 = .227$). The mean normalized LF/HF

TABLE 2

Correlations between change in POMS TMD and change in physiological markers over the course of intervention sessions.

Physiological Marker	Rho	*p*-value
Cortisol ($N = 16$)		
Active	−.1183	.6627
Passive	.1665	.5376
α-Amylase ($N = 16$)		
Active	−.0916	.7357
Passive	.0162	.9525
HF ($N = 16$)		
Active	−.1449	.5924
Passive	−.6618	.0052[a]
LF/HF ($N = 16$)		
Active	.6209	.0103[b]
Passive	.5763	.0195[b]

[a]Statistical significance after Bonferroni correction (0.05/8, adjusted $\alpha = 0.00625$).
[b]Statistical significance.

change was less (−.3872) in the active MT intervention condition than in the passive MT intervention condition (.3731), indicating that the active MT intervention decreased LF/HF, while the passive MT intervention increased it (Figure 2A). There were no observed effects for session or sequence.

HF: No Evidence for Condition Effect

The change in normalized HF pre to post sessions was assessed with a 2 × 2 ANOVA with factors session (within-participant, first session, second session) and condition (within-participant, active MT, passive MT), producing no significant effects (condition effect, $F(1, 27) = 0.004$, $p = .952$, $\eta_p^2 = .000132$). Though there was no effect for condition, we performed paired sample *t*-tests on the normalized HF pre- and post-session values for active MT and passive MT intervention data separately, allowing us to see whether either intervention produced a significant change on its own. None of the paired sample *t*-tests produced a significant effect. We found no evidence that HF was impacted by either intervention (Figure 2B).

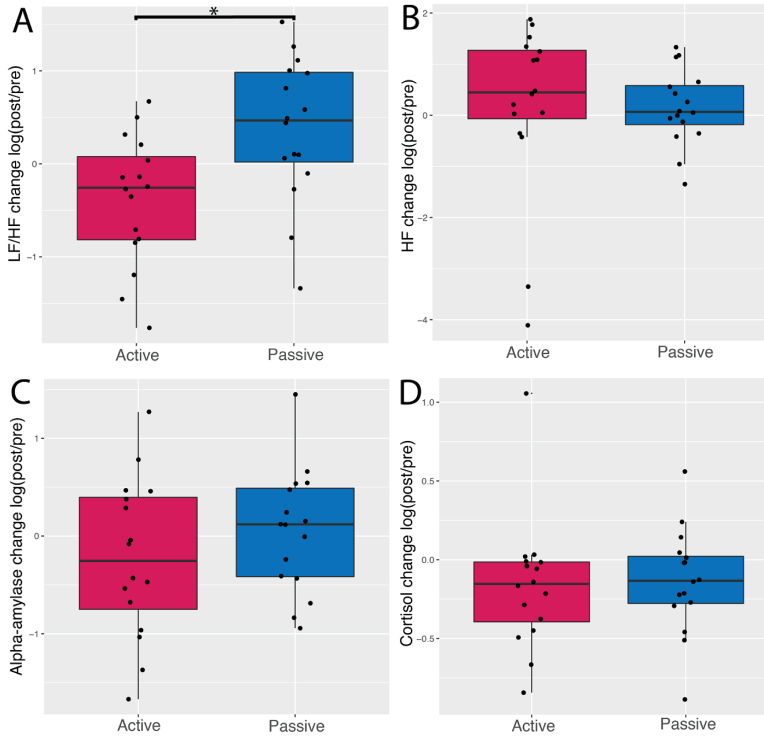

FIGURE 2.
Change in physiological markers over the course of the active MT and the passive MT intervention sessions. (A) Change in normalized LF/HF for the active MT and passive MT groups. Asterisk indicates statistically significant differences between the active MT and the passive MT groups. (B) Change in normalized HF for the active MT and passive MT groups. (C) Change in normalized salivary α-amylase (U/mL) for the active MT and passive MT groups. (D) Change in normalized salivary cortisol (μg/dL) for the active MT and passive MT groups.

