# The "NeuroDante Project": Neurometric Measurements of Participant's Reaction to Literary Auditory Stimuli from Dante's "Divina Commedia"

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**Abstract.** This work is a pilot study that used neurometric indexes during the listening of selected pieces of Dante's "Divina Commedia" in 20 participants. Half of them had a literary formation (Humanist; university students of literature) while the other half of is attending other university courses (Not Humanist). The study applied the electroencephalographic (EEG) rhythms variations, the heart rate (HR) and galvanic skin response (GSR) during the listening of the excerpts. The neurometric indexes here employed were the Approach Withdrawal (AW), the Cerebral Effort (CE) and the Emotional indexes (EI). Results for the comparisons of the estimated AW, CE and EI related to the perception of the *canticas* showed as the Humanist group reported higher AW and EI values when compared to the Not Humanist sample ($p < 0.03$ and $p < 0.01$, respectively). Results suggest that the perception of the aesthetic experience is significantly modulated by the previous specific knowledge experienced by the participants. Finally, results of this kind of research could find application in the implementation of software and devices based on symbiotic relation with the perspective reader or listener of a literature opera, in order to personalize and maximize the fruition of them.

**Keywords:** Approach Withdrawal · Cerebral Effort · EEG · Alpha · Theta · Electrodermal Activity · HR · GSR · Emotion · Russell's circumplex model of affects

## 1 Introduction

Reading and listening stories is a very peculiar human activity. In fact, other animal species on earth have not engaged (as far as we know) in such task. On a more basic level, a lot of knowledge has been accumulated in these last three decades of neuroscientific studies on the perception and appreciation of visual stimuli and the "internal" factors able to shape such perception [1]. Moreover, a lot of knowledge has been also obtained on the evaluation of the cerebral activity related to the judgment of syntactic

and grammatical violations on speech listening [2]. However, a recent research path moves from the measurements and the relative understanding of the basic characteristic of the sensory perception towards the more complex way in which we, as specie, perceive and enjoy the reading and listening of stories [3]. In this attempt, researchers have started to measures cerebral and emotional activities manipulating some factors that could alter or increase the pleasure in the story perception [4, 5]. Furthermore, the knowledge of the features modulating the emotional involvement in the reader could be also implemented in designing e-books [6], also potentially based on a symbiotic inter-action with the user. Additionally, the neurophysiological approach could provide meas-urable information on the emotional content of a text, as evidenced by the lowering of the heart rate and the variation of the breathing and the electroencephalographic (EEG) alpha rhythm asymmetry [7].

In this scenario, neuroaesthetics is an emerging disciplines investigating the biolog-ical underpinnings of aesthetic experiences, and since its formal birth in 90s by Semir Zeki (for a review [8]) it constitutes a field receiving growing interest by the scientific community. Although traditional topic of neuroaesthetic investigation are visual art and music [9, 10], an enlargement in the horizon of artistic items to be investigated is begin-ning and literature and poetry are experiencing a renewed scientific interest from the neuroaesthetics perspective [3]. That is, the question we would like address here is "Which biological underpinnings make classical authors cognitively and emotionally engaging?". Two aspects of poetry may contribute to the emotional responses it may elicit: its lexical content and its structural features (i.e., poetic form). Meter and rhyme constitute the key features in poetry [11], additionally they have been found to be significant contributors to the aesthetic and emotional perception of poetry [4], but it is difficult to investigate the contribution of the content "per se" due to the needing to compare different kinds of texts. A possibility to overcome this limitation is offered by the famous Italian XIV century poem the "Divina Commedia" by Dante Alighieri (1265–1321). The book is characterized by a repetitive and constant structure, as it is composed by three parts (canticas: Inferno –Hell–, Purgatorio –Purgatory- and Paradiso –Para-dise-), each part is composed by thirty-three cantos, for an average length of 142 verses. The verse scheme used, "terza rima", is hendecasyllabic (lines of eleven syllables), with the lines composing tercets relying to the rhyme scheme xyx yzy z. Each cantica, despite the conservation of the metric structure is characterized by a different content. The reader follows Dante's journey through Hell, Purgatory and Paradise, where the poet respec-tively meets damned souls, then souls expiating their sins and finally enjoys the vision of God. Studying the reaction to the exposure to stanzas belonging to each of the three canticas would enable to test the effect of the content of the excerpts, maintaining the meter and the rhyme scheme constant. Furthermore, the comparison among different canticas would enable to assess the effect of a potentially differential previous knowledge of the peculiar cantica.

