Universality vs experience: A cross-cultural pilot study on the consonance effect in music at different altitudes (#46935)

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Universality vs experience: A cross-cultural pilot study on the consonance effect in music at different altitudes

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Background. Previous studies have shown that music preferences are influenced by cultural “rules”, some others have suggested a universal preference for some features over others. **Methods.** We investigated cultural differences on the “consonance effect”, consisting in higher pleasantness judgments for consonant compared to dissonant chords – according to the Western definition of music: Italian and Himalayan participants were asked to express pleasantness judgments for consonant and dissonant chords. An Italian and a Nepalese sample were tested both at 1450 m and at 4750 m of altitude, with the further aim to evaluate the effect of hypoxia on this task. A third sample consisted in two subgroups of Sherpas: lowlanders (1450 m of altitude), often exposed to Western music, and highlanders (3427 m of altitude), less exposed to Western music. All Sherpas were tested where they lived. **Results.** Independently from the altitude, results confirmed the consonance effect in the Italian sample, and the absence of such effect in the Nepalese sample. Lowlander Sherpas revealed the consonance effect, but highlander Sherpas did not show this effect. **Conclusions.** Results show that neither hypoxia (altitude), nor demographic features (age, schooling, or playing music), nor ethnicity *per se* influence the consonance effect. We conclude that music preferences are attributable to music exposition.

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Abstract

Background. Previous studies have shown that music preferences are influenced by cultural "rules", some others have suggested a universal preference for some features over others. **Methods.** We investigated cultural differences on the "consonance effect", consisting in higher pleasantness judgments for consonant compared to dissonant chords – according to the Western definition of music: Italian and Himalayan participants were asked to express pleasantness judgments for consonant and dissonant chords. An Italian and a Nepalese sample were tested both at 1450 m and at 4750 m of altitude, with the further aim to evaluate the effect of hypoxia on this task. A third sample consisted in two subgroups of Sherpas: lowlanders (1450 m of altitude), often exposed to Western music, and highlanders (3427 m of altitude), less exposed to Western music. All Sherpas were tested where they lived. **Results.** Independently from the altitude, results confirmed the consonance effect in the Italian sample, and the absence of such effect in the Nepalese sample. Lowlander Sherpas revealed the consonance effect, but highlander Sherpas did not show this effect. **Conclusions.** Results show that neither hypoxia (altitude), nor demographic features (age, schooling, or playing music), nor ethnicity *per se* influence the consonance effect. We conclude that music preferences are attributable to music exposition.

Keywords: Consonance; Dissonance; Music pleasantness; Hypoxia; Culture; Altitude.

Running title: Consonance effect: Cultural or universal?

Introduction

The topic of music pleasantness extends towards a plethora of scientific fields, from psychology to neurology, from musicology to sociology, from ethnology to biology (Bowling & Purves, 2015; Bowling et al., 2017). The first issue in this domain is the definition of music pleasantness itself, followed by the difficulty in understanding whether universal laws exist according to which music can be categorized as pleasant vs unpleasant, or it is a personal preference, possibly influenced by culture (Cazden, 1980; Higgins, 2012). Concerning the first issue, in Western music pleasantness seems to be linked to harmony (McDermott, Lehr & Oxenham, 2010; McDermott et al., 2016): a harmonic chord (a set of notes played together) sounds as pleasant if it is consonant, and consonance is defined by the specific interval among notes (Bowling & Purves, 2015). According to this view, in fact, consonance is associated with pleasantness, and dissonance with unpleasantness (the so-called "consonance effect"; (Prete et al., 2015, 2019)). Music harmony is a central feature of Western music, and it is less diffuse in other cultures (Malm, 1996). This leads to the second issue raised above: if harmony is the base for the consonance effect, how are consonant and dissonant chords evaluated in those cultures in which harmony is not present? Answering this question can help in defining music preferences as established by nature or by nurture (Bowling et al., 2017): on the one hand, some agreement should be expected in the evaluation of pleasant vs unpleasant music across different cultures if music preferences are innate and biologically determined, but – on the other hand – different preferences for different music should be found among cultures if music preference is culturally defined.

Both of the aforementioned hypotheses found support in previous studies. Some evidences suggested music pleasantness to be a universal principle, independent from the cultural environment: for instance, a preference for consonance was described even in different species, such as birds and monkeys (Fishman et al., 2001; Chiandetti & Vallortigara, 2011), and it has been shown that 2-month-old infants prefer listen to consonant over dissonant chords (Trainor, Tsang & Cheung, 2002). Nevertheless, this evidence was not confirmed in a different study with 6-month-old infants (Plantinga & Trehub, 2014), and in other studies with monkeys (McDermott & Hauser, 2004), suggesting that music pleasantness might not be universal, developing instead with experience and listening habits, namely on culture (McDermott et al., 2016). Along similar lines, it has been suggested that the consonance/dissonance spectrum would be context-sensitive to the original ecological listening experience (Popescu et al., 2019).

A possible way to empirically disentangle the innate vs cultural origin of music preferences is represented by cross-cultural studies: the comparison among music preferences expressed by individuals belonging to very different cultures and living in countries very far apart from each other can help in shedding light on this topic. In this respect, McDermott and colleagues (McDermott et al., 2016) provided evidence for a cultural basis of music preferences, showing that music pleasantness is attributable to exposure to musical harmony. In particular, they tested Western (US Americans) participants, native Amazonian participants without exposure to Western culture (Tsimane'), and Bolivians living either in the capital city or in a rural town. The results showed that the Tsimane' did not evaluate differently consonant and dissonant chords, the participants from US confirmed the expected consonance effect, whereas the Bolivian groups were placed in the middle, showing a "consonance effect", but less strong than that of US participants. These findings confirm the usefulness of cross-cultural studies in the investigation of the possible biological substrate of music preferences.

