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Individual brain-frequency responses to self-selected music

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ABSTRACT

Music is a stimulus which may give rise to a wide range of emotional and cognitive responses. Therefore, brain reactivity to music has become a focus of interest in cognitive neuroscience. It is possible that individual preference moderates the effectof music on the brain.

In the present study we examined whether there are common effects of listening to music even if each subject in a sample chooses their own piece of music.

We invited 18 subjects to bring along their favorite relaxing music, and their favourite stimulating music. Additionally, a condition with tactile stimulation on the foot and a baseline condition (rest) without stimulation were used. The tactile stimulation was chosen to provide a simple, non-auditory condition which would be identical for all subjects. The electroencephalogram was recorded for each of the 3 conditions and during rest.

We found responses in the alpha range mainly on parietal and occipital sites that were significant compared to baseline in 13 subjects during relaxing music, 15 subjects during activating music, and 16 subjects during tactile stimulation. Most subjects showed an alpha desynchronization in a lower alpha range followed by a synchronization in an upper frequency range. However, some subjects showed an increase in this area, whereas others showed a decrease only. In addition, many subjects showed reactivity in the beta range. Beta activity was especially increased while listening to activating music and during tactile stimulation in most subjects.

We found interindividual differences in the response patterns even though the stimuli provoked comparable subjective emotions (relaxation, activation), and even if the stimulus was the same for all subjects (somatosensory stimulation). We suggest that brain responsivity to music should be examined individually by considering individual characteristics.

1. Introduction

The use of music in psychiatric and neurologic disorders is a promising therapeutic method (Thaut et al., 2009). There is evidence for beneficial effects of music on attention and mood in patients with Parkinson's disease and dementia (Sacks, 2006), on memory in patients with dementia (Foster and Valentine, 2001), on mood in patients with depression (Thaut et al., 2009), and on epileptic brain activity in patients with epilepsy (Hughes et al., 1998; Kuester et al., 2010; Lin et al., 2010a; Wieser, 2003). Music therapy in neurology may act through activation of the motor system by acoustic stimulation and through synchronization of motor reactions (Levitin and Tirovolas, 2009; Thaut et al., 2009). The rhythmic synchronization may coincide with the timing of attentional processes (Klein and Riess Jones, 1996).

Music listening may evoke strong and consistent cognitive and emotional responses in the human brain (Brattico et al., 2010; Koelsch, 2010). A preference for consonant sounds and, thus, some sense for musical aesthetics is detectable in early childhood (see Nieminen et al., 2011, for a review). Even people without musical education can tell if a piece of music is harmonically appropriate. The cognitive aspect

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can be measured as a specific reaction in the brain (Koelsch and Friederici, 2003; Koelsch and Siebel, 2005). For example, the electroencephalogram (EEG) shows that inappropriate chord endings elicit an early right anterior negativity (Koelsch and Friederici, 2003).

The cognitive judgment on the correctness of music may not always be too concordant with the subjective appraisal of an individual (Brattico et al., 2010). The subjective experience, i.e. liking or disliking a specific piece of music, depends on the individual's biography, preferences, age, and the resulting duration of exposure to music (McDermott et al., 2010; Nieminen et al., 2011; Shahin et al., 2010). In addition, socialization and culture (Levitin and Tirovolas, 2009; Wieser, 2003) play important roles.

While there are numerous research projects on the cognitive and emotional aspects of music (see Levitin and Tirovolas, 2009, for review), there are only a few researchers focusing on the brain correlates of personal preference. Kornysheva et al. (2010) examined appreciation of musical rhythms. The authors found that the cerebellum and premotor areas are involved by preferred tempo compared to not preferred musical rhythms Flores-Gutiérrez et al. (2007) found that unpleasant music activated right frontopolar and paralimbic areas whereas pleasant music activated the left primary auditory area, posterior temporal, inferior parietal and prefrontal regions. Upper alpha couplings link anterior and posterior regions in response to pleasant music (Flores-Gutiérrez et al., 2009). Unpleasant music leads to posterior midline coherence. In both reports (Flores-Gutiérrez et al., 2007, 2009) the same music was used for all subjects (Bach and Mahler as pleasant music and Prodromidés as unpleasant music). Thaut and Davis (1993) examined the effects of self-selected compared to experimenter chosen music. They found comparable effects on relaxation and hostility with both types of music. Similarly, Bernardi et al. (2006) report a progressive reduction of mid-cerebral artery flow velocity with exposure to music which was independent of musical style. But there was a greater effect of tempo on breathing rate in musicians than non-musicians. Burns et al. (1999) examined the relaxation effect of classical music, self selected music and rock music. The authors found that classical and self-selected relaxing music leads to higher relaxation levels than hard rock music. Salamon et al. (2003) report significant reduction of anxiety levels, as measured by systolic and diastolic blood pressure values, with preferred music, only.

