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THE RELATIONSHIP BETWEEN VISUAL AND VERBAL INFORMATION AND EMOTION PROCESSING: REPORTS FROM EEG AND SELF-ASSESSMENT

Master's thesis

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Running head: Visual and verbal information processing

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The relationship between visual and verbal information and emotion processing: reports from EEG and self-assessment

Abstract

People receive emotion-related information through different mediums. In vision, emotional content could be presented in either a visual or verbal manner (pictorially or as text). In the current thesis, we investigated whether perceived emotional material is processed homogeneously and whether the processing manner (visual/verbal) affects how people process and express emotional content. For that, 108 healthy adults were shown pictures depicting facial expressions (Ekman database) and words presenting six basic emotions (anger, happiness, sadness, surprise, fear, disgust) and one depiction of neutral. The participants had to either mirror the facial expression or express the written emotion while their EEG was recorded, as well as give a rating of the task difficulty. The results for self-reported task difficulty indicated that expressing an emotion was consistently assessed easier in the verbal condition, congruous with our hypothesis that verbal labelling helps reduce the uncertainty related to facial portrayals of expression. We chose three time-intervals for the EEG analyses (representative of the N1, N170 and LPP ERP-components). The results comparing the visual and verbal condition showed that surprise and fear were processed in a significantly different manner in the N1 and N170 time-interval, and all emotions except fear were dissimilar in the LPP time-interval. This is indicative of a preferential treatment for fear stimuli. We concluded that processing emotional content is highly dependent on how it is presented in the task, and the perceived emotional ambiguity emerging from stimuli being presented in a visual or verbal manner could therefore play an important role in how emotions are processed, expressed and perceived by others.

Keywords: visual and verbal information processing, EEG, N1, N170, LPP, self-reported task difficulty

Visuaalse ja verbaalse infotöötluse seos emotsioonitöötlusega ajus ja enesekohaste hinnangutega

Kokkuvõte

Emotsioonidega seotud teave jõuab meieni erinevate meelte kaudu. Nägemismeele kaudu võime me omakorda informatsiooni saada kas visuaalsel või verbaalsel viisil, pildi või sõna kujul. Käesolevas uurimistöös küsisime, kas emotsionaalset materjali töödeldakse sarnaselt ning kas informatsiooni edasikandmise viis (visuaalne/verbaalne) mõjutab seda, kuidas inimesed emotsionaalset sisu mõistavad või väljendavad. Selleks näitasime 108 tervele täiskasvanud osalejale näoilmeid (Ekmani näopiltide andmebaasist) ning sõnu, mis väljendasid kuut baasemotsiooni (viha, rõõmu, kurbust, üllatust, hirmu, vastikust) ning neutraalsust. Osalejad pidid nähtud näoilmet järgi tegema või kirjas olevat emotsiooni näoilmega väljendama. Samal ajal mõõtsime osalejate aju elektrilist aktiivsust (EEG) ning palusime neil hinnata, kui hästi nad ülesandega hakkama said. Enesekohaste hinnangute järgi peeti emotsiooni väljendamist verbaalses tingimuses järjepidevalt lihtsamaks kui visuaalses tingimuses. See on kooskõlas meie hüpoteesiga, et verbaalne sildistamine aitab vähendada võimalikku emotsionaalsete näoilmete tähendusega seotud ebakindlust. Valisime EEG tulemuste võrdlemiseks kolm ajaintervalli (esindamaks N1, N170 ja LPP sündmuspotentsiaale). Visuaalse ja verbaalse tingimuse võrdlemisel ilmnes, et üllatust ja hirmu töödeldi N1 ja N170 sündmuspotentsiaali ajaintervallis erinevalt ning LPP-intervallis erinesid üksteisest kõik emotsioonid peale hirmu. Antud tulemused viitavad hirmuga seotud sisu eelistöötlusele. Emotsioonide töötlemine sõltub niisiis palju sellest, kuidas neid inimesele esitatakse. Emotsionaalse sisu ebaselgus ja mitmetähenduslikkus, mis tuleneb sellest, millisel viisil emotsioone esitame, võib seetõttu mängida olulist rolli emotsioonide töötlemise, tajumise ja väljendamise puhul.

Märksõnad: visuaalne ja verbaalne infotöötlus, EEG, N1, N170, LPP, eneseraporteeritud ülesande raskus

Introduction

The ability to perceive the emotion of others around us as well as to express it in a comprehensible manner holds an immense evolutionary and social significance. Theories on the essence of felt and expressed emotion vary greatly, from approaches of basic emotion (Ekman, 1993), appraisal (Lazarus, 1982; Moors, 2007; Oatley & Johnson-Laird, 1987) to constructivist (Barrett, 2006; Russell & Barrett, 1999), but most seem to embrace the dimensional account of emotion, with valence and arousal conceptualised as the core dimensions (Russell, 1979). Valence can be defined as a continuum specifying how negative or positive an event is, whereas arousal refers to the intensity of an event, ranging from very calming to highly exciting or agitating (Fox, 2018; Kensinger & Schacter, 2006; P. J. Lang et al., 1993; Russell, 1979). There has been much interest in how these dimensions interact, what the implications for emotion processing are and how the dimensions are related to the neural processes employed during the processing of an emotional event.

The relative dominance of emotions with high valence (e.g., anger, happiness) over the ones with less valence (e.g., surprise, sadness) have been shown in studies on emotion perception in visual search paradigms (Öhman et al., 2001; Weymar et al., 2011), binocular rivalry (Alpers et al., 2005; Coren & Russell, 1992) as well as brain imaging (Batty & Taylor, 2003; Smith et al., 2013). A prominent theory on the relative dominance in the perception of emotion states that since expressions of threat are incredibly salient stimuli, having significant social and evolutionary implication to survival, these types of emotion (i.e., fear, anger) are processed preferentially (Batty & Taylor, 2003; Foti et al., 2009; Smith et al., 2013; Vuilleumier, 2005). This has also been referred to as “negativity bias”, an automatic initial sensitivity to threatening stimuli. Negativity bias has not always been confirmed, however, as much research has also been found to be in the favour of detecting happy stimuli better or faster in lieu of fearful or angry targets (Becker et al., 2011; Calvo & Nummenmaa, 2008; Juth et al., 2005; Purcell et al., 1996). While several models of the relationship between valence and arousal have been offered, Brainerd (2018) proposes that the relation between perceived valence and arousal is controlled by an unmeasured variable, namely valence ambiguity. Valence ambiguity is the degree of indefiniteness or uncertainty in people’s subjective impression of the valence of an item or event. Brainerd (2018) has shown the impact of emotional ambiguity on both emotional words as well as affective pictures. Indeed, it seems that *surprise* stands out as an especially ambiguous emotion, with its level of positivity or negativity creating some confusion for the perceiver (Noordewier & Breugelmans, 2013).

Visual and Verbal Modalities in Emotion Processing

Vision is our primary means for receiving information from the external environment. It is the main way we decipher the emotional content from outside situations as well as interpret the emotions of others. It is not, however, the only way to process information, as the tone, stress or style of a person's voice also alter how their emotional state is perceived. Similarly, written words fall under the umbrella of verbal communication, although they require no speech.

The importance of written word in the processing of emotional content has been studied in experiments with priming visual stimuli or emotional faces with emotional words (J. M. Carroll & Russell, 1996; N. C. Carroll & Young, 2005; Fugate et al., 2018), and on the impact of emotional words on visual awareness and attention, showing that emotion words shift attention toward congruent emotional faces (Fugate et al., 2020). Research has found that reducing the accessibility of emotional words impairs emotion perception (Gendron et al., 2012; Lindquist et al., 2006). Specifically, participants whose access to a relevant emotional word (e.g., "anger") was reduced by semantic satiation were slower and less accurate in perceptually matching two faces (e.g., two scowling faces) (Lindquist et al., 2006). Children are also better at matching facial depictions of emotion to an emotional word (e.g., "happy") than they are at matching two faces with similar expression (Widen, 2013). The categories of *happy*, *angry*, and *sad* emerge earlier in childhood than do categories of *scared, surprised,* and *disgusted* (Widen & Russell, 2003). This discovery fits in well with the idea of emotional ambiguity. Neurological studies have shown that patients with semantic dementia could not make meaning of facial expressions beyond the broad dimension of valence (unpleasantness vs. pleasantness) without the use of available linguistic emotion concepts (Lindquist et al., 2014). These results indicate the necessity and use of emotional categories when processing emotional content. Emotion words help to provide an "internal context" to affective information around us and one of the implications, therefore, could be that classifying emotion, whether it be implicitly or explicitly (by available words in a given language) into internal emotional categories could help reduce the ambiguity of either felt, perceived or expressed emotion.