With the present multicultural and globalized world, it is increasingly difficult to explore genuine cross-cultural variations (Segall et al., 1990). English language-based elements are indeed a key factor of modern cultural evenness, and this trend did not spare music listening habits. In this regard, the possibilities offered by extreme environmental research projects, such as the present "Kanchenjunga Exploration & Physiology" project, may be really useful. Indeed, the history of altitude physiology still continues to be enriched, especially by the current developments in the understanding of the peculiarities of high-altitude populations (West, 2016). For these reasons, in the present study we tested European and Himalayan participants, exploiting the different music cultures and habits of the two samples. Nepal had its declaration of democracy only in 1951, thus only in the last decades it started to open to different cultures, mainly near India and China (Dinnerstein & Alter, 2018). In the same year Radio Nepal was created and it broadcasted in Kathmandu alone, being the only radio station until the 1990s. Nepal has its own music culture, even if it is quite heterogeneous (Henderson, 2002), also due to the fact that these territories are inhabited by a mix of different populations, sometimes separated by mountains and thus very different from one another, some other times living together (Greene, 2003). In particular, in the North-East of the country, Tibetan groups are frequent, including Sherpas, an independent ethnical group coming from Tibet. The "Kanchenjunga Exploration & Physiology" project, a scientific expedition that took place mainly in the Himalayas, offered us the possibility to investigate music preferences in both Nepalese and Sherpa samples, and this in turns allowed us not only to compare music preferences of Western (European) and Himalayan participants, but also to further investigate differences between ethnical groups living close to one another (Nepalese and Sherpa), but having different music habits.

It is well known that altitude hypoxia negatively affects some aspects of physiology and, specifically, sensory systems (Cingi, Erkan & Rettinger, 2010; Jha, 2012; Ruffini et al., 2015); however, to our knowledge, there is still a lack of results regarding the effect of altitude hypoxia on music pleasantness. As well, cognitive and emotional adaptations were reported during altitude volitional exposition or during hypoxia confinement, suggesting that high motivation may drive pleasantness of the experience, even with highly demanding hypoxic expositions (Karinen & Tuomisto, 2017; Stavrou et al., 2018); in addition, despite the effect of music on mood has been extensively studied, also in their modulation of stress response (Koelsch et al., 2016), few studies, if any, investigated the modulation of mood in specific measures of music pleasantness. We therefore saw, among the other research lines of the project, the special possibility to explore the above-mentioned topics.

Aim

This study aimed to evaluate cultural variation of music consonance/dissonance pleasantness, a possible role of altitude and a possible mediation by mood, age, being a musician and Western music listening habit. To this aim, we exploited a musical test already used to describe the consonance effect in Western participants (see(Prete et al., 2015)), with three samples belonging to different cultures: an Italian sample was tested both at lower and higher altitudes with the aim to evaluate the possible effect of hypoxia at high altitude. Moreover, a mood questionnaire was also administered to this sample, in order to investigate the effect of hypoxia also on this variable. The second sample was Nepalese, with no or little exposition to Western culture and music. As for the Italian group, also this sample was tested both at lower and higher altitude, in order to evaluate the possible interaction between culture and hypoxia on the consonance effect. The third sample was composed of Sherpas: in this group, half of participants were lowlanders, the majority of which were used to listen to Western music, and they were tested only at low altitude (their living altitude); the other half were highlanders, rarely exposed to Western music, who were tested only at high altitude (their living altitude). This last group allowed us to evaluate the effect of exposition to Western music within the same culture (Sherpa). Starting from the results described by McDermott and colleagues (McDermott et al., 2016), we expected to confirm the consonance effect in the Italian group, and likely in lowlander Sherpas, often exposed to Western music, and we did not expect to find such effect in the other groups. Concerning altitude, due to the absence of previous evidence in this regard, we did not have specific expectations on the effect of hypoxia on music pleasantness evaluation. Moreover, we also took into account the possible effects of time spent listening to music, frequency of exposition to Western music, years of education and playing music or otherwise on the consonance effect.

Materials and methods

Participants

The task was carried out by three groups of participants (N = 22; see Table 1 for demographic information self-reported by each participant): Italians, Nepalese, and Sherpas. The Italian group was composed of six healthy Caucasian lowlanders (5 males, 1 female; age: 43.83 ± 15.30 years; BMI: 25.81 ± 3.25 Kg/m^2; schooling: 18.50 ± 3.27 years), who were used to listen to Western music, on average 1.5 hours/day. The Italian group spoke on average 1.33 foreign languages (range: 0-2, all Western languages). The Nepalese group was composed of six healthy porters, lowland dwellers (all males; age: 30.33 ± 8.55 years; BMI: 24.36 ± 4.70 Kg/m^2;

schooling: 5.86 ± 4.71 years), who declared to listen on average 1.37 hours/day, but only one participant reported to listen to Western music sometimes. This group also reported to speak on average 1.33 foreign languages (range: 0-3, including 3 participants who spoke English; the other spoke Eastern languages). The third group was composed by ten healthy Sherpa (all males). This group was further divided into five lowlanders (age: 28.60 ± 5.23 years, schooling: 11.20 ± 3.63 years) and five highlanders (age: 37.00 ± 16.51 years, schooling: 6.40 ± 4.28 years). Lowlander Sherpas were used to spend much time to listen music (on average, 4 hours/day) and, except one participant, they declared to be often exposed to Western music. This seems to be in line with the self-reported data according to which all of them spook at least three foreign languages, included English (range: 3-4, average: 3.2). Highlander Sherpas listened to less music (0.9 hours/day) and only one participant in this subsample stated to sometimes listen to Western music. Only this participant and another one in this subsample declared to speak English, with a mean of 1.6 foreign languages spoken in the subsample (range: 0-3; Eastern languages). Among all participants, 7 of them played music since at least 3 years (2 Italian, 1 Nepalese, 2 lowlander and 2 highlander Sherpas). Table 1 summarizes demographic data of the whole sample.