There is evidence that individuals show a high variability in the processing of stimuli, e.g. in an oddball-task (Höller et al., 2011a). We argue that considering a patients preference for a specific type of music may be crucial for the success of music therapy. One patient may experience Mozart as relaxing, while the same music may be tedious for another person.

Music therapy in neurology aims at certain changes in brain activity, for example, a reduction of delta (0–4 Hz) activity, or an increase of alpha (8–13 Hz) activity. For the success of music therapy it is important to get reliable and universal brain responses to music across all individuals. In this study we examined whether there is a common brain response to music when the piece of music is chosen individually or whether there are still interindividual variations due to general variability in EEG-reactivity. We analyzed the brain responses of individuals to self selected music with frequency transforms of the EEG. Each subject chose one piece of music which he or she found subjectively relaxing and one which he or she experienced as activating. We assume that relaxing music enhances specific patterns of alpha activity, since alpha oscillations are highly reactive to several kinds of cognitive activity (Klimesch et al., 2007; Palva and Palva, 2007). Activating music is often linked to activities suchas dancing or other sportive movements. Thus, activating music may stimulate motor-relevant regions of the brain and therefore it may result in universal activation patterns in the alpha and beta (14–30 Hz) frequency bands (Baker, 2007). As a third stimulus we tested a rhythmic stimulation on the sole of the foot. This stimulus was used as a simple, non-auditory condition which is the same in all subjects. We chose a non-auditory condition since we could not guarantee that a single piece of music would induce the same emotion in all subjects. In such a way we compared the variability of brain activations in the 2 music conditions – which are different for all subjects, with the somatosensory condition – which is the same for all subjects. Moreover, a non-auditory condition may reveal if a possible variability is restricted to the auditory system or if it is a general pattern.

2. Materials and methods

2.1. Subjects

A sample of 18 high school graduated subjects (age: 19–44 years; mean: 24 years; standard deviation: 5.80 years; 8 male) were recruited and tested. None of the participants reported any history of neurological or psychiatric diseases, nor were they receiving any psychoactive medication or using a hearing aid.

In the sample, 3 subjects play no musical instrument. The other subjects play up to 3 instruments for up to 13 years (mean: 5 years; standard deviation: 3.51 years). There are 7 subjects who are or were members of a choir, 7 subjects who reported that they could not sing, and 4 subjects who could sing but who weren't part of a choir or a comparable musical group.

Informed consent was obtained from each subject according to the ethical guidelines of the Declaration of Helsinki. All subjects were remunerated for their expenditure of time.

2.2. Experiment

The experiment compared the effect of self selected relaxing and activating music to a resting condition and to tactile stimulation on the soles of the feet. Subjects were asked to bring along music they liked. Two pieces of music were chosen by each subject; one piece of music which they experienced as relaxing (relax music), and one piece of music which they experienced as activating (power music). For the tactile foot stimulation the PSR-shoe was used (Pollmann Austria GmbH). This shoe gives sensory stimulation with 5 coils moving with an amplitude of 1.5 mm and a frequency of 6 Hz.

The subjects were invited for 2 sessions with a time interval of 2 weeks. At each of the 2 EEG-sessions, the same procedure was applied. Each condition lasted for 2 min. The duration of most Pop-music is between 3 and 5 min (Warner, 2003), a Radio Edit lasts between 2.5 and 4 min. Thus, by choosing 2 min recording time we ensured that all music pieces were long enough. Subjects were asked to keep their eyes closed and to sit calmly during each condition. First, the baseline (that is, a resting condition) was recorded for each subject. Then, the 3 conditions (relaxing music, power music, and tactile stimulation) were recorded in a pseudo-randomized order; that is, for each of the 6 possible orders the same number of subjects (i.e., 3 or – in one case – 4 subjects) was assigned.

The music was presented with the computer-soundsystem (Realtek 2-channel ALC262-Codec with internal speakers), ca. 120 cm behind the head of the subjects with a volume of 45–60 dB. The volume was adjusted individually within this range since the individually chosen pieces of music were typically listened at different sound volumes. For example, Hard-Rock is typically louder than classical music.

