Title: Emotion Induction through Music: Peripheral correlates of hedonic valence and arousal during a passive listening task

Running Head: Emotion induction through music in a passive listening task

Authors: Adrián Aparicio-Cuenca[a], M. Carmen Pastor[a*]

*Corresponding author. Universitat Jaume I. Facultad de Ciencias de la Salud. Área de Psicobiología. Avda. Sos Baynat s/n. Castellón de la Plana E-12071, Spain

Funding: This work was supported by Universitat Jaume I [UJI-B2019-34]

ABSTRACT

Music is a very interesting experimental stimulus due to its universal capacity to induce emotions. Empirical studies have mainly focused on self-reports and central measures effects, with only a few works exploring peripheral psychophysiological correlates. In this study we use electrodermal activity (EDA) and facial electromyography (EMG) in zygomatic and corrugator with the aim to investigate several peripheral mechanisms of hedonic valence and arousal. A sample of 50 healthy participants (25 women) listened and rated 42 excerpts from FMSS (14 of each category: unpleasant, neutral, pleasant) while their psychophysiological responses were continuously recorded. Results showed the reliability of EDA and facial EMG to measure arousal and valence, respectively. Both EDA and zygomatic activity were larger during pleasant vs. unpleasant and neutral stimuli, whereas corrugator showed higher activity for unpleasant music. Taken together, our findings provide additional evidences of the capacity of music to induce emotions in laboratory contexts, opening new avenues regarding plausible interventions based on music in pathologies with underlying emotion deregulatory processes.

KEYWORDS: emotion induction, music, electrodermal activity, zygomatic, corrugator

1. **Introduction**

Music is very important for humans, to the point that human inborn neural architecture is sensitive to musical aspects at birth (Koelsch, 2013). In addition, music has shown capacity to produce universal emotional responses, which makes extremely interesting for affective neuroscientists. Merely listening to music prompt relevant changes in the components of human emotion: is: (a) physiological arousal (for example endocrine and autonomic activity); (b) motor expression (smiling, frowning, etc.); (c) subjective feeling (sadness, happiness, etc.); (d) action tendencies (like foot or finger tapping, etc.); and even some times (e) cognitive appraisal. All these affective reactions happen as specific brain circuits underlying emotions are the same independently of being triggered by real-life situations or by music. Nevertheless, there is an unresolved debate regarding how music is able to elicit emotions. Moreover, the emotional response to music is different in each individual, as a result of a complex series of interlacing elements, such as memories or moods during hearing a piece of music (Daly et al., 2015).

To test these reactions, we measured electrodermal activity (EDA) and facial electromyography (EMG) based on corrugator and zygomatic muscles activity. These peripheral correlates have been consistently associated with the emotional arousal (calm-aroused) and affective valence dimensions of emotional experience, respectively (Bradley, Codispoti, Cuthbert & Lang, 2001; Steinbeis, Koelsch & Sloboda, 2006).

Electrodermal activity, which reflects the changes in electrical resistance or conductance of the skin, has shown to be a reliable, direct measure of the sympathetic nervous system (Bradley et al., 2001; Ribeiro, Santos, Albuquerque & Oliveria-Silva, 2019). Furthermore, arousal is related to the dynamical modulation of homeostatic functions through sympathetic and parasympathetic autonomic systems, which involves the activity of eccrine sweat glands. Accordingly, EDA has been considered as a clear psychophysiological index of emotional arousal (Critchley, 2002). This is in line with prior studies showing that EDA is enhanced in emotional or motivational significant music excerpts compared to neutral ones (Hodges, 1993; Ribeiro et al., 2019), probably due to the higher arousal produced by pleasant or unpleasant music in contrast to neutral. Moreover, many studies have found that pleasant music leads to larger electrodermal responses as compared to unpleasant stimuli (Lundqvist, Carlsson, Hilmersson & Juslin, 2009; Roy, Mailhot, Gosselin, Paquett & Peretz, 2009; Bullack, Büdenbender, Roden & Kreutz, 2017).