**** Table 1 here ****

Design of the study

The research project "Kanchenjunga Exploration & Physiology" was a subset of "Environmentally-modulated metabolic adaptation to hypoxia in altitude natives and sea-level dwellers: from integrative to molecular (proteomics, epigenetics, and ROS) level". The present study did not involve patients, children or animals, as well as drugs, genetic samples or invasive techniques, thus it was not subject to ethical review by the academic medical research board. Nevertheless, verbal informed consent was obtained from all participants and the experiment was conducted in accordance with the ethical standards prescribed by the Declaration of Helsinki and its later amendments.

The expedition consisted of a combined circuit of 300 Km distance (south and north base camps), covering a daily average of 6 hours walk, for a total of 110 hours, along a demanding route with ascent and descent covering totally over 16000 meters in altitude, in the Himalayan mountain range of eastern Nepal, at the border with Sikkim (India). The project investigated adaptive physiological responses during a trekking at moderate and high altitude, in different experimental groups (Italians and Nepalese, for more details see Participant section).

The study protocol involved music pleasantness testing on Italian (group 1) and Nepalese (group 2) participants at lower and higher altitudes (respectively ML and MHA, see Figure 1). Italians and Nepalese carried out the same auditory test twice, in Kathmandu (1450 m) and in Lhonak (4780 m). Only Italian participants also underwent mood state testing on the same days, at the end of the auditory test.

Sherpas were tested once, in a between-subjects design: lowlander Sherpas were tested in Kathmandu, where they lived, whereas highlander Sherpas were tested in Ghunsa (MA, see Figure 1) at 3427 m, where they lived.

Figure 1 here

Stimuli and procedure

The stimulus set was composed of 24 triad chords, including 12 consonant and 12 dissonant chords, according to the Western music definition of consonance and dissonance. The same set of stimuli and paradigm had already been used with an Italian sample (Prete et al., 2015), confirming the "consonance effect", namely the lower and higher pleasantness evaluation of dissonant and consonant chords, respectively. Consonant chords consisted of major third intervals, perfect fifth intervals and minor third and sixth intervals, whereas dissonant chords consisted of minor and major second and seventh intervals (for more details see (Prete et al., 2015)). By exploiting these intervals, three consonant and three dissonant triads were created with a piano timbre and, by means of GoldWave v5.25 software (GoldWave Inc., Canada), they were then transposed up by 4, 6 and 9 semitones for a total of 12 consonant and 12 dissonant chords. Each stimulus lasted 1330 ms and included 630 ms of linear fade out. Each stimulus was repeated four times for a total set of 96 stimuli, presented in a random order and they were presented by means of headphones (see Figure 2).

Before the beginning of the task, experimental instructions were verbally presented: participants were instructed that very brief audio clips would be presented one at time, and that they will be required to express a pleasantness judgment for each clip, by using a 4 point-Likert scale (1=not at all; 2=little; 3=enough; 4=very much). The list of four responses were also printed in the mother tongue of each participant in order to avoid possible confounding effects on the scale used, and to make sure that the response provided by the participant could be clearly recognized by the experimenter.

The paradigm was presented by means of a tablet pc (Microsoft Surface Pro 6) and it was controlled by the experimenter, who sat behind the participant for the whole task. The participant was asked to listen to each stimulus and to express a pleasantness judgment by pointing to the desired alternative on the response sheet, that remained in front of the participant. Once the response was provided, the experimenter recorded the number corresponding to the response on a sheet previously prepared, and started the next trial.

Figure 2 here

After the end of the auditory task, only Italian participants were required to fill the 58-item Italian version of Profile Of Mood State (POMS). In this questionnaire, a global score, called Total Mood Disturbance (TMD), is calculated from the sub-scores as follows: Tension + Depression + Anger + Fatigue + Confusion −Vigour + 100. This type of testing had already been used in monitoring the mood state in sports and hypoxic environments (Peri, Scarlata & Barbarito, 2000; Kenttä, Hassmén & Raglin, 2006; Karinen & Tuomisto, 2017).

Statistical analyses

Statistical analyses were carried out using the R-based open-source software Jamovi (The Jamovi project. jamovi (Version 1.0) [Computer Software]. https://www.jamovi.org 2019) for General Linear Model (GLM) Mediation Analyses, and by means of Statistica 8.0.550 (StatSoft. Inc., Tulsa, OK, USA) for Analyses of Variance (ANOVAs).

Mean pleasantness evaluations for consonant and dissonant chords expressed at the lower altitude (Kathmandu) and at the higher altitude (Ghunsa and Lhonak) were considered separately. Moreover, the difference of pleasantness evaluation between consonant and dissonant chords was also calculated, obtaining an overall measure in which negative scores corresponded to unpleasant judgments, positive scores corresponded to pleasant judgments and a score of 0 corresponded to a neutral judgment (neither pleasant nor unpleasant).