The chosen music was Pop (7), Classical (5), Soul (3), and Rock (3) for the relax-music condition (5 of the without lyrics, instrumental) and Rock (14), Techno (2), Ska (1), and Classical (1) in the power-music condition (1 of them without lyrics).

The subjects were asked to describe the pieces of music. They described the relaxing music with the words “calming” (8), “slow” (2), and “deep” (1). The power music was described with the words “exciting” (4), “fast” (3), and “aggressive” (2). Only one subject reported to have certain memories connected with the chosen piece of music.

After each condition, subjects were asked to indicate their subjective experience of relaxation and excitation on 2 Likert-scales from 1 to 5. The lowest value 1 was chosen to be totally relaxed and the highest value 5 totally tensed for the relaxation scale. The lowest value 1 was chosen to be totally excited and the highest value 5 totally relaxed on the excitation scale.

2.3. Data registration

EEG-Data was recorded using a BrainCap with a 10–20 montage and a BrainAmp (Brain Products GmbH, Germany) 16-bit ADC amplifier. The sampling rate was 500 Hz. Of the 32 recorded channels, 2 were used to monitor the left and right horizontal electrooculogram. One was used to monitor lower-site vertical electrooculogram. Two were positioned at the mastoids for re-referencing purposes to remove the bias of the original reference, which was placed at Fcz. The other electrodes were Fp1, Fp2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T7, T8, P7, P8, Fz, Cz, Pz, FC1, FC2, CP1, CP2, FC5, FC6, CP5, and CP6. Data analysis was conducted for data collected from the electrodes F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T7, T8, P7, P8, Fz, Cz, and Pz. Impedances were keptbelow 10 kΩ.

2.4. Data preparation

Data pre-processing was done with Brain Vision Analyzer (Version 1.05.0005, Brain Products GmbH). First, mastoid electrodes were used to build a new averaged reference for all other channels. To obtain a bipolar vertical electrooculogram, the average of Fp1 and Fp2 was used as a reference for the lower-site vertical electrooculogram. Left and right horizontal electrodes formed a bipolar configuration of the horizontal electrooculogram. To reduce noise, Butterworth Zero Phase Filters from 1 to 25 Hz (time constant 0.1592 s, 48 dB/oct) were applied.

Independent component analysis (ICA) was applied, since this procedure has been shown to effectively detect, separate, and remove ocular, muscle, or cardiac artifactual sources in EEG data (Jung et al., 1998; Jung et al., 2000; Makeig et al., 1996). The ICA was calculated on all channels, including the prepared electrooculographic channels. After visual inspection of the ICA components, those components containing ocular or muscle artifacts were determined and removed by performing the corresponding ICA back-transformation.

An automatic data inspection was carried out in order to exclude remaining artifacts. Maximal allowed voltage step per sampling point was 50 μV (exceeding values were excluded with a surrounding of ±100 ms); maximal allowed absolute difference on an interval of 200 ms was 200 μV and lowest allowed absolute difference on an interval of 100 ms was 0.5 μV (exceeding values were excluded with a surrounding of ±500 ms).

2.5. Frequency analysis

To perform frequency analysis on individual trials, data was segmented into 2000 ms epochs. The preprocessed segments were exported into a generic data format and imported to Matlab (the Mathworks). These segments were transformed with the discrete fast-Fourier-transform into frequency domain, resulting in μV-values for the amplitude at each frequency step (0.24 Hz).

2.6. Statistics

2.6.1. EEG

Statistics were performed by a nonparametric statistical test according to Maris and Oostenveld (2007) on a single-subject level. This test was carried out as follows. The trials of two conditions were compared with each other with a t-test for each frequency step and each electrode position. All significant t-values with $p<.05$ were then collected into clusters according to adjacency of significant t-values at 0.24 Hz steps from 1 to 49 Hz, electrode positions, and sign of the t-value (positive or negative). As such, clusters were built over two dimensions, frequency and topography, separately for positive and negative effects. For each cluster, the sum of all t-values was built. The trials of the two conditions were then shuffled and separated into two sets which had the same size as the original trial sets. Then, the described t-test and clustering process was carried out on these random sets. These random t-tests were repeated a 1000 times. For each repetition the largest positive and the largest negative cluster-sum was recorded. Finally, for each of the original cluster-sums from the initial t-test, the percentage of random cluster-sums which yielded higher values was calculated. Thus, we got an estimate of the probability of more extreme results than the original ones under random conditions. This estimate is then considered as the *p*-value of the cluster. For further explanation we refer to Maris and Oostenveld (2007).

