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MUSIC ENHANCES THE EFFECT OF POSITIVE EMOTIONAL STATES ON SALIVARY IgA

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SUMMARY

This study examines the effects of music and positive emotional states on autonomic and immune functions in normal, healthy individuals. Autonomic activity was assessed using power spectral density analysis of heart rate variability, and salivary IgA was used as a marker of immunity. The effects of rock, new age and designer music were examined alone, and in conjunction with a self-induced positive emotional state. The results indicate that only the designer music and the self-induced state of appreciation produced a significant increase in autonomic activity and salivary IgA (S-IgA). In addition, the combination of the designer music and the self-induced appreciation produced a much greater immunoenhancement than either of these two conditions alone. We conclude that music can be designed to enhance the beneficial effects of positive emotional states on immunity, and that this effect may be mediated by the autonomic nervous system. These data raise the tantalizing possibility that music and emotional self-management may have significant health benefits in a variety of clinical situations in which there is immunosuppression and autonomic imbalance.

KEY WORDS—heart rate variability; S-IgA; music; autonomic nervous system; emotion; self-regulation

It is well recognized that mental and emotional activity can alter autonomic nervous system (ANS) function.[1,2] Similarly the ANS has been shown to profoundly affect the cardiovascular,[3] neuroendocrine[4] and immune functions.[5] It has been suggested that the immunosuppression known to occur during negative emotional states, such as bereavement, depression,[6,7] or anger,[8] and the immunoenhancement associated with positive emotional states[8,9] may be mediated, in part, by the ANS.[10] It is also well recognized that music can alter mood and emotional states.[11–14] However, few studies have examined the effects of music on the immune system,[15,16] and none have determined whether these effects are mediated by the ANS.

We investigated the effects of music on autonomic activity and immunity using power spectral density (PSD) analysis of heart rate variability (HRV). Changes in HRV have been used to characterize a number of psychological illnesses including major depression and panic disorders,[17,18] in addition to its use as a non-invasive test of integrated neurocardiac function.[19] Thus the mathematical transformation of heart rate variability into power spectral density provides a potential link between perception, emotional states, cardiovascular function and immunity. The interaction of mood, immunity and autonomic function has been highlighted by a number of studies showing that anger and hostility increase sympathetic activity[1,20] and suppress immunity,[8,21] while positive emotional states, such as appreciation, enhance parasympathetic activity[2] and boost immunity.[8,22]

Scientific investigation of the use of music as a therapeutic modality began after World War II when its positive effects on emotionally disturbed, shell-shocked individuals were observed. Music therapy research has since demonstrated beneficial effects on the cardiovascular system,[23] pain perception,[24,25] stress[26,27] and endocrine activity.[28] Music therapy has been shown to increase S-IgA in hospitalized children after a single session,[16] or after six weeks of ongoing therapy.[29] Anxiety associated with the stress of surgery was reduced after listening to music,[26,30] and music has been shown to decrease anxiety levels even in the absence of a specific stressor.[31–33] Music has not only been used to promote relaxation[14,34–37] and

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improve mood,[12,38] but has also been employed in a wide variety of other medical settings.[39] The major difficulty in interpreting these data is that music was frequently used in conjunction with either relaxation therapy or guided imagery. Therefore it remains unclear to what extent music, by itself, can modify autonomic or immunological parameters. We have previously demonstrated that self-induced positive emotional states can alter sympathovagal balance[2] and increase S-IgA.[8] In this study we assessed the effects of three different types of music including a new type of music called 'designer music', which is reported by the composer to have a balancing effect on one's mental and emotional states. Specifically, we investigated the effects of a single music session on autonomic function and S-IgA and whether 'designer music' could enhance the autonomic and immunological effects of positive emotional states in a synergistic manner.

METHODOLOGY

Subjects

All 10 individuals (four male and six female) used in this study were in good health and free from respiratory symptoms, colds and headaches. The age of the subjects varied between 27 and 53 yr (mean 41). All individuals maintained the same work schedule, sleep cycle, social environment and diet. None of the subjects were currently taking prescription drugs and all refrained from smoking, exercising and eating or drinking anything except water for at least 8 hours prior to each testing period.

