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Music induces different cardiac autonomic arousal effects in young and older persons

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ABSTRACT

Background: Autonomic arousal-responses to emotional stimuli change with age. Age-dependent autonomic responses to music-onset are undetermined.
Objective: To determine whether cardiovascular-autonomic responses to "relaxing" or "aggressive" music differ between young and older healthy listeners.
Methods: In ten young (22.8 ± 1.7 years) and 10 older volunteers (61.7 ± 7.7 years), we monitored respiration (RESP), RR-intervals (RRI), and systolic and diastolic blood pressure (BPsys, BPdia) during silence and 180 second presentations of two "relaxing" and two "aggressive" classical-music excerpts. Between both groups, we compared RESP, RRI, BPs, spectral-powers of mainly sympathetic low-frequency (LF: 0.04–0.15 Hz) and parasympathetic high-frequency (HF: 0.15–0.5 Hz) RRI-oscillations, RRI-LF/HF-ratios, RRI-total-powers (TP-RRI), and BP-LF-powers during 30 s of silence, 30 s of music-onset, and the remaining 150 s of music presentation (analysis-of-variance and post-hoc analysis; significance: $p < 0.05$).
Results: During silence, both groups had similar RRI, LF/HF-ratios and LF-BPs; RESP, LF-RRI, HF-RRI, and TP-RRI were lower, but BPs were higher in older than younger participants. During music-onset, "relaxing" music decreased RRI in older and increased BPsys in younger participants, while "aggressive" music decreased RRI and increased BPsys, LF-RRI, LF/HF-ratios, and TP-RRI in older, but increased BPsys and RESP and decreased HF-RRI and TP-RRI in younger participants. Signals did not differ between groups during the last 150 s of music presentation.
Conclusions: During silence, autonomic modulation was lower – but showed sympathetic predominance – in older than younger persons. Responses to music-onset, particularly "aggressive" music, reflect more of an arousal- than an emotional-response to music valence, with age-specific shifts of sympathetic–parasympathetic balance mediated by parasympathetic withdrawal in younger and by sympathetic activation in older participants.

1. Introduction

There is increasing interest in the effects of music on bodily functions, particularly on cardiovascular and respiratory parameters (Haas et al., 1986; Krumhansl, 1997; Baumgartner et al., 2005; Iwanaga et al., 2005; Bernardi et al., 2006; Etzel et al., 2006; Bernardi et al., 2009).

Brain areas activated while listening to music (Blood et al., 2001; Koelsch et al., 2006) largely coincide with areas that constitute master controllers of the central autonomic network (Bennaroch, 1997; Spyer, 1999). During musical stimulation, functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) studies show activation or deactivation of multiple brain regions, including areas of central autonomic control (Bennaroch, 1997; Spyer, 1999) such as the ventral medial prefrontal cortex, anterior cingulate cortex, insula, and amygdala (Blood et al., 2001; Koelsch et al., 2006).

Activation or deactivation of these brain regions depends on the emotional valence and on arousal, associated with a music excerpt (Blood et al., 1999; Blood et al., 2001; Altenmuller et al., 2002; Koelsch et al., 2006).

In healthy young persons, Bernardi et al. describe different autonomic cardiovascular responses to music excerpts of different rhythms

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and tempi (Bernardi et al., 2006). With faster music rhythms, the authors found arousal responses with increases in ventilation, heart rate (HR), blood pressure (BP), and mid-cerebral artery blood-flow velocity and a decrease in baroreflex sensitivity (BRS) (Bernardi et al., 2006). In contrast, signs of relaxation including decrease in HR, BP and ventilation occurred during music pauses or while listening to slower rhythms (Bernardi et al., 2006).

Thus, the initial autonomic and cardiovascular responses to music seem to reflect more of an arousal response than a response to the emotional valence of the presented music.

However, arousal responses may change with age (Tsai et al., 2000). Similarly, emotional valence attributed to a music excerpt may change with age (Laukka et al., 2007). Such age-dependent differences in arousal specific responses as well as in the emotional appreciation of a music excerpt may subsequently induce differences between old and young persons in autonomic responses to the onset of music intended to have negative or positive valence.

Increasing age itself also modifies autonomic modulation and is associated with increasing sympathetic activity and decreasing parasympathetic activity (Barnett et al., 1999; Kuo et al., 1999; Jones et al., 2001; Ferrari, 2002; Brown et al., 2003; Stratton et al., 2003; Lavi et al., 2007; Park et al., 2007; Lipsitz et al., 2008).

Based on the age-dependent differences in arousal responses (Tsai et al., 2000) and valence attributed (Laukka et al., 2007) to emotional stimuli and on age-related changes in autonomic modulation (Barnett et al., 1999; Kuo et al., 1999; Gerritsen, 2000; Jones et al., 2001; Parati et al., 2001; Ferrari, 2002; Brown et al., 2003; Stratton et al., 2003; Lavi et al., 2007; Park et al., 2007), we hypothesize that the onset of “relaxing” or “aggressive” music induces different autonomic cardiovascular responses in young and older healthy persons.