The test was applied to each pair of conditions, that is, rest vs. relax music, rest vs. power music, rest vs. tactile stimulation, relax music vs. power music, relax music vs. tactile stimulation, and power music vs. tactile stimulation. The test was performed for each of the 2 EEG-sessions separately. For these six comparisons a correction was necessary since the procedure of Maris and Oostenveld (2007) was applied only for frequency steps and electrode positions. According to the Bonferroni-correction, the resulting *p*-values for the 3 comparisons were considered to yield significant differences if the *p*-value of the cluster was ≤0.008 (that is, 0.05/6 for the six comparisons). We applied no Bonferroni-correction to the re-test (two tests in two weeks) since we considered only results which were consistent in both tests.

The test statistics indicate significant differences at certain frequency ranges and certain electrode locations for each pair of conditions for each EEG-session and each subject. Following this, only those differences that were found consistently at both EEG-sessions were considered as reliable. That is, only differences with the same frequency steps and electrode locations for both EEG-sessions were maintained. This procedure should prevent us from interpreting unsystematic responses. This lead toexclusion of on average $n=5$ (range: 0–10; standard deviation: 2.83) clusters per subject and comparisons which were significant only at one of the two sessions.

To get an overview of the reactivity of the subjects in certain frequency ranges we counted the number of subjects showing significant clusters in the specific frequency bands (delta 1–4 Hz, theta 5–7 Hz, alpha 8–13 Hz, and beta 14–25 Hz) regardlessthe topology of the effect (Table 1).

For plotting purposes the power spectra for each condition were averaged over all subjects and both sessions. Then, the resting condition was subtracted from the other three conditions and the difference-waves were plot on the scalp (Fig. 1). This image suggested that the effects were strongest over occipital and parietal electrodes. Therefore, for each subject the power spectra for each condition were averaged over occipital and parietal electrodes, and over both sessions. The resulting spectra were plot for each subject individually (Fig. 2(a)). The single subject statistics for these electrodes were plot for each subject, indicating significant differences in the comparisons at certain

Table 1
Number of subjects showing differential activity in the respective comparisons and frequency ranges. "Relax" refers to the relax music condition, "power" to the power music condition, and "tactile" to the condition with tactile stimulation. Note that a subject can show reactivity in more than one of the frequencies, that is, a subject can appear in more than one column.

Comparison	Nothing	Delta	Theta	Alpha	Beta
Rest–relax	0	4	1	13	8
Rest–power	0	2	3	15	11
Rest–tactile	1	6	4	16	14
Relax–power	4	0	1	9	7
Relax–tactile	2	1	0	10	10
Power–tactile	5	0	1	8	9

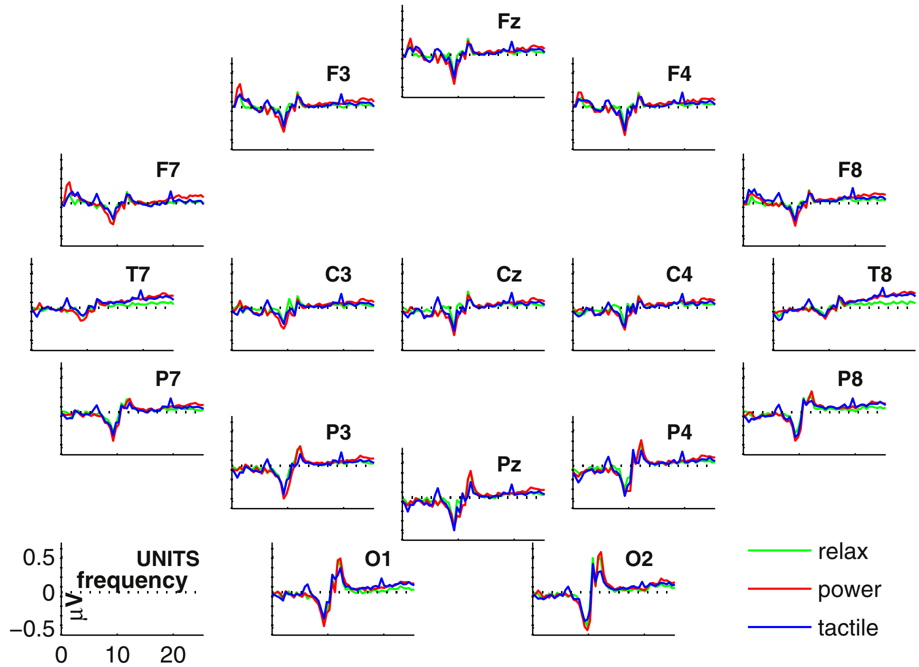

Fig. 1. Differences of the single-sided amplitude spectra for the 3 conditions vs. rest. Deviations from zero indicate a difference (de/synchronization) between the respective condition vs. rest. "Relax" refers to the relax music condition, "power" to the power music condition, and "tactile" to the condition with tactile stimulation.

frequency steps, at least at one of the parietal and occipital electrodes (Fig. 2(b)).