Experimental Design

The autonomic and immunological effects of three categories of music (rock, new age and designer) were assessed in a crossover design in which the subjects acted as their own controls. Each category of music was presented for 15 minutes on separate days with a 2-day washout period between each session. Subjects were instructed as follows: 'Sit quietly and listen to the music, without distracting one another. Listen in a casual, relaxed way, but try to avoid falling asleep. Allow the music to take you wherever it takes you in regards to your moods, feelings, memories, sensations, etc.' In order to determine whether the designer music enhanced the autonomic shifts previously observed during positive emotional states, subjects were asked to consciously focus on generating and maintaining a feeling of heart-focused appreciation for someone or something as best they could throughout the 15-minute period. In addition, autonomic and immunological functions were assessed during the self-induced positive emotional state in the absence of music, and during a control session in which no music was played.

Electrophysiological data

All electrophysiological and immunological recording was commenced at 10 am to minimize diurnal variations. Subjects were seated in straight, highback chairs to minimize postural changes, and fitted with Ag/AgCL disposable ECG electrodes. The positive electrode was located on the left side of the chest over the sixth rib and the reference was placed in the right supraclavicular fossa. Grass model 7P4 ECG amplifiers were used. ECG measurements were recorded throughout the entire 15-minute baseline period, and throughout the 15 minutes of music that followed. This was repeated for each music category. Heart rate (HR), short-term HRV and PSD measures were calculated for the baseline and active listening periods during each session. For the purposes of analysis the baseline and active listening periods were reduced to 5-minute epochs and the HRV and PSD variables for each 5-minute period were averaged to produce a mean baseline and active listening score. Five subjects were recorded per session over 12 sessions. Prior to each session subjects were asked to refrain from talking, falling asleep, exaggerated body movements and intentionally altering their respiration. Subjects were carefully monitored to ensure there were no significant respiratory or postural changes during the session.

HRV Analysis

The short-term HRV signal was in the form of an R–R interval tachogram. PSD was obtained from the mathematical transformation of a series of consecutive but discrete R–R intervals taken from the ECG signal, which was sampled at 256 Hz. All data were digitized by a Bio Pac 16-bit digitizer and software system. Analyses of HRV, fast Fourier transforms (FFT), PSD (calculated as $(BPM)^2/Hz$) and time domain measurements were performed using DADiSP/32 digital signal processing software.

The power spectrum was divided into three major frequency ranges (LF, MF and HF) as previously described.[40] The integral of the power spectrum within each region was calculated. The LF region (0.01–0.05 Hz) is primarily considered a measure of sympathetic activity with a minor parasympathetic component.[40,41] In contrast, the HF region (0.15–0.5 Hz) is associated with respiratory sinus arrhythmia and is almost exclusively due to parasympathetic activity.[40] Power in the MF region is a mixture of sympathetic and parasympathetic activity, but predominantly the latter.[40] The MF region (0.05–0.15 Hz) has also been used as an indirect measure of baroreceptor activity which controls blood pressure.[42]

S-IgA Determinations

Unstimulated, whole saliva samples were collected over a 4-minute period as previously described.[43] Samples were collected immediately before and after each 15-minute music listening period and frozen at −200°C in liquid nitrogen.

Salivary IgA concentrations were determined using the single radial immunodiffusion method as previously described.[44] Briefly, 5 µl aliquots of saliva were diluted 1:2 (v/v) with phosphate buffered saline (Fisher, San Francisco, CA) and loaded into 14 well plates (The Binding Site, San Diego, CA) coated with monospecific sheep anti-human S-IgA (Binding Site, San Diego, CA). The 14 well plates were simultaneously loaded with 15 µl of purified human serum S-IgA standard (Binding Site, San Diego, CA), and incubated at 20°C for 72 hours. The diameter of the precipitation ring was measured using an 8× ocular micrometer to an accuracy of 0.1 mm. All measurements were made blind, by two separate observers, and the average of two separate readings by each observer was calculated. Interobserver variance ranged from 0 to 10%. S-IgA concentration values were estimated by comparison to the standard curve values. All S-IgA concentrations are expressed as mg/l.