In this work, we described the results of a pilot study that used neurometric indexes during the listening of a selected pieces of the Divina Commedia in a reduced sample of voluntary participants. Noteworthy, half of the participants had a literary formation in their advanced studies (Humanist; they are students of literature at the University) while the other half of the sample are attending other university courses (Not Humanist).

The study applied the gathering of the electroencephalographic rhythms variations, as well as the heart rate (HR) and galvanic skin response (GSR) during the listening of the excerpts. The neurometric indexes here employed were the Approach-Withdrawal (AW) [12], the Effort (CE) [13] and the Emotional indexes (EI) [14]. It is worth noticing that different research teams previously validated those indexes in literature. Results are related to the comparisons of the estimated AW, CE and EI related to the perception of the analyzed canticas in the sample population.

## 2    Methods

In the present study, 20 healthy participants (mean age Humanist 24.9 and Not Humanist 26.2 years old) have been enrolled on a voluntary base and not receiving any compensation from taking part in the research. Participants were university students at Sapienza University of Rome, half of them attending humanistic courses and the second half scientific courses. All participants were given of detailed information on the study and signed an informed consent.

The experiment was performed in accord to the principles outlined in the Declaration of Helsinki of 1975, as revised in 2000, and it was approved by the University ethical committee. Participants were sitting on a comfortable chair and instructed to listen to the auditory stimuli. The three target stimuli were randomly played among, so producing different trains of auditory stimuli. The train was preceded and followed by sentences in Italian language that belongs to a standardized set of sentences used normally for audiometric purposes in clinic (Audiometria Vocale. Cutugno, Prosser, Turrini). Such sequence of short phrases lasted 1 min of length and has been used as the baseline in this experimental setup. The target stimuli belonged to excerpts from the reading of the Dante Alighieri's Divina Commedia. The excerpts texts were read by an Italian professional actor, so to ensure the quality of the elocution. The three selected emblematic pieces have been chosen by experts in Italian literature (academic professors and researchers) and each belonged to one of the three canticas of the poem: Inferno (Hell), Purgatorio (Purgatory) and Paradiso (Paradise) respectively. The neurometric indexes employed in the study were the Approach-Withdrawal (AW) [14], the Effort (CE) [15] and the Emotional indexes (EI) [16].

### 2.1    Behavioral Assessment

At the end of the listening session, participants underwent a short recognition test. Participants were asked whether they recognized the audio pieces and to say what they thought to have listened. These behavioral data were collected and analyzed.

### 2.2    EEG Recordings and Signal Processing

The EEG activity was recorded by means of a portable 24-channel system (BEmicro, EBneuro, Italy). Nineteen electrodes were used in this experiment according to the 10–20 international system. The impedances were kept below 10 kΩ and the signals have

been acquired at a sampling rate of 256 Hz. To detect and remove components due to eye movements, blinks, and muscular artefacts, over the EEG traces were applied a notch filter (50 Hz), lowpass filtered (lp = 30 Hz) and the Independent Component Analysis (ICA). For each participant, the Individual Alpha Frequency (IAF) has been calculated in order to define the frequency bands of interest according to the method suggested in the scientific literature [15]. The Global Field Power (GFP) has been calculated for each frontal channel and for each participant. Several studies in literature (e.g. [12, 16, 17]) describe the frontal cortex as an area of interest for the analysis of the approach or withdrawal attitude [12, 18, 19] and the cerebral effort [15, 20] in response to a wide range of stimuli. In particular there are evidences indicating a link between dorso-lateral prefrontal cortex (PFC) area and approach motivation [21, 22]. Concerning approach motivation, the PFC has been found to be systematically related [23] to approach-motivated states, as well as the nucleus accumbens (ACC). The same authors also found systematic relations between avoidance-motivated states and the amygdala and the ACC. Thus, there is increasing evidence that emotional states related to approach and avoidance involve localisable brain circuits [24, 25].