Therefore, we studied whether onset of music after a period of silence induces cardiovascular, respiratory and autonomic responses that differ with the emotional valence of the music and with younger or older age of the listeners.

2. Material and methods

We examined ten young (4 females, 6 males, mean age 22.8 ± 1.7 years) and ten older healthy, right-handed volunteers (6 females, 4 males, mean age 61.7 ± 7.7 years). All participants had an unremarkable physical, neurological and cardiologic examination with electrocardiogram (ECG) and transthoracic echocardiography, and normal audiometric test results. We excluded persons with a background in music or music-related professions, a history of psychiatric disorders, alcohol or other substance abuse, or diseases that might affect autonomic regulation, and persons on any medication that might interfere with autonomic function. All study participants were non-smokers and were asked not to consume caffeine or alcohol for the last 12 h or an abundant meal within 3 h before testing.

The study protocol was approved by the ethics committee of the University of Erlangen-Nuremberg, and written informed consent according to the declaration of Helsinki was obtained from all participants prior to testing.

The study was performed in a quiet room with an ambient temperature of 24 °C and stable humidity.

After a 30 minute resting period in supine position, participants listened to four excerpts of classical music, interrupted by 5 min of quiet relaxation periods. All participants were unfamiliar with the music excerpts. Music was presented via high-fidelity stereo-headphones at an individually comfortable volume determined by initial presentation of a different piece of music.

Excerpts were supposed to induce “relaxing” or “aggressive” emotions. For “relaxing” stimulation, we presented excerpts from Ferrucio Busoni's “Turandot Suite, Turandot's chamber” and from N. Rimsky-Korsakov's “Shéhérazade, The Young Prince and the Young Princess”. For “aggressive” stimulation, we presented excerpts from Igor Stravinsky's “The Rite of Spring, Ritual Action of the Ancestors” and from Béla Bartòk's “The miraculous Mandarin, Suite, Op. 19”. Appropriate excerpts had been selected by an experienced professional conductor and musician (S.W.).

We presented each excerpt for 3 min, to provide enough time for each participant to determine his or her subjective emotional valence of the music. Then, participants were asked to score their perception of “relaxing” and “aggressive” emotions on a five score Likert scale, with a score of “1” reflecting no perception of “relaxing” respectively “aggressive” emotions, and a score of “5” reflecting very intense perception of “relaxing” respectively “aggressive” emotions.

2.1. Cardiovascular recordings

To assess whether cardiovascular and autonomic responses to the arousing onset of music differ between young and older listeners, and between excerpts of “relaxing” or “aggressive” valence, we analyzed recordings of heart rate (HR), assessed as RR-intervals (RRI), systolic and diastolic blood pressure (BPsys and BPdia), and respiratory frequency (RESP) during 30 s of silence, prior to music presentation and during the first 30 s as well as the subsequent 150 s upon onset of the music excerpt.

RRI were measured using a standard 5-lead electrocardiogram with superficial skin electrodes attached to the chest under the right and left clavicles, over the right and left costal arches, and over the fifth intercostal space at the left midclavicular line. BP was continuously recorded from the left radial artery at the wrist positioned at heart level by means of non-invasive applanation tonometry (Colin Pilot, Colin, San Antonio, TX, USA). The tonometer consists of an array of 32 equally spaced piezoresistive pressure transducers, an automated positioning system, signal conditioning, and initial as well as intermittent calibration by oscillometric cuff measurements of the brachial artery BP (Kemmotsu et al., 1992).

We monitored respiration using a piezoelectronic respiratory belt (Suess Medizin-Technik, Aue, Germany) attached at the thorax-level of maximal respiratory excursions but did not pace respiratory frequency. Respiration is well known to have a strong effect on cardiovascular autonomic modulation (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Hilz, 2002; Kotani et al., 2008). Respiratory sinus arrhythmia with inspiratory acceleration and expiratory slowing of HR depends on the rate of breathing and may influence results of TRS (Kotani et al., 2005). Paced breathing has been used to limit the influence of respiratory sinus arrhythmia on cardiovascular autonomic modulation (Bernardi et al., 1996). Yet, paced breathing might distort autonomic and arousal responses to musical stimulation due to focused attention and has not been applied in our study.

2.2. Data storage and off-line analysis

All signals were sampled, digitized by a custom-made analog-to-digital converter at 300 Hz sampling rate and displayed on a personal computer and a custom designed data acquisition and analysis system (SUEmpathy™, Suess Medizin-Technik, Aue, Germany), and stored for off-line analysis. A C-language program identified all electrocardiographic QRS complexes in each sequence, located the peak of each R-wave, and calculated consecutive RRI.

To avoid too many statistical comparisons violating statistical requirements, we merged and averaged data recorded during the two baselines preceding the presentation of “relaxing” (respectively “aggressive”) music. In analogy, we merged and averaged data recorded during the presentation of the two “relaxing” (respectively “aggressive”) music excerpts. Thus, mean values and standard deviations (SD) of RRI, BPsys, BPdia, and RESP at baseline, prior to “relaxing” (respectively “aggressive”) music, represent the averages of two 30 second baseline recordings. For data analysis during music presentation, we also merged