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ELECTRODERMAL RESPONSES TO DISSONANT AND CONSONANT MUSIC

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Owing to the close relation between music and emotions, autonomic responses to music have been often studied. In particular, we have previously shown that musical excerpts can elicit skin conductance responses (SCRs) depending on the level of arousal of the emotion as expressed by the music. In the present study, we extend the SCR sensitivity to valence, as conveyed by musical consonance/dissonance. Dissonant music is generally considered as unpleasant whereas consonant music is generally pleasant. Hence we tested the SCR to consonant and dissonant excerpts in university students. In order to assess whether the expected SCR sensitivity to consonance/dissonance is linked to valence rather than to differences in musical characteristics, rare individuals having no perceptual deficit but having difficulties in experiencing pleasure have been included in the experiment. These subjects who have no psychiatric disorders are known as non-clinical physical anhedonics. Anhedonics are expected to perceive the consonance/dissonance distinction as well as controls but to exhibit smaller SCR in comparison to normal listeners. The results are consistent with these predictions in showing larger SCRs to consonant than to dissonant musical excerpts, particularly so in controls. Thus, the results are in accordance with the notion that SCR is sensitive to valence, and not only to arousal in musical settings.

Introduction

Emotion is an integral part of music experience. Emotional responses appear to be the primary reason why people listen to music (Panksepp, 1995; Sloboda, 1991). Indeed, some emotions elicited by music seem able to modulate physiological responses (e.g., Krumhansl, 1997). In a recent study

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of ours (Khalfa et al., 2002), a measure of the sympathetic nervous system, the skin conductance response (SCR), was found to depend on the emotion expressed by the music. The SCRs were larger for the high-arousal stimuli (happy and scary music) than for the low-arousal stimuli (sad and peaceful music). In the present study, we focus on another emotional dimension, that of valence.

The valence (or pleasantness) of music is strongly related to its degree of consonance. Listeners often judge consonant music as pleasant whereas they find dissonant music unpleasant. Dissonance is related to the ratio in pitch frequencies between successive tones in a melody, or between simultaneous tones in a chord. When this ratio is complex (as in a minor second), the musical tones are considered dissonant (Schellenberg & Trehub, 1994). The preference for consonance over dissonance arises from mechanical constraints in the inner ear (often referred to as sensory dissonance; Plomp & Levelt, 1965), from psychological interpretation (referred to musical dissonance; Krumhansl, 1990), and from listener's experience (Cazden, 1945). This preference for consonance over dissonance is already present in infants (Trainor & Heinmiller, 1998; Zentner & Kagan, 1998) suggesting that this phenomenon may be innate (Trainor & Heinmiller, 1998).

At a neuroanatomical level, it has been shown in a PET study that dissonant and consonant musical excerpts may recruit brain regions such as prefrontal cortices and the subcallosal region, which have been previously associated with pleasant and unpleasant emotional states (Blood et al., 1999). This result confirms the ability of dissonant/consonant excerpts to evoke emotional states.

The degree of pleasantness conveyed by dissonant and consonant melodies can be assessed in subjects' reports. Its physiological impact is less easy to evaluate. In order to explore further the autonomic responses related to the emotional reaction to music, we assessed here whether SCRs are sensitive to the dissonance/consonance dimension in music (including both sensory and musical dissonance), that is to musical valence.

SCR represents the changes in electrical conductivity of a person's hand skin related to the amount of sweat within the eccrine sweat gland. The more sweat, the greater the skin conductance (Boucsein, 1992). The phasic changes of skin conductance, occurring between 1 and 4 sec after stimulus onset, are especially sensitive to emotions (Katkin, 1965). The electrodermal activity is controlled by the sympathetic branch of the autonomic nervous system, through the release of acetylcholine (Millington & Wilkinson, 1983). Via the sympathetic system, the SCR is under the control of cerebral structures that are involved in emotion processing, such as the prefrontal cortices (Papousek & Schulter, 2001), and the orbito-frontal cortex (Tranel & Damasio, 1994) that is known to participate in valence judgments (e.g., Anderson, 2003; Blood et al., 1999; Tranel & Damasio, 1994). It is because of these neural connections that we expect SCRs to vary according to musical valence.