It must be noted that the data here analyzed are relative to the scalp level, and a one-to-one correspondence between the frontal scalp recorded EEG and the cortical activity of the prefrontal areas cannot be precisely determined. The formula defining the Approach Withdrawal (AW) index is the following:

$$AW = \text{GFPa\_right} - \text{GFPa\_left} \tag{1}$$

where the GFPa_right and GFPa_left stand for the GFP calculated among right (Fp2, F4, F8) and left (F7, F3, Fp1) electrodes, in the alpha band. Electrode's labeling follows the International 10–20 Positioning system. The estimated cerebral AW index has been computed for each second and then averaged for all the duration of the auditory stimuli proposed to the participants. The AW index was then standardized according to the baseline EEG activity acquired at the beginning and at the end of the experiment. Positive AW values mean an approach motivation toward the stimulus expressed by the participant, while negative AW values a withdrawal tendency.

To evaluate the cerebral effort frontal electrodes in theta band (Fp2, F4, F8, Fz,F7, F3, Fp1) have been used. The GFP from such frontal electrodes have been successively estimated. Then the cerebral effort index (CE) data have been standardized according to the baseline EEG activity acquired at the beginning and at the end of the experiment. Higher level of CE imply higher level of task difficulty [13, 26].

## 2.3  HR and GSR Recordings and Signal Processing

Electrodermal Activity (EDA) and Heart Rate (HR) were recorded by means of a NeXus-10 (Mindmedia, The Netherlands) system with a sampling rate of 128 Hz. Disposable electrodes provided by the Mindmedia company were applied to the participant's wrist to collect cardiac activity. To obtain the HR signal the Pan-Tompkins algorithm [27] has been employed. Skin conductance was acquired by the constant voltage method (0.5 V). The electrodes were attached, on non-dominant hand, to the palmar side of the middle phalanges of the second and third fingers of the participant,

following published procedures [28]. The tonic component of the skin conductance (Skin Conductance Level, SCL) was obtained using LEDAlab software [29]. In the attempt to match SCL and HR signals we referred to the circumplex model of affect plane [30, 31], where the coordinates of a point in the space are defined by the HR (horizontal axis) to describe the valence and by the SCL (vertical axis) to describe the arousal phenomena (see [32] for a review). In order to obtain a monodimensional variable, the emotional state of a participant has been described by the Emotional Index (EI), as defined in previous studies [14]. The interpretation of the EI implies that the higher the value the more positive the emotion experienced by the participant and vice versa.

### 2.4   Statistical Analysis

Statistical analysis has been performed on the biometric results obtained during the exposure to the three *canticas* by repeated measures analysis of variance (ANOVA) for all the considered biometric indices (AW, CE and EI). Factors considered in the ANOVA were: (i) BACKGROUND, with 2 levels (Humanistic and Not Humanistic); (ii) CANTICA, with 3 levels (Inferno, Purgatorio e Paradiso). Duncan's post hoc test has been used to investigate the significant interactions resulting from ANOVA test. Fisher's exact test has been used for the analysis of the behavioral data concerning the recognition of the *canticas*. Logistic regression analysis has been performed between values reported for each index (AW, CE and EI) and the behaviorally declared recognition of each cantica by the participants [33].

## 3   Results

### 3.1   Behavioral Results

The Humanist group reported a higher average number of participants who correctly recognized the different *canticas*. Approximately the 90% of the Humanist group verbally recognized the *canticas* in comparison to the 40% of the Not Humanists (Fisher's exact test p = 0.06).