Surprisingly little work has been published on contrasting the use of visual and verbal coding in emotion processing. Most studies come from the field of communication and marketing, where empirical research suggests that pictures are processed differently than words. Studies have shown the importance of visual stimuli (over text) in eliciting highly arousing and salient responses. One of the core aspects of visual material is its ability to arouse emotion and the ability to produce arousal has been offered to be one of the key distinctions between visual and verbal messages (Boholm, 1998; Iyer & Oldmeadow, 2006). Studies on the comparison of visual and **vocal** cues have mostly found a predominant influence of the visual channel over the auditive channel in terms of conveyance of affective meaning (Burns & Beier, 1973; Mehrabian & Ferris, 1967; Zaidel & Mehrabian, 1969). It has also been argued that visual emotion processing is a relatively automatic process (Compton, 2003; Palermo & Rhodes, 2007; Vuilleumier et al., 2003), while verbal encoding is a relatively controlled process (A. Lang et al., 1999). Some have suggested the relative independence of separate channels of processing that seem to differ in the amount of information they contribute (Burns & Beier, 1973), while others suggest a general communication factor (Thompson & Meltzer, 1964; Zaidel & Mehrabian, 1969; Zuckerman et al., 1975). Lupyan & Spivey (2010) found that auditory verbal, but not visual cues enhanced the detection of visual stimuli, indicating at least some level of independence in sensory processing.

Objective Markers of Emotion Processing

The use of physiological measurement is a great way to both obtain improved reliability and validity of emotional perception and response, as well as to examine the extent of coherence among different methods (i.e., self-report and electrophysiological responses). The electroencephalogram (EEG) is a recording of the difference in the electrical potentials between various points on the surface of the scalp. EEG patterns are wavelike, and their analysis is based on measurements of the frequency and amplitude of the waves (Hugdahl, 2001b). EEG recordings provide a good temporal resolution and therefore allow for very accurate measurement of perceptual speed (Erickson et al., 2018; Sturzbecher & de Araujo, 2012). The measurements provide a way to calculate event-related potentials (ERPs), which are averaged repeated measurements of specific EEG signal sections. ERPs are “answers” from the brain that are “time-locked” to a stimulus or event – it either coincides with or follows the stimulus after a brief delay (Hugdahl, 2001a). ERPs are a good way of measuring response to stimuli because they can show how rapidly brain activity in response to the stimuli ensues, whether there is an increase or a decrease in the measured electrical activity and roughly where in the brain this activity occurs (Hole & Bourne, 2010). Good temporal resolution can prove beneficial for the examination of emotion processing, because of the rapid onset and short duration of the processing of emotional content in the brain (Olofsson et al., 2008).

Indeed, there has been an increase in research exploring the time course of emotional processing in which ERPs have proven to be particularly useful for their temporal resolution of electrocortical activity (Foti et al., 2009; Frühholz et al., 2011; Olofsson et al., 2008). The first ERP we aim to examine is the N1, a negative-going wave around 100 ms, usually detected at most recording sites, but often peaking earlier in frontal than in posterior regions (Ciesielski, 1989; Mangun & Hillyard, 1991). It is commonly linked to the modulation of selective attention with the N1 being enhanced for stimuli that are attended to as opposed to unattended stimuli (Luck, 1995; Vogel & Luck, 2000). In terms of emotional stimuli, conflicting results have been found with reports of enhanced elicitation to neutral over fearful faces (Eimer & Holmes, 2002; Smith et al., 2013), enhancement of fearful over neutral faces (Luo et al., 2010) and no interaction between emotional and neutral expression (Eimer et al., 2003).

A key early marker for face processing, the N170, has also been identified in the ERPs. The N170 has been reported to be elicited by schematic and photographic faces (Bentin et al., 1996; Sagiv & Bentin, 2001; Smith et al., 2013) and shows up less prominently for non-face stimuli (Bentin et al., 1996; Carmel & Bentin, 2002; Itier & Taylor, 2004; Liu et al., 2016). These studies support the idea that the N170 is specifically associated with face processing rather than being a more general response to visual stimuli. The early onset, as well as the fact that the N170 doesn’t vary according to the familiarity (Bentin & Deouell, 2000; Eimer, 2000) or the sex of the face (Mouchetant-Rostaing et al., 2000), give rise to the idea that the N170 is a face-specific response that occurs with the encoding of a face prior to the processing of familiarity, identity or other information derived information. N170 has also been reported to be sensitive to emotional words (Frühholz et al., 2011). Early reports of the N170 claimed it to be insensitive to emotional expression (Ashley et al., 2004; Bobes et al., 2000; Herrmann et al., 2002; Krolak-Salmon et al., 2001; Münte et al., 1998; Smith et al., 2013), but there have also been reports of modulation by emotional expression (Batty & Taylor, 2003; Blau et al., 2007; Hendriks et al., 2007; Keil et al., 2001; Pegna et al., 2008; Stekelenburg & Gelder, 2004). Reports of ERP studies in the processing of emotional faces and words also show that facial expressions affect earlier stages of emotion processing compared to emotional words, but the emotional value of words may be detected at early stages of emotional processing (i.e., in the N170 component) (Frühholz et al., 2011).

We also aim to examine the effect of emotional content in the visual and verbal condition on the event-related potential called the LPP (late positive potential). It is a positive-going slow wave often found maximal over central and parietal sites around 300ms after stimulus onset (Hajcak et al., 2010; Schupp et al., 2006). It is often associated with reflecting facilitated attention, motivational relevance and intensity of emotional stimuli (Brown et al., 2012; Cuthbert et al., 2000; Dennis & Hajcak, 2009; Hajcak et al., 2010). In terms of the importance of emotional expression, enhanced LPP has been found for emotional, as compared with neutral expression (Foti et al., 2009; Krolak-Salmon et al., 2001; Luo et al., 2010). A negativity bias has also been found in research with the LPP, with some findings indicating fearful and threatening faces elicit a larger LPP than happy, sad or neutral faces (Foti et al., 2009; Morel et al., 2009; Schupp et al., 2004; Smith et al., 2013; Williams et al., 2006). The LPP has also been shown to be related to the subjective rating of emotional intensity (Cuthbert et al., 2000; Weinberg & Hajcak, 2010), making it a useful marker for exploring subjective emotional experience.

Present Study and Hypotheses

The current study aims to investigate the processing of emotional information in case of either visual or verbal task instructing the participants to act out a specific emotion (to put it very simply – make a face with the given emotion). This allows comparing the time course and emergence of emotion-related ERP components as well as the task performance in both the visual and verbal processing mode. We expect the labels (written emotion words) provided in the verbal condition to help participants better understand the task at hand and relieve the uncertainty that comes from simply mirroring an expression during seeing an emotional face in the visual condition. We hypothesise that **(H1) self-reports of the level of ability to express an emotion are rated higher in the verbal condition as opposed to the visual condition.**

Based on the theory of valence ambiguity, we expect that **(H2) in both the visual and verbal condition, elevated electrocortical activity appears in the event-related potentials of emotions with greater variance in self-reports.** We base this on the idea that highly uniformly rated emotions are also more consistently understood and appear more steadily in the averaged electrocortical responses of participants.

Based on the previous studies on the time course of emotional processing we expect that **(H3) the visual condition elicits an elevated electrocortical activity in the time window of the N170 event-related potential in comparison to the verbal condition.**

Method

Participants

The final sample consisted of 108 healthy participants (43 males) with a mean age of 25.08 years, ranging from 18 to 49 (*SD* = 6.50). The initial sample consisted of 119 healthy volunteers, but due to technical errors in video recordings (no recording (3), no sound (7) or erroneous output file (1)), 11 participants were excluded. All participants signed a written consent form, stating they are aware of the task at hand, agree to look at presented words and pictures, some of which may be unpleasant, are currently healthy and have not been diagnosed with migraines, epilepsy, cramps, stroke or intracranial haemorrhage. The onset of migraines and epilepsy have been associated with exposure to rapidly changing pictures (Binnie et al., 2002; Steppacher et al., 2016) and can be unsafe for participants at risk. The sample consisted of 84 Estonian speaking, 17 Russian speaking and 7 English speaking participants. A preliminary ANOVA on the self-reported ratings of the different groups showed no significant differences and we concluded that all groups can be included in the final report. 97 participants described themselves as right-handed, 8 left-handed and 3 (main hand right) ambidextrous. They were gathered from university mailing lists and experimenters' personal social media pages. For the approximate time they had to spend on different methods of data collection (4 hours), they were compensated with a 15 EUR department store gift card. Psychology students were able to earn course credit points. The participants were naive to the aim of the experiment, to the pictures used and were briefed with the aims of the study after the fact. The study was approved by the Research Ethics Committee of the University of Tartu (based on The Code of Ethics of the World Medical Association (Declaration of Helsinki)).

Procedure

Before attending the laboratory, participants were shortly briefed via e-mail about the general aim of the study and directions to the laboratory. They were sent a link to an online questionnaire on the Institute of Psychology web server (kaemus.psych.ut.ee). Participants filled out a 240-item personality self-questionnaire (EPIP-NEO; Mõttus et al., 2006) designed to evaluate traits based on the Five-Factor model of personality. They also filled out the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988) to assess the general mood of the participant in the previous two weeks. These items were gathered due to the larger aim of the research project, which is to assess differences in emotion expression and experience in relation to personality traits and baseline emotionality. Due to the scope of the current thesis, these aspects will not be analysed here.

