***AN ERP STUDY ON THE EFFECT OF CHOCOLATE ON PROCESSING VISUAL STIMULI IN THE BRAIN***

**My brain on Chocolate: Exploring brain activations using EEG when people have consumed chocolate**

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# PREFACE

Getting admitted to the Erasmus School of Economics has been one of the greatest achievements in my life so far. Last year, when I arrived here, I did not exactly know what was ahead of me, but now, looking back, I can truly say I have had the experience of my life both from the academic standpoint, as well as from the student life point of view.

I have enjoyed equally studying all the marketing courses within the Marketing Master program of ESE, as well as working on my master thesis. Working on this thesis has been both very enjoyable and fun, as well as very challenging, getting me acquainted with the amazing domain of neuro-marketing.

I would like to use this space in order to express my gratitude to the people who made possible this research and who have believed in me.

First, I would like to thank to my supervisor Mr. Prof. Dr. Willem J.M.I. Verbeke. He has proved a lot of enthusiasm and passion throughout the entire process of my thesis and has always had patience to discuss and respond to all my requests. Moreover, he has made possible the financing of my research and has enabled me to have access to all the necessary facilities in order to carry out this present research.

Secondly, my gratitude goes to Mr. Rumen Pozharliev who has not only contributed intellectually to my research, but has offered valuable feedback and has had the patience to read through the paper. He has always been happy to help and I would like to thank him for all the time that he invested in my research. Fernando Perelló is also on my list, as he has been always happy to help with any technical questions I had and has been very supportive and encouraging with me throughout the entire process of working on the thesis.

Last but not least, my gratitude goes to my amazing parents, who have believed in me, encouraged me and made financial efforts to support me here. If it was not for them I would not have been here. Also, my fiancé, who has proposed to me this year, in between two experiments, I need to thank for all the patience and support.

I will end by thanking to all my amazing colleagues who have participated in my experiment, as well as to my great friends who have made everything so enjoyable.

Iulia-Andreea Talangă

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# INTRODUCTION

***“Caviar is exquisite, but people don’t declare their love with ten-pound heart-shaped boxes of it… No one makes 3:00 AM runs to the 7-Eleven for butterscotch. But chocolate…chocolate inspires a passion normally reserved for things grander than food” (Roach, 1898)***

An overall aim of this paper is to investigate the brain responses that are issued, in the sensory and especially affective/emotional situations, to face images when palatable food is ingered.

The experiment carried out for this research, studies whether ERPs are able to detect a differential neural processing between facial expressions with diverse physical and affective characteristics, when two different types of chocolate are administered.

Facial expression processing specificity mediated by two types of chocolate was investigated by means of event-related potentials (ERP).

A comparison of the intensity of emotions elicited in each chocolate condition is studied by means of ERP, in order to determine at brain level, if chocolate has a beyond sensorial impact or if the sensorial impact is sufficient and generates a placebo effect when distinct emotional states are induced.

Further on, emotional responses elicited by face expressions are studied in an attempt to decode the brain responses to one of the most basic non-verbal communicational stimuli.

The thesis will focus on the analysis of the ERP components studied in previous researches in relation to face elicited emotions, which will be presented from the theoretical point of view as well as analyzed based on the experiment carried out here. Secondly, the relationship between chocolate, as an affective taste stimuli, and induced emotional states will be analyzed in the context of the EEG experiment performed.

The research question followed in this paper is: **Is face-specific brain potential modified by the emotional valence of the face stimuli when two different types of chocolate are ingered?** The research question will be further on discussed in terms of:

1. Does chocolate give higher or lower amplitudes and latencies when emotionally induced states are tested?

2. Do pictures portraying different face expressions elicit waveforms with different amplitudes over the brain?

3. Which face expression/stimulus gives the highest amplitudes and is there any difference in the amplitudes measures when tested with two chocolate types, as tested in the experiment?

The relevance of this thesis is that it provides a new insight over how emotions elicited by face expressions are decoded in the brain. The thesis gives a perspective of the impact of chocolate as a mediator for emotionally induced states and it tries to provide a better understanding to the non-verbal communicational stimuli which we face in everyday life (the body language).

The thesis will first discuss the taste stimuli impact of chocolate over emotionally induced states, as found in the literature. The main researches discussed here will be of Macht and Mueller (2007); Zald et al. (1998); Francis et al. (1999); Royet et al. (2000); Savic et al. (2000). Secondly, ERP researches in correlation with emotions elicited by face pictures will be presented based on the works of Balconi and Pozzoli (2003); Vanderploeg et al. (1987); Marinkovic and Halgren (1998); Streit et al.(2000); Herrmann et al. (2002); Junghöfer et al, (2001); Morita et al. (2001); Carretié and Iglesias (2005); Bentin et al. (1996); Eimer and Holmes (2007). A quantitative research will be done based on the presented theories; its methodology will be discussed in detail, followed by the results of the research. Interpretation and discussion points will be provided in the end.

# 2. LITERATURE REVIEW

With this thesis, the impact of emotional stimuli elicited by different face expressions to the brain is studied, when two types of chocolate are sampled. In order to do this, the paper will deal with impact of palatable food on brain responses, ERP measurements, chocolate composition and its effects, and brain responses to correlated sensorial stimuli. The literature review will start with a synthesis of palatable stimuli, then it will discuss the affective visual stimuli and it will deal with the ERP measurements of several studies performed to measure the impact of face expressions and their decoding by the brain.

## **2.1. ERP RESEARCH**

### 2.1.1. WHAT IS ERP?

In 1929, Hans Berger reported a remarkable and controversial set of experiments in which he showed that one could measure the electrical activity of the human brain by placing an electrode on the scalp, amplifying the signal, and plotting the changes in voltage over time (Berger, 1929). This electrical activity is called the electroencephalogram, or EEG. However, embedded within the EEG are the neural responses associated with specific sensory, cognitive and motor events, and it is possible to extract these responses from the overall EEG by means of a simple averaging technique. These specific responses are called event-related potentials (ERP) to denote the fact that they are electrical potentials associated with specific events (Luck, S.J., 2005, p. 3). “Most cognitive neuroscientists view the ERP technique as an important complement to PET and fMRI” (Luck, S.J., 2005, p.6).

“The term “event related potentials” (ERP) is proposed to designate the general class of potentials that display stable time relationships to a definable reference event” (Vaughan, 1969, p.46).

“The averaged ERP waveforms consist of a sequence of positive and negative voltage deflections, which are called peaks, waves or components. The ERP technique is particularly useful for addressing questions about which neurocognitive process is influenced by a given manipulation” (Luck, S.J. 2005, p. 10)

S.J. Luck (2005)defines the ERP component as “a scalp-recorded neural activity that is generated in a given neuroanatomical module when a specific computational operation is performed. By this definition, a component may occur at different times under different conditions, as long as it arises from the same module and represents the same cognitive function” (Luck, S.J., 2005).

### 2.1.2. ERP COMPONENTS

#### THE N170 COMPONENT – FACE DETECTION

Jeffreys (1989) compared the responses to faces and non-faces stimuli and he found a difference between 150 and 200ms at central midline sites that he named the vertex positive potential (the Cz electrode). More recent studies from other laboratories that used a broader range of electrode sites have found that faces elicit a more negative potential than non-face stimuli at lateral occipital electrode sites, especially over the right hemisphere, with a peak at approximately 170ms. This effect is typically called the N170 wave (S.J. Luck, 2005, p.38).

Bentin et al. (1996) and Eimer (1998) discover through their studies that “an early face-specific component (N170) elicited at the posterio-temporal region has been considered to reflect early stage of face recognition”. However, studies undertaken by Carretié and Iglesias (1995); Munte et al. (1998) and Orozco et al. (1998) reveal that ERP components sensitive to facial expression are usually observed after 300ms post-stimulus.

To summarize, the N170 component is responsible for the face recognition and distinction task undertaken by the brain.

#### THE N230 COMPONENT – ASSOCIATED WITH THE EMOTIONAL VALENCE of stimuli

Balconi and Pozzoli (2003) discovered in their study that an emotional face elicited a negative peak at approximately 230ms (N230), distributed mainly over the posterior site for each emotion. The electrophysiological activity observed, may represent specific cognitive processing underlying the decoding of emotional facial-expressions. Differences in peak amplitudes were observed when comparing high-arousal negative expressions with positive (happiness) and low arousal expressions (sadness). The N230 amplitude changed, eliciting the highest amplitude for happy picutres and the lowest amplitude for neutral pictures with faces, suggesting that subjects’ ERP variations are affected by experienced emotional intensity, related to arousal and unpleasant value of the stimulus (Balconi and Pozzoli, 2003, p. 67).

Jung et al. (2000) states that “the different profiles of ERPs, as a function of the emotional valence of the stimulus, may indicate the sensibility of the negative-wave variation N230 to the ‘semantic’ value of the expressions”

To conclude, the N230 component captures the emotional valence of the stimuli.