The music

The effects of rock and new age music were compared to a new type of music described as 'designer music'.[45,46] The designer music utilized in this study was titled 'Heart Zones'. The composer specifically designed this music 'to facilitate mental and emotional balance and create a calm yet energetic alertness'.[47] The rock and new age music was chosen for its popularity as rated by the Billboard music charts. The mixed selection of rock music consisted of the following songs: 'Start the Car' by Jude Cole, 'Tall Cool One' by Robert Plant, 'Pearl Necklace' by ZZ Top and 'Addicted to that Rush' by Mr. Big. The new age music consisted of the following songs: 'Dance with a Stranger' by Yanni, 'Kathleen's Song' by Ray Lynch and 'Oasis' by Kitaro. All music selections were played on a high quality stereo system, at a level of 70 dB at head height at the focal point of the stereo field.

Self-induced positive emotional states

Self-induced positive emotional states were generated by instructing the subjects to: 'First think of someone or something you feel deep, sincere appreciation towards. Do your best to actually feel appreciation and maintain that feeling for the next 15 minutes; if you find your mind wandering or lose your focus, simply shift your attention back to the feeling of appreciation.'

Statistical analysis

The Friedman two-way ANOVA was used to compare baseline values between sessions for all variables. Comparisons of raw baseline data with those obtained during the three different categories of music were performed using the Wilcoxon signed rank sum test (t), utilizing the sum of the ranks for positive and negative differences for each group. Wilcoxon p-values were taken from the table of critical values for the Wilcoxon signed rank test. Pre and post music S-IgA values were also analysed for significance using the two-tailed Wilcoxon sign-ranked test. Salivary IgA results are expressed as a percentage change relative to baseline values.

RESULTS

HRV analysis

We demonstrated an increase in total autonomic activity (LF+MF+HF) during the 'Heart Zones' music session ($p < 0.02$) (Fig. 1A), the self-induced positive emotional state ($p < 0.01$) (Fig. 1B) and during the session combining the self-induced state of appreciation and 'Heart Zones' music ($p = 0.02$) (Fig. 1C). In contrast, there was no change in total