A first GLM Mediation Analysis was used to test the mediation role of age and years of schooling, with Consonance-Dissonance difference as the dependent variable and Ethnicity (Italian, Nepalese, Sherpa), Listening to Western music (yes vs no) or Playing music (yes vs no) as the independent variables. A second GLM Mediation Analysis was used on the Italian sample to test TMD (from POMS questionnaire) as a mediator, with Consonance pleasantness, Dissonance pleasantness and Consonance-Dissonance difference as the dependent variables, and Altitude (low, high) as the independent variable. Both mediations were carried out with the jAMM (Advanced Mediation Models) suite for jamovi software (https://jamovi-amm.github.io/index.html).

Then, by means of two mixed repeated-measures ANOVAs, Ethnicity (Italian, Nepalese, Sherpa) was considered as a between-subjects factor, and Chord (consonant, dissonant) was used as a within-subject factor. Pleasantness evaluations recorded at the lower altitude were used as the dependent variable in the first ANOVA, and those recorded at the higher altitude were used in the second ANOVA. This separation was necessary because, if Italian and Nepalese participants carried out the task at both altitudes, Sherpa participants who carried out the task at lower and higher altitudes were two different subgroups. For this reason, in a third ANOVA, only Italian and Nepalese participants were included, and both Chord (consonant, dissonant) and Altitude (low, high) were used as within-subject factors, whereas Ethnicity (Italian, Nepalese) was used as between-subject factor. Finally, considering only the Sherpa subgroups, a fourth ANOVA was carried out, using Chord (consonant, dissonant) as within-subject factor and Altitude (low, high) as between-subject factor. In all ANOVAs post-hoc tests were carried out by means of Duncan test.

Results

No participant reported symptoms of Acute Mountain Sickness (AMS) during the trek.

The first GLM Mediation Analysis revealed that, among the variables of Ethnicity, Playing music and Listening to Western music, with Age and Schooling as mediators, the only one that significantly predicted Consonance-Dissonance difference was Listening to Western music (β weight = 0.572, p<0.001), mainly and significantly with a direct effect (β = 0.441, p = 0.021), not with the mediation of Age (β = 0.010, p = 0.813) nor Schooling (β = 0.121, p = 0.241).

The second GLM Mediation Analysis, carried out to test the role of TMD (from POMS questionnaire), revealed that altitude significantly predicted TMD ($\beta = -0.550$, p = 0.023), with lower TMD values at high (93.50 ± 9.16) with respect to low altitude (115.83 ± 24.65). No significant prediction was found for TMD with respect to any of the variables (Consonance, Dissonance, Difference between consonance and dissonance), nor any mediation was revealed (see Figure 3).

Figure 3 here

In the first ANOVA (lower altitude), the main effect of Chord was significant ($F_{(1, 14)}$ = 40.62, $p < 0.001$, $\eta_p^2 = 0.74$), confirming the "consonance effect", with higher pleasantness scores for consonant chords (M ± SEM: 2.63 ± 0.15) with respect to dissonant chords (2.1 ± 0.15). Importantly, the interaction between Ethnicity and Chord was significant ($F_{(2, 14)}$ = 12.58, $p < 0.001$, $\eta_p^2 = 0.64$) and post-hoc tests confirmed the consonance effect in both Italian and Sherpa samples ($p < 0.001$ for both comparisons), but not in Nepalese participants ($p = 0.82$).

In the second ANOVA (higher altitude), the main effect of Chord did not reach significance ($F_{(1, 14)} = 3.53$, $p = 0.081$). The main effect of Ethnicity was significant ($F_{(2, 14)} = 3.82$, $p = 0.048$, $\eta_p^2 = 0.35$), revealing lower pleasantness scores for Sherpa (1.85 ± 0.25) with respect to both Italian (2.45 ± 0.25, $p = 0.028$) and Nepalese (2.46 ± 0.08, $p = 0.033$) participants. Finally, the interaction was also significant ($F_{(2, 14)} = 10.88$, $p = 0.001$, $\eta_p^2 = 0.61$), and post-hoc comparison showed that only in the Italian sample consonant chords (2.94 ± 0.31) were judged as more pleasant than dissonant chords (1.97 ± 0.29, $p < 0.001$). Furthermore, consonant chords received lower pleasantness judgments by Sherpa (1.74 ± 0.17) compared to both Italian (2.94 ± 0.31, $p < 0.001$) and Nepalese (2.42 ± 0.12, $p = 0.038$) participants.

The third ANOVA, carried out considering lower and higher altitude scores of the Italian and Nepalese groups, further confirmed the consonance effect, as shown by the main effect of Chord ($F_{(1, 20)} = 24.64$, $p < 0.001$, $\eta_p^2 = 0.55$), with higher pleasantness scores for consonant (2.61 ± 0.12) than for dissonant (2.17 ± 0.11) chords. Importantly, the interaction between Ethnicity and Chord was significant ($F_{(1, 20)} = 32.33$, $p < 0.001$, $\eta_p^2 = 0.62$; Figure 4), and post-hoc comparisons showed that the consonant effect was due exclusively to the Italian group ($p < 0.001$), who rated consonant chords as more pleasant than dissonant chords. Accordingly, consonant chords were evaluated as more pleasant by Italian than Nepalese participants ($p = 0.03$), whereas dissonant chords were evaluated as less pleasant by Italian than Nepalese participants ($p = 0.025$). The other main effects and interactions were not significant, revealing no effect of the altitude on the auditory test.

Figure 4 here

The fourth ANOVA, carried out on the pleasantness scores of the two Sherpa groups tested either at lower or higher altitude, showed a trend toward the consonant effect which failed to reach statistical significance ($F_{(1, 8)} = 3.23$, $p = 0.056$). Only the interaction between Altitude and Chord was significant ($F_{(1, 20)} = 17.22$, $p = 0.003$, $\eta_p^2 = 0.68$; Figure 5), revealing a consonance effect only in the lowlander group ($p = 0.002$), but not in the highlander group ($p = 0.21$). Furthermore, consonant chords were judged as more pleasant by lowlanders than by highlanders ($p = 0.018$).