The recordings of EEG and facial expressions were conducted in an electrically shielded quiet room in the laboratory of experimental psychology at the University of Tartu from May 2018 until May 2019 through every weekday from 9:00-19:00. Upon arriving at the laboratory, general demographic data (age, gender, smoking, alcohol consumption, average hours of sleep, etc.), as well as self-reported measures of fatigue and hunger (0-100) before and after the experiment were registered. Before the onset of the main experiment, participants were instructed to use a practice program (MATLAB, MathWorks, Natick, Massachusetts, United States) to get acquainted with the main test program. The experimenter was present at this time and answered any questions the participant had. Practice stimuli differed from the main stimuli and were not used in the main experiment. The duration of one session (including pre- and post-procedures) was approximately 3 hours and varied based on the answering time of the participant. The experiment took place in the same place and environment. Changing variables include the experimenter (3 different female experimenters) and the time of day (either 9:00, 10:00, 12:00, 13:30, 15:00, 16:00, 17:00 or 18:00).

The participants were seated on a comfortable office chair approximately 0,9-1,2 meters from the computer screen. Stimuli were shown in Psychtoolbox (MATLAB, MathWorks, Natick, Massachusetts, United States) on a standard PC monitor (LCD display, 19-inch diagonal). Throughout the duration of the experiment, measures of EEG, skin conductance (SCR), as well as video recordings of the facial expressions of the participants, were recorded. Due to the scope of the current thesis, aspects of the video material and SCR will not be analysed further. The participant was instructed to follow the instructions depicted (either as a written word or a picture of a face) on the screen and use a mouse to answer questions provided by the test program if needed. Blocks of emotional pictures or words were displayed for 6 seconds, followed by questions to the participant (see subchapter “Visual Stimuli and Experiment Set-up” and for detailed specifications).

Visual Stimuli and Experiment Set-up

The visual stimuli consisted of Ekman's facial expressions (Ekman & Rosenberg, 1997), emotion-depicting words (e.g., "happiness", "anger"), and the International Affective Picture System pictures (IAPS; Bradley & Lang, 2017). All emotional stimuli depicted or were selected to elicit 7 emotions: anger, disgust, happiness, neutral, sadness, surprise, and fear. The Ekman picture block consisted of 7 (types of emotion) × 6 (different variants in one emotion category) stimuli. The emotional word stimuli set consisted of 7 (types of emotion) × 6 repetitions, and the IAPS set of 7 (type of emotion) × 2 (variants in one emotion category) × 5 repetitions. The IAPS set was also repeated for 2 blocks (under- and over-expressing emotions).

Different variants of pictures in an emotion category were used to attain variability in emotional expressions as well as to avoid the problem of habituation, as it has shown to diminish the effects of brain imaging recordings (Breiter et al., 1996; Feinstein et al., 2002). The stimuli were semi-randomly presented in 4 conditions as follows:

1. Mirroring emotional expressions based on Ekman's facial stimuli (VISUAL condition).
2. Expressing an emotion in response to an emotion-depicting word (i.e "happiness", "anger"; VERBAL condition)
3. Exaggerating expression in response to IAPS pictures (OVER condition).
4. Hiding an emotion in response to IAPS pictures (UNDER condition).

Due to the scope of the current thesis, conditions 3 and 4 will not be analysed further (depicted in previous text as grey). Stimuli were presented in a semi-randomized manner, meaning that for the duration of one set of repetitions (i.e., 7 emotion stimuli) they were shown in a random order. In the first block, the participant was shown the target picture for 6 seconds, asked to mirror the expression and to report the difficulty of the task (i.e., "How well did you express this emotion?") on a slider scale from 0-100. In the second block, the participant was shown the target word for 6 seconds, asked to express the expression (as they would naturally) and to report the difficulty of the task on a slider scale from 0-100. Self-reported ratings were used to evaluate the perceived difficulty of the task in further analyses. A black and white grid was shown in-between target pictures (500 ms) to reduce the sequential effects from rapid image playback. The time course of a single trial in both conditions under observation is illustrated in Figure 1.

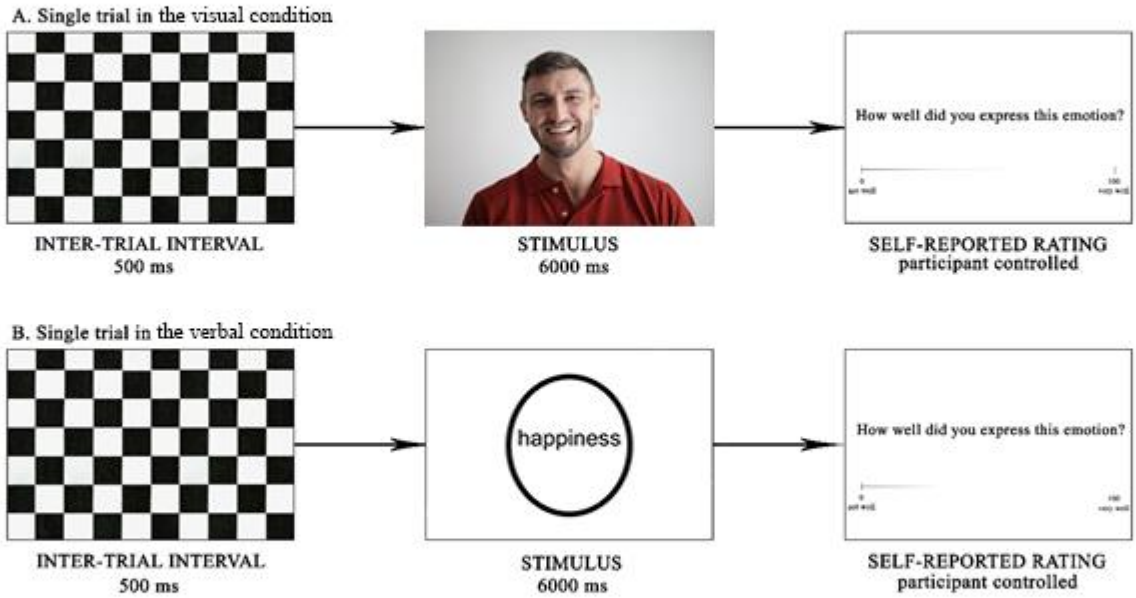

Figure 1. *The general set up of the two conditions (visual and verbal) analysed in the current thesis describing the time interval of a single trial in milliseconds (ms). The picture depicting a face is an illustrative copyright free stock photo and was not used in the experiment*.

EEG Recordings and Pre-Processing

A BioSemi ActiveTwo (BioSemi, Amsterdam, The Netherlands) active electrode system was used to record signals from 64 scalp locations. Two reference electrodes were placed behind the earlobes and four ocular electrodes (above and below the left eye and near the outer canthi of both eyes) were used to correct for eye movement and blinks. The data were recorded with 0.16-100 Hz band-pass filter and 512 Hz sampling rate. The placement of the electrodes followed the international 10-20 system (Jasper, 1958).

The raw EEG data was processed offline in BrainVision Analyzer 2.1 (Brain Products GmbH, Munich, Germany). The data was referenced to the earlobe electrodes, names from the 10-20 system were added and correction for eye blinks was applied (Gratton et al., 1983). The Butterworth Zero Phase filter was applied (0,16-30 Hz; 24 dB/oct) and the data was separated into segments from -200 ms to 1000 ms. Baseline correction was made at 100 ms before stimulus onset and segments lower than 0,5 μV and higher than 300 μV were removed. Event-related potentials were calculated by averaging the segments from the six stimulus repetitions.

All statistical analyses were conducted in the R environment for statistical computing (R Core Team, 2013) with RStudio interface (RStudio Team, 2015). The analyses were separated into self-report ratings and average electrocortical activity based on the EEG measurements. For all statistical tests, the level of significance was set to 0.05 and the Greenhouse-Geisser correction was applied when the homogeneity of variances assumption was violated.

Results

Self-reported Ratings

A three-factor repeated measures ANOVA was conducted to investigate the effect of the type of emotion, experimental condition and the effect of repetition on the self-reported ratings of successful execution of the task. The assumptions for Mauchly's Test of Sphericity were violated and the Greenhouse-Geisser correction was applied when analysing the results. Paired t-tests with the Tukey corrected *p*-values are reported for the following self-reported ratings.

The three-factor repeated measures ANOVA revealed a significant main effect for type of emotion ($F(6, 642) = 50.07$, $p < .01$, Greenhouse-Geisser $p < .01$, $\eta^2 = 0.06$), experimental condition ($F(1, 107) = 89.38$, $p < .01$, $\eta^2 = 0.03$) and the interaction of emotion and experimental condition ($F(6, 642) = 11.92$, $p < .01$, Greenhouse-Geisser $p < .01$, $\eta^2 = 0.01$). Although the mean ratings of task achievement gradually rose through task repetition, the repeated measures ANOVA revealed no significant main effects in repetition or its interaction with other factors and it was concluded it did not affect results in a significant matter. Mean ratings of the task with confidence intervals are represented in Figure 2a.