#### THE N300 COMPONENT – CAPTURES THE HAPPY FACES distinction in the brain

In Carretié and Iglesias (1995) study, they find a significant differentiation between the amplitude evoked by happy faces and the rest of the stimuli in the 250-350ms interval (which involved N300). “Although it is also face sensitive, particularly at the midline locations (Bötzel and Grüsser, 1989), recent data indicate that this component (N300) reflects an affective processing too. Thus, when the configurational characteristics of facial expressions are controlled through composite photographs, N300 reacts more to the emotional value attributed to stimuli by subjects than to their physical characteristics” (Carretié and Iglesias, 1995, p. 190).

Consequently, the N300 component most likely retrieves different amplitudes between happy faces and the rest of the stimuli.

## **2.2. AFFECTIVE STIMULI**

### 2.2.1. VISUAL STIMULI: PICTURES WITH FACES

“Facial expressions constitute phylogenetically shaped drive-relevant signals which are specialized in emotion communication during social exchanges”(Eibl-Eibesfeldt,1989). “It is remarkable that humans recognize with great accuracy certain basic emotions across different cultures as Ekman et al.(1972) states in their 1972 study” (Carretié and Iglesias, 1995, p. 183).

Eimer and Holmes (2007) mention in their study from 2007 that “Emotional facial expressions are particularly salient stimuli conveying important nonverbal communications to other species members, and in humans, are immediate indicators of affective dispositions in other people”. “Perceiving and recognizing faces is considered one of the most complex and demanding visual processes” as postulated by Deffke et al. (2007) (Deffke et al., 2007, p. 1495)

Furthermore, Damasio (1999) talks at a general level about the emotional states as being “evolutionary adaptations that are critically involved in the regulation of basic survival mechanism and in the control of behavior in complex environments”.

### 2.2.2. ERP STUDIES ON BRAIN RESPONSES ELICITED BY FACE EXPRESSIONS

Previous results measuring affective impact of face pictures are contradictory. In some studies (Carretié and Iglesias; 1991; 1993; Laurian et al., 1991) the neutral faces evoked lower amplitudes than emotional ones, in others (Vanderploeg et al., 1987), they do quite the opposite, evoking the highest.

Electroencephalographic studies of Bentin et al., (1996); Maurer et al., (2002); Streit et al., (2000) have demonstrated that “the process of facial-expression recognition starts very early in the brain, by approximately 180 ms after stimulus onset, only slightly later than the face selective activity reported between 120 and 170 ms”. (Balconi and Pozzoli, 2003, p.68)

Studies of Lane et al. (1998), Pizzagalli et al. (1999) and Junghöfer et al. (2001) reveal that “the first perceptive stage, in which the subject completes the ‘structural codes’ of face, is thought to be processed separately from complex facial information such as emotional meaning” (Balconi and Pozzoli, 2003).

Vanderpoleg et al. (1987) reported that “the visual presentation of emotional facial-expressions elicited more negative amplitudes during 230-400ms than it did neutrally rated stimuli”. In a similar way, Marinkovic and Halgren (1998) observed that “the presentation of emotional facial expressions evoked a larger lateral **occipital-temporal** negativity during 200-400ms with a peak at approximately 240ms, than a neutral face”.

Sato et al. (2001) demonstrated that “faces with emotions (both fear and happiness) elicited a larger negative peak at approximately 270 ms than neutral faces over the posterior temporal area, covering a broad range of posterior visual areas. However, there were no differences between negative and positive emotions.”

Herrmann et al. (2002) did an ERP study to analyze if different face expressions elicit different ERP responses. However, their study failed to find emotion-specific correlates for the studied emotions.

Balconi and Pozzoli (2003) designed their study to clarify the issue “as to whether the face-specific brain potential is modified by the emotional valence of the face stimuli”. In their study they used both the arousal effect and the hedonic valence of the stimuli. “Negative low-arousal emotions (like sadness) represent a negative situation and at the same time, subject’s deactivation of an active response (low-arousal). Positive high-arousal emotions, like happiness, express the effectiveness in managing an external stimulus and its positive value. For this reason, facial expressions are an important key to explaining the emotional situation, as they can produce different reactions in the viewer.”(Balconi and Pozzoli, 2003, p. 68-69). Consequently, “the ‘significance’ of emotional expressions for the subject and their low/high threatening power should influence both the physiological and the cognitive level (mental responses in terms of evaluation) with interesting reflects on ERP correlates” (Balconi and Pozzoli, 2003, p.68-69). They also mention that “each emotional expression represents the subject’s response to a particular kind of significant event.”

Herrmann et al. (2002) did a study in order to investigate the effect of facial expressions with different emotional content on face specific brain EEG potentials. They based their study on previous evidences which indicate that faces are processed in different brain regions compared to control stimuli. From their study, Herrmann et al. (2002) suggest that the face-specific brain potential is most prominent at Cz (electrode position).

Pizzagalli et al. (1999) and Herrmann et al. (2002) found throughout the studies they carried out, differences in amplitude of brain electrical activity associated with the emotional valence of the stimuli, discovering that sad faces elicit the highest amplitude, followed by happy faces and neutral faces at a latency of 160ms.

1. Streit et al., (1999) postulate that “the processing of different facial expressions is supposed to start at approximately 180 ms post-stimulus”. Streit et al. (2000) are also the only ones to investigate the influence over ERP of different facial expressions and blurred faces.
2. Tsurusawa et al. (2005) did also a similar study, investigating the information processing of facial expressions by ERPs to Chernoff’s face. Their study revealed that “the recognition of facial expressions is set between 230 and 450 ms after the appearance of the face and is influenced by the duration of the stimulus.”
3. Eimer and Holmes (2007)have studied as well the impact of attention on the processing of emotional facial expression and found that “ERP modulations are strongly dependent on spatial attention”. They conclude that “the analysis of emotional facial expression is based on a complex neural network, and includes both a rapid, obligatory and pre-attentive classification of emotional content (implemented within amygdala, orbitofrontal cortex and ventral striatum), and the subsequent in-depth analysis of emotional faces in higher order neocortical emotion areas. In spite of the fact that ERP effects of emotional facial expression are triggered at very short latencies, they are likely to reflect processes that form part of the second, higher level and attention-dependent emotional processing system, where representations of emotional content are generated in a strategic and task-dependent fashion for the adaptive intentional control of behavior” (Eimer and Holmes, 2007, p. 15). Lang et al. (1997) also postulated that affective pictures draw attention resources.
4. Lang, Bradley and Cuthbert (1997) also postulated that “affective pictures are effective cues to engage emotional response output systems”. Codispoti et al. (2001) demonstrated that “affective pictures draw more heavily on attention resources at encoding than do neutral pictures”. Schupp et al. (2004), proved the hypothesis that “emotional cues prompt a motivational regulation of cortical visual processing and draw attentional resources. A quick glimpse of emotionally relevant stimuli seems sufficient to tune the brain for selective perceptual and post-perceptual stimulus encoding”

In terms of the brain regions where there can be seen differences in terms of processing faces, Bailey et al. (2011) mentions that “the early posterior negativity (EPN) and late positive potential (LPP) represent two components for the ERPs that are commonly modulated by the valence of the pictures. The EPN reflects a transient negativity over the posterior region of the scalp between 200 and 300ms after stimulus onset. The EPN distinguishes emotionally valenced pictures from neutral pictures as subsequently researched by Codispoti et al. (2007) and Schupp et al.(2003) and is greater in amplitude for highly arousing pictures than for the less arousing pictures that have the same valence (Schupp et al., 2003)”. As Schupp et al. (2004) suggest, “the EPN is thought to reflect the allocation of attention to emotionally arousing stimuli” (Bailey et al, 2011, p. 260-261)

### 2.2.3. TASTE STIMULI: CHOCOLATE

Previous studies have shown that “the orbitofrontal cortex can be activated by the sight, smell, taste and texture of food, and that the activations in this region are related to the pleasantness of food”. (Rolls and McCabe, 2007, p. 1067)

Macht and Mueller (2007) prove in their research that “experimentally induced negative mood state can be improved immediately by eating a piece of chocolate. Their study revealed only marginal effect of chocolate over neutral mood and happy mood. The effects they managed to obtain are dependent on palatability. Immediate hedonic effects of palatable foods play an important role in emotion regulation through eating”(Macht and Mueller, 2007, p. 667-674).Their research was however conducted only at declarative level, so no internal measurements were carried out to further validate their theory.