2.6.2. Subjective appraisal

The responses on the scales relaxation and excitation were evaluated for each session and the 2 scales separately with non-parametric statistics using PASWStatistics 18.0. For each session and each of the 2 scales a one-factorial Friedman-test was calculated with the factor condition (4 conditions). If this test yielded significant differences at the Bonferroni-corrected critical alpha-level $p \leq 0.012$ (for the 2 sessions and 2 scales), the Wilcoxon test was applied to pairs of conditions. These results were interpreted at the Bonferroni-corrected critical alpha-level $p \leq 0.002$ (for the 6 pairs of conditions, 2 sessions, and 2 scales).

3. Results

3.1. EEG

Table 1 gives an overview of the number of subjects showing differential responses in the specific frequency ranges. There were only a few subjects with significant clusters in the delta and theta frequency ranges. In the alpha and beta frequency ranges effects more subjects showed significant differences in the 6 comparisons. The comparisons with the baseline (rest) indicate the basic reactivity. All subjects showed some reactivity to music (relax as well as power music).

Fig. 1 shows the distribution of difference-power spectra over the scalp. In the alpha frequency range the most prominent differences were found on parietal and occipital sites. Fig. 2(a) shows the difference-power spectra, averaged across parietal and occipital electrodes for each subject individually, while Fig. 2(b) indicates at which frequencies the waves of Fig. 2(a) differ from each other.

Most subjects showed a lower activity in all three conditions compared to rest followed by a higher activity in all three conditions compared to rest in the alpha frequency range. This change from desynchronization in a lower alpha range to synchronization in the upper alpha range did not become evident in the statistics for all subjects. Moreover, there were subjects with only very small desynchronization (e.g., S16) or no desynchronization at all (e.g., S1). Other subjects (e.g. S7) showed adesynchronization but no synchronization. The differences between the three conditions (power/relax music and tactile stimulation) varied highly between subjects.

In the beta frequency range there were only small differences. Relax music provokes beta-synchronization in subject S16, but beta-desynchronization in subjects and S17 and S18. There are 9 subjects with beta synchronization during power music. In 8 subjects tactile stimulation lead to beta synchronization, while there were 2 subjects with beta desynchronization. In 4 subjects beta activity was higher during power music than during relax music, while one subject (S15) showed the opposite pattern. There was lower beta activity during relax music than during tactile stimulation in 6 subjects. The opposite effect was found in 3 subjects. In 5 subjects beta activity was higher during tactile stimulation than during power music, in 4 subjects the activity was higher during power music.

3.2. Subjective appraisal

The means and medians of the subjective appraisal on both scales and for both sessions are shown in Table 2.

Relax music yields the most relaxed values (that is, small values on the relaxation scale) at both sessions. Analogously, power music yields the most excited values (that is, small values on the excitation scale) at both sessions. The relaxing effect of relax music seemed to be stronger than the exciting effect of power music. Tactile stimulation was neither experienced as relaxing, nor as exciting. The Friedman-tests yielded significant results for both scales and both sessions (see Table 3).

To find out which conditions differed from each other, Wilcoxon tests were calculated for each comparison. As can be seen in Table 4,