In comparing the visual and verbal conditions, pairwise comparisons revealed that task difficulty (a higher rating indicating a better assessment of task execution) was rated statistically significantly different for all emotions, except for fear. The ratings for fear did not vary in the visual ($M = 59.0$; $SD = 20.1$) and verbal ($M = 60.7$; $SD = 23.1$) condition ($p > .05$). Participants rated all emotions to be more easily expressed in the verbal condition (Table 1, Figure 2b). Expressing the neutral expression was rated easiest in both the visual ($M = 69.9$; $SD = 18.9$) and verbal ($M = 82.1$; $SD = 15.7$) condition ($t(647) = -17.7$, $p < .001$). Among the emotion-related expressions (i.e., excluding the neutral expression), happiness was rated as the easiest to express in both the visual ($M = 67.5$; $SD = 18.5$) and verbal ($M = 76.0$; $SD = 16.3$) condition ($t(647) = -11.9$, $p < .001$). Fear was rated as the hardest emotion to express in both the visual (*M* = 59.0; *SD* = 20.1) and verbal (*M* = 60.7; *SD* = 23.1) condition (*t*(647) = -1.96, *p* =.05).

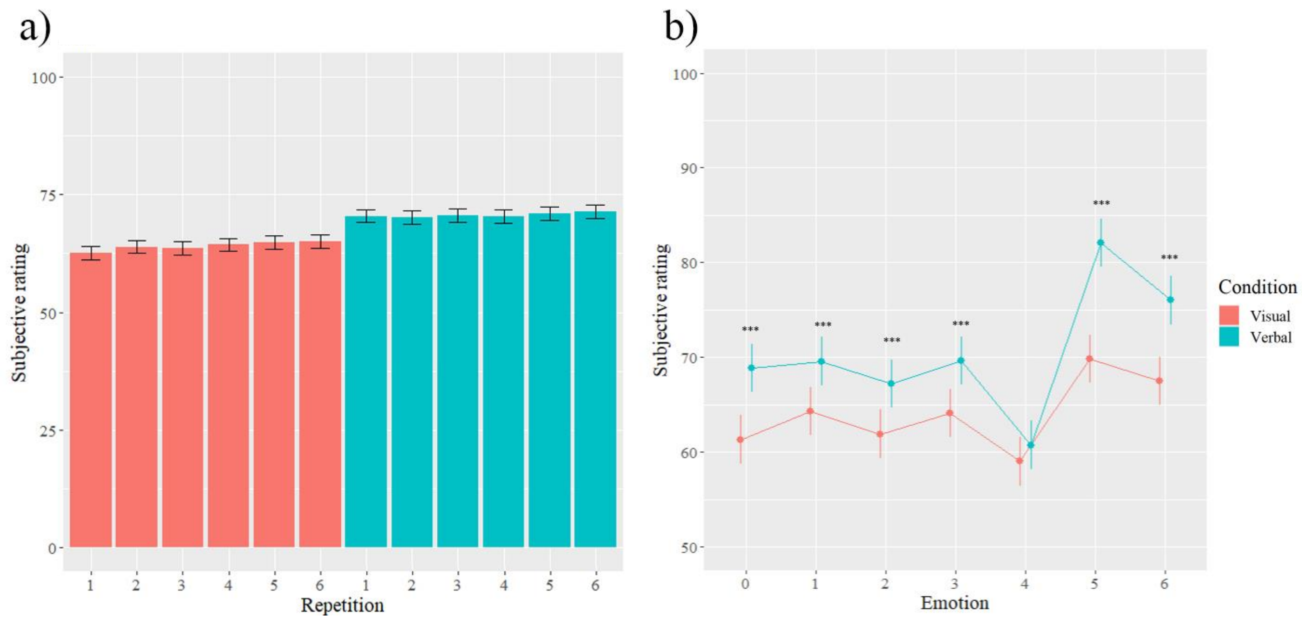

Figure 2. *a) Mean ratings of task difficulty pooled across all emotions shown in each repetition with 95% confidence intervals (note that a higher rating indicates a higher evaluation of task success). Numbers 1-6 represent the mean ratings for each repetition (6 in the visual and 6 in the verbal condition); b) Comparison of the mean ratings (with significance levels) of task difficulty of the same emotion in the visual and verbal condition. Types of emotion are specified as 0 – disgust, 1 – surprise, 2 – sadness, 3 – anger, 4 – fear, 5 – neutral and 6 – happy. Please note that the second scale starts from 50. Statistically significant results are marked as * = p < .05, ** = p < .01, *** = p < .001.*

Table 1

Results of paired t-tests comparing the differences of self-reports of the same emotion in the visual and verbal condition.

	Visual		Verbal		*t*(647)	*p*	Cohen's *d*
	M	*SD*	*M*	*SD*			
Neutral	69.9	18.9	82.1	15.7	-17.7	**<.001**	0.70
Happy	67.5	18.5	76.0	16.3	-11.9	**<.001**	0.49
Surprise	64.3	18.0	69.6	19.1	-7.04	**<.001**	0.29
Sadness	64.1	17.5	69.6	18.7	-7.27	**<.001**	0.30
Anger	61.9	18.9	67.2	19.3	-7.14	**<.001**	0.28
Disgust	61.3	19.5	68.9	19.2	-9.39	**<.001**	0.39
Fear	59.0	20.1	60.7	23.1	-1.96	.05	0.08

Table 2

Results of paired t-tests comparing the differences of self-reports of task difficulty across different emotion in the visual and verbal condition. The 7 columns represent the visual and the 7 rows the verbal condition.

Variable	0	1	2	3	4	5	6
0. Disgust	-	** [-4.49, -1.50]		** [-4.28, -1.29]		*** [-10.26, -6.82]	*** [-7.74, -4.65]
1. Surprise			* [0.91, 3.90]		*** [3.85, 6.73]	*** [-7.10, -4.00]	*** [-4.73, -1.68]
2. Sadness		* [0.98, 3.79]			* [1.27, 4.51]	*** [-9.56, -6.35]	*** [-7.16, -4.06]
3. Anger			** [-3.79, -1.08]		*** [3.54, 6.63]	*** [-7.24, -4.27]	*** [-4.92, -1.90]
4. Fear	*** [6.54, 9.75]	*** [7.18, 10.49]	*** [4.90, 8.01]	*** [7.26, 10.52]		*** [-12.51, -9.17]	*** [-10.09, -6.91]
5. Neutral	*** [-14.59, -11.84]	*** [-13.96, -11.08]	*** [-16.33, -13.48]	*** [-13.88, -11.06]	*** [-23.17, -19.55]		
6. Happy	*** [-8.50, -5.75]	*** [-7.75, -5.11]	*** [-10.27, -7.36]	*** [-7.83, -4.93]	*** [-17.00, -13.57]	*** [4.84, 7.34]	

Note. Types of emotion are specified as 0 – disgust, 1 – surprise, 2 – sadness, 3 – anger, 4 – fear, 5 – neutral and 6 – happy. Statistically significant results are marked as * = $p < .05$, ** = $p < .01$, *** = $p < .001$. Values in square brackets indicate the 95% confidence interval for each value in association to the mean difference of the ratings of emotions.

EEG Measurements

Based on previous research findings (e.g., Batty & Taylor, 2003; Eimer & Holmes, 2002; Smith et al., 2013) as well as visual inspection of the data, the ERP wave was divided into three intervals of interest: 60-90 ms, 150-190 ms and 250-550 ms post stimulus onset, roughly corresponding to the latency of N1, N170 and LPP ERP components, respectively. We calculated the average EEG activity in a given interval for each electrode for each stimulus for each participant.

We used a linear mixed model with participant as a random factor with the R packages *lmerTest* (Kuznetsova et al., 2017) and *psycho* (Makowski, 2018) to determine the general effect of emotion, condition and region on the average activity of the selected intervals (60-90 ms, 150-190 ms and 250-550 ms) that correspond to the chosen event-related potentials (N1, N170 and LPP). A linear mixed model has been shown to be more flexible, accurate and suited for psychological data (Jaeger, 2008; Kristensen & Hansen, 2004). We obtained similar results with a traditional ANOVA approach, but concluded a linear mixed model was more adaptive to our data as it has been shown to be more accurate when dealing with incomplete or unbalanced data (Krueger & Tian, 2004). We ran the first analysis across emotion (7) × condition (2) × region (64). The region factor consisted of the 64 electrode sites used (see page 12 for specifics).

N1. A repeated-measures ANOVA on our model indicated that there was a significant main effect in the first interval (60-90 ms) of emotion (F(6, 89580 = 53.65, p <.001, η^2 = 0.01), condition (F(1, 89589 = 139.68, p <.001, η^2 = 0.01), region (F(63, 89589 = 73.34, p <.001, η^2 = 0.05), the interaction between emotion × condition (F(6, 89589 = 39.24, p <.001, η^2 = 0.003), the interaction between condition × region (F(63, 89576 = 6.40, p <.001, η^2 = 0.01) and the interaction between emotion × region (F(378, 89576 = 1.13, p <.05, η^2 = 0.01). No three-way interaction of emotion × condition × region was observed.