A further demonstration that SRCs are elicited by emotions (including valence) is to show that these autonomic responses are attenuated in people who do not experience pleasure or emotions in general. To this aim, we tested rare individuals having no musical deficit but a specific disorder in experiencing emotions (Ribot, 1896). Those subjects are known as non-clinical physical anhedonics. Physical anhedonia is a failure in experiencing sensorial pleasure. In pathological cases, it may be a symptom of psychiatric disorders such as depression (Klein, 1974) and schizophrenia (Bernstein, 1987). In healthy subjects, anhedonia may appear as a personality trait identified using the Physical Anhedonia Scale (PAS) (Chapman et al., 1976). This scale measures the judgments of pleasantness for diverse sensory stimulations. Items include commonly pleasurable sights, sounds, smells, tastes, and tactile sensations. There is compelling evidence that anhedonics differ from controls in processing pleasant stimuli, and that self-described anhedonia is not a self-report response bias (Miller & Yee, 1994). This difficulty in experiencing pleasure is not due to perceptual disorders, such as deafness, hyperacusia or other similar deficits (Fernandes & Miller, 1995).

Given their impairment in experiencing pleasure, anhedonics should be less responsive to the emotional difference between consonant and dissonant music. That is, anhedonics' SRCs should be less sensitive to the pleasantness of the music than normal control individuals. To test this hypothesis, pleasantness judgment scores as well as the SCR were collected in both controls and healthy anhedonics while listening to pleasant and unpleasant musical stimuli, that were the consonant and dissonant versions of the same excerpts. The excerpts were taken from Western classical (consonant) music and modified so as to create dissonance by shifting the pitches of the leading voice by one semitone either upward or downward relative to its accompaniment, as used in Peretz et al. (2001).

Method

Participants

Participants were selected among 290 university science students, according to their score obtained on the Physical Anhedonia Scale (PAS) (Chapman et al., 1976). This scale has been validated in French (Loas, 1993), the native language of the participants. This questionnaire includes 61 items that must be rated as false or true. A response reflecting anhedonia gives 1 point and 0 otherwise. Hence, the higher the score, the more likely the participant suffers from physical anhedonia. According to the literature, a score of 29 and more on the PAS is sufficient to classify subjects as anhedonics (Loas, 1995; Lutzenberger et al., 1983). Control subjects were then selected if their scores were inferior to 10. Eleven anhedonic subjects accepted to participate in the experiment. However, despite the strong test-retest reliability of the PAS scores ($r=0.94$, $d.f.=22$, $p<0.001$), the score of one subject changed from 29 on the day of subjects' selection, to 22 on the day of the experiment. Since the mean scores of the two subjects' groups are calculated from the data obtained on the day of the experiment, this subject has been included as anhedonic in the study.

Four out of the 26 participants were excluded because they did not show detectable electrodermal responses (a minimum of 0.1 microSiemens (μS)) to any one stimulus. The remaining subjects were aged from 19 to 27 years. Eleven control subjects (7 males and 4 females) with a mean age of 22.9 years ($SD= 2.5$) and a mean anhedonic score of 4.5 ($SD= 2.8$) participated to the experiment as well as eleven anhedonics, all males, with a mean age of 22.7 years ($SD= 2.7$) and mean anhedonic score of 34.8 ($SD= 5.72$). None of subjects were taking medication.

The experiment has been approved by the institutional Ethics Committee of the University Institute of Geriatric Care of Montreal and was conducted with the fully informed consent of each subject.

Material

Twenty musical excerpts including 10 consonant and 10 dissonant versions of the same excerpts were used. They were taken from the set employed by Peretz et al. (2001) and shortened to the initial 7-sec duration. They were computer-generated via a synthesizer and delivered with a piano timbre. Auditory examples are available at: www.fas.umontreal.ca/psy/iperetz.html. To ensure that the pleasant and unpleasant excerpts do not differ in level of arousal, 9 pilot university subjects (mean age= 21.7 years, SD= 2.4) judged each of the 20 musical clips, on a 10-point rating scale from 1 (relaxing) to 10 (stimulating). A paired t-test performed on the averaged score obtained for each excerpt showed no difference (t=0.72, $d.f.$=14, p=0.5) between the arousal ratings for the consonant (mean= 5.63, SD= 0.61) and the dissonant excerpts (mean= 6.08, SD= 0.38).

Electrodermal measures

Skin conductance was recorded from the right hand, with a pair of Ag-AgCl electrodes (0.8 cm diameter) attached on the palmar surface of the medial phalange of the index and middle fingers. These electrodes were filled with a 0.050 molar NaCl paste. All recording procedures followed the recommendations set forth by Fowles et al. (1981). Data acquisition, acoustic stimuli presentation and quantification were performed using a Coulbourn S71-23 Coupler, and a customized program created with InstEP Systems v3.3.