### 3.2   Approach Withdrawal Index

The effect of the factor BACKGROUND didn't reach the statistical significance alone (F = 2.65, p = 0.12), as well as the effect of the CANTICA (F = 1.01, p = 0.37) (Fig. 1). The AW index showed a statistical significant effect of the interaction between the factors BACKGROUND and CANTICA (F = 3.74, p = 0.03) (Fig. 2).
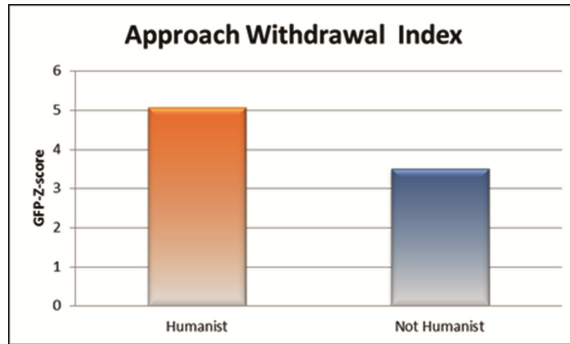
**Fig. 1.** Approach Withdrawal Index mean values for the Divina Commedia canticas over-all in the Humanist and Not Humanist groups.
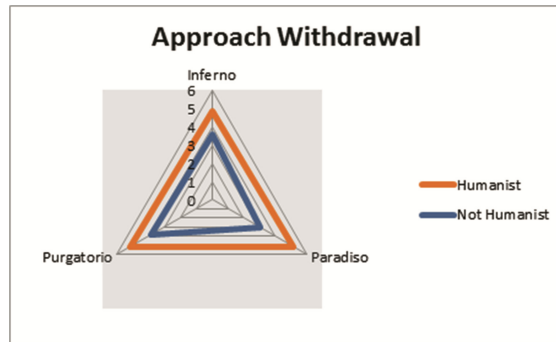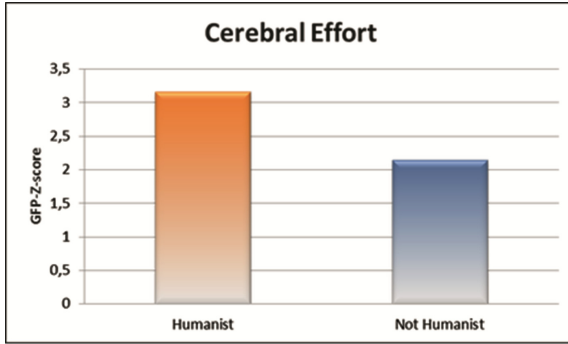


**Fig. 2.** Approach Withdrawal Index mean values for the different Divina Commedia canticas in the Humanist and Not Humanist groups.

Results of the logistic regression performed between AW values and verbally declared recognition scores showed a statistical significance ($p = 0.04$). Furthermore, the logistic regression analysis between AW values reported for each cantica and verbally declared behavioral recognition highlighted a statistical significance for Paradiso ($p = 0.04$), while Purgatorio and Inferno didn't show any significance ($p = 0.12$ and $p = 0.92$ respectively).

### 3.3 Cerebral Effort

The factor BACKGROUND (Fig. 3) didn't show a statistically significant difference between Humanist and Not Humanist ($F = 2.71$, $p = 0.12$), as long as the factor CANTICA ($F = 0.82$, $p = 0.44$). The CE values (Fig. 4) showed a statistically significant effect of the interaction between the factors BACKGROUND and the kind of CANTICA ($F = 3.30$, $p = 0.05$).