Figure 5 here

Discussion

The first important finding of the present cross-cultural study supports the cultural origin of music preference: the consonance effect was confirmed in the Italian sample and it was not found in the Nepalese sample. This first result would exclude the possibility that music preference is innate and biologically determined, because if this hypothesis were true we should have found a similar preference in all the samples tested. Importantly, a further crucial result was obtained in the group of Sherpa: the results showed that a consonance effect was present in lowlander Sherpas, namely the subsample who declared to listen to Western music, but the effect was completely absent in highlander Sherpas, the subsample who declared to listen to music less frequently and, importantly, not to listen to Western music. This latter result is the most important of the present study, because it shows that music exposition is the key factor determining the consonance effect: even if they belong to the same ethnicity, only Sherpas often exposed to Western music showed a consonance effect, even if to a lesser degree than the Italian sample. This conclusion is statistically confirmed also by the mediation analysis, revealing that the only effect which influences the consonance effect is the exposition to Western music, independently from the ethnical group.

In the present study we also explored the possible effect of some demographic features on the consonance effect, such as age, schooling and playing music: the results revealed that none of these variables influences music pleasantness, stressing that the exposure to a particular kind of music is the only variable responsible for the consonance effect. It has to be underlined that previous evidence revealed that preference for consonance is related to musical experience, showing a higher preference for harmonic chords in participants who had music training, even if aesthetic judgments for dissonant chords were not influenced by musical training (McDermott, Lehr & Oxenham, 2010). Moreover, in a cross-cultural study with Western and African (Cameroon) participants, Fritz and colleagues (Fritz et al., 2009) found no group differences in judging both emotional content (happy, sad, fearful) and pleasantness of Western and African music, suggesting a biological basis of music processing, independent from the culture.

Even if we did not have specific hypotheses in this regard, we also considered altitude hypoxia as a possible influencing variable, because of the well-known affecting role of such condition in sensory systems and cognitive performance (Cingi, Erkan & Rettinger, 2010; Jha, 2012; Ruffini et al., 2015; Limmer & Platen, 2018), but our results showed that neither pleasantness, nor consonance-dissonance difference, were influenced by altitude. Only the mood was influenced by hypoxia, with the Italian sample revealing lower mood disturbance scores (index of tension, depression, anger, fatigue and confusion) at higher compared to lower altitudes. We speculate that this difference could be due to the fact that once climbed the mountain, the more positive mood can be due to a kind of gratification compared to the possible concern before the climb. This result agrees with the findings of Karinen and Tuomisto, who reported that during a prolonged expedition in Everest mountain well-motivated participants were capable to maintain a good mood state (Karinen & Tuomisto, 2017); on the contrary, Stavrou and colleagues, who reported that hypoxia was capable to negatively affect the mood, exacerbating the effect of bed rest and ambulatory confinement (Stavrou et al., 2018). Other evidences linked mood and altitude hypoxia, affirming that mood states were adversely affected by duration and level of altitude, but with a main role of physical exertion (Shukitt-Hale & Lieberman, 1996). Heinrich and colleagues recently affirmed that acclimatization plays a big role in cognitive and mood alterations during a sojourn at altitude (Heinrich et al., 2019). To be noted that none of our participants suffered remarkable altitude sickness symptoms. Thus, from these findings and from our results, we support the idea that hypoxia may increase the mood disturbance during non-rewarding conditions or in association with altitude sickness symptoms, but that hypoxia *per se*, or hypoxia during motivating conditions does not promote mood disturbances.

The present results, suggesting a crucial role of music exposition on music pleasantness, are largely in accordance with those described by McDermott and colleagues (McDermott et al., 2016) who tested US, Bolivian and Amazonian participants. In their study, the authors found that Western participants judged consonant chords as more pleasant than dissonant chords, and they found that Amazonians – not exposed to Western culture – did not show this preference, and Bolivians' scores were halfway. This pattern of results is confirmed also by the present study, in which the preference for consonant over dissonant chords was high for Italians, it was absent for Nepalese and Sherpa not exposed to Western culture, but it was present (in a lesser degree compared to Italians) in Sherpa often exposed to Western music. Compared to their findings, the present study adds the evidence of null effects of other demographic information on music preference, as well as it shows a null effect of hypobaric hypoxia on the pleasantness of music.

We should highlight that, due the low sample size tested in the present study and to the absence of control tasks, caution is needed in the generalization of the present results. Nevertheless, the fact that our findings strictly resemble those recently described by McDermott and colleagues allows us to be quite confident about the validity of our conclusion. It has to be noted, moreover, that the relatively low sample size is also due to the difficulty in testing participants belonging to remote cultures, and mainly to the fact that the test was administered at different altitudes, including Lhonak (4780 m); the same contextual factors limited the possibility to perform control tasks. However, these limitations are typical of field studies in extreme environments.

To summarize, we could consider these results as a further evidence in favor of the crucial role of music exposition in music preference, having found that neither physiological changes possibly due to altitude, nor demographic differences influence this preference. Cross-cultural studies represent unique opportunities to test the biological bases of the most disparate human behaviors, and the present results add further evidence supporting that music pleasantness is not universally shared, but strongly depends upon habits.

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Competing interests

Luca Tommasi is an Academic Editor for PeerJ.