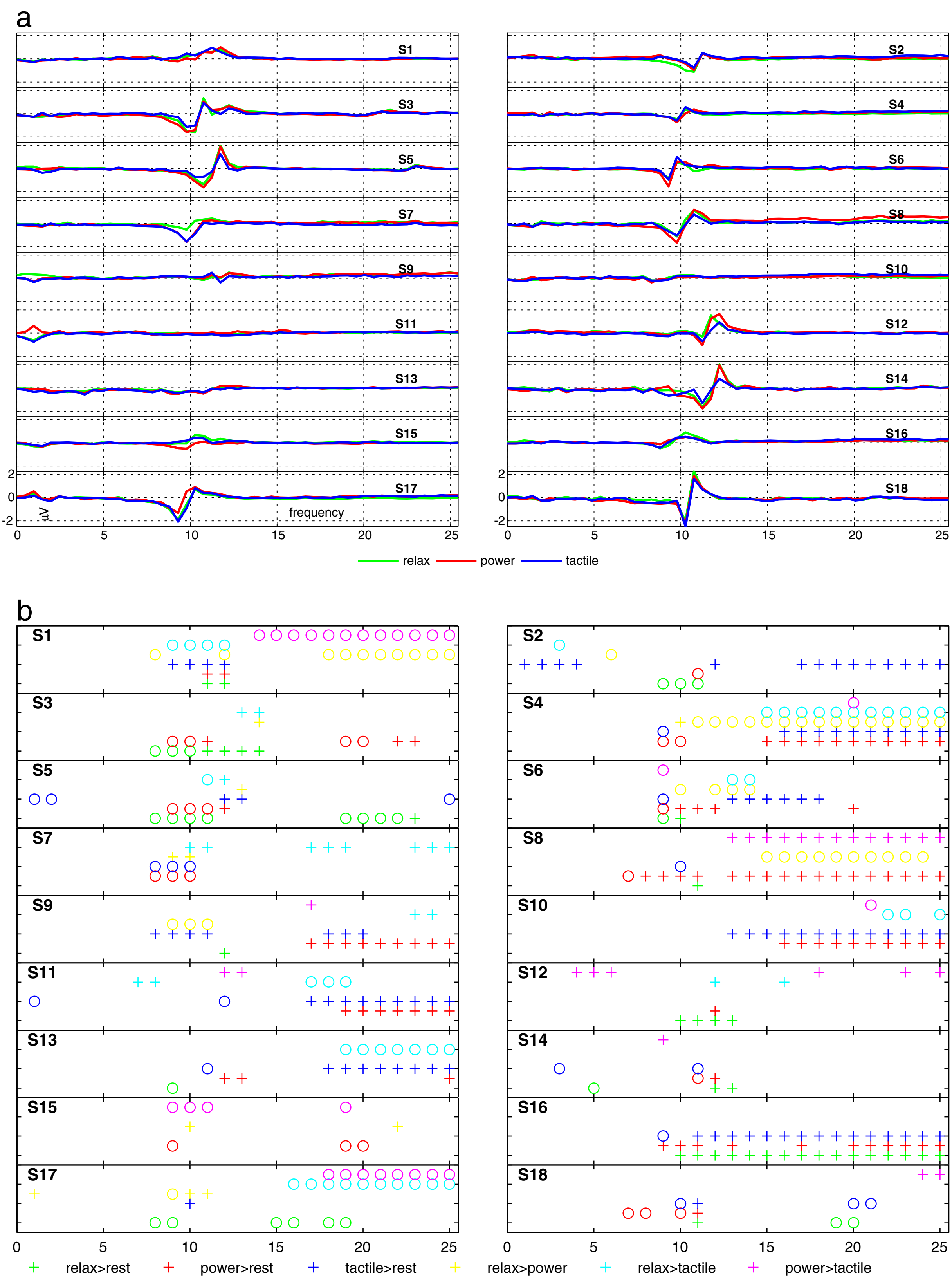

Fig. 2. a) Difference-power spectra averaged across parietal and occipital electrodes for each subject individually. b) '+' markers indicate the frequency steps with significant differences first condition > second condition, 'o' markers indicate the frequency steps with significant differences first condition < second condition. "Relax" refers to the relax music condition, "power" to the power music condition, and "tactile" to the condition with tactile stimulation.

all effects except one are stable over the 2 sessions. The differences between rest and relax music for both scales are significant at the first session, only. Power music only differs from rest at both scales and from tactile stimulation at the excitation scale. Relax music only differs from power music at both scales and from tactile stimulation at the relaxation scale. Relax music was more relaxing than rest and less

Table 2
Mean/median values for the 4 conditions, both sessions and both scales.

Comparison	Session 1		Session 2	
	Relaxation	Excitation	Relaxation	Excitation
Rest	2.06/2	2.83/3	2.06/2	3.17/3
Relax music	1.5/1.5	3.33/3	1.67/2	3.39/3
Power music	2.61/3	2.22/2	2.5/3	2.33/2
Tactile stimulation	2.56/2.5	3.06/3	2.22/2	3/3

exciting than rest in the first session, more relaxing than power music and tactile stimulation in both sessions, and less exciting than power music in both sessions. Power music was less relaxing than rest and more exciting than tactile stimulation at both sessions.