**Fig. 3.** Effort Index mean values for the Divina Commedia canticas over-all in the Humanist and Not Humanist groups. On the axis GFP Z-score unit is displayed.
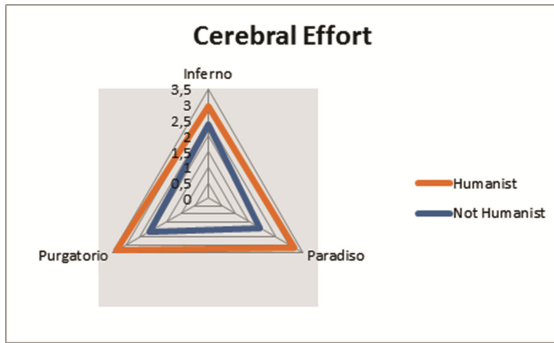


**Fig. 4.** Effort Index mean values for the different Divina Commedia canticas in the Humanist and Not Humanist groups. On the axis GFP Z-score unit is displayed.

The logistic regression analysis performed between CE values and verbally declared recognition scores showed a statistical significance (p = 0.02). In addition, the logistic regression analysis between CE values reported for each cantica and verbally declared behavioral recognition highlighted a statistical significance for Paradiso (p = 0.02), while Purgatorio and Inferno didn't show any significance (p = 0.45 and p = 0.34 respectively).

### 3.4   Emotional Index

A statistically significant effect was reported for the factor CANTICA (F = 17.38, p < 0.01), while the BACKGROUND factor did not show a statistical significance (0.84, p = 0.37) (Fig. 5). Furthermore, the EI index (Fig. 6) showed a statistical significant effect of the interaction between the factors BACKGROUND and the CANTICA (F = 7.47, p < 0.01). Post hoc comparison showed a higher emotional reaction to Inferno and Paradiso canticas in comparison to the Purgatorio (p < 0.01) in the Humanist group, while in the Not Humanist group the Inferno reported higher values in comparison to

both Paradiso and Purgatorio ($p < 0.01$, $p = 0.04$ respectively). When the comparison of the Inferno cantica has been performed between the two groups no statistical significant differences were shown ($p = 0.18$). Conversely, statistical significant differences have been reported for Paradiso and Purgatorio comparisons between the groups ($p < 0.01$ and $p = 0.01$ respectively).
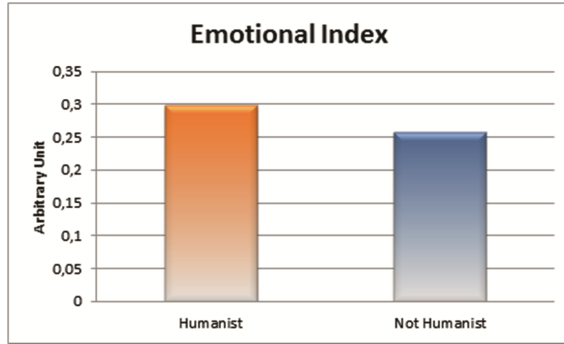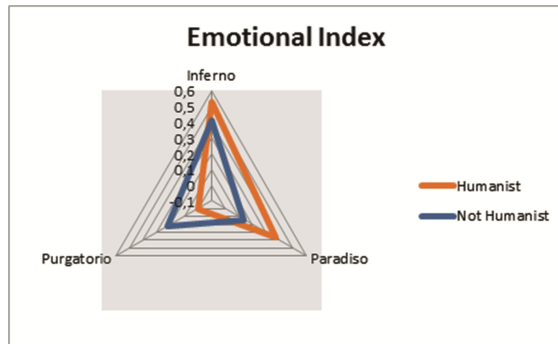


**Fig. 5.** Emotional Index mean values for the Divina Commedia canticas over-all in the Humanist and Not Humanist groups.



**Fig. 6.** Emotional Index mean values for the different Divina Commedia canticas in the Humanist and Not Humanist groups. On the axis an arbitrary unit related to the emotional index, whose range is between $-1$(very sad) to 1(very happy) is displayed.

Results of the logistic regression performed between EI values and verbally declared recognition scores didn't show a statistical significance ($p = 0.64$). Finally, the logistic regression analysis between EI values reported for each cantica and verbally declared behavioral recognition highlighted a statistical significance for Paradiso ($p = 0.02$) and Purgatorio ($p = 0.04$), while Inferno didn't show any significance ($p = 0.30$).