Regarding affective valence, facial EMG reactivity has been established as a reliable physiological correlate to measure emotional facial expressions. Specifically, zygomatic reactivity going from cheekbones to mouth corners and involved in smile, seems to be a good measure of the pleasantness of musical stimuli, whereas corrugator reactivity portrays the unpleasantness of the stimulus, as its function is implicated in unspecific frowning found in negative emotions such as disgust, anger or fear (Hodges,1993). However, as there is not consensus across studies, this question is still discussed in the literature.

Accordingly, the current study aimed to investigate peripheral mechanisms underlying emotional reactions during passive listening of pleasant, neutral, unpleasant film music excerpts. Here we explored psychophysiological and subjective correlates of emotional reactions induced through music that vary in terms of hedonic valence (affective ratings, facial EMG) and arousal measures (arousal ratings, EDA).

In line to prior studies, we expected enhanced responses in EDA during both pleasant and unpleasant music excerpts, since those two categories are motivationally relevant and rated as more arousing. In addition, we expected greater zygomatic and corrugator reactivity to pleasant and unpleasant music conditions, respectively. Regarding subjective ratings, we predicted that pleasant excerpts would be rated as more positive than neutral and unpleasant ones. We also expected to have higher arousal ratings for both pleasant and unpleasant excerpts compared to neutral.

2. **Method**

2.1. **Participants**

A total of 50 participants (25 Female) aged between 18 and 42 years (Mean age = 22.58, SD = 4.35) took part in this experiment. All were students at Universitat Jaume I (Castellón, Spain). For the statistical analyses of zygomatic, one participant was excluded due to technical problems during data acquisition or excessive artifacts. As a result, statistical analyses reported here were performed with a total of 49 participants for zygomatic, 50 for electrodermal changes and 50 for corrugator.

Ethical approval from the Deontological Comision at Universitat Jaume I was obtained, and all participants provided informed consent. Participants were compensated either with course credit or economic incentive for their participation, to ensure they were properly engaged in the experimental task.

2.2. **Stimuli and Design**

A total of 42 musical excerpts (14 unpleasant, 14 pleasant and 14 neutral) were selected from a Film Music Stimulus Set (FMSS; Eerola & Vuoskoski, 2011), using the normative values for affective dimensions and discrete emotions in Spanish sample (Fuentes-Sánchez, Pastor, Eerola & Pastor, in press).

FMSS normative affective ratings for each category were as follows: unpleasant (valence: M = 2.86, SD = 0.45; arousal: M = 6.71, SD = 0.61); neutral (valence: M = 5.02, SD = 0.56; arousal: M = 3.17, SD = 0.48); pleasant (valence: M = 7.01, SD = 0.64; arousal: M = 6.87, SD = 0.52).

Music excerpts were distributed into seven blocks with six excerpts each one (2 unpleasant, 2 neutral, 2 pleasant). Furthermore, participants were presented with two practice excerpts prior to the study start, taken from Vieillard et al (2008) to practice the instructions.

Each musical excerpt was presented during 8 s, with no more than two consecutive trials of the same music category. Afterward, participants rated different affective dimensions (valence, arousal) using a 1 to 9-point scale. Finally, each trial ended with an inter-stimulus interval (ITI) of 8 or 10 s, randomly.

2.3. **Psychophysiological data acquisition and reduction**

Raw signals were recorded using Biopac MP36 system. Acqknowledge 4.4 software was used to collect, rectify, integrate, and smooth the physiological data.

Electrodermal activity (EDA) was recorded through a Biopac SS57LA transductor with two disposable snap electrodes, placed on the hypothenar eminence of the palm. Electrodes were attached 10 minutes before beginning the experiment to ensure the stability of the recording. Previously, the hand was gently cleaned using a tissue with distilled water. The signal was calibrated for each participant before the experiment start and was continuously recorded using a sampling rate of 1000 Hz, and Low pass filters (LP: 66.5 Hz, Q = 0.5 and LP: 38.5 Hz, Q = 1). For each trial, the peak response was scored as the maximum EDA value within a 1 to 6 s time window following picture onset, and amplitude was computed as the maximum electrodermal change score with respect to a baseline of 1 s prior to the music excerpt onset. Logarithms of raw scores (log (SCR +1)) were calculated to normalize the data.