N170. A repeated-measures ANOVA on our model indicated that there was a significant main effect in the second interval (150-190 ms) of emotion (F(6, 92088 = 71.73, p <.001, η^2 = 0.01), condition (F(1, 92094 = 83.41, p <.001, η^2 = 0.001), region (F(63, 92086 = 52.00, p <.001, η^2 = 0.03), the interaction between emotion × condition (F(6, 92087 = 66.04, p <.001, η^2 = 0.004), the interaction between emotion × region (F(378, 92086 = 1.40, p <.001, η^2 = 0.01) and the interaction between condition × region (F(63, 92086 = 5.31, p <.001, η^2 = 0.004). Similarly, no three-way interaction of emotion × condition × region was observed.

LPP. A repeated-measures ANOVA on our model indicated that there was a significant main effect in the third interval (250-550 ms) of emotion (F(6, 91631 = 44.32, p <.001, η^2 = 0.003), condition (F(1, 91633 = 2543.25, p <.001, η^2 = 0.03), region (F(63, 91629 = 98.59, p <.001, η^2 = 0.06), the interaction between emotion × condition (F(6, 91631 = 31.73, p <.001, η^2 = 0.02), the interaction between emotion × region (F(378, 91629 = 2.09, p <.001, η^2 = 0.01) and the interaction between condition × region (F(63, 91629 = 41.37, p

$<.001$, $\eta^2 = 0.03$). Similarly, no three-way interaction of emotion × condition × region was observed.

Based on previous research findings (i.e., Foti et al., 2009; Smith et al., 2013) and the inspection of activity in electrode sites, we chose 12 electrodes most representative of activity in the frontal (Fz, F7, F8), fronto-central (Cz, C3, C4), parietal (Pz, P3, P4) and occipital (Oz, PO3, PO4) scalp regions. The same analysis (a three-way ANOVA of emotion (7) × condition (2) × region (12)) indicated that all main effects and interactions except for emotion × region relation in the 60-90 ms (N1) interval remained qualitatively the same, thus we concluded the chosen electrodes were representative of the EEG activity in a respective scalp location.

The new model with 12 electrode sites indicated that there was a significant main effect in the first interval (60-90 ms; N1) of emotion (F(6, 16735 = 14.85, $p <.001$, $\eta^2 = 0.01$), condition (F(1, 16744 = 14.34, $p <.001$, $\eta^2 = 0.001$), region (F(11, 16735 = 127.61, $p <.001$, $\eta^2 = 0.08$), the interaction between emotion × condition (F(6, 16735 = 6.71, $p <.001$, $\eta^2 = 0.004$), and the interaction between condition × region (F(11, 16732 = 4.95, $p <.001$, $\eta^2 = 0.003$). No interaction between emotion × region or a three-way interaction of emotion × condition × region was observed.

N170. A repeated-measures ANOVA on our model indicated that there was a significant main effect in the second interval (150-190 ms) of emotion (F(6, 17195 = 13.80, $p <.001$, $\eta^2 = 0.01$), condition (F(1, 17200 = 44.92, $p <.001$, $\eta^2 = 0.003$), region (F(11, 17194 = 30.88, $p <.001$, $\eta^2 = 0.02$), the interaction between emotion × condition (F(6, 17194 = 14.48, $p <.001$, $\eta^2 = 0.01$), the interaction between emotion × region (F(66, 17193 = 1.68, $p <.001$, $\eta^2 = 0.01$) and the interaction between condition × region (F(11, 17193 = 8.80, $p <.001$, $\eta^2 = 0.01$). Similarly, no three-way interaction of emotion × condition × region was observed.

LPP. A repeated-measures ANOVA on our model indicated that there was a significant main effect in the third interval (250-550 ms) of emotion (F(6, 17168 = 11.96, $p <.001$, $\eta^2 = 0.004$), condition (F(1, 17169 = 251.83, $p <.001$, $\eta^2 = 0.02$), region (F(11, 17167 = 120.79, $p <.001$, $\eta^2 = 0.07$), the interaction between emotion × condition (F(6, 17168 = 8.26, $p <.001$, $\eta^2 = 0.01$), the interaction between emotion × region (F(66, 17166 = 2.09, $p <.001$, $\eta^2 = 0.01$) and the interaction between condition × region (F(11, 17166 = 50.05, $p <.001$, $\eta^2 = 0.03$). Similarly, no three-way interaction of emotion × condition × region was observed.

The effect of emotion. Post hoc pair-wise comparisons with the Tukey correction for significance comparing all emotions across conditions are shown in Table 4.

Table 4

Results of the post hoc comparisons in the differences in the main effects of mean activity of emotion processing across the chosen 12 electrodes in 3 intervals corresponding to the N1, N170 and LPP event-related potentials.

	I INTERVAL (N1) 60-90 ms			II INTERVAL (N170) 150-190 ms			III INTERVAL (LPP) 250-550 ms		
	M	*SD*	*p*	*M*	*SD*	*p*	*M*	*SD*	
0. Disgust	-0.54	4.35	**$<.01^{3,6}$**	1.01	6.28	**$<.01^{6}$**	1.44	8.03	**$<.01^{1}$** **$<.05^{2}$**
1. Surprise	-0.86	4.58	**$<.01^{3,4,6}$**	0.72	6.17	**$<.01^{3,6}$**	0.84	8.60	**$<.01^{0,3,6}$**
2. Sadness	-0.57	4.15	**$<.01^{3,6}$**	0.77	5.84	**$<.01^{3,4,6}$**	0.84	7.55	**$<.01^{3,6}$** **$<.05^{0}$**
3. Anger	-0.07	4.37	**$<.01^{0,1,2,5}$**	1.48	5.70	**$<.01^{1,2,5}$**	1.93	7.86	**$<.01^{1,2,4,5}$**
4. Fear	-0.35	4.34	**$<.01^{1}$** **$<.05^{6}$**	1.31	6.32	**$<.01^{2}$** **$<.05^{5,6}$**	1.26	8.36	**$<.01^{3,6}$**
5. Neutral	-0.63	4.32	**$<.01^{3,6}$**	0.80	5.71	**$<.01^{3,6}$** **$<.05^{4}$**	1.04	7.60	**$<.01^{3,6}$**
6. Happy	0.03	4.37	**$<.01^{0,1,2,5,6}$** **$<.05^{4}$**	1.78	5.93	**$<.01^{0,1,2,5}$** **$<.05^{4}$**	1.93	8.53	**$<.01^{1,2,4,5}$**

Notes. Comparisons were calculated interval-wise across the visual and verbal condition. Numbers in superscript represent the types of emotions that provided a significant difference, specified as 0 – disgust, 1 – surprise, 2 – sadness, 3 – anger, 4 – fear, 5 – neutral and 6 – happy.

The effect of the condition. The effect of the condition calculated across all emotions was present in the first interval (60-90 ms) when comparing the visual (M = -0.31; SD = 4.44) and verbal (M = -0.55; SD = 4.29) condition ($t(8486) = 3.79$, p <.001). The effect of the condition was also present in the second interval (150-190 ms) when comparing the visual (M = 1.40; SD = 6.13) and verbal (M = 0.84; SD = 5.88) task ($t(8732) = 6.70$, p <.001). It was also present in the third interval (250-550 ms) when comparing the visual (M = 0.47; SD = 8.51) and verbal (M = 2.18; SD = 7.55) task ($t(8701) = -15.87$, p <.001).

The interaction of emotion and condition. There was a significant difference in surprise and fear in the first (60-90 ms; N1) and second interval (150-190 ms; N170) when comparing the visual condition to the verbal condition. All emotions were statistically significantly different in the third interval (250-550 ms; LPP), except for the comparison of fear in the visual and verbal condition (the processing of fear is depicted in Figure 4). All means, standard deviations and *p*-values are depicted in Table 5. A graphical visualisation of the different emotions across the visual and verbal conditions with significance levels is shown in Figure 3.

Table 5

Post hoc comparisons of emotions across the two conditions (visual and verbal) in the 3 chosen intervals corresponding to the N1, N170 and LPP event-related potentials.

	I INTERVAL					II INTERVAL					III INTERVAL				
	Visual		Verbal			Visual		Verbal			Visual		Verbal		
	M	*SD*	*M*	*SD*	*p*	*M*	*SD*	*M*	*SD*	*p*	*M*	*SD*	*M*	*SD*	*p*
0	-0.49	4.34	-0.59	4.36		1.14	6.14	0.89	6.41		0.40	8.49	2.51	7.36	**<.001**
1	-0.57	4.58	-1.17	4.57	**<.05**	1.10	6.41	0.34	5.89	**<.05**	-0.06	9.06	1.75	8.02	**<.001**
2	-0.60	4.30	-0.53	4.01		0.90	6.00	0.64	5.69		0.04	7.93	1.63	7.08	**<.001**
3	0.07	4.47	-0.21	4.26		1.63	5.63	1.32	5.76		1.28	7.73	2.59	7.93	**<.001**
4	0.13	4.40	-0.83	4.23	**<.001**	2.48	6.38	0.14	6.04	**<.001**	1.18	9.33	1.33	7.26	
5	-0.78	4.46	-0.48	4.17		0.89	6.09	0.71	5.30		-0.10	7.84	2.15	7.20	**<.001**
6	0.08	4.40	-0.03	4.33		1.68	6.04	1.89	5.82		0.56	8.98	3.32	7.80	**<.001**

Notes. Types of emotion are specified as 0 – disgust, 1 – surprise, 2 – sadness, 3 – anger, 4 – fear, 5 – neutral and 6 – happy. Mean levels of activity measured in micro-voltage (μV).