## 4   Discussion

Results from this pilot study showed that the Humanist group reported higher AW values for the canticas in comparison to the Not Humanist group and this evidence could be related to the higher knowledge of these texts in comparison to the other experimental group, as reflected in the behavioral data. However, it must be noted that such difference did not reach the statistical significance due to the limitation of the sample size here employed (low statistical power of the ANOVA performed). Nevertheless this evidence could be supported by the statistical significance of the logistic regression analysis between AW values and verbally declared recognition scores of the canticas. To partially discuss this finding, we reported that in literature Leder and colleagues [34] theorized a descriptive information-processing stage model for the aesthetic experience, consisting of 5 stages: perception, explicit classification, implicit classification, cognitive mastering and evaluation. The model differentiates between aesthetic emotion and aesthetic judgments as two types of output. This hypothesis is in accord with our data when considering results for the AW index and for the Emotional Index. In particular, the Humanist group showed a cerebral approach motivation towards the canticas in general, but a more selective emotional involvement for two of them: both Inferno and Paradiso in comparison to the Purgatorio. Additionally, except for the Inferno, there was a statistical significant difference in the EI for Paradiso and Purgatorio between the two experimental groups. This result could be explained by the evidence that Inferno is the most studied cantica by Italian students (also in high schools) and the one that reported the highest percentage of recognition among all our experimental participants, so don't producing a differential emotional reaction due to previous specific knowledge. On the other hand, as a comment of the absence of statistical significance in the logistic regression analysis between EI values and recognition scores could come the evidence found by Leder and colleagues [35] saying that the emotional reaction is attenuated by attention to style and artistic execution. This could explain the reason of a lack of increase of EI values along with the increase in the recognition scores. Additionally, evidences deriving from behavioral rating of abstract artworks, support the hypothesis that affective components of art appreciation (valence and arousal) are less driven by expertise acquired through training, while more cognitive aspects (beauty and wanting) of aesthetic experience depend on viewer characteristics such as art expertise [36].

Concerning the cerebral effort, probably the canticas were more cognitively involving for the Humanist group, since their previous knowledge of them. That could stimulate the transferring of information subserving the processing of the content and the application of art-specific classifications [37]. The present result could find confirmation in the statistical significance highlighted in the logistic regression analysis between CE values and verbally declared recognition scores of the cantica. In other words, Humanist group generated more effort in following the proposed canticas, because such canticas were in an ancient language when compared to their actual natural language. The opposite could be hypothesized for the not Humanist group, that probably faced difficulties in follow the Dante's ancient language of the two not popular excerpts (from Purgatorio and Paradiso) that they have not studied in the high schools or at the university. This difficulty in turn partially switch off the effort in such group to follow

the narration and release cognitive faculties from the listening, causing a decrease of the measured cognitive efforts in such group. As already pointed out, the excerpt from the Inferno is very popular in Italy and all the participants involved already know in greater part the words and the meaning involved in such part.

## 5   Conclusion

In general, the collected data suggest a difference for the cerebral and emotional perceptions of the aesthetic experience related to the Divina Commedia listening on the base of the previous cultural background for the two investigated groups. This result could be explained by the evidence that aesthetic experience is a function of previous knowledge [38]. In this framework, experts and non-experts rely on different cues to evaluate artworks in terms of liking and comprehension [35, 39]. The present results, obtained by a pilot study, need further investigation on an enlarged sample so to provide indications on the literature and poetry aesthetic experience in experts and non-experts. Recent studies showed the employment of the neurofeedback using a real-time PFC alpha asymmetry, as an index of subjective empathy and positive disposition toward the character, in order to modify the development of a drama [40]. In addition, seeking for the personalization of the experience, a similar approach has been used presenting cultural heritage material, with the aim of developing an adapting provision of information in order to sustain the interest of the visitor [41]. Finally, as a future perspective the present study approach to the literature perception could be implemented in the building of personalized narrative experiences, based on the detection by a symbiotic system participant's response from both the cognitive and emotional nature.

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