Facial electromyography was recorded with four Ag/AgCl electrodes (4-mm diameter) placed directly on corrugator supercilii and zygomaticus major muscle, over the left eye and the left cheek, respectively, using the placement recommended by Fridlund and Cacioppo (1986). The EMG was continuously sampled at 1000 Hz and filtered online with a high-pass (30 Hz) and low pass (500 Hz). The signal was integrated and rectified online using rectify integration with a time constant of 500 ms. For analysis purposes, facial EMG was averaged over the 8-s music presentation interval.

2.4. **Procedure**

Each subject participated in one laboratory session, which lasted approximately 1 hour. After reading an overview of the task, participants completed a written consent form, and completed a survey to collect socio-demographic variables. Then sensors were attached while participants reclined in a comfortable armchair, where they were sat comfortably in a dark quiet room for the rest of the experiment.

The experiment started with the instructions of the main task, explaining that a series of musical excerpts would be presented, and participants should listen carefully the entire time that each film excerpt was presented. Then 2 practice trials were presented in order to train participants about how to rate the affective dimensions with the scales. Also, a two minutes baseline was recorded before the main task, which lasted around 30 minutes. At the end of the session the MPIA (Montreal Protocol for Identification of Amusia) was administered to discard lacks in musical perception (Vuvan, Paquette, Goulet, Royal, Felezeu, & Peretz, 2018).

2.5. **Data analysis**

A repeated measures analyses of variance (ANOVA) was conducted separately for affective valence and arousal ratings with Music category (pleasant, neutral, unpleasant) as the within-subjects factor. Post-hoc pairwise comparisons were performed using *t* test to evaluate differences between conditions of music category. In addition, a repeated measures ANOVAs was performed with each peripheral measure (EDA, corrugator, zygomatic), with *Music category* as the within-subjects factor. Post-hoc pairwise comparisons were performed using t test to evaluate differences between conditions.

In addition, pairwise correlations were performed in order to test plausible associations between subjective ratings (affective valence and arousal) and psychophysiological correlates measured here.

Statistical analyses were performed using JMP 5.0.1, SPSS 24, and G*Power 3.1.9.2. Alpha level was set at 5%.

3. **Results**

3.1. **Subjective ratings**

The means and standard deviation of affective valence and arousal ratings were calculated for each type of music category (see Table 1). The overall ANOVA reveals a significant main effect of music type either for hedonic valence, $F(2, 98) = 381.32$, $p < .0001$, $\eta^2_p = .89$, or arousal ratings, $F(2, 98) = 219.62$, $p < .0001$. Specifically, a post hoc *t* test comparison showed that pleasant excerpts were rated as more pleasant compared to neutral, $t(49) = 12.04$, $p < .0001$, and unpleasant excerpts, $t(49) = 25.28$, $p < .0001$. Similar results were found for arousal ratings, with pleasant excerpts being rated as more arousing than neutral, $t(49) = 22.87$, and unpleasant, $t(49) = 5.10$, $p < .0001$, ones.

TABLE 1 AROUND HERE

3.2. Psychophysiological peripheral measures

3.2.1. **Electrodermal activity**

The ANOVA revealed a significant main effect of type of music for EDA, $F(2, 48) = 11.27$, $p < .0001$. Post hoc pairwise comparisons showed that electrodermal activity was enhanced for pleasant (M = .056, SD = .073, CI 95% [.035, .077]) compared to neutral (M = 0.01, SD = .036, CI 95% [-.0006, 0.02]), $t(49) = 3.906$, $p < .0001$, and unpleasant (M = .029, SD = .041, CI 95% [.018, .041]), $t(49) = 2.901$, $p = .006$ excerpts, and also for unpleasant compared to neutral, $t(49) = 2.486$, $p = .016$ music, as shown in Figure 1.

INSERT FIGURE 1 AROUND HERE

3.2.2. **Zygomatic**

For zygomatic EMG reactivity, a significant main effect of music type was found, F (2, 47) = 9.90, $p < .0001$. Specifically, t test pairwise comparison revealed that zygomatic activity was higher during listening to pleasant excerpts, (M = .0004, SD = .001, CI 95% [.0001, .0008]), compared to neutral ($M = -3{,}29^{-6}$, SD = .0003, CI 95% [-8.06^{-5}, <.0001]), $t(48) = 2{,}821$, p = .007, and unpleasant music excerpts ($M = -3.89^{-5}$, SD .0003= , CI 95% [-.0001, 5.25^{-5}]), $t(48)$ = 3,379, p = .001, whereas no significant differences were found when comparing unpleasant to neutral ones, $t(48) = .641$, $p > .05$ (see Figure 1).