***FIG. 1 D.M.H. Thomson et al. / Food Quality and Preference 21 (2010) 1117–1125***



#### 2.2.3.1. CHOCOLATE HISTORY

“Chocolate, a complex emulsion, is a luxury food that during consumption evokes a range of stimuli that activate pleasure centers in the human brain.” (Afoakwa et al., 2007, p. 290)

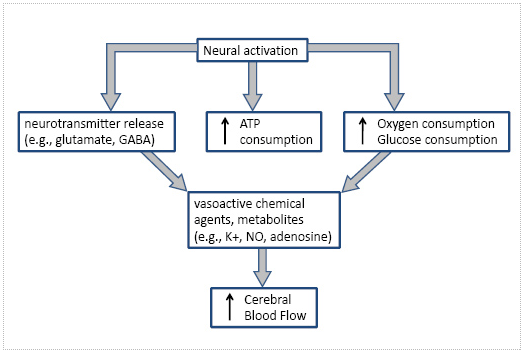
“White chocolate differ from milk and dark through the absence of cocoa nibs containing antioxidants” (Afoakwa et al., 2007, p.290). “Pure chocolate has a strong taste that requires chewing, which leads to prolonged and enhanced sensory stimulation.” (Smeets et al., 2006, p.1298)

#### 2.2.3.2. CHOCOLATE PROPERTIES ASSOCIATED TO CHOCOLATE CONSUMPTION

In a very recent study performed in the US, and published online in the article of Sorond F.A. et al. (2013), *Neurovascular coupling, cerebral white matter integrity, and response to cocoa in older people,* they investigated “the relationship between neurovascular coupling and cognitive function in elderly individuals with vascular risk factors and tried to determine whether neurovascular coupling could be modified by cocoa consumption”.

The study, carried out on sixty senior people trough cognitive measures and measures from the beat-to-beat blood flow velocity responses in the middle cerebral arteries to the N-Back Task (to measure neurovascular coupling), revealed that “there is a strong correlation between neurovascular coupling and cognitive function, and both can be improved by regular cocoa consumption in individuals with baseline impairments. (Pasley, B.N. and Freeman, R. D. 2008, p.5340)

***FIG.2. Summary of physiological changes linking***[***neural***](http://www.scholarpedia.org/article/Neuron)***and vascular responses (Brian N. Pasley and Ralph D. Freeman, 2008***



Possible effects of chocolate, under basic research include anticancer, brain stimulator, cough preventer and antidiarrheal activities. “It sounds almost too good to be true, but preliminary research at West Virginia's Wheeling Jesuit University suggests chocolate may boost your memory, attention span, reaction time, and problem-solving skills by increasing blood flow to the brain. Chocolate companies found comparable gains in similar research on healthy young women and on elderly people”. (CNN Health)

### 2.2.4. GENDER INFLUENCE IN TESTING AFFECTIVE TASTE STIMULI

Smeets et al. (2006) advise that for a better understanding of the regulation of food intake, it might be important to differentiate between men and women. Sex differences in the effect of satiation were found in the hypothalamus, ventral striatum and medial prefrontal cortex. Their study adds to the growing number of studies reporting sex differences in stimulus processing in the brain, including responses to visual emotional stimuli (Smeets et al., 2006, p. 1303).

Their research reveals that men and women differ in their response to satiation and suggest that the regulation of food intake by the brain may vary between sexes. “Therefore, sex differences are a covariate of interest in studies of the brain responses to food” (Smeets et al., 2006, p.1303).

# 3. HYPOTHESIS

The studies performed so far had measured the chocolate impact either at declarative level (self-rated moods) or they have followed on the brain regions activated when eating chocolate with fMRI studies. To my best of knowledge so far, there is no study which underlines and quantifies in terms of amplitude and latency, the impact of chocolate on emotionally induced states at brain level by performing an EEG research.

Following the previous studies presented above, related to face specific brain event related potentials and the evidence they have generated, the thesis will investigate the following hypothesis:

*Hypothesis 1: In the chocolate condition, ERP amplitudes and latencies measured for each type of emotion are likely to be higher in comparison to the no chocolate condition.*

*Hypothesis 2: The N170 component is expected to have higher amplitudes and earlier latencies in the chocolate condition for the emotional stimuli than in the no chocolate condition.*

*Hypothesis 3: The N300 component is expected to indicate higher amplitudes for happy faces than to sad and neutral faces in the chocolate condition then in the control condition.*

The hypothesis states the effect that we are following to observe, however, in the discussion part, according to the results, a broader image will be presented, as well as the regions where effects are observed to take place.

# 4. METHODOLOGY AND MATERIALS

24 healthy volunteers took part in the study (only men, aged 22-26) after giving informed consent. All participants had normal or corrected to normal visual acuity and were in an excellent health condition.

Stimulus material was selected from the online environment, presenting, respectively 8 sad, 8 happy and 8 neutral faces. Pictures were presented in a randomized order in the center of a computer monitor, placed approximately 80 cm from the subject. The stimulus was presented for 5000ms (5 seconds) on the monitor with an inter-stimulus interval of 2500ms (2.5 seconds). The inter-stimulus fixation point was projected at the center of the screen (a white point on a black background).

The participants were told to relax and observe the faces carefully. Participants were seated in sound-attenuated, electrically shielded room and were asked not to blink during the task and not to move their head or their body. Prior to recording ERPs, the subjects were familiarized with the overall procedure (training session).

Additionally, one third of the subjects received before watching the pictures, a piece (5 g) of milk chocolate, one third of the subjects received before watching the pictures a piece (5g) of pure chocolate and one third were assigned to the control group, so they did not receive chocolate at all.

The two types of chocolate used in the experiment were: Dégustation 86% noir brut - contains 86% cocoa and Milk Chocolate 100g - Pure Côte d'Or Milk Chocolate. (See Appendix 1)

The experiment session lasted for approximately 3 minutes, where every participant saw in a random order all the emotional stimuli (all the 24 emotionally valenced pictured with faces) (See Appendix 2)

## **4.1. ERP RECORDING AND MEASUREMENTS**

The EEG was recorded with a 32-channel DC amplifier (Biosemi Systems) at 32 electrodes (frontal: Fp1, Fp2, Fz, F3, F4, F7,F8, F9, F10; central: Cz, C3, C4, FC3, Fc4, Cp5, Cp6; temporal: T7, T8, T9, T10; parietal: Pz, P3, P4, P7, P8, P9, P10; occipital: O1, O2, Oz) (international 10-20 system) with reference electrodes at the mastoids. Electrooculograms (EOG) were recorded from electrodes lateral and superior to the left eye. (See Appendix 3)

The signal (sampled at 512 HZ) was amplified and processed with a pass band from 0.05 to 50 Hz and was recorded in continuous mode.

The skin was prepared beforehand by rubbing with alcohol. The electrode cups were filled with EEG paste. The fitting of the electro-cap was briefly described to the participants when they arrived for the study.

Three trials affected by artifacts were automatically identified, marked by the software and rejected from further analyses, based on a maximum gradient of 30 µV/ms and maximum amplitude of ±100 µV (removed from the sample due to high artifacts frequency). For the remaining subjects, less than 10% epochs were rejected for EOG or muscular artifacts. The artifact-free trials (21) were separately averaged off-line for each subject and for the facial expressions happiness, sadness and neutral (an averaged waveform (off-line) was obtained from 21 artifact-free individual target stimuli for each type of emotion). To evaluate differences in ERPs response for 3 facial expressions we focused data analysis within the first second post-stimulus.

After a preliminary investigation with variable electrode locations, we decided to study the responses at brain regions level, so the electrodes were combined accordingly (for the frontal area: Fz, F3 and F4; for the occipital area: Oz; for the temporal area: T7 and T8; for the parietal area: Pz, P3 and P4 and for the central area: Cz). The latencies and amplitudes of the N170, N230, N300 were computed. Parameters were calculated for the following electrodes: Fz, F3, F4, Oz, T7, T8, Pz, P3, P4, Cz.