4. Discussion

As expected, we found most effects in the alpha and beta frequency ranges. A majority of the subjects showed reactivity in the alpha range to relax music, power music, and tactile stimulation. Similarly, we found reactivity in the beta range in most subjects in response to tactile stimulation. In the alpha frequency range the spectra of most subjects showed a desynchronization in a lower alpha range followed by a synchronization in an upper alpha range. The frequency of change from de-to synchronization differed between subjects. There were also some subjects who showed synchronization or desynchronization only. In the beta frequency range most of the responses consisted of a higher beta activity during music or tactile stimulation than during rest. This was especially true for the power-music condition and the tactile stimulation. The effects were most pronounced over parietal and occipital sites.

Responses in the alpha and beta range may reflect activations of the motor system, since there is an association between music and movement (Levitin and Tirovolas, 2009). There is also evidence for activation of the μ-rhythm and the mirror neuron system in response to music (Hadjidimitriou et al., 2010). However, music as an auditory stimulus also involves top-down regulation of perceptive processes which coincide with alpha-desynchronisation (Hartmann et al., 2012).

In our study, the pattern of alpha reactivity to self-selected relaxing or activating music showed highly variable response patterns even though the stimuli provoked comparable subjective emotions (relaxation, activation). The reactivity varied in the type of alternation between subjects, i.e., if it was an increase, a decrease, or a decrease followed by an increase of activity (as found in the alpha range). One could argue that this variation is caused by the individual choice of the music, that is, the music was different for every subject. However, this argumentation becomes invalid with the results from the tactile condition. This condition was the same for every subject. The reactivity was also variable between subjects for somatosensory stimulation. Instead, it seems that the responses to music and somatosensory stimulation within subjects are very similar to each other. Thus, the variability of the responses to music is not necessarily due to the differences between the chosen pieces of music. The variance is not restricted to the auditory system but can be found for a somatosensory condition. We consider the responses to somatosensory stimulation as normal variation. Taking this into consideration, the interindividual variability of brain responses to music are probably not due to different pieces of music but due to inherent characteristics of the individual brains.

Table 3
Results of the Friedman-ANOVAs with df = 3 comparing the 4 conditions for both scales and both sessions. The asterisks (*) mark significant results, that is, p<.012.

Scale/session	Session 1	Session 2
Relaxation	$\chi^2 = 37.44$ p<.001*	$\chi^2 = 24.36$ p<.001*
Excitation	$\chi^2 = 33.86$ p<.001*	$\chi^2 = 37.58$ p<.001*

As a consequence, before applying the music as a therapy, the individual response must be examined. If it is of the desired nature, e.g. synchronization in a certain frequency range, music therapy may be beneficial for the specific patient. In fact, the interindividual variance of responses to music is moderated by so many factors that music therapy can only be successful if the individual pattern of brain response is taken into account. In the following, we will discuss some of these moderating factors.

The first source of variance may be the subjectively experienced effect. Subjective appraisal of the conditions suggests that especially tactile stimulation and power music were not unambiguously relaxing or exciting. Thus, the subjective effect could be different for the individuals and cause the differences in reactivity of brain oscillations. Although the relaxing effect of the chosen music pieces was confirmed by the subjective appraisal, the term “relaxing” may be a very subjective matter.

In addition, the role of music may be considerably different in the individuals' lives. While for one subject music is just a background stimulus, another subject may experience music as a cognitive stimulus. Brattico et al. (2010) found that there are specific brain responses (event related potentials) for cognitive and for affective listening, and for judgment of music. At about 1200 ms a late positive potential can be found for the affective listening task, while a negative potential is elicited by the cognitive judgment task. In both cases, music may be subjectively relaxing. As proposed by several theories concerning the role of alpha activity in the brain, cognitive engagement leads to specific patterns of alpha increase or decrease, depending on the kind of cognitive activation (Klimesch et al., 2007; Palva and Palva, 2007). It is possible that the variance is due to interindividual differences in listening modes.

It is not only the listening modes but also the emotional processes linked to the specific piece of music that may play a role. Some individuals may experience sad music as relaxing while other individuals prefer happy music. Lin et al. (2010b) reported interindividual differences in emotional activation during listening to music. They found specific differences in the independent components located in the delta and theta frequency ranges. The authors argued that there might be a variance in the involved brain circuits which process emotions.