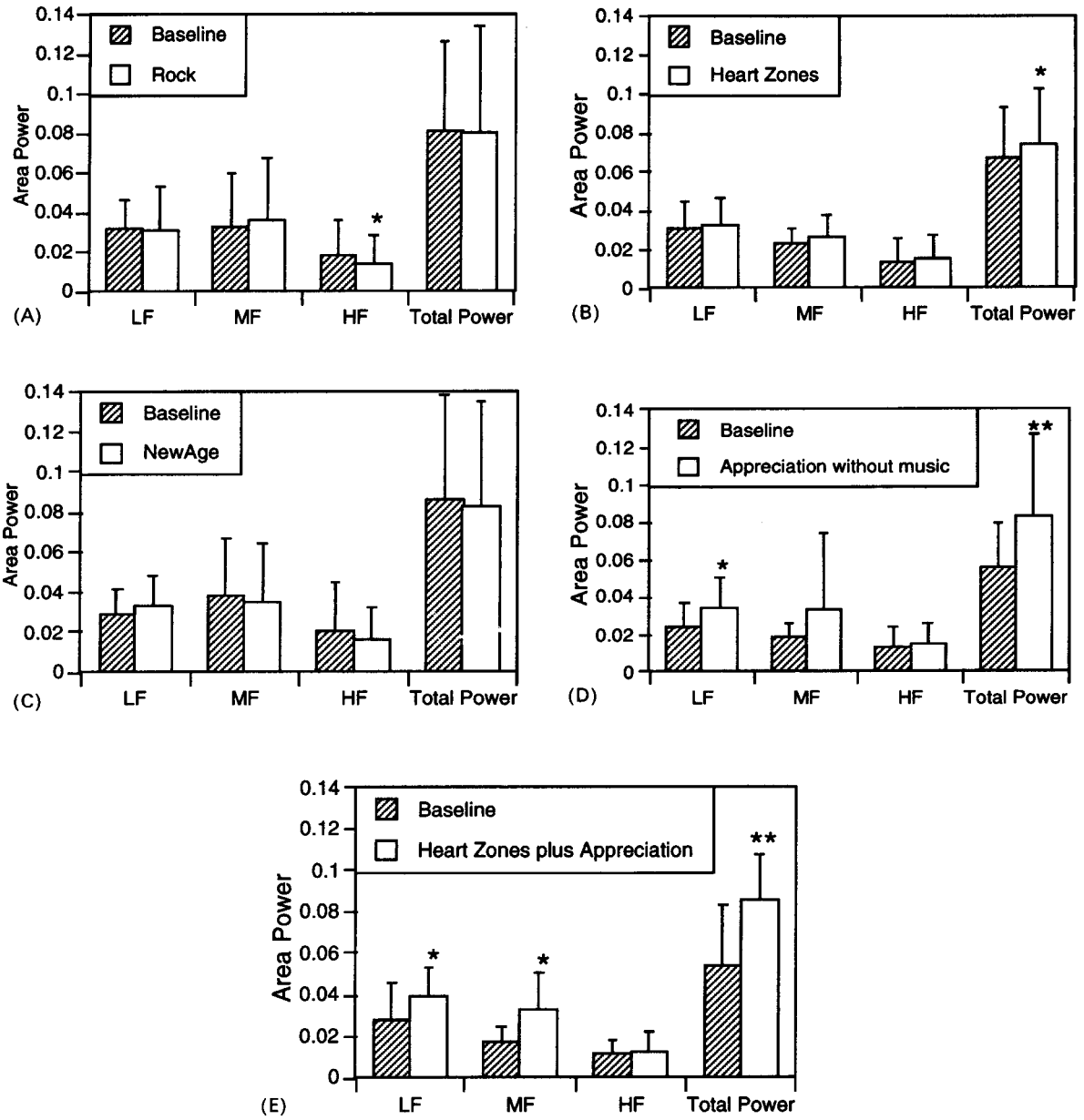

Fig. 1A–E—The graphs in Figs 1A–1C illustrate the autonomic variables LF, MF, HF and total power during the baseline and music periods for each category of music, in 1D during self-induced appreciation, and in 1E while listening to the 'Heart Zones' music during self-induced appreciation. *, Significance $p < 0.05$; **, $p < 0.01$

autonomic activity during the new age or rock music (Figs. 1D and 1E). There was also an increase in the mean HR standard deviation (HRSD) during the self-induced appreciation session ($p = 0.02$) and the session combining appreciation and 'Heart Zones' music ($p = 0.02$). In addition, there was an increase in LF power during appreciation ($p < 0.05$) and also during appreciation while listening to 'Heart Zones' ($p = 0.05$). Appreciation alone produced no effects on the MF power whereas the addition of 'Heart Zones' music to self-induced appreciation

Table 1—Baseline and intervention scores and SDs of heart rate variability measures while listening to the rock music

Variable	Pretest mean	Pretest SD	Post-test mean	Post-test SD	Wilcoxon *t*	*p*
LF	0.031	0.015	0.031	0.022	24	NS
MF	0.032	0.027	0.036	0.033	24	NS
HF	0.018	0.017	0.014	0.014	7	<0.05
Total pwr	0.082	0.044	0.081	0.053	26	NS
HR	65.268	5.948	65.900	6.023	22	NS
HRSD	3.676	0.891	3.601	1.117	21	NS

Table 2—Baseline and intervention scores and SDs of heart rate variability measures while listening to the 'Heart Zones' music

Variable	Pretest mean	Pretest SD	Post-test mean	Post-test SD	Wilcoxon *t*	*p*
LF	0.030	0.014	0.032	0.014	16	NS
MF	0.023	0.008	0.026	0.011	9	NS
HF	0.014	0.012	0.015	0.013	11	NS
Total pwr	0.067	0.026	0.074	0.030	4	<0.02
HR	67.896	4.916	69.240	6.886	14	NS
HRSD	3.457	0.792	3.379	0.881	23	NS