α-Amylase: No Evidence for Condition Effect

The change in normalized α-amylase pre- to postsessions was assessed with a 2 × 2 ANOVA with factors session (within-participant, first session, second session) and condition (within-participant, active MT, passive MT) revealing no effects (condition effect, $F(1,27) = 1.216$, $p = .280$, $\eta_p^2 = .0416$). Though there was no effect for condition, we performed paired sample *t*-tests on the normalized α-amylase pre- and post-session values for active MT and passive MT intervention data separately, allowing us to see

whether either intervention produced a significant change on its own. None of the paired sample *t*-tests produced a significant effect. We found no evidence that α-amylase was impacted by either intervention (Figure 2C).

Cortisol: No Evidence for Condition Effect

The change in normalized cortisol pre- to post-sessions was assessed with a 2 × 2 ANOVA with factors session (within-participant, first session, second session) and condition (within-participant, active MT, passive MT), producing no significant effects (condition effect, $F(1, 27) = 0.054$, $p = .817$, $\eta_p^2 = .00194$). Though there was no effect for condition, we performed paired sample *t*-tests on the normalized cortisol pre- and post-session values for active MT and passive MT intervention data separately, allowing us to see whether either intervention produced a significant change on its own. None of the paired sample *t*-tests produced a significant effect. We found no evidence that cortisol was impacted by either intervention (Figure 2D).

It is well known that salivary cortisol levels are impacted by circadian rhythm (Dorn, 2007). Of our 32 intervention sessions, 25 occurred between 3 and 6 pm, but another 7 took place anywhere between 9:30 a.m. and 2 p.m. To account for this, a post hoc analysis was conducted where participants were split into early and late groups. If at least one of their sessions was considered early, then that participant was sorted into the early group (early, 9:30 am to 2 pm, $n = 6$, mean pre-session value = −1.320518, SD of pre-session values = 0.4386508; late, 3 to 6 pm, $n = 10$, mean pre-session value = −1.89907, SD of pre-session values = 0.516932). Normalized pre-session and change values were compared between both groups. A significant difference was seen between the early and late groups for cortisol pre-session values (two-sample *t*-test, $p = .0023$). To verify that our analyses of change in cortisol were valid and not biased by these six individuals with early saliva collection times, the same ANOVA analyses were repeated excluding these six individuals. This analysis produced no effects (condition effect $F(1, 27) = 0.663$, $p = .428$, $\eta_p^2 = .0399$), providing no evidence that cortisol was impacted by either intervention.

Changes in Mood Correlate With Changes in ANS Activity

The change in POMS TMD score pre- to post-sessions was assessed with a 2 × 2 ANOVA with factors session (within-participant, first session, second session) and condition (within-participant, active MT, passive MT), producing no significant effects (condition effect, $F(1,27) = 1.405$, $p = .246$, $\eta_p^2 = .0478$). Though there was no effect for condition, we performed paired sample *t*-tests on the POMS TMD score pre- and post-session values for active MT and passive MT intervention data separately, allowing us to see whether either intervention produced a significant change on its own. None of the paired sample *t*-tests produced a significant effect.

In an exploratory correlation analysis, we performed Spearman correlations comparing the change in TMD and the change physiological markers (HF, LF/HF, cortisol, α-amylase) over the course of interventions for participants in the active MT and passive MT intervention conditions (Table 2). Statistically significant correlations were found between the change in TMD and change in HF in the passive MT intervention condition (Rho = –0.6618, $p = .0052$), and change in LF/HF in and active MT (Rho = 0.6209, $p = 0.0103$) and passive MT intervention conditions (Rho = 0.5763, $p = .0195$). After a Bonferroni correction (0.05/8, adjusted $\alpha = 0.00625$), only the correlation seen between change in TMD and change in HF in the Passive MT intervention condition remained significant. These results present exploratory evidence that changes in mood correlates with HRV frequency domain parameters, and that increased parasympathetic and decreased sympathetic activation are associated with improved mood.