Table caption:

Table 1: Self-reported demographic data: Eth (Ethnicity: ITA = Italian, NEP = Nepalese, SHEh = highlander Sherpas; SHEl = lowlander Sherpa); Sex (F = female, M = male); Age; Sch (schooling: years of instructions); Music (YES = musician, NO = not musician); Y/Mus (years of music study); WestM (YES = listening to Western music; NO = not listening to Western music); Freq (frequency of Western music listening); Lang (number of foreign language spoken); Lang (foreign language spoken: Eng = English, Fre = French, Ger = German, Tib = Tibetan, Hin = Hindi, Chi = Chinese, Ara = Arabic); Hand (handedness: L = left, R = right).

Figure captions

Figure 1: Altimetric plan of "Kanchenjunga Exploration & Physiology" project.

Figure 2: Actual experimental setting at high altitude.

Figure 3: Mediation Analysis of Total Mood Disturbance (TMD) from Profile Of Mood State (POMS) questionnaire, on the relation between altitude and music pleasantness. Values displayed are β weights. Dotted lines represent the indirect effects (i.e. those mediated by TMD), while the whole lines represent the direct effects. Panel A shows the analysis on Consonance (Cons.), panel B on Dissonance (Diss.) and panel C on the difference Consonance – Dissonance (Diff.).

Figure 4: Interaction between Ethnicity (Italian, Nepalese) and Chord (consonant, dissonant), on the pleasantness judgments (from 1 to 4). Bars represent standard errors and asterisks show significant comparisons ($p < 0.05$).

Figure 5: Interaction between Altitude (low altitude: lowlander subsample, high altitude: highlander subsample) and Chord (consonant, dissonant), on the pleasantness judgments (from 1 to 4). Bars represent standard errors and asterisks show significant comparisons ($p < 0.05$).

Table 1 (on next page)

Self-reported demographic data

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Table 1

N	Eth	Sex	Age	Sch	Music	Y/Mus	WestM	Freq	N Lang	Lang	Hand
1	ITA	F	36	21	YES	30	YES	often	2	Eng-Ger	R
2	ITA	M	63	18	NO		YES	always	0		R
3	ITA	M	59	13	NO		YES	always	1	Fre	R
4	ITA	M	25	17	NO		YES	always	1	Eng	R
5	ITA	M	32	20	YES	10	YES	often	2	Eng-Esp	R
6	ITA	M	48	22	NO		YES	always	2	Eng-Fre	R
7	NEP	M	26	12	NO		YES	little	3	Hin-Eng-Ara	R
8	NEP	M	18	10	NO		NO		0		R
9	NEP	M	39	0	NO		NO		0		R
10	NEP	M	40	7	NO		NO		2	Hin-Eng	R
11	NEP	M	30	4	YES	3	NO		2	Hin-Eng	L
12	NEP	M	29	0	NO		NO		1	Hin	R
13	SHEh	M	56	7	NO		NO		3	Tib-Hin-Eng	R
14	SHEh	M	23	12	YES	7	YES	often	3	Tib-Hin-Eng	L
15	SHEh	M	25	6	NO		NO		0		R
16	SHEh	M	54	0	NO		NO		1	Tib	R
17	SHEh	M	27	7	YES	6	NO		1	Tib	R
18	SHEl	M	37	16	YES	5-10	YES	often	3	Hin-Eng-Tib	R
19	SHEl	M	23	12	YES	5-10	YES	often	3	Hin-Eng-Tib	R
20	SHEl	M	29	6	NO		YES	often	4	Tib-Eng-Chi-Hin	R
21	SHEl	M	28	12	NO		NO		3	Hin-Tib-Eng	R
22	SHEl	M	26	10	NO		YES	often	3	Tib-Hin-Eng	R