Table 3—Baseline and intervention scores and SDs of heart rate variability measures while listening to the new age music

Variable	Pretest mean	Pretest SD	Post-test mean	Post-test SD	Wilcoxon *t*	*p*
LF	0.029	0.012	0.033	0.015	19	NS
MF	0.037	0.029	0.035	0.029	19	NS
HF	0.020	0.025	0.016	0.016	15	NS
Total pwr	0.087	0.051	0.083	0.053	22	NS
HR	63.300	5.098	63.465	4.420	19	NS
HRSD	3.779	0.958	3.822	1.061	25	NS

produced a significant increase in MF power ($p = 0.02$). We also demonstrated a decrease in HF power during the rock music session ($p < 0.05$). There were no significant differences in any variables between the baseline and the no music control session. The raw data values are shown for each category of music and the control and appreciation only intervention in Tables 1–6.

Salivary IgA

There were no changes in S-IgA concentrations during the no music control, rock or new age music sessions. In contrast, S-IgA increased by 55 per cent ($p < 0.01$) when listening to the 'Heart Zones' music alone. Similarly, self-induced appreciation alone also produced a significant increase in S-IgA of 50 per cent ($p < 0.05$). Self-induced appreciation while simultaneously listening to 'Heart Zones', produced a substantially greater (141 per cent) increase in S-IgA than either 'Heart Zones' or appreciation alone ($p < 0.01$).

DISCUSSION

The relationship between positive and negative emotional states and immunity is complex and

Table 4—Baseline and intervention scores and SDs of heart rate variability measures while feeling appreciation only

Variable	Pretest mean	Pretest SD	Post-test mean	Post-test SD	Wilcoxon *t*	*p*
LF	0.024	0.012	0.034	0.016	7	<0.05
MF	0.019	0.006	0.034	0.040	12	NS
HF	0.013	0.011	0.015	0.011	17	NS
Total pwr	0.056	0.024	0.083	0.044	0	<0.01
HR	67.728	7.515	68.393	7.436	16	NS
HRSD	3.227	0.771	3.759	0.954	5	0.02

Table 5—Baseline and intervention scores and SDs of heart rate variability measures while feeling appreciation and listening to the 'Heart Zones' music

Variable	Pretest mean	Pretest SD	Post-test mean	Post-test SD	Wilcoxon *t*	*p*
LF	0.028	0.018	0.040	0.013	8	0.05
MF	0.017	0.007	0.033	0.018	3	0.01
HF	0.011	0.006	0.013	0.009	26	NS
Total pwr	0.054	0.029	0.085	0.023	5	0.02
HR	68.888	9.019	70.198	8.434	14	NS
HRSD	3.219	0.889	3.914	0.656	5	0.02

Table 6—Heart rate variability measures and SDs during the no music control. Subjects sat quietly for the same time period as when listening to the music

Variable	Pretest mean	Pretest SD	Post-test mean	Post-test SD	Wilcoxon *t*	*p*
LF	0.029	0.015	0.033	0.024	22	NS
MF	0.027	0.018	0.031	0.014	19	NS
HF	0.016	0.015	0.014	0.012	21	NS
Total pwr	0.071	0.036	0.078	0.038	13	NS
HR	66.391	6.407	66.294	6.633	27	NS
HRSD	3.506	0.865	3.639	0.968	11	NS

depends on a number of factors including how the emotional state was induced and the immune parameter measured.[8,48] We have previously shown that self-induced care and compassion produced an increase in S-IgA nearly five times greater than watching a videotape of Mother Teresa,[8] a technique previously used by McClelland to modulate immunity[22]. In the present study, the self-induced state of appreciation also produced a substantial increase in S-IgA, and this increase was significantly enhanced by simultaneously listening to designer music. Several studies have reported the enhancing effects of music on visualization,[15,24,28,49] psychotherapy[50] and self-induced emotional states.[51] For example, music has been shown to enhance the effect of imagery on S-IgA, whereas music in the absence of imagery had no effect.[16] In contrast to the above study, we demonstrated that designer music alone produced a significant increase in S-IgA, whereas the other forms of contemporary music did not.