3.2.3. **Corrugator**

A main effect of music type was found for corrugator activity, $F(2, 48) = 8.37$, $p = .0004$. Specifically, *t* test pairwise comparisons showed that corrugator EMG activity was enhanced for unpleasant ($M = .0003$, $SD = .0006$, CI 95% [.0001, .0005]) music compared to neutral ($M = .0001$, $SD = .0003$, CI 95% [2.47^{-5}, .0002]), $t(49) = 2,796$, $p = .007$, and pleasant ($M = .0003$, $SD = .0006$, CI 95% [.0001, .0005]), $t(49) = 3,366$, $p = .001$, but no significant differences were found when comparing neutral and pleasant excerpts, $t(49) = 1,769$, $p = .08$ (see Figure 1).

3.3. **Correlations between subjective ratings and psychophysiological measures**

Pairwise correlations showed that affective valence ratings were positively related with EDA ($r = .312$, $p = .044$), and zygomatic ($r = .586$, $p < .0001$), and a negatively related with corrugator ($r = -.649$, $p < .0001$). In addition, arousal ratings were positively associated with EDA ($r = .533$, $p < .001$) and zygomatic ($r = .399$, $p < .009$), whereas no significant correlation was found with corrugator ($r = -.102$, $p = .52$).

4. **DISCUSSION**

The present study aimed at investigating peripheral measures (EDA & EMG) while passively listening to affective versus neutral music stimuli, based on the normative values of affective valence and arousal for Spanish sample, considering the subjective ratings of the participants for each musical excerpt too.

The subjective ratings were consistent with the a priori classification of musical excerpts based on its affective valence and arousal, being the pleasant stimuli rated as the most pleasant and the unpleasant as the least, as well as both pleasant and unpleasant rated as more arousing than neutral. That implies the FMSS normative values for affective dimensions and discrete emotions in Spanish sample were appropriated (Fuentes-Sánchez et al., in press; Eerola & Vuoskoski, 2011).

Correlations showed the utility of peripheral techniques measured here in order to test affective valence and arousal. Both EDA and zygomatic activity were larger in positive arousing excerpts (pleasant) than in any other characteristic, even though unpleasant music was arousing, the results showed that pleasant excerpts were rated as the most arousing. Otherwise, corrugator response only seems to be higher in negative valence conditions, regardless of arousal. This is in line with previous studies conclusions (Lundqvist et al., 2009; Roy et al., 2009; Bullack et al., 2017). One study of two peak emotions (Mori & Iwanaga, 2017), referring to tears and chills, also found that chills are produced mainly by happy music (pleasant in our study), evoking larger electrodermal activity, whereas tears are only prompted by sad music, which is considered calming. According to this, sad music is not necessarily unpleasant but “pleasantly sad” as stated by Koelsch (2013). In this line, neutral excerpts in terms of hedonic valence presented in our experiment elicit lower electrodermal activity, mainly corresponding to sad, low arousing music.

Regarding facial electromyography (EMG), prior literature has not been entirely conclusive. For example, Roy et al. (2009) found that corrugator had larger response in unpleasant conditions, which is in agreement with our results, but they did not find significant differences on zygomatic activity, maybe due to their small sample size (n = 16). Additionally, no differences have been found for corrugator reactivity in other studies (Lundqvist et al., 2009), maybe because of their discrete classification of music excerpts, as their conditions were happy and sad instead of pleasant and unpleasant, not controlling for arousal values. However, there are studies whose results were similar to ours, being zygomaticus reactivity larger for pleasant or happy music compared to neutral and unpleasant, while corrugator reactivity was enhanced for unpleasant conditions (Thayer & Faith, 2001; Witvliet & Vrana, 2007; Khalfa, Roy, Rainville, Dalla Bella & Peretz, 2008). Therefore, our study sheds a light upon this question and confirm the validity of facial electromyography to measure peripheral reactions during emotion induction through this type of stimulation.