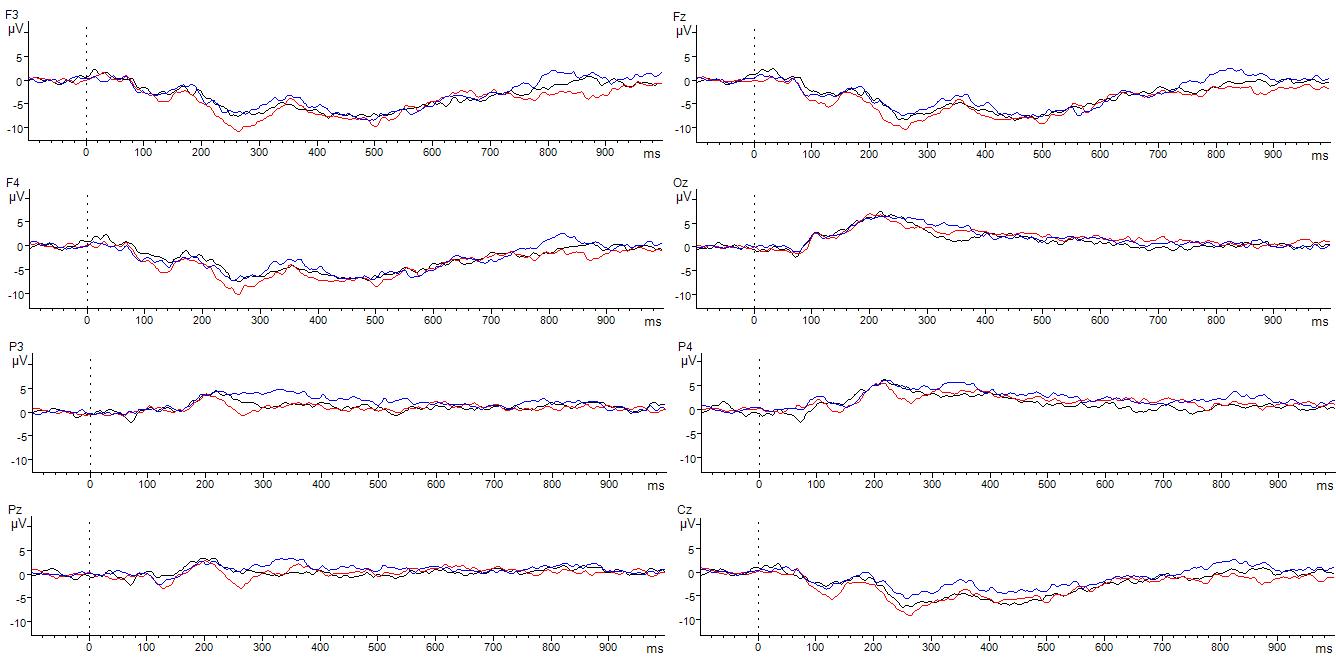
The EEG was processed using the software package BrainVision Analyzer 2.0 (Brain Products GmbH, Germany). The EEG responses were averaged separately according to the stimulus categories and adjusted relative to a 100ms pre-stimulus baseline.

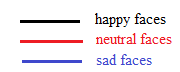
# 5. RESULTS

## **5.1. EEG RESULTS**

The EEG results will be interpreted both from the wave forms point of view as well as from the statistical point of view. First we will look at the wave form results and explain for every chocolate condition, what was the impact over the emotions elicited to the brain by the face stimuli. Secondly, we will analyze, with the statistical tools, the significance of each stimulus in each chocolate condition and discuss over the main effects and the interaction effects of them over the brain.

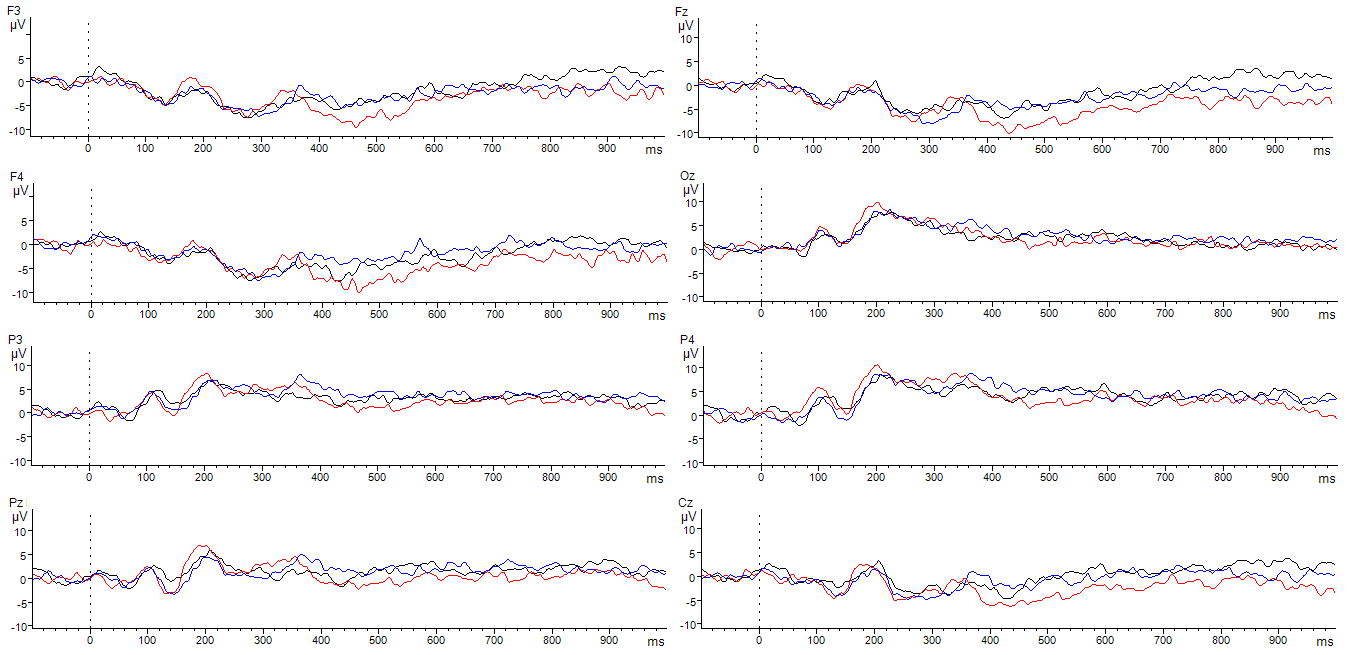
### 5.1.1. CHOCOLATE CONDITION vs. CONTROL CONDITION RESULTS

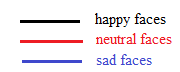
***FIG. 3 Grand average waveforms at frontal, midline, parietal, temporal and occipital lobes for the three face stimuli* *expressions in the chocolate condition (here pure and milk are taken together for a total chocolate overview)***



After a general visual inspection of the waveform elicited by the three face stimuli in the chocolate condition, it can be observed that the stimuli elicit the highest effects in the frontal, midline-parietal and occipital lobe. The waveforms elicited in the temporal regions do not capture significant differences in between the three emotions, so the discussion section will follow the above mentioned areas, leaving aside the temporal regions.

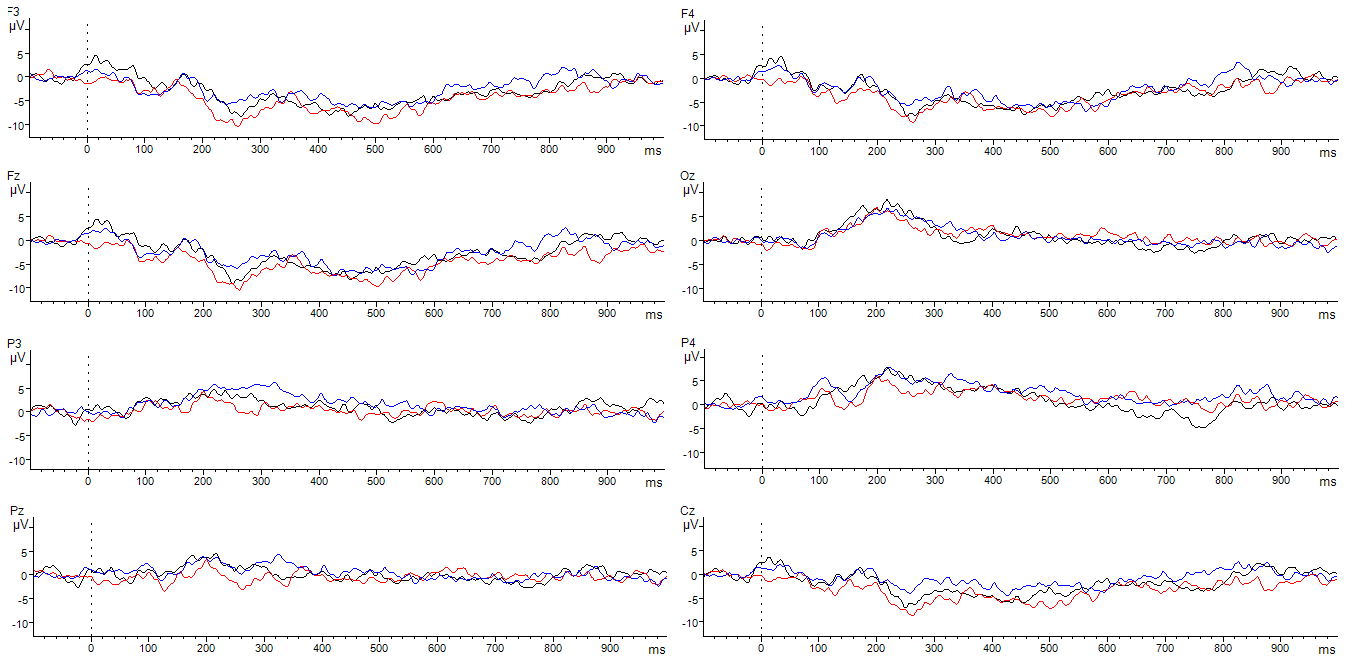
***FIG. 4 Grand average waveforms at frontal, midline, parietal, temporal and occipital lobes for the three face stimuli expressions in the control condition (no chocolate condition)***