Procedure

The experiment was performed in a quiet room. After skin conductance electrodes were attached, the subject was instructed to rest quietly during the ensuing 5-min rest period.

Subjects were seated comfortably, asked to avoid moving as much as possible, and to listen attentively to the 20 musical selections presented through headphones. The excerpts were presented binaurally in an identical pseudo-randomized order for each participant, through MDR-v200 Sony headphones. Their task was to verbally determine the valence of the stimulus, on a 10-point scale ranging from 1 (désagréable/unpleasant) to 10 (agréable/pleasant). SCRs were recorded throughout the task. A microphone system allowed the experimenter to hear and then write the subjects' verbal answers.

Each stimulus presentation was followed by an interval of at least 20 seconds to allow for skin conductance recovery to baseline before the next stimulus was presented. This inter-trial interval lasted as long as necessary for skin conductance to regain stability, generally not more than 30 seconds. After SCR recording, subjects had to fill up the Physical Anhedonia Scale (Loas, 1993). The whole session lasted about 40 minutes.

Data quantification and analysis

The first three stimuli were considered as examples and were excluded from the analysis as they may have evoked strong orienting component in response to novelty rather than to consonance or dissonance. SCRs and ratings for each excerpt were only considered if control subjects gave a rating superior to 5.5 for consonant stimuli and inferior or equal to 5.5 for dissonant stimuli. From the 20 excerpts, only 14 matched these criteria. These 14 stimuli comprised 7 dissonant and 7 consonant stimuli. Moreover, given that the SCR decreases with time in most subjects due to habituation (Dawson, Schell & Filion, 1990), to compare results for the two categories of musical excerpts, it is necessary to take into account a putative order effect. As the average rank orders of presentation for the 7 pleasant and 7 unpleasant stimuli are almost similar, with 12.3 and 13 respectively, the habituation effect was controlled.

SCRs were considered in the analyses when they occurred within a latency window of 1–4 s following stimulus onset (Venables & Christie, 1980). Maximal amplitude of the SCR elicited by each stimulus was the electrodermal parameter measured. SCR magnitudes and valence ratings for the 7 melodies of each category were averaged for each participant. Statistical analyses on SCRs were performed using non-parametric tests such as the Mann-Whitney, since the Kolmogorov-Smirnov normality test failed to reach significance. In contrast, ratings were normally distributed. Hence, mean ratings obtained for each excerpt in term of pleasantness were analyzed with a 2 X 2 analysis of variance (ANOVA) using Population (anhedonics vs controls) as between-subjects factor and Category (Dissonant vs Consonant) as within-subjects factor. Pairwise comparisons (Bonferroni test) were performed when the ANOVA tests reached significance ($p<0.05$).

Results

Valence ratings

The ANOVA yielded a significant main effect of Valence ($F(1, 20)= 38.6, p<0.001$) and Group ($F(1, 20)= 916, p<0.001$) on pleasantness ratings, and the interaction between these two factors almost reached significance ($F(3, 40)= 3.9, p=0.06$). As can be seen in Figure 1, consonant excerpts were judged as more pleasant than dissonant ones, and controls judged all excerpts as more pleasant than anhedonics did. This group difference tends to be especially pronounced for consonant excerpts.

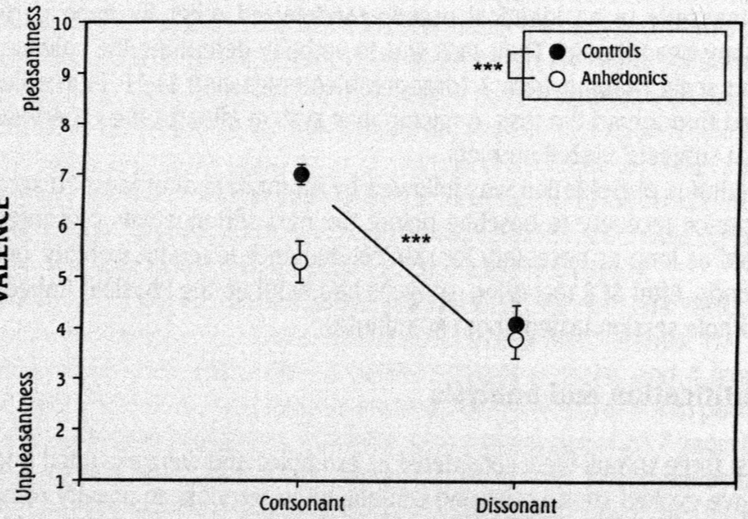

Figure 1. Means and standard error bars of pleasantness judgements for consonant and dissonant musical excerpts, in both anhedonic and control subjects. *** $p<0.001$