Further studies should be conducted in order to solve the limitations of the current work. For example, the FMSS is composed by a few excerpts, so it hinders the suitable stimuli selection for the experiment. In addition, other factors have not been considered in our experimental design, as low arousing (pleasant and unpleasant) stimuli were not selected. Here the unpleasant music film excerpts were rated as high arousing, but different physiological reactions might occur during passive listening of low arousing excerpts since arousal seems key to discriminate between neutral and affectively relevant stimuli. Also, all the excerpts were fragments of films, so it is unknown what would had happened with other genres more atypical music, less common in West world.

Other methodological limitations were the use of only two physiological measures of hedonic valence (zygomatic and corrugator) that might not be the best indicators, as the results have not been conclusive accordingly to previous studies. To this extent, other more reliable indicators of appetitive or aversive motivational system activation (such as startle reflex) would have been certainly more appropriate, according to the cumulative evidence provide with the passive picture viewing paradigm (Bradley, Codispoti, Cuthbert & Lang, 2001). Besides, gender differences have not been explored in our study, and literature review with affective stimuli (pictures, films, sounds), suggests that women and men might react differently when inducing emotions in laboratory contexts (Moltó, Segarra, López, Esteller, Fonfría, Pastor & Poy, 2013; Kuypers, 2017).

Ultimately, the final goal of the works studying the underlying mechanisms of emotion regulation processes is to contribute to the development of psychological interventions in clinical population. As Hou et al. (2017) suggested, emotion dysregulation appears when emotional regulation is damaged and adaptive behavior can not properly function. This kind of failures immensely affects the mental health and characterizes most psychiatric disorders. Because music has been shown to alter neural activity in these same networks, further research is needed in order to design treatments for emotion dysregulation pathologies. Additionally, certain music characteristics like familiarity and pleasantness of music seem to elicit desired activation patterns, whereas other characteristics could induce undesired activations patterns (Sena Moore, 2013), an issue that should be certainly explored in future studies.

CONCLUSIONS

Psychophysiological peripheral techniques showed to be a reliable tool for measuring emotional induction through music. Electrodermal activity clearly reflects the motivational significance of affective stimuli, being the most emotionally arousing those that elicit larger skin conductance responses, whereas facial electromyography (zygomatic and corrugator) showed to be a reliable physiological measure of the hedonic valence of film excerpts.

REFERENCES

Bradley, M. M., Codispoti, M., Cuthbert, B. N., & Lang, P. J. (2001). Emotion and Motivation I: Defensive and appetitive reactions in picture processing. *Emotion*, *1*(3), 276.

Bullack, A., Büdenbender, N., Roden, I., & Kreutz, G. (2018). Psychophysiological responses to “happy” and “sad” music: A replication study. *Music Perception: An Interdisciplinary Journal*, *35*(4), 502-517.

Critchley, H. D. (2002). Electrodermal responses: what happens in the brain. *The Neuroscientist*, *8*(2), 132-142.

Daly, I., Williams, D., Hallowell, J., Hwang, F., Kirke, A., Malik, A., ... & Nasuto, S. J. (2015). Music-induced emotions can be predicted from a combination of brain activity and acoustic features. *Brain and cognition*, *101*, 1-11.

Eerola, T., & Vuoskoski, J. K. (2011). A comparison of the discrete and dimensional models of emotion in music. *Psychology of Music*, *39*(1), 18-49.

Fridlund, A. J., & Cacioppo, J. T. (1986). Guidelines for human electromyographic research. *Psychophysiology*, *23*(5), 567-589.

Fuentes-Sánchez, N., Jaén, I., Escrig, M. A., Lucas, I., & Pastor, M. C. (2019). Cognitive reappraisal during unpleasant picture processing: Subjective self-report and peripheral physiology. *Psychophysiology*, *56*(8), e13372.

Fuentes-Sánchez, N., Pastor, R., Eerola, T. & Pastor, M. C. (in press). Standardization of a Film Music Stimulus Set (FMSS) to the Spanish Population: Cultural and Gender Differences in the Perception of Emotions Prompted by Music Excerpts. *Psychology of Music.*

Hodges, D. A. (2010). Psychophysiological measures. *Handbook of music and emotion: Theory, research, applications*, 279-311.