The mechanisms mediating the immunoenhancing effects of music and positive emotional states on S-IgA are unknown. However, we provide evidence that links the ANS to this process. Specifically, we demonstrated an increase in autonomic spectral power in all experimental conditions where there was an increase in S-IgA.

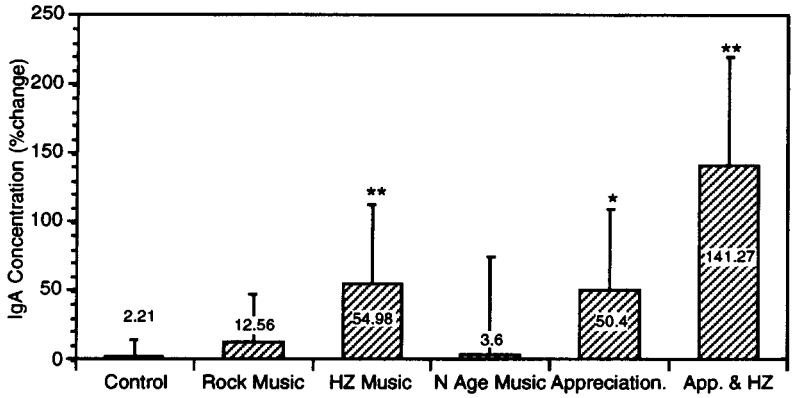

Fig. 2—Comparison of changes in S-IgA levels after listening to 15 minutes of music or a no music control. Values represent per cent change (±SD) relative to baseline levels. Saliva was collected from each individual before and immediately after listening to the music. *, Significance $p < 0.05$; **, $p < 0.01$

The salivary glands are known to receive a rich autonomic innervation;[52] however, whether the secretion of S-IgA is predominantly under the control of sympathetic or parasympathetic innervation is not yet clear.

We have previously shown that positive emotional states reduce sympathetic activity and increase parasympathetic activity, as reflected by an increase in MF and HF power.[2] In the present study, we demonstrated that the positive emotional state of appreciation produced an increase in total autonomic power, but the increase in MF power just failed to reach significance. The failure to demonstrate an increase in parasympathetic activity may be due to the fact that the technique used in this study to produce the positive emotional states was not as refined as that used previously, and the subjects were not as well practised in self-inducing positive emotional states as those used in the previous study. Nevertheless, we were able to demonstrate that the combination of listening to 'Heart Zones' music while in a state of appreciation did produce a significant increase in parasympathetic activity, and this was associated with an increase in S-IgA. Taken together, these data suggest that increased parasympathetic activity may promote S-IgA secretion. This is in keeping with previous research suggesting that stressful environments reduce S-IgA,[21,53] while positive situations enhance S-IgA.[8,22]

While new age music is believed to promote a relaxed state, we were unable to demonstrate any changes in autonomic function or immunity with the selections chosen in this study. In sharp contrast, we provide evidence that the immunoenhancing effects of the designer music used in this study were mediated by the autonomic nervous system, since listening to the 'Heart Zones' music alone produced an increase in total autonomic power. Although a number of studies have demonstrated that music can alter autonomic function,[14,34,54,55] this is, we believe, the first demonstration that the autonomic effects of music can potentiate the immunoenhancing effects of positive emotional states.

In conclusion, this study provides support for the view that music affects autonomic function and that music can be designed to enhance the beneficial effects of positive emotional states. The immunoenhancing effects seen here may be brokered by the parasympathetic nervous system, as reflected in the increase in MF power during the combination of designer music and appreciation. Increased MF power has been shown to be a marker of baroreceptor activity and therefore the use of designer music, which enhances MF power, may prove to be an important adjunct in the management of hypertension.

A larger study involving over 200 subjects is now in progress to determine whether the autonomic effects of music, which we believe mediate the observed immunoenhancement, are secondary to the induction of a positive emotional state. Whether the beneficial effects on autonomic function and immunity of positive emotional states and designer music can be extended to clinical health benefits is a tantalizing possibility that warrants further investigation.

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