Valence and group effect on SCR

The representation of SCR in Figure 2 shows that the SCRs average magnitudes corresponding to the consonant clips were lower in anhedonics than in controls (U=30, p<0.05) whereas no significant difference was demonstrated between the two populations for the dissonant melodies. It is also shown in this figure that SCRs magnitudes were larger for consonant than for dissonant excerpts, in control subjects (z=-2.3, p<0.05) but this difference did not reach significance in anhedonic subjects.

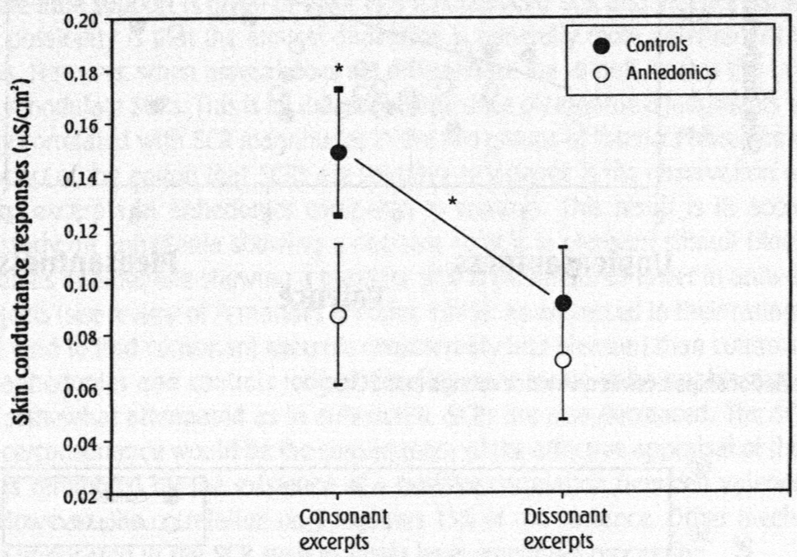

Figure 2. Means and standard error bars of SCR magnitudes while listening to consonant and dissonant musical excerpts, in both anhedonic and control subjects. * p<0.05

Relationships between SCRs, pleasantness judgments and PAS scores

Pleasantness judgments and SCR magnitudes were significantly correlated across the two groups (r=0.36, $d.f.$=44, p<.05). This correlation is not due to extreme SCR values (superior to 0.30 $\mu S/cm^2$); when these are discarded, the correlation is still significant (r=0.34, $d.f.$=42, p<.05). The higher the rating score (i.e. the more pleasant the excerpt), the greater the SCR magnitude (see Figure 3). No significant correlation was found between the SCR magnitudes and the PAS scores. However, as can be seen in Figure 4, when considering only the responses obtained for the consonant excerpts, pleasantness judgments did correlate with PAS scores (r=-0.75, p<0.001, N=22). That is, the higher the PAS score, the lower the valence rating for the consonant excerpts.