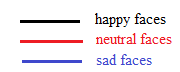


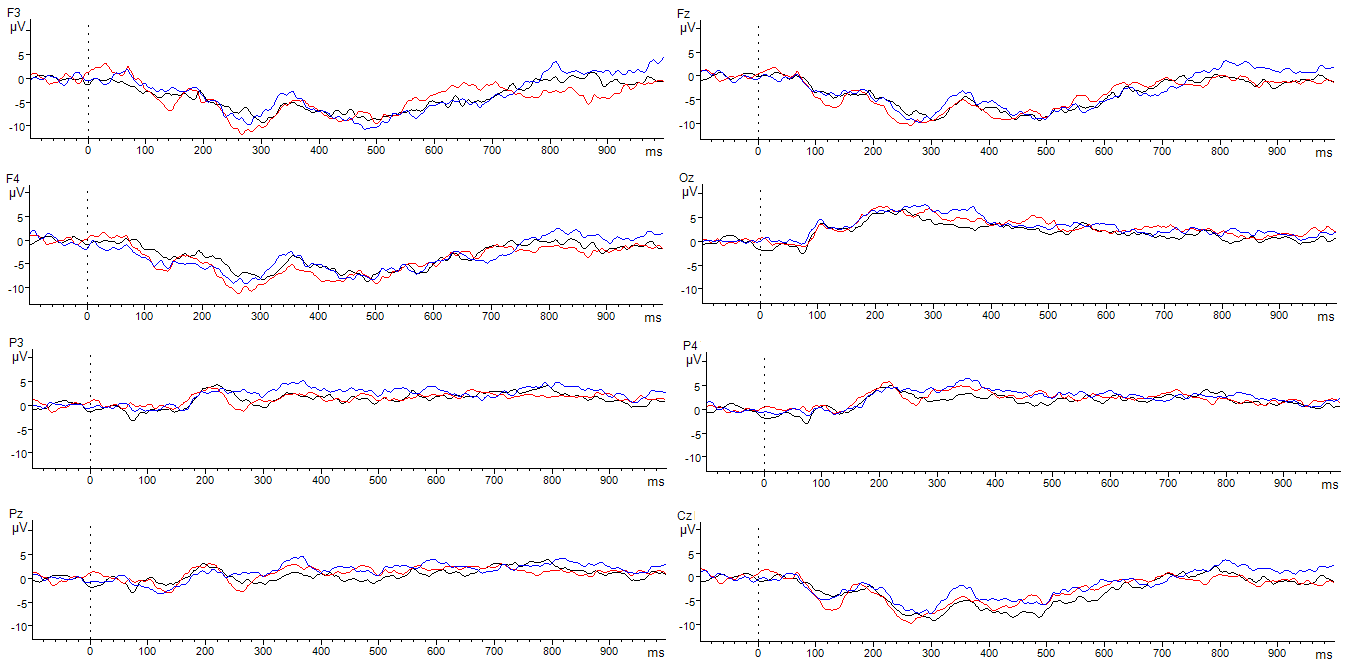


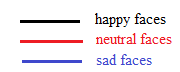
After a general visual inspection of the waveform elicited by the three face stimuli in the control condition (no chocolate), it can be observed that the stimuli elicit the highest effects in the frontal, midline-parietal and occipital lobe. Similar to the chocolate condition, the waveforms elicited in the temporal regions do not capture significant differences in between the three emotions, so the discussion section here will also follow the above mentioned areas, leaving aside the temporal regions.

### 5.1.2. PURE CHOCOLATE CONDITION vs. MILK CHOCOLATE CONDITION vs. CONTROL CONDITION RESULTS

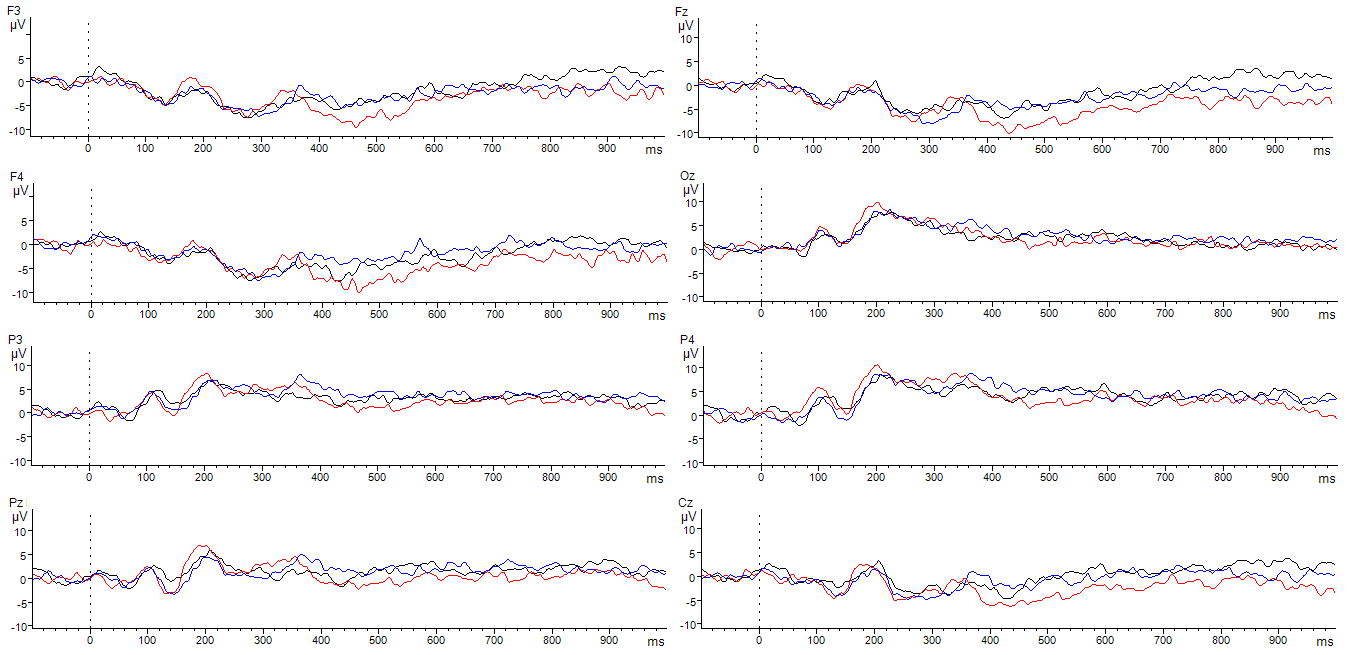
***FIG. 5 Grand average waveforms at frontal, midline, parietal, temporal and occipital lobe for the three face stimuli expressions in the pure chocolate condition***

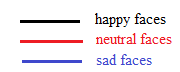


*****FIG. 6 Grand average waveforms at frontal, midline, parietal, temporal and occipital lobe for the three face stimuli expressions in the milk chocolate condition***



When comparing the two chocolate conditions one with the other, in terms of elicited waveforms, there can be observed that in the **pure chocolate condition**, the face stimuli elicit higher amplitudes than in the **milk chocolate condition.** Again, there can be made clear observations for the frontal, midline-parietal and occipital lobes, but in the temporal lobes locations, the recordings do not catch relevant information, most probably due to the noise interference whith this particular regions. For this reason, in the discussion section, there will be placed emphasis over the above mentioned areas and elaborate over the ERP components and their significance in contrast.

*****FIG.7 Grand average waveforms at frontal, midline, parietal, temporal and occipital lobe for the three face stimuli expressions in the control condition (no chocolate condition)***



An overview of the three tested conditions shows us that:

* Comparing the **pure chocolate condition** with the **control condition**, it can clearly be observed that the sad stimuli elicit the higher amplitudes in all brain regions whereas in the control situation, the neurtal

stimuli appear to have the highest impact. In the discussion part a more detail will be placed over the ERP components and the different brain regions where responses are most present.

* Comparing the **milk chocolate condition** with the **control condition**, differences in amplitude can be observed in the parietal-midline, occipital, and frontal areas of the brain. Here as well, there can be observed a difference in the emotions which trigger the brain responses: in the milk condition the sad emotions are the most impactfull in terms of brain wave amplitudes, whereas in the control condition the waveform amplitudes are stronger for the neutral emotions.

## **5.2. STATISTICAL ANALYSIS**

To analyze the effect of the two different types of chocolate over the brain responses elicited by different facial-expressions, we computed the peak amplitude and latency measurements. These have been entered into separate two-way repeated-measures ANOVA with the emotion stimulus (happy/sad/neutral) and brain region (parietal/occipital/temporal/frontal and central) as within subject variable and chocolate type (pure/milk/control) as between subject variable.

Prior to the statistical analysis the electrodes have been grouped per regions as follows: parietal region (P3-P4-Pz); occipital region (Oz); temporal region (T7-T8); frontal region (Fz-F3 and F4) and central midline region (Cz).