Discussion

In this study, we compared the effects of our active MT and passive MT interventions on physiological markers associated with the ANS and HPA axes activity in healthy participants. We implemented a cross-over design, where each individual participated in a single session of the active MT and passive MT intervention separated by at least a week. Physiological measurements—salivary cortisol and α-amylase, HF and LF/HF—were taken immediately before and after each intervention session. We found that the active MT and passive MT interventions differentially impact LF/HF,

with the active MT intervention decreasing LF/HF and the passive MT intervention increasing LF/HF.

The differential impact of intervention condition on LF/HF suggests that the differences isolated between active MT and passive MT interventions—rhythmic movement with music—lead to contrasting modulation of the sympathetic ANS associated with LF/HF (Shaffer & Ginsberg, 2017). Since the active MT intervention decreased LF/HF, rhythmic movement with music reduced sympathetic ANS activity; in contrast, since the passive MT intervention increased LF/HF, passive listening without rhythmic movement increased sympathetic ANS activity. Thus, the presence of rhythmic movement with music seems to change the way the sympathetic ANS responds to rhythm-based MT interventions.

Although the addition of rhythmic movement to MT interventions produced a decrease in sympathetic ANS activity, this does not directly explain why a lack of rhythmic movement would increase sympathetic ANS activity. In our study, participants could have found the 40 min of music listening tiresome or boring, leading to agitation or a desire to leave while waiting through the intervention and potentially greater sympathetic ANS activity. The lack of participant agency—for example participant-selected music or duration—could have also lead to an adverse intervention experience. In contrast, the active MT intervention involved a variety of tasks, providing musical and social engagement, movement, instrument preferences, as well as improvisational expression, giving the participant more agency over the intervention experience. These differences could have made the active MT intervention more enjoyable and less agitating, preventing an increase in sympathetic ANS activity.

Rhythm is an important component of music that has been used in MT interventions to address a range of needs associated with various disorders (Aldridge, 1996; Berger, 2012; Faulkner, 2017; Hanser, 2016; Thaut et al., 2014; Tierney & Kraus, 2014). Rhythm-based MT interventions are hypothesized to utilize the process of entrainment—the coordination of the internally generated rhythm of an individual with an external rhythm—to organize motor and neural activity through patient interaction with a structured musical pulse (Berger, 2016; Slater, Ashley, Tierney, & Kraus, 2018; Thaut et al., 2014; Thut, Schyns, & Gross, 2011; Tierney,

White-Schwoch, MacLean, & Kraus, 2017). Motor entrainment is potentially explicitly driven in active but not passive MT interventions, which instead emphasize passive listening without motor coordination. The process of motor entrainment likely recruits additional physiological and mental functions, such as mental tracking of the musical pulse, the execution of movements in time with the music to produce musical sound, proprioceptive feedback from rhythmic body movements, auditory feedback from sounds created on instruments, and interpersonal synchronization between patient and clinician. The incorporation of these additional components should lead to a unique activation of neural and physiological systems, producing a novel intervention experience that has the potential to modulate and target physiological systems. The ability of active MT to target physiology makes it a promising intervention for psychiatric disorders, such as depression and generalized anxiety, that exhibit aberrances in physiological systems (Alvares et al., 2016).

Growing evidence has shown that musical rhythms engage and modulate network brain oscillations, making entrainment a potential mechanism of therapeutic efficacy (Fujioka, Trainor, Large, & Ross, 2009; Iversen, Repp, & Patel, 2009; Nozaradan, Peretz, Missal, & Mouraux, 2011; Nozaradan, Peretz, & Mouraux, 2012; Snyder & Large, 2005; Stefanics et al., 2010; Tal et al., 2017). Functional imaging studies have also demonstrated that novel "music networks" are activated when participants engage with music (Bangert et al., 2006; Lahav, Saltzman, & Schlaug, 2007). These networks have been implicated in action–perception coupling of sensory and motor processes (Hasegawa et al., 2004; Haslinger et al., 2005), leading us to hypothesize that rhythmic action–perception coupling (RAPC) may be a driving mechanism underlying the rhythmic movement that is specific to our active MT intervention.