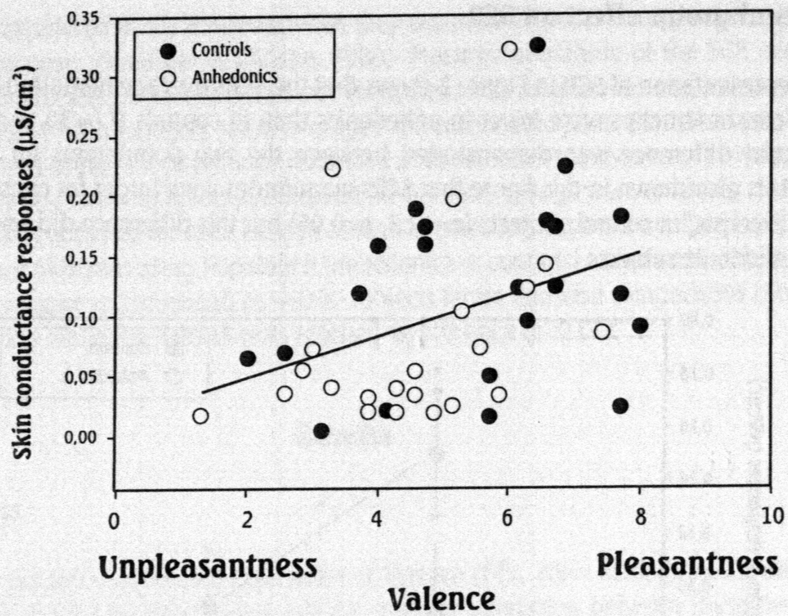

Figure 3. Relationships between valence ratings and SCRs

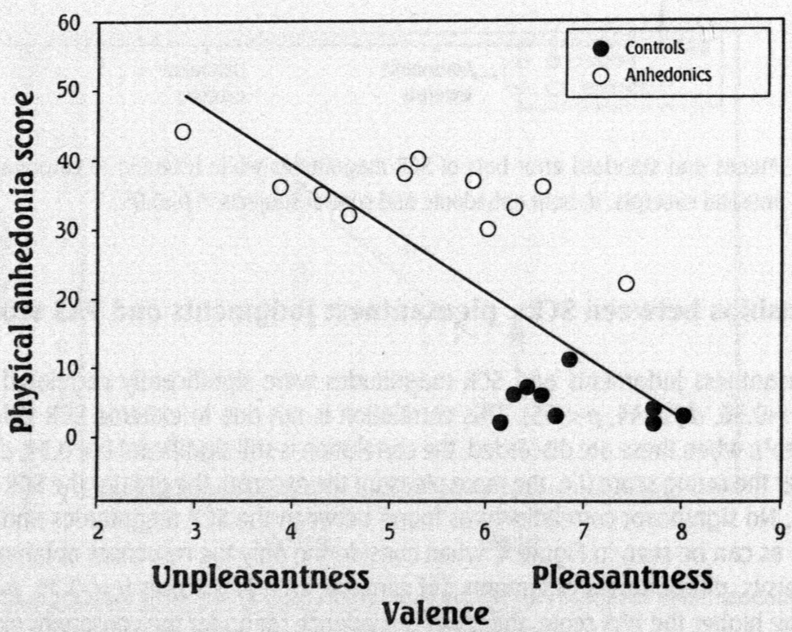

Figure 4. Relationships between physical anhedonia scores and valence ratings for the consonant excerpts

Discussion

The first important result of this experiment is the SCR sensitivity to differences between consonant and dissonant music. This distinction cannot be attributed to arousal differences between consonant and dissonant excerpts, since we controlled for this factor. Rather, the difference arises from the differential valence of consonant and dissonant music, as shown by the pleasantness judgments given by normal subjects. Therefore, SCR amplitude when listening to consonant as compared to dissonant music seems to reflect a valence effect. This finding contrasts with the literature where little support is given in favor of a link between SCR and valence (Bradley & Lang, 2000). One possibility is that the arousal dimension is generally more determinant than valence to elicit SCRs. However, when arousal does not differentiate the stimuli, as it is the case here, then valence may modulate SCRs. This is all the more likely since pleasantness judgments were found to be positively correlated with SCR magnitudes in the two groups of listeners tested here.

In support of the notion that SCRs are sensitive to valence is the observation of lower SCRs to consonant excerpts in anhedonics compared to controls. This result is in accordance with a previous study on anhedonia showing a decrease in SCR to pleasant stimuli (Rockstroh et al., 1982) as well as another one showing a trend for SCR to be similar or lower in anhedonia than in normal subjects (see review of Fernandes & Miller, 1995). As expressed in their ratings of valence, anhedonics tend to find consonant excerpts considerably less pleasant than controls did. In contrast, both anhedonics and controls judged the dissonant music to be unpleasant. Thus, when pleasure is somewhat attenuated as in anhedonia, SCRs are also decreased. The SCR sensitivity to dissonance/consonance would be the consequence of the affective appraisal of the music. This hypothesis is reinforced by the existence of a positive correlation between valence judgments and SCRs. However, the correlation only explains 13% of the variance. Other mechanisms may therefore be implicated in the SCR such as lower level emotional processing.

To conclude, our results support the idea that measuring SCR to musical excerpts is an appropriate means to assess emotional processing elicited by music. In the present experiment, this autonomic measure proved to vary according to the emotional content of the excerpts, especially the valence dimension which depends on the musical characteristics of dissonance/consonance. Further experiments on musical emotions would benefit from the use of SCR measures in conjunction with brain imaging techniques to deepen our understanding of emotion processing.

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