***TABLE 1. Tests of Within-Subjects Effects for amplitudes***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure** | **df** | **Mean Square** | **F** | **Sig.** |
| **Emotion** | 2 | 15.377 | 0.669 | 0.52 |
| **Emotion \* Chocolate** | 4 | 6.171 | 0.269 | 0.90 |
| **Error(Emotion)** | 36 | 22.973 |  |  |
| **Region** | 4 | 1071.765 | 51.915 | 0.00 |
| **Region \* Chocolate** | 8 | 19.637 | 0.951 | 0.48 |
| **Error(Region)** | 72 | 20.645 |  |  |
| **Emotion \* Region** | 8 | 1.882 | 0.661 | 0.73 |
| **Emotion \* Region \* Chocolate** | 16 | 1.386 | 0.486 | 0.95 |
| **Error(Emotion\*Region)** | 144 | 2.849 |  |  |

***Note: p< .05***

In terms of amplitude, the computed ANOVA does not show a significant interaction nor between the chocolate and the brain region (F(2,18)=0.652, p=0.533>p=.05), neither between the emotion stimuli and the brain region (F(1,18)=1.809, p=0.195>p=0.5), nor between the emotion in combination with the chocolate over the brain regions (F(2,18)=0.005, p=0.995>.05). So from the statistical point of view, there cannot be drawn any conclusions over the assumption that chocolate brings an extra impact over the responses elicited by the brain to the visual face stimuli.

The within subjects output reveals however significant results for the regions of the brain which are activated (p=.00 <p=.05) thus indicating that the brain regions (namely the elecrode locations) are impacted differently by the visual tested stimuli as well as by the taste stimuli.

***TABLE 2. Tests of Between-Subjects Effects for amplitudes***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure** | **df** | **Mean Square** | **F** | **Sig.** |
| Intercept | 1 | 118.782 | 1.229 | 0.28 |
| Chocolate | 2 | 142.237 | 1.472 | 0.26 |
| Error | 18 | 96.638 |  |  |

***Note: p< .05***

Chocolate, when tested as between subjects factor, does not shows a significant effect (F (2, 18) = 1.472, p=0.256 > p=0.05). However, the insignificant results may be explained by the small number of records.

***TABLE 3. Multiple Comparisons between the chocolate conditions***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Method** | **(I) Chocolate** | **(J) Chocolate** | **Mean Difference (I-J)** | **Std. Error** | **Sig.** |
| Tukey HSD | control | milk | 2.416 | 1.412 | 0.228 |
|  |  | pure | 1.260 | 1.314 | 0.611 |
|  | milk | control | -2.416 | 1.412 | 0.228 |
|  |  | pure | -1.156 | 1.371 | 0.682 |
|  | pure | control | -1.260 | 1.314 | 0.611 |
|  |  | milk | 1.156 | 1.371 | 0.682 |
| Dunnett t (2-sided) | control | pure | 1.260 | 1.314 | 0.547 |
|  | milk | pure | -1.156 | 1.371 | 0.623 |

**Notes: Based on observed means; p< .05**

Post-hoc tests have been performed in order to determine if there are significant differences between the groups of subjects tested namely the group which has received milk chocolate and the group which has received pure chocolate. The performed tests are the Tukey HDS test and the Dunnett (2 sided) t test.

The purpose of Tukey's HSD test is to determine which groups in the sample differ. While ANOVA can prove if groups in the sample differ, it cannot indicate which groups differ. Tukey's HSD can clarify which groups among the sample in specific have significant differences.

The Tukey results showed that mean differences computed between the control vs. the milk chocolate (p=0.228) and the control vs. the pure chocolate (p=0.611) are not statistically significant. These difference approached statistical significance (p=0.228) between control and milk chocolate but did however not reach the conventional p<.05 level. So from the statistical point of view we cannot imply and discuss the differences which we would expect to get between the 3 conditions. A new research can be performed with a sensibly higher number of participants and see if the statistical conditions change.

The Dunnett’s test did not reach statistical significance as well. With this test, every mean from the pure and milk group was compared to the control group mean. (p=0.547>p=.05)

***TABLE 4. Mean amplitudes in every chocolate condition per brain region***

|  |  |  |  |
| --- | --- | --- | --- |
| **Brain region** |  | **Chocolate condition** |  |
|  | **Pure** | **Milk** | **Control** |
| **Occipital** | 4.289 | 6.033 | 4.886 |
| **Parietal** | 3.647 | 1.515 | 4.114 |
| **Temporal** | -2.608 | -2.468 | -1.123 |
| **Frontal** | -3.777 | -5.850 | -2.236 |
| **Central** | -2.028 | -5.066 | -1.553 |

The occipital brain region registerd the highest mean amplitudes in every chocolate condition. In the **control condition**, the highest mean amplitude is elicited for the neutral pictures (M= 4.885). In the **milk chocolate condition**, the highest mean amplitude is elicited for sad pictures(M=6.033). In the **pure chocolate condition**, the highest mean amplitude is elicited for happy pictures (M=4.289). We observe that the highest amplitude is elicited in the milk chocolate condition, while the lowest amplitude is elicited in the pure chocolate condition.

The next region of the brain where the amplitudes recorded have high vales is the parietal region. Here, pure chocolate gives higher amplitudes than milk chocolate (M=3.647).

The observations do not support our hypothesis, that in the chocolate condition the recorded amplitudes give higher values that in the control condition. On the contrary, we observe that in the chocolate conditons the amplitude valuesa are consistently lower than in the control condition, for every brain region, exept from the occipital lobe.

***TABLE 5. Mean amplitudes in every chocolate condition per emotional stimuli***

|  |  |  |  |
| --- | --- | --- | --- |
| **Emotional stimuli** |  | **Chocolate condition** |  |
|  | **Pure** | **Milk** | **Control** |
| **Happy** | 5.011 | 4.697 | 4.828 |
| **Sad** | 4.289 | 6.033 | 4.885 |
| **Neutral** | 3.567 | 5.568 | 5.206 |

When comparing the amplitudes elicited by each type of emotional stimuli, we observe that in the pure chocolate condition, the happy stimuli elicit the highers amplitude. In the milk condition, the highest amplitude is elicited by the sad stimuli, whereas in the control condition, the neutral stimuli gives the highest value. We can conclude from here that when chocolate is administered, the emotional stimuli give a higher impact over the brain or that chocolate increases the impact that the emotional stimuli have over the brain.

***TABLE 6. Tests of Within-Subjects Effects for latencies***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure** | **df** | **Mean Square** | **F** | **Sig.** |
| **Emotion \* Region** | 8 | 81.305 | 1.281 | 0.258 |
| **Emotion \* Region \* Chocolate** | 16 | 38.787 | 0.611 | 0.871 |
| **Error(Emotion\*Region)** | 144 | 63.475 |  |  |
| **Emotion** | 2 | 122.450 | 0.712 | 0.498 |
| **Emotion \* Chocolate** | 4 | 225.720 | 1.312 | 0.284 |
| **Error(Emotion)** | 36 | 172.097 |  |  |
| **Region** | 4 | 2300.064 | 1.952 | 0.111 |
| **Region \* Chocolate** | 8 | 1131.698 | 0.961 | 0.473 |
| **Error(Region)** | 72 | 1178.027 |  |  |

***Note: p< .05***

In terms of latency, the computed ANOVA does not show significant interaction nor between the chocolate and the brain regions (F(8,72)=0.961; p=0.473) neither between emotional stimuli and the brain regions (F (8,144)=1.218; p=0.258), nor between the emotion in combination with the chocolate over the brain regions (F(16, 144)=0.611, p=0.871).

***TABLE 7. Tests of Between-Subjects Effects for latencies***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure** | **df** | **Mean Square** | **F** | **Sig.** |
| **Intercept** | 1 | 16598816.148 | 8073.025 | 0.000 |
| **Chocolate** | 2 | 2203.626 | 1.072 | 0.363 |
| **Error** | 18 | 2056.084 |  |  |

***Note: p< .05***

Chocolate, tested as between subjects factor, does not give signinficant results effect (F (2, 18) = 1.072, p=0.363 > p=0.05).

A possible explanation for the insignificant results obtained through the statistical analyses might be the small number of records over which the analysis was carried out.

***TABLE 8. Mean latencies in every chocolate condition per brain region***

|  |  |  |  |
| --- | --- | --- | --- |
| **Brain region** |  | **Chocolate condition** |  |
|  | **Pure** | **Milk** | **Control** |
| **Occipital** | 227.783 | 234.131 | 235.352 |
| **Parietal** | 235.942 | 240.804 | 239.955 |
| **Temporal** | 208.008 | 243.368 | 219.134 |
| **Frontal** | 237.447 | 242.269 | 227.330 |
| **Central** | 234.924 | 239.665 | 238.909 |

When comparing the latencies from every condition in relation with the brain regions, we can observe that in earliest latency in the pure chocolate condition is issued in the temporal lobe and the latest in the frontal lobe. For the milk chocolate condition, the earliest latency is elicited in the occipital lobe and the latest in the temporal lobe as well. Looking at the control conditions, the earliest latency appears in the temporal lobe whereas the latest appears in the parietal lobe. There can be observed that in all brain regions, the pure chocolate conditions holds the earliest latencies. We can thus assume that pure chocolate speeds the brain reaction to emotional stimuli.