The interaction of condition and region. We found a significant interaction in the first interval (60-90 ms) of the visual (M = 2.09; SD = 5.14) and verbal (M = 1.21; SD = 5.05) condition in the frontal right-side electrode site F8 ($t(670) = 4.22$, $p < .01$). There was a significant interaction in the second interval (150-190 ms) in the visual (M = 1.30; SD = 5.37) and verbal (M = -0,57; SD = 4.69) condition in the posterior left-side P3 site ($t(735) = 6.50$, $p < .001$). There was also a significant interaction in the second interval in the visual (M = 1.89; SD = 6.02) and verbal (M = -0.39; SD = 5.59) condition in the posterior-occipital left-side PO3 site ($t(714) = 7.62$, $p < .001$).

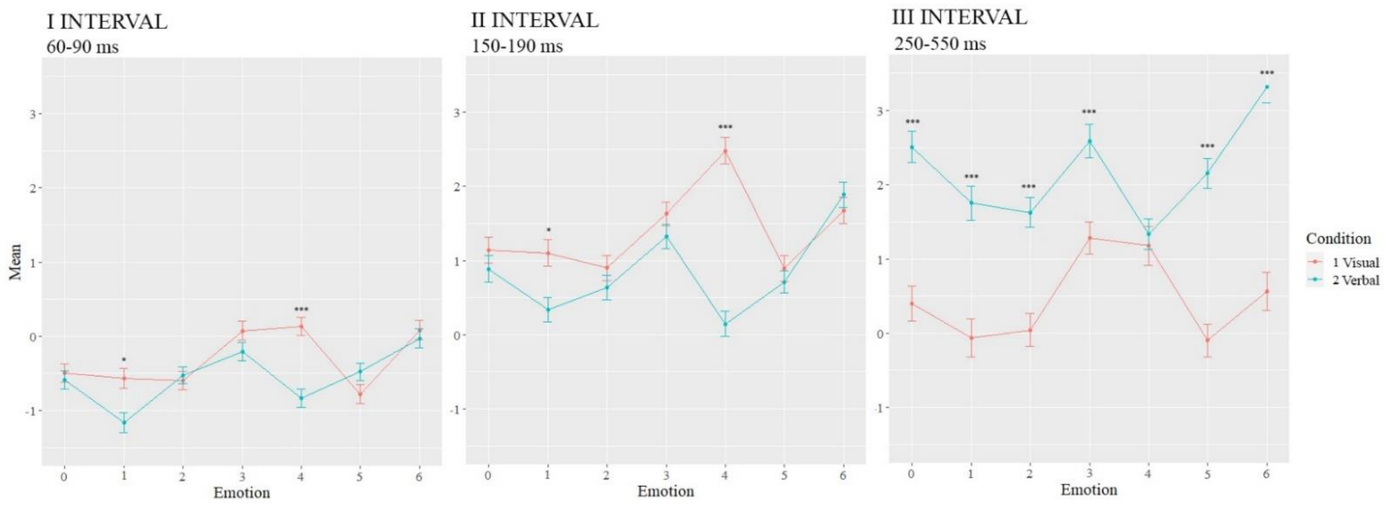

Figure 3. *The interaction between emotion × condition in the 3 chosen intervals corresponding to the event-related potentials N1, N170 and LPP. Vertical axis represents mean electrocortical activity in micro-voltage (µV). Types of emotion (horizontal axis) are specified as 0 – disgust, 1 – surprise, 2 – sadness, 3 – anger, 4 – fear, 5 – neutral and 6 – happy. Significance levels are specified at *p < .05, **p < .01, ***p < .001.*

There were seven significant interactions in the third interval (250-550 ms), namely the visual (M = -3.95; SD = 8.41) and verbal (M = 2.15; SD = 7.50) condition in the middle frontal Fz site ($t(732) = -12.64$, $p < .001$), in the visual (M = -4.42; SD = 9.91) and verbal (M = 0.39; SD = 10.33) condition in the frontal left-side F7 site ($t(678) = -16.46$, $p < .001$), in the visual (M = -0.79; SD = 10.69) and verbal (M = 2.36; SD = 10.25) condition in the frontal right-side F8 site ($t(678) = -8.05$, $p < .001$). There were also significant interactions in the visual (M = -2.32; SD = 7.70) and verbal (M = 1.51; SD = 7.00) condition in the middle central Cz site ($t(738) = -10.37$, $p < .001$), in the visual (M = -2.14; SD = 7.27) and verbal (M = 1.70; SD = 6.29) condition in the central left-side C3 site ($t(734) = -10.39$, $p < .001$) and in the visual (M = -0.74; SD = 7.56) and verbal (M = 1.72; SD = 6.62) condition in the central right-side C4 site ($t(736) = -6.65$, $p < .001$). Additionally, there was a significant interaction in the visual (M = 5.09; SD = 6.92) and verbal (M = 3.47; SD = 6.69) condition in the parietal-occipital right-side PO4 site ($t(730) = 4.39$, $p < .01$).

The effect of region and the interaction of emotion and region. Results of post hoc comparisons with a Tukey correction for p-values are reported in supplementary materials (Tables 1 and 2). Due to space restraints as well as the scope of the current thesis, these results won't be discussed further.

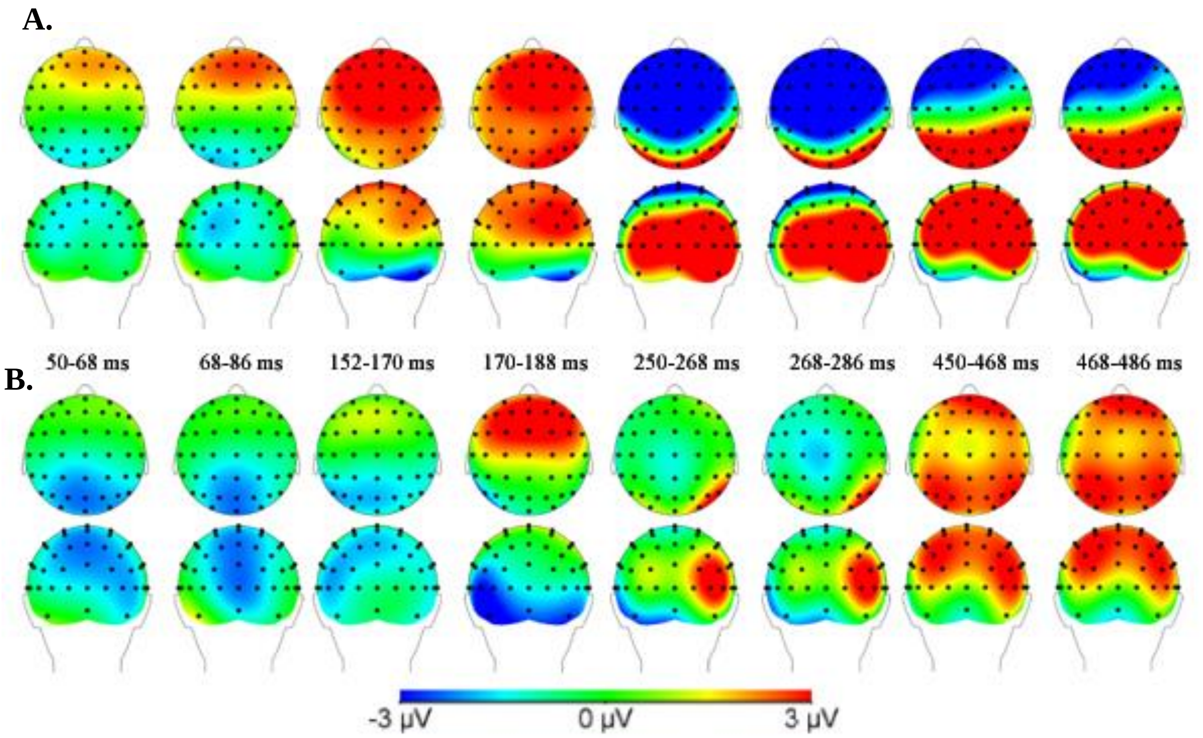

Figure 4. *The distribution of EEG activity (in micro-voltage, µV) across the scalp in superior view (upper rows in panels A and B) and posterior view (bottom rows in panels A and B) for fear in the visual (A) and verbal (B) condition. 18 ms intervals representative of our chosen time-intervals (50-68 and 68-86 ms for N1; 152-170 and 170-188 ms for N170 and 250-268, 268-286, 450-468 and 468-486 ms for the LPP component) are used for the visualization.*

Discussion

The aim of the current thesis was to investigate the neural underpinnings and behavioural responses to visual and verbal information processing when presented with emotion-related content in either a picture or a word format. We designed the study to compare the processing of different emotions (e.g., happiness compared to anger) as well as the processing of the same emotions in different conditions (e.g., how fear is processed when represented in a visual or verbal manner). We obtained the results from electrocortical responses as well as self-reported ratings to task performance when communicating an expression based on emotion stimuli.