Figure 1

Altimetric plan of the project

Altimetric plan of “Kanchenjunga Exploration & Physiology” project

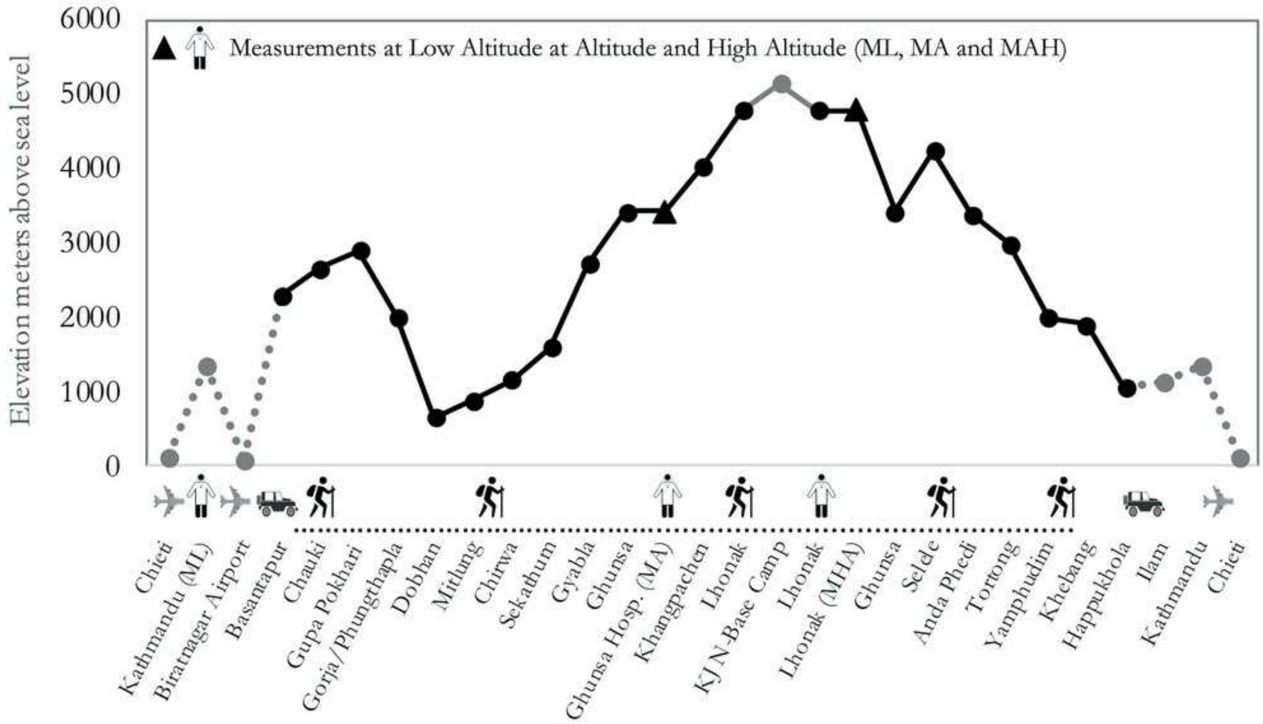

Figure 2

Experimental setting

Actual experimental setting at high altitude.

Figure 3

Mediation Analysis of Total Mood Disturbance (TMD) from Profile Of Mood State (POMS) questionnaire

Mediation Analysis of Total Mood Disturbance (TMD) from Profile Of Mood State (POMS) questionnaire, on the relation between altitude and music pleasantness. Values displayed are β weights. Dotted lines represent the indirect effects (i.e. those mediated by TMD), while the whole lines represent the direct effects. Panel A shows the analysis on Consonance (Cons.), panel B on Dissonance (Diss.) and panel C on the difference Consonance – Dissonance (Diff.).

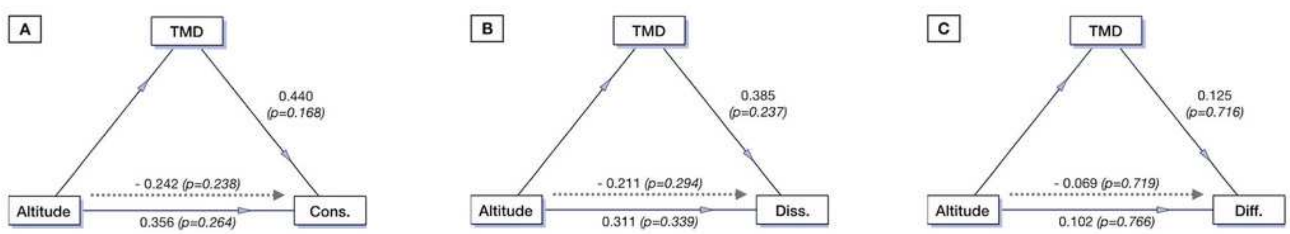

Figure 4

Interaction between Ethnicity (Italian, Nepalese) and Chord (consonant, dissonant)

Interaction between Ethnicity (Italian, Nepalese) and Chord (consonant, dissonant), on the pleasantness judgments (from 1 to 4). Bars represent standard errors and asterisks show significant comparisons ($p < 0.05$).