***TABLE 9. Mean latencies in every chocolate condition per emotional stimuli***

|  |  |  |  |
| --- | --- | --- | --- |
| **Emotional stimuli** |  | **Chocolate condition** |  |
|  | **Pure** | **Milk** | **Control** |
| **Happy** | 234.192 | 243.368 | 239.258 |
| **Sad** | 234.802 | 242.269 | 239.955 |
| **Neutral** | 237.447 | 239.054 | 236.072 |

When comparing the latencies elicited by each type of emotion, we can observe that in the pure chocolate condition, the happy pictures have the earliest latency measure (M=234.192) whereas in the milk conditions the earliest latency is observed for the neutral pictures (M=239.054) and is the same in the case of the cotrol condition.

We can also observe that both happy and sad pictures elicit the earliest latency in the pure chocolate conditon and that the waveforms are elicited at approximately the same latency (234 ms).

From these observations, we are inclined to say that pure chocolate has indeed an effect over the brain responses towards emotional stimuli, and that it triggers a faster response as compared to the milk chocolate and the control conditions.

# 6. DISCUSSION

The discussion points will focus first on findings between the overall chocolate and control conditions and will then go into more detail over the two types of chocolate separately and discuss over the main results obtained.

Dealing with the first hypothesis, the ERP profiles observed in the emotional face expression decoding in the two conditions, there can be observed several important differences.

In **the overall chocolate condition**, brain regions which have been highly activated are the frontal lobe, the occipital lobe, the parietal lobe and the central midline. Less impact can be observed over the temporal lobes.

In *the frontal lobe*, there is first a positive peak in the first 100ms post-stimulus and the highest peak captured is elicited by the happy pictures. At approximately 140ms post stimulus, there appears a significant negative deflection. This deflection has the highest amplitude for neutral pictures, whereas the sad and happy pictures do not show significant differences in amplitude. This is most probably the N170 which is related to the structural elaboration of the face-stimulus. The N170 captured here has lower amplitude for emotional pictures as opposed th neutral pictures. The next important ERP profile observed is a positive peak at approximately 180ms for the happy pictures. This is followed by a new significant negative deflection registered at approx. 260ms. This negative deflection captures a clear difference between neutral stimuli and emotional stimuli. However, no significant difference between the two emotional stimuli can be observed. This can be attributed to the N230 component. As supported by previous literature, this component is strictly related to the decoding of emotion (Streit et al, 2000). The following important ERP profile is a positive peak detected at 360ms for neutral and sad pictures and slightly earlier for happy pictures. At this latency, the sad pictures generate the highest amplitude. The N300 component in the overall chocolate condition is not distinctly present. This component, as suggested in the literature, is the borderline for the happy faces and the rest of the stimuli.

In the overall chocolate condition, it can be observed that the neutral faces are the ones who elicit the highest negative wave forms and the happy and the sad elicit the highest positive waveforms. With this we can suggest that chocolate influences the impact of emotions captured in the EEG brain waves, as in the chocolate condition the neutral faces waveforms are always distinct in amplitude from the emotions waveforms. This can only result from an impact of the chocolate over how the brain reacts to emotional stimuli.

In *the occipital lobe,* there can be observed a clear negative deflection in the first 100ms post stimulus, elicited the highest by the positive emotions. In the next 120ms there is captured a positive peak but with no distinction between emotions and the neutral stimuli. At 220ms the neutral emotions elicit a positive peak followed at 240ms by the positive and negative emotions peaking. At 320ms there is a negative deflection by the happy and the sad pictures with clear difference in amplitudes, the happy pictures eliciting the highest amplitude, followed shortly at 340ms by a negative deflection by the neutral stimuli as well. These observed deflections in the 300ms range distinctly for the happy pictures can support our third hypothesis that the N300 component actually retrieves stronger signals by happy faces than sad and neutral faces, acting as a facial expression recognition component, in the occipital lobe.

In *the parietal lobe,* the observations can conclude that in the first 100ms post stimulus, the happy faces elicit a severe negative peak, followed then in the 170ms by a negative deflection observed for all three stimuli. In this region it can be observed a distinct difference in amplitude elicited by neutral stimuli as opposed to emotional stimuli. There cannot be draw any conclusion over a difference at emotional stimuli level, however it is important to mention that emotional stimuli generate stronger positive deflections in this brain area.

The *central line,* it can as well be observed a clear difference between the emotional stimuli and the neutral stimuli in terms of the amplitude of the observed components. Even it we cannot draw specific remarks per type or emotion, it is clear that here as well the emotional stimuli draw stronger positive amplitudes in the 180ms and 360ms post stimulus latencies, whereas the neutral stimuli draw stronger amplitudes on the negative peaks in the 120ms and 260ms post stimulus.

In **the control condition**, the frontal, parietal, central and occipital brain lobes are observed, with the frontal and the occipital standing out among the others. Similarly, the temporal lobes do not offer significant variations in waveforms to be analyzed. We observed that the negative variation is different among the three emotions in terms of peak amplitude as compared to the chocolate condition. The different profiles of ERP as a function of the impact of chocolate over the emotional perception of the stimulus from the brain may indicate that the chocolate clearly changes the way the emotions impact the brain as opposed to how emotions impact the brain in the no chocolate condition.

In *the frontal lobe*, both the N170 component and the N230 component are present, however, the difference in amplitude elicited by each emotion is not that visible as in the chocolate condition, leading us to conclude also that chocolate increases the natural selective attention actions and draws on attentional resources, as also presented in the theory.

In *the occipital lobe* there can be observed that neutral stimuli draw higher amplitudes for the positive peaks at 120ms and 200ms as opposed to the chocolate condition in the same brain region, where positive emotions peaked at a slightly later latency.

In *the parietal lobe* there can as well be observed high positive amplitudes for neutral stimuli elicited also at an early latency than for emotional stimuli. In the chocolate condition the emotional stimuli as opposed to neutral stimuli, bring higher amplitudes in this area, suggesting thus that chocolate indeed generates a difference over how emotions are processed by the brain.

The *central midline* also shows stronger effect of neutral emotions giving 2 earlyer positive peaks at 180ms and 340ms as opposed to the chocolate condition, where the emotional stimuli elicited stronger positive waveforms at 180ms and 360ms.

Thus, the first hypothesis is only partially supported, as we cannot make distinct observations over each type of emotion. However, we observe that in the chocolate condition the emotional stimuli elicit higher amplitudes as opposed to neutral stimuli, than in the no chocolate condition.

Going into more detail, we observed and compared the differences between the two types of chocolate tested.

For **the pure chocolate**, in terms of emotions, we observe that at *the frontal lobe*, the happy emotions elicit a first strong positive peak in the first 100ms timeframe, followed by a new positive peak at 160ms this time accompanied as well by the sad emotions. There is a clear distinction in terms of the waveforms elicited between the emotional stimuli and the neutral stimuli. The latter bring higher negative peaks at earlier latencies as well than the emotional stimuli. The N170 component is elicited at around 140ms post stimulus for the emotional stimuli and slightly later for the neutral stimuli. Similarly, we observe the N230 component which as well elicits an earlier latency for the emotional stimuli, and almost in the same time (220ms) and at a later latency (260) and higher amplitude for the neutral stimuli. The N300 component is presents also different profiles, having lower amplitude and an earlier latency for the emotional stimuli (320ms) as opposed to the neutral stimuli which generate stronger negative amplitude at a later time moment (360ms).

For *the occipital lobe* it can be observed how the positive emotions have a constant dominance in terms of stronger amplitudes for both negative and positive peaks.

In *the parietal region,* emotional faces elicit as well a stronger positive signal than neutral faces. Here, the N170 component retrieves an earlier latency for the emotional faces as opposed to neutral faces (at approx. 140ms). The N230 captures in this region a clear distinction between emotional stimuli and neutral stimuli and the emotional faces have lover amplitude than the neutral faces. The N300 component does not bring a clear differentiation between happy faces and the rest of the stimuli; it captures however a clear differentiation in between the emotional stimuli and the neutral ones, with the emotional stimuli having as well lower amplitudes.

The *central midline* offers as well a clear image over the emotional stimuli as opposed to neutral stimuli. A thin distinction between the motional stimuli can be made as well, however it is clearly visible that emotional stimuli draw higher positive amplitudes at the first 100ms and then at 180ms and then at 320ms and that for the observed components, both N230 and N300 capture lower amplitudes for the emotional stimuli than for the neutral ones. In terms of latencies, it can also be observed that emotional stimuli have earlier latencies than the neutral ones.