Self-reports. The self-reports were obtained during the EEG recording with participants rating the difficulty of expressing a specific emotion after each repetition. The verbal condition was consistently rated higher (i.e., it was easier to express an emotion) and our analyses found no significant effect of repetition on self-reported task difficulty. The set-up of our experiment prevented us from varying between the sequence of blocks (i.e., visual condition first for some and verbal for others) and this analysis provided reassurance that the high ratings in the verbal condition were more likely the result of condition manipulation than that of practice. Therefore, our first hypothesis – self-reports of the level of ability to express an emotion are rated higher in the verbal as opposed to the visual condition – was confirmed. We based this on the idea that attaching a verbal label to an emotional expression would help reduce the potential uncertainty related to facial portrayals and therefore the confidence ratings would be greater. This is in concordance with the hypothesis of emotional ambiguity and with the idea that emotion words provide an "internal context" to affective information to help to reduce the ambiguity in felt, perceived or expressed information.

In order to investigate the brain processes related to emotional information processing, we divided our time-intervals of interest into three: 60-90 ms descriptive of the event-related potential N1, 150-190 ms for N170 and 250-550 ms for the component LPP and analysed average activity (in μV) within these intervals . We chose 12 representative electrodes: 3 in the frontal (Fz, F7, F8), 3 in central (Cz, C3, C4), 3 in parietal (Pz, P3, P4) and 3 in parietal-occipital (Oz, PO3, P/4) regions for further analyses. Our choice of electrodes was supported both by previous studies (Foti et al., 2009; Smith et al., 2013) as well as the fact that the results of three-way ANOVA (emotion × condition × region) for the 3 intervals provided similar results in the large 64 electrode model and the small 12 electrode model (with the exception of the emotion and electrode interaction in the first chosen interval).

Electrocortical activity in the N1 component across emotions and between conditions. Results for the N1 component across conditions indicated that happiness differentiated from all emotions except anger. We also observed enhanced activity for the neutral condition that was only different to the happy and angry conditions. An enhanced N1 to neutral compared to emotional faces coincides with some previous findings (Eimer & Holmes, 2002; Smith et al., 2013), but not others (Eimer et al., 2003; Luo et al., 2010). Smith et al. (2013) state that an enhanced N1 for neutral faces has been observed when participants are allowed to freely view stimuli (as was the case in our manipulations), but studies reporting a more negative N1 to fearful than neutral faces tend to utilize tasks that explicitly cue participants' attention to faces. Alternatively, they suggest that a larger N1 for neutral than emotional faces could be the reflection (or so called "contamination") of the increased occipital P1 for emotional faces. P1 is an early positive-going ERP component at approximately 100 ms, which has also been reported to be enhanced in response to emotional faces (Batty & Taylor, 2003; Foti et al., 2009; Luo et al., 2010).

In comparing the visual and verbal conditions, we observed differences in the N1 component in surprise and fear emotional content. The elicitation of fear stimuli coincided with observations from the self-reported ratings for task difficulty. They indicated it was also the hardest emotion to express with the greatest variability across assessments. This supported our second hypothesis, which stated that elevated electrocortical activity appears in the event-related potentials of emotions with greater variance in self-reports. We based this on the idea that highly uniformly rated emotions are also more consistently understood and appear more steadily in the averaged electrocortical responses of participants. The same cannot be said for surprise, however, because it was not rated low nor with a particularly high variance. The separation of surprise from the other emotions does not contradict the hypothesis of valence ambiguity, however. Surprise can stand out as an especially ambiguous emotion, with its level of positivity or negativity creating some confusion for the recipient (Noordewier & Breugelmans, 2013). Brainerd (2018) also emphasises the role of ambiguity in surprise as states of arousal change when perceived positivity or negativity becomes more uncertain. It is possible that surprise is still perceived as ambiguous, even though we did not detect a substantial level of uncertainty from self-reported ratings.

Electrocortical activity in the N170 component across emotions and between conditions. The results for the N170 component again indicated that happiness was processed differently from all other emotional content except for anger. Happiness, fear, and anger elicited the highest (positive) cortical activity and were the only emotions to significantly differ from the neutral condition. Thus, in the current context it cannot be said that our results indicated that emotional faces elicit an enhanced negative activity compared to the neutral condition (but rather in this framework a positive one). However, it should be taken into consideration that these results involve electrodes pooled from across the whole head (including frontal and central sites), while N170 has mostly been reported in parietal and temporal sites. We did observe very clear N170-like component in both visual and verbal condition in parietal and occipital sites, in concordance with previous results (Batty & Taylor, 2003; Blau et al., 2007; Frühholz et al., 2011), so a possibility for future investigations would be to only choose sites with clear N170-like activity (mainly parietal, parietal-temporal and occipital electrode locations).

Similarly to the 60-90 ms interval (the N1 time range), we observed a difference in the 150-190 ms interval (N170 time range) in the visual and verbal conditions for surprise and fear. We offer a similar explanation as to the N1 interval with emotional ambiguity influencing the average electrocortical activity when perceiving emotion-related stimuli. It is again interesting to mention that the verbal condition produced a stronger negative activity than the visual condition. Therefore, our third hypothesis - the visual condition elicits a stronger electrocortical activity in the time window of the N170 event-related potential in comparison to the verbal condition – did not hold up to the test. We propose a similar explanation as to the comparison of different emotions across conditions – it is possible that while observing only parietal, temporal and occipital electrode activity, the results would have varied. With the analyses we conducted, however, it must be concluded that surprise and fear elicit a stronger positive response in the visual as opposed to the verbal condition. This is in concordance with studies emphasizing the processing of fear as a special stimulus (Foti et al., 2009; Smith et al., 2013), but when basing this on the idea of “negativity bias”, it doesn’t explain why anger was not processed in a preferential manner. Also, it should be clarified that these studies used faces and emotional pictures (from the International Affective Picture System) as opposed to comparing material represented in a visual or verbal manner. The reason for drawing conclusions based on studies comparing only visual material comes from the fact that to the best of our knowledge, studies comparing the processing of emotional content (specifically face versus word) in a visual and verbal manner using EEG techniques are not very common, so we could not obtain any articles using a similar experimental design as ours.

Electrocortical activity in the LPP component across emotions and between conditions. The results for the LPP component indicated the largest positive activity for happiness and anger. These two emotions were also the only ones to differ significantly from the neutral condition. This is in accordance with some findings (Bublatzky et al., 2014). However, specifically the elicitation of the happy stimulus contradicts some others (Schupp et al., 2004; Smith et al., 2013; Williams et al., 2006), where fearful stimuli elicited a stronger response than happy stimuli. In terms of comparing the visual and verbal condition in the 250-550 ms interval, all emotions except for the fear stimuli differed from each other significantly. The dissimilarity in emotions in the different conditions was somewhat expected as late time intervals have been associated with reflecting facilitated attention (Dennis & Hajcak, 2009; Hajcak et al., 2010). Indeed, conscious awareness of visual stimuli has been observed around the 200-300 ms mark (Rutiku et al., 2016) and it could be argued that by this time interval, awareness about differences in stimuli is reached. This does not explain the clear dissimilarity in the fear stimuli, however, with it being the only emotion not to differ between conditions in the third interval. Coupled with the fact that it was one of the only two emotions to differ in the first and second timeframe, it could be argued that stimuli related to fear were processed in a preferential manner. This could support the idea of a "negativity bias", but again doesn't explain the processing of the anger stimuli.

A potential explanation comes from the appraisal theory of emotion, which states that decoding a situation's personal meaning plays a pivotal role in an organising emotional response (Yih et al., 2019). Fear might be an especially self-relevant emotion and this could explain the numerous studies (e.g., (Alpers et al., 2005; Pegna et al., 2008)) where it stands out as an particularly salient stimulus. Whatever conclusions might be drawn, it is clear that fear stimuli behaved differently from other emotional content when comparing emotion-related information processing in a visual and verbal manner in our chosen intervals.

Limitations and Future Directions

The aim of the current study was to observe potential differences between processing of specific emotions as well as possible variation between the visual and verbal condition. Our study came with its' set of limitations, however. As mentioned earlier, there is a possibility that using electrodes only in parietal, temporal and occipital sites would have provided different results when analysing the N170 component. Our aim was to analyse the differences between the visual and verbal condition across the whole head (from the same sites across all three intervals), but this might have sabotaged our attempt of making inferences about the N170 component. We also experienced a high number of technical difficulties with two posterior electrodes: P1 and P2. They could have been a valid region of interest for electrocortical activity, but we opted for P3 and P4 due to many channels having to be disregarded for the P1 and P2.