In psychophysiology the alpha-peak frequency is often discussed as an important factor. Kabuto et al. (1993) examined EEG-power changes in response to relaxing music. They found that the alpha-peak frequency correlates negatively with a decrease of an extracted score in the left occipital region which is related to calmness. Moreover, the authors found that the relaxation effect of pleasant music was associated with the change in the total theta power. This effect varied with personality traits. Itis possible that the interindividual variances are due to stress-related traits and are reflected by individual patterns of the EEG power spectrum, i.e. the baseline. Furthermore, we argue that the reactivity of frequency bands shows interindividual variance. It is known that even for very simple stimuli the reactivity of alpha activity varies between subjects. In an oddball task we found decreases and increases of alpha activity in a sample of healthy subjects (Höller et al., 2011a). A high variability was also found for subject's own name (Höller et al., 2011b; Kotchoubey et al., 2004). Thus, the individual responses can be an increase or a decrease even if the stimulus is very simple. Most studies on effects in the alpha range used group-level statistics and found decreases, that is, desynchronization of power in response to stimuli. We found an alpha desynchronization followed by an alpha synchronization in most subjects and some subjects with desynchronization or synchronization, only.It could be possible that the samples of most experiments contained more subjects who reacted with a desynchronization of alpha power in the examined frequency range. In such a case, one would find an alpha desynchronization as a

Table 4
Results of the Wilcoxon tests (Z (p)) with $df=1$, comparing single condition-pairs for both scales and both sessions. "relax" refers to the relax music condition, "power" to the power music condition, and "tactile" to the condition with tactile stimulation. The asterisks (*) mark significant results, that is, $p<.002$.

Comparison	Session 1		Session 2	
	Relaxation	Excitation	Relaxation	Excitation
Rest–relax	−3.16(<.002)*	−3(.003)	−2.65(.008)	−2(.046)
Rest–power	−3.16(<.002)*	−3.05(<.002)*	−2.53(.011)*	−3.64(<.001)*
Rest–tactile	−3(.003)	5(.025)	−2(.046)	−1.73(.083)
Relax-power	−3.13(<.002)*	−3.70(<.001)*	−3.44(<.001)*	−3.95(<.001)*
Relax–tactile	−3.58(<.001)*	4–1.89(.059)	−3.16(<.002)*	−2.65(.008)
Power–tactile	−0.58(.564)	−3.64(<.001)*	−1.67(.096)	−3.46(.001)*

group effect while other experiments found a synchronization of alpha power. Taken to the extremes, a failure to detect an effect could be a consequence of the number of subjects showing alpha increases equalling the number of subjects showing alpha decreases in the examined frequency range. The chosen frequency band may determine the kind of the detected effect. In the presented study the frequency at which the alpha oscillation changes from de- to synchronization differs between subjects. Thus, by just averaging over all subjects at a certain frequency the effects between subjects may cancel out each other.

A further distinction can be made between professional music players and non-musicians. Hadjidimitriou et al. (2010) compared brain responses of advanced music students to non-musicians. The authors found an activation of motor control areas during processing of rhythm and an involvement of the mirror neuron system in motor representation during perception of music. Advanced music students showed a higher sensorimotor response when listening to Mussorgsky's "Promenade" and stronger correlation between brain activation and auditory stimulation.

Finally, there are studies reporting on gender differences in the brain responses to music. Flores-Gutiérrez et al. (2009) examined upper alpha couplings in response to music. This study reported that the coherent network was larger in women than in men. Similarly, Günther et al. (1993) found gender related differences in all frequency bands of the EEG when examining the beneficial effect of music in patients with Alzheimer's disease.

This list of possible sources of variance is not exhaustive. It is obvious that with so many sources of variance it is impossible to record universal patterns of response even if the same piece of music is used for every subject. To really disentangle the various moderating factors of brain responses to music a larger sample of subjects would be needed, being well balanced in gender, musical education, and alpha peak frequency. In addition, the individual listening modes and experienced emotions during listening to music should be considered.

5. Conclusion

In this study we sought to answer the question of whether or not there are universal brain reaction patterns to music even when each examined individual brings their own music. Although there is a long list of possible sources of variance, we have found some interindividual consistencies in the brain responses to relaxing and activating music. Most subjects showed reactivity in the alpha and beta frequency ranges. The alpha responses consisted of a desynchronization in a lower-alpha range followed by a synchronization in a higher alpha range in response to stimulation. The frequency of change between de- to synchronization varies between subjects. This alpha-reactivity may reflect the alternation of arousal. Increases of power in the beta frequency are probably due to activation of the motor system.

We argue that the variance was probably due to individual characteristics of the EEG, which are individually moderated by many different factors. For music therapy, it will be necessary to determine individually for each patient whether music can have beneficial effects, and if so, which kind of music will have the desired effect on brain activity.

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