In **the milk chocolate condition**, in terms of emotions, we observe that at *the frontal lobe*, the waveforms elicited by the sad and happy emotions elicit a positive followed by a negative deflection similar to the pure chocolate condition. However, in the pure chocolate condition, the peaks and the slopes have been more pronounced and clearer for the emotional stimuli.

In *the occipital lobe*, the milk chocolate condition retrieves a milder influence over the waveforms as opposed to the pure chocolate condition. The same components are present but the amplitudes at which they are elicited are stronger in the pure chocolate condition, thus suggesting that when comparing the two of them, pure chocolate has a stronger, more visible and pronounced impact over how emotional stimuli are processed by the brain.

*Central midline* in the pure chocolate condition captures a distinct effect of the emotional faces as opposed to the neutral faces, whereas in the milk chocolate condition, in this region the difference between the three stimuli for the observed components is not very distinct.

In *the parietal lobe*, for the followed components, the milk chocolate condition reveals the N170, N230 and N300 but they do not hold distinct significant observations over the specific face emotions which trigger these components. However, in the pure chocolate condition, there is a significant difference at these components also with respect to the difference that can be observed between the emotional stimuli and the neutral stimuli.

The observations made so far, allow us to believe that, as also explained by Bruinsma and Taren (1999), chocolate brings a sensory reward.

Same as Carretié and Iglesias (1995), we observed that the affective implications of facial expressions are processed more pronounced in the occipital regions of the brain. Our observations also allow us to believe that, as presented by Eimer(2000), “there is clearly a functional specialization for the processing of emotional information” due to the fact that clear differences can be observed through the ERP profiles in the undertaken research between neutral stimuli and emotional stimuli.

We can see from the research that there is a clear distinction for the N230 component in terms of amplitudes elicited by emotional faces as opposed to neutral faces. This is the most pronounced in the pure chocolate condition.

Similar to others, we discovered that in the control condition the neural faces elicited the highest amplitudes, whereas in the chocolate condition we observed higher amplitudes for emotional stimuli.

In our study, similar to Sato et al (2001), we observe that in the control condition the neutral emotions indeed give the highest peak whereas there can be done no mention about a difference in the two happy and sad emotions as there is not recorded any significant difference.

As presented in Balconi and Pozzoli’s paper (2003) “subjects might have a more intense emotional reaction while viewing a negative rather than a positive emotion”. We were not able to prove this result, which is also mentioned in the hypotheses. So no clear distinction could be observed emotion related with the ERP measures, but there could be observed important differences in between the neutral stimuli and the emotional stimuli.

In their research, Eimer and Holmes (2007) find that “facial expressions are very similar in terms of the magnitude and duration of their effects on ERP waveforms relative to neutral faces” (Eimer and Holmes, 2007, p. 19). This is also a finding retrieved by our study, and it can be best observed in the pure chocolate condition.

Our observations are in line with the studies performed so far by Keil et al. (2002); Schupp et al. (2000); Schupp et al. (2004) who observe that the LPP has higher amplitude for emotional pictures than for neutral ones. These results we observe in a more emphasized and clear way in the chocolate condition, namely in the pure chocolate condition.

# 7. CONCLUSIONS

This study is one of the first to examine the impact of pure chocolate and milk chocolate on the brain responses when emotional valenced stimuli are presented.

The results imply that chocolate does indeed have the power to modify the face-specific brain potential elicited by different emotional stimuli. A first conclusion is that in the chocolate condition as opposed to the control condition, the observed ERP profiles capture differences and that these differences are distinctly observable for the emotional stimuli in contrast with the neutral stimuli, whereas in the control condition, the ERP waveforms do not capture the difference in the emotional stimuli in such a clear way.

Going more into detail it has been observed that pure chocolate influences the impact of emotions in a higher way that milk chocolate, triggering a different impact for each type of emotion, over the brain. We can conclude thus from this that pure chocolate has a stronger impact than milk chocolate when it comes to processing different types of emotions elicited by face stimuli.

# 8. SDUDY LIMITATIONS AND FURTHER RESEARCH

There are several limitations to the undertaken research. First of all there is the gender limitation. The study has been performed only on male participants. As indicated in the literature part, brain responses to food are different according to gender category. Moreover, as Gohier et al. (2013) present, “Differences in emotional processing between men and women have been consistently reported. Healthy women were found to perform better in tasks requiring emotional face categorization (Thayer and Johnsen, 2000).

The present study however did not aim to research the differences that appear between genders when it comes to processing the affective stimuli. Consequently, based on previous findings in terms of gender differences, we decided to carry out the study only with male participants in order to keep less variation in the external factors which might have interfered (such as hormonal changes for women participants – as Bruisma and Taren (1999) reveal in their article, p. 1253, etc.).

Next studies might therefore be carried out having the gender variable as well and observing, at brain level, the activated parts per each gender when chocolate is ingered, as well as the difference in intensity when stimuli are presented (both visual and taste)in each gender instances.

The next shortcoming might consist in the visual stimuli used. Several researches have employed stimuli from the International Affective Picture System (IAPS), known to reliably alter emotional states. In Huster et al. (2009) it is however stated that “relevant studies, (using this stimuli), have most often been unable to find predicted effects. One reason for such failures might be the inadequate knowledge about the minimum number of stimuli needed for psychometrically stable results.” (Huster et al., 2009, p 212) In the current research, pictures were selected on a subjective rationale in terms of their valence, as happy, sad and neutral, due to the long time interval needed to obtain approval for using the IAPS pictures. Therefore, a new research might try to employ the IAPS stimuli and replicate the conditions of the current study and measure the differences. The present study however did not intend to validate or invalidate the efficiency of the visual stimuli used, but aimed to focus on the impact of the different types of chocolate over brain activations.

Further research could examine two forms of collecting the data, such as EEG and fMRI as well as it should include more participants in the study.

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# 8. APPENDIXES

## APPENDIX 1 – SORTIMENTS OF CHOCOLATE USED



## APPENDIX 2 – IMAGES USED

**Happy**

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**Neutral**

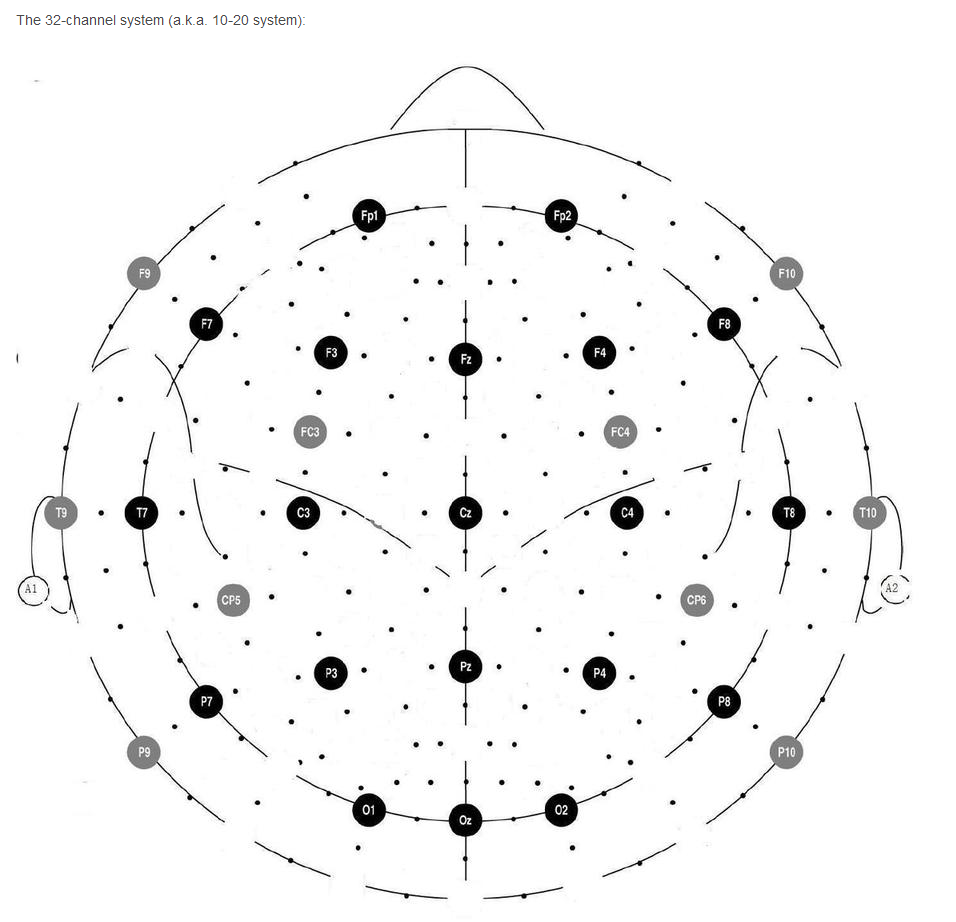






**Sad**

## APPENDIX 3 – EEG CHANNELS LOCATION

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