Hou, J., Song, B., Chen, A. C., Sun, C., Zhou, J., Zhu, H., & Beauchaine, T. P. (2017). Review on neural correlates of emotion regulation and music: implications for emotion dysregulation. *Frontiers in Psychology*, *8*, 501.

Khalfa, S., Roy, M., Rainville, P., Dalla Bella, S., & Peretz, I. (2008). Role of tempo entrainment in psychophysiological differentiation of happy and sad music?. *International Journal of Psychophysiology*, *68*(1), 17-26.

Koelsch, S. (2013). Music and emotion. *The Cambridge Handbook of Human Affective Neuroscience*, 286-303.

Kuypers K. (2017). Emotional Empathic Responses to Dynamic Negative Affective Stimuli Is Gender-Dependent. *Frontiers in psychology*, *8*, 1491.

Lundqvist, L. O., Carlsson, F., Hilmersson, P., & Juslin, P. N. (2009). Emotional responses to music: Experience, expression, and physiology. *Psychology of music*, *37*(1), 61-90.

Moltó, J., Segarra, P., López, R., Esteller, Àngels, Fonfría, A., Pastor, M. C., & Poy, R. (2013). Spanish adaptation of the "International Affective Picture System" (IAPS). Third part. *Anales De Psicología / Annals of Psychology*, *29*(3), 965-984.

Moore, K. S. (2013). A systematic review on the neural effects of music on emotion regulation: implications for music therapy practice. *Journal of music therapy*, *50*(3), 198-242.

Mori, K., & Iwanaga, M. (2017). Two types of peak emotional responses to music: The psychophysiology of chills and tears. *Scientific reports*, *7*, 46063.

Ribeiro, F. S., Santos, F. H., Albuquerque, P. B., & Oliveira-Silva, P. (2019). Emotional induction through music: Measuring cardiac and electrodermal responses of emotional states and their persistence. *Frontiers in psychology*, *10*, 451.

Roy, M., Mailhot, J. P., Gosselin, N., Paquette, S., & Peretz, I. (2009). Modulation of the startle reflex by pleasant and unpleasant music. *International Journal of Psychophysiology*, *71*(1), 37-42.

Steinbeis, N., Koelsch, S., & Sloboda, J. A. (2006). The role of harmonic expectancy violations in musical emotions: Evidence from subjective, physiological, and neural responses. *Journal of cognitive neuroscience*, *18*(8), 1380-1393.

Thayer, J. F., & Faith, M. L. (2001). A Dynamic Systems Model of Musically Induced Emotions: Physiological and Self-Report Evidence. *Annals of the New York Academy of Sciences*, *930*(1), 452-456.

Vieillard, S., Peretz, I., Gosselin, N., Khalfa, S., Gagnon, L., & Bouchard, B. (2008). Happy, sad, scary and peaceful musical excerpts for research on emotions. *Cognition & Emotion*, *22*(4), 720-752.

Vuvan, D. T., Paquette, S., Goulet, G. M., Royal, I., Felezeu, M., & Peretz, I. (2018). The montreal protocol for identification of amusia. *Behavior research methods*, *50*(2), 662-672.

Witvliet, C. V., & Vrana, S. R. (2007). Play it again Sam: Repeated exposure to emotionally evocative music polarises liking and smiling responses, and influences other affective reports, facial EMG, and heart rate. *Cognition and Emotion*, *21*(1), 3-25.

Table 1. Descriptive statistics (M = Mean, SD = Standard Deviation, CI = Confidence Interval) for affective ratings of pleasant, neutral and unpleasant musical excerpts.