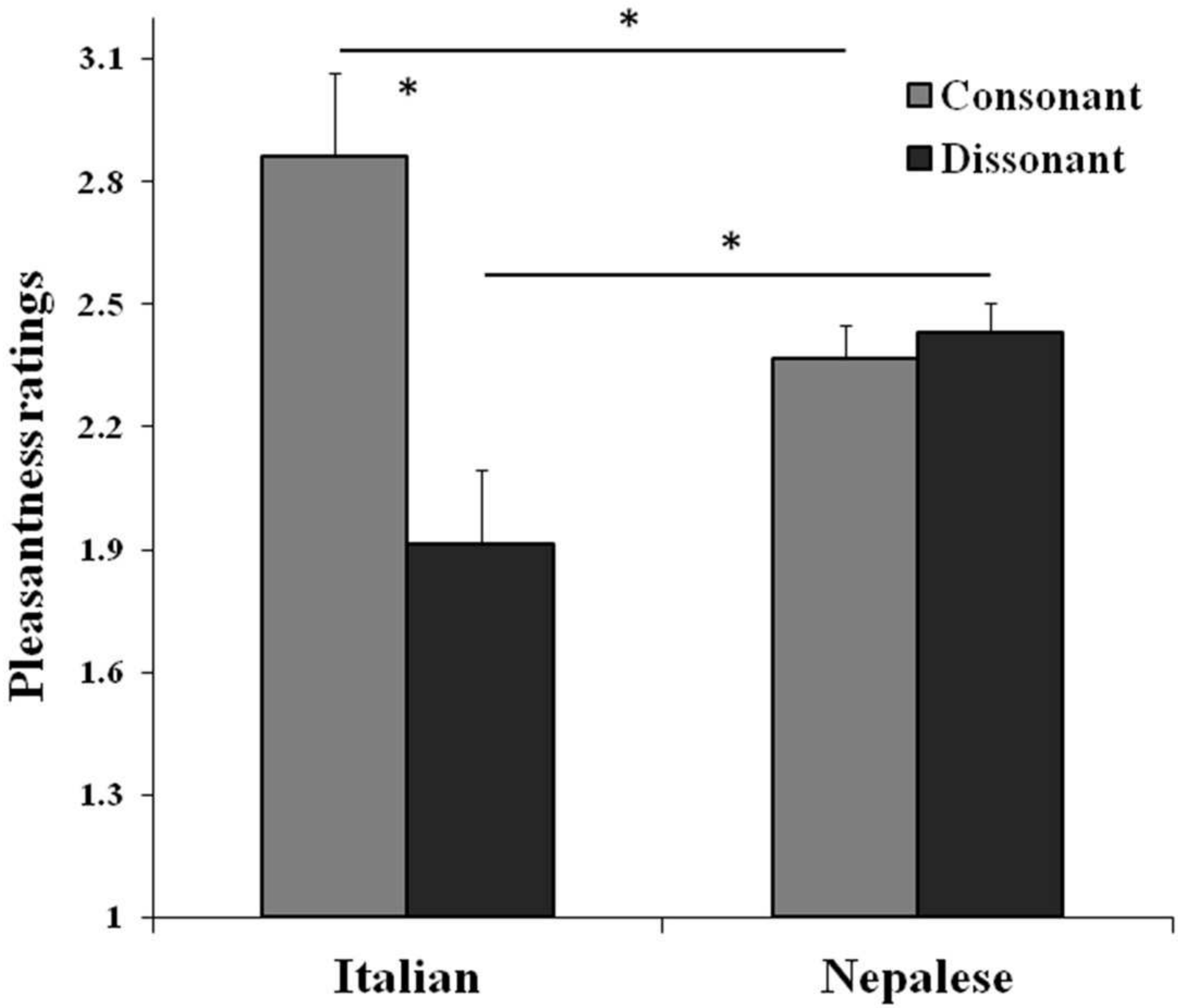

Figure 5

Interaction between Altitude (low altitude: lowlander subsample, high altitude: highlander subsample) and Chord (consonant, dissonant)

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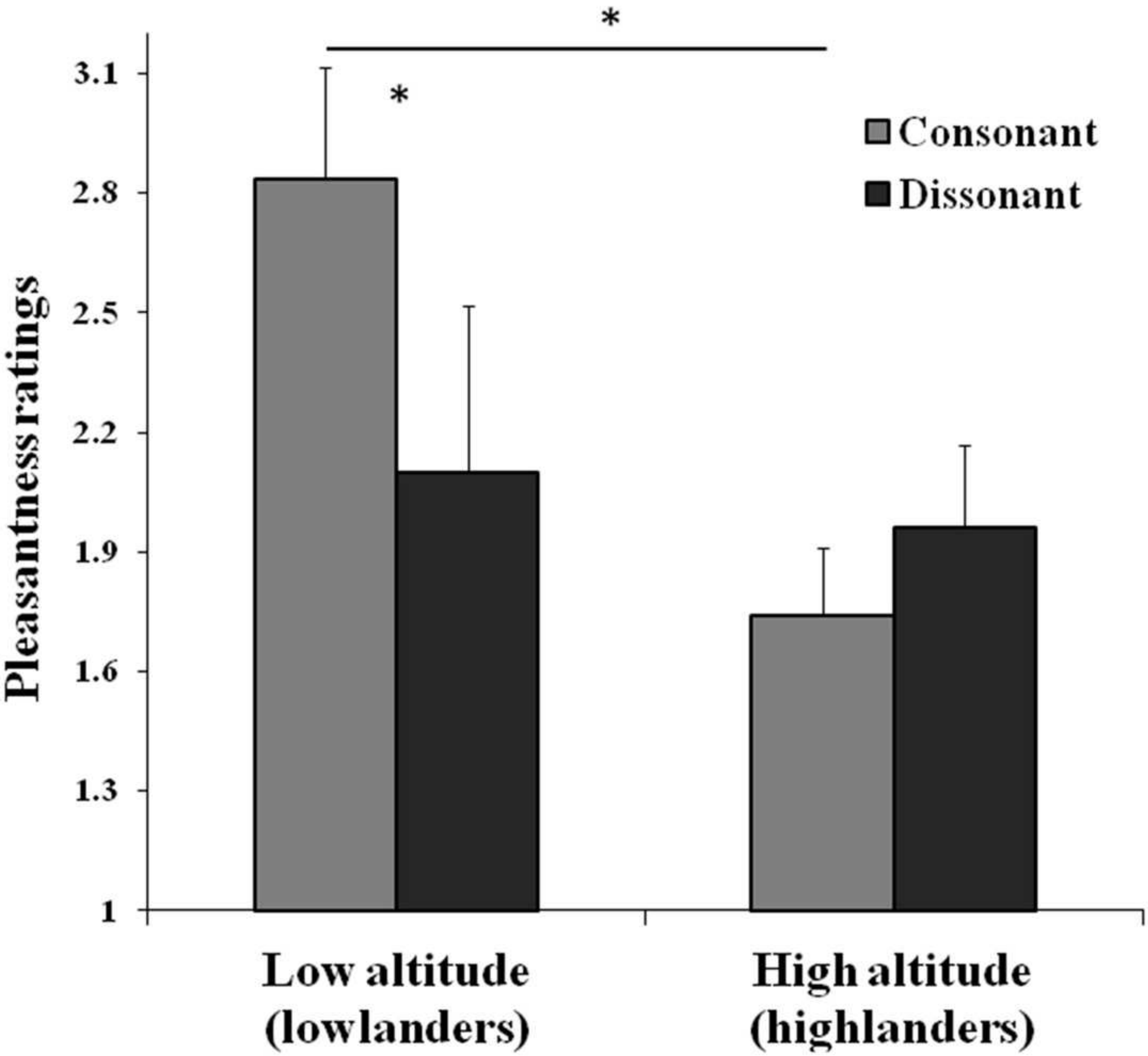

*
*
Consonant
Dissonant
3.1
2.8
2.5
2.2
1.9
1.6
1.3
1
Pleasantness ratings
Low altitude (lowlanders)
High altitude (highlanders)