We found that rhythmic movement with music (active MT) decreased sympathetic ANS activity while passive listening (passive MT) increased sympathetic ANS activity in healthy subjects. Although it remains to be studied whether similar differential modulation occurs in a patient population, our results support future investigation of the effect of active MT and passive MT on the ANS in patients with depression, who are characterized elevated sympathetic ANS activity. Extrapolated to the context of

depression, the decreased sympathetic ANS activation produced by the active MT intervention can be seen as a modulation of the ANS to a physiological state less associated with depression, while the passive MT intervention can be seen as modulating the ANS to a state that is more associated with depression. In line with this, we also found that changes in mood reflected the differential modulation of ANS activity, where greater mood disturbance was correlated with increased sympathetic ANS activation and decreased parasympathetic activation, consistent with the ANS aberrances seen in patients with depression (Chen et al., 2017; Jangpangi et al., 2016). This suggests that our active MT interventions may be potentially more ideal than our passive MT intervention for targeting the ANS in people with depression. Active MT may also be preferable to passive MT for use with other psychiatric disorders that exhibit pathologically elevated sympathetic ANS activity, such as generalized anxiety (Alvares et al., 2016).

Overall, our results suggest that MT clinicians could implement active MT interventions that incorporate rhythmic movement processes to preferentially engage and reduce sympathetic ANS activation in their patients. We acknowledge that our findings are preliminary and protocol-specific, and that deviations from our active MT intervention may lead to an inability to generalize predicted effects of our active MT to patient populations. Since the population we examined in this study consisted of healthy individuals, it remains unknown whether our findings would be replicated in a clinical context. Future research needs to be conducted to verify that active MT interventions preferentially engage and reduce sympathetic ANS activation in patient populations.

Limitations

As with any scientific study, our design has several limitations. Although our comparative intervention protocols attempted to isolate rhythmic movement with music between active MT and passive MT interventions, we acknowledge that potential confounds exist. Movement and exercise have been known to influence salivary markers and HRV (Cozma et al., 2017; Shaffer & Ginsberg, 2017), suggesting that differences between active MT and passive MT interventions could have been driven by motion performed through rhythmic movement, in spite of the presence of music.

Future studies should employ a third group that controls for motor engagement in a nonmusical way to ensure that effects are driven by music-related engagement. Changes in our physiological outcomes could have also been modulated by shifts in mood produced by the interventions, as opposed to rhythmic movement, as mood and ANS change were correlated. Interpersonal interaction or other unconsidered components of the active MT and passive MT interventions could have contributed to mood shifts that could then have downstream impacts on physiology, producing the differential effect of active MT and passive MT intervention conditions on the sympathetic ANS. Additionally, the last segment of the active MT intervention consisted of a reflective listening period that resembles the passive listening in the passive MT intervention; this could have lead to similarity between the active MT and passive MT interventions when we intended to implement contrasting segments that isolated rhythmic movement.

We also point out that this study employed a single session of each intervention. Rigorous longitudinal MT clinical trials are necessary to validate our results, as participant familiarity with the intervention and long-term exposure to RAPC have the potential to change physiological response to MT. Null findings for salivary cortisol can be explained by inter-individual variability in circadian rhythm and hence cortisol level (Dorn, 2007). In future studies, assaying participant cortisol levels at a number of time points throughout a given day would allow for a more comprehensive assessment of cortisol response to the intervention, letting us characterize how baseline cortisol levels fluctuate with participant circadian rhythm. Respiration is also known to impact HRV (Shaffer & Ginsberg, 2017). Future studies that monitor respiration rate during HRV recordings and during interventions would allow for an assessment of how respiration influences physiological markers. Ultimately, more research is needed to assess the differences between Active MT and Passive MT interventions, their effects on physiological systems, and their ability to produce efficacy.

Conclusions

In summary, we experimentally isolated rhythmic movement in MT by contrasting within participant response to single-session active MT and passive MT interventions. Physiological markers

collected before and after each intervention session indicate that MT interventions can successfully target the ANS, and that active MT reduces sympathetic ANS activity while passive MT increases it. This suggests that rhythmic movement with music is a key component of MT interventions, leading to a differential modulation of physiology.

Supplementary Data

Supplementary data are available at *Journal of Music Therapy* online.

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