	Unpleasant			Neutral			Pleasant		
		95% CI			95% CI			95% CI	
	M (SD)	Lower	Upper	**M** (SD)	Lower	Upper	**M** (SD)	Lower	Upper
Valence	**2.90** (0.92)	2.64	3.16	**5.67** (1.22)	5.02	5.71	**7.48** (0.80)	7.25	7.71
Arousal	**6.49** (1.59)	6.04	6.94	**3.75** (1.02)	3.46	4.03	**7.45** (0.69)	7.26	7.65

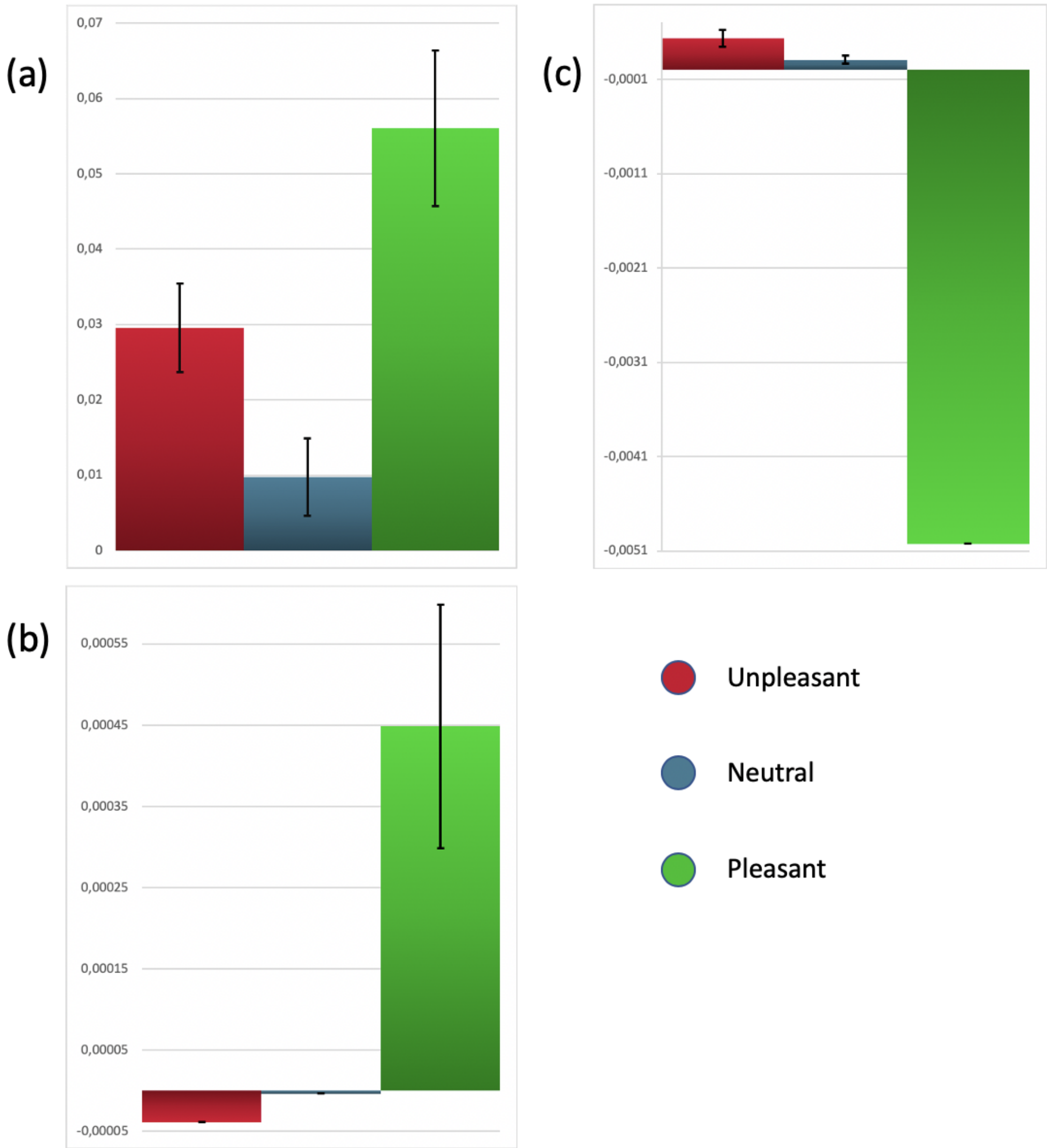

Figure 1. Results of peripheral psychophysiological measures for unpleasant, neutral and pleasant excerpts. (A) Means of EDA changes, (B) Means of zygomatic activity, (C) Means of corrugator activity.