A possible problem could also be that our stimulus set contained only one positive emotion. This is not uncommon for picture sets containing seven (or a similar number) of "basic" emotions. However, the fact that participants are exposed to several negative emotions and only one positive one might create a condition where the "outlier" produces preferential processing. We also had unbalanced groups across nationalities. Although we ran analyses of the self-reported ratings and found no differences between the groups, there is the possibility of this influencing our results (even from the aspect of unintentional alterations in experiment set-up in different languages). There is always also the question of whether our experimental manipulations are extendable to reality. Rigid and controlled manipulations may not always provide results we would expect in real life, especially when dealing with a typically spontaneous phenomenon such as emotion.

The topic of visual and verbal information processing when presented with emotion-related content is relatively underrepresented. Surprisingly little research has been conducted, most studies originate from marketing or communication fields and rarely use brain-imaging techniques. In fact, we found almost no articles comparing an emotional face to a corresponding word using EEG when conducting our initial research. Despite the lack of studies, we believe it is an important topic to explore: our suggestion that ambiguity among presented emotional content might affect the way it is preliminarily processed is significant for deciding how emotional content might be presented. Understanding the manner of which emotional content is presented or influences how we experience the affective content around us might hold immense importance in a therapeutic, teaching or communication settings.

A somewhat more philosophical question associated with this type of research is how labels attached to emotional content influence the way we perceive the expressions connected to them. The question of “real” emotional expression has always been prevalent in psychological research, but has received a special amount of attention with the increasing interest in machine learning influenced emotion recognition. If we cannot be sure how specific emotions are processed nor what true expressions look like on the face (not even to mention how facial expressions are related to true feeling), this type of technology cannot be used in a reliable, science-backed manner. It is therefore crucial to try to pin-point the psychophysiological correlates of emotion expressing and processing in order to make educated inferences on how emotion is processed in the brain.

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Supplementary Material

Table 1

Post hoc results of electrode sites with a significantly different mean electrocortical activity level.

	Mean difference	Std Error	*t*	*p*	Lower bound	Upper bound
I INTERVAL						
C3 - Oz	1.75	0.15	11.59	<.001	1.26	2.24
C3 - Pz	2.04	0.15	13.63	<.001	1.55	2.53
C4 - Pz	1.87	0.15	12.51	<.001	1.38	2.36
Cz - F8	-1.88	0.15	-12.38	<.001	-2.38	-1.38
F7 - Oz	2.60	0.15	16.83	<.001	2.09	3.10
F7 - P3	2.16	0.15	14.10	<.001	1.66	2.66
F7 - P4	2.18	0.15	14.24	<.001	1.68	2.69
F7 - PO3	2.55	0.16	16.41	<.001	2.05	3.06
F7 - PO4	2.51	0.15	16.30	<.001	2.01	3.01
F7 - Pz	2.89	0.15	18.88	<.001	2.39	3.38
F8 - Oz	3.23	0.15	20.99	<.001	2.73	3.74
F8 - P3	2.79	0.15	18.29	<.001	2.30	3.29
F8 - P4	2.82	0.15	18.41	<.001	2.32	3.32
F8 - PO3	3.19	0.16	20.54	<.001	2.68	3.70
F8 - PO4	3.15	0.15	20.46	<.001	2.64	3.65
F8 - Pz	3.52	0.15	23.09	<.001	3.02	4.02
Fz - Oz	2.75	0.15	18.22	<.001	2.26	3.25
Fz - P3	2.31	0.15	15.44	<.001	1.82	2.80
Fz - P4	2.34	0.15	15.57	<.001	1.85	2.83
Fz - PO3	2.71	0.15	17.78	<.001	2.21	3.21
Fz - PO4	2.67	0.15	17.67	<.001	2.17	3.16
Fz - Pz	3.04	0.15	20.33	<.001	2.55	3.53
C3 - PO3	1.71	0.15	11.20	<.001	1.21	2.20
C3 - PO4	1.66	0.15	11.03	<.001	1.17	2.16
Cz - Oz	1.35	0.15	8.97	<.001	0.86	1.84
C3 - P4	1.34	0.15	8.90	<.001	0.84	1.82
Cz - Pz	1.64	0.15	10.99	<.001	1.15	2.13
C3 - P3	1.31	0.15	8.76	<.001	0.82	1.80
C4 - PO4	1.50	0.15	9.92	<.001	1.01	1.99
C4 - Oz	1.59	0.15	10.49	<.001	1.09	2.08
Cz - PO3	1.31	0.15	8.60	<.001	0.81	1.80
C4 - F8	-1.65	0.15	-10.80	<.001	-2.14	-1.15
Cz - Fz	-1.40	0.15	-9.41	<.001	-1.89	-0.91
Cz - PO4	1.26	0.15	8.40	<.001	0.78	1.76
C4 - PO3	1.54	0.15	10.11	<.001	1.04	2.04
C3 - F8	-1.48	0.15	-9.74	<.001	-1.98	-0.98
Cz - F7	-1.25	0.15	-8.18	<.001	-1.74	-0.75
C4 - Fz	-1.17	0.15	-7.80	<.001	-1.66	-0.68
C4 - P4	1.17	0.15	7.80	<.001	0.68	1.66
C4 - P3	1.15	0.15	7.65	<.001	0.66	1.64
C3 - Fz	-1.00	0.15	-6.72	<.001	-1.49	-0.51
C4 - F7	-1.01	0.15	-6.62	<.001	-1.51	-0.51
Cz - P4	0.94	0.15	6.26	<.001	0.45	1.43
Cz - P3	0.91	0.15	6.11	<.001	0.43	1.40
C3 - F7	-0.85	0.15	-5.56	<.001	-1.35	-0.35
P3 - Pz	0.73	0.15	4.84	<.001	0.24	1.22
P4 - Pz	0.70	0.15	4.66	<.001	0.21	1.19
F7 - F8	-0.63	0.16	-4.08	.003	-1.14	-0.13
	Mean difference	Std Error	*t*	*p*	Lower bound	Upper bound
II INTERVAL						
Fz - Oz	2.94	0.21	14.25	<.001	2.27	3.62
Fz - P3	2.33	0.21	11.34	<.001	1.66	3.00
Fz - Pz	2.39	0.21	11.65	<.001	1.72	3.06
F7 - Fz	-1.87	0.21	-8.97	<.001	-2.55	-1.19
Cz - Oz	2.07	0.21	10.03	<.001	1.39	2.74
F8 - Oz	2.23	0.21	10.65	<.001	1.54	2.91
C3 - Oz	1.75	0.21	8.47	<.001	1.07	2.42
Fz - PO3	1.92	0.21	9.29	<.001	1.24	2.59
Fz - P4	1.68	0.21	8.17	<.001	1.01	2.35
F8 - Pz	1.67	0.21	8.06	<.001	1.00	2.35
Fz - PO4	1.61	0.21	7.83	<.001	0.94	2.28
C4 - Oz	1.63	0.21	7.88	<.001	0.95	2.30
F8 - P3	1.61	0.21	7.75	<.001	0.93	2.29
Cz - Pz	1.51	0.20	7.40	<.001	0.85	2.18
Cz - P3	1.45	0.20	7.09	<.001	0.78	2.12
Oz - PO4	-1.33	0.21	-6.45	<.001	-2.01	-0.66
C4 - Fz	-1.32	0.21	-6.41	<.001	-1.99	-0.64
Oz - P4	-1.26	0.21	-6.10	<.001	-1.94	-0.59
C3 - Pz	1.194	0.20	5.83	<.001	0.53	1.86
C3 - Fz	-1.20	0.21	-5.83	<.001	-1.87	-0.53
F8 - PO3	1.20	0.21	5.75	<.001	0.52	1.89
C3 - P3	1.13	0.20	5.52	<.001	0.46	1.80
F7 - F8	-1.16	0.21	-5.47	<.001	-1.85	-0.47
C4 - Pz	1.07	0.21	5.24	<.001	0.40	1.74
F7 - Oz	1.07	0.21	5.11	<.001	0.39	1.76
Cz - PO3	1.04	0.21	5.06	<.001	0.37	1.72
C4 - P3	1.01	0.21	4.93	<.001	0.34	1.68
Oz - PO3	-1.02	0.21	-4.92	<.001	-1.70	-0.34
Cz - F7	1.00	0.21	4.78	<.001	0.32	1.68
F8 - P4	0.97	0.21	4.63	<.001	0.28	1.65
F8 - PO4	0.89	0.21	4.29	.001	0.21	1.58
Cz - Fz	-0.88	0.20	-4.28	.001	-1.55	-0.21
Cz - P4	0.81	0.21	3.92	.005	0.13	1.48
PO4 - Pz	0.78	0.21	3.80	.008	0.11	1.45
Cz - PO4	0.73	0.21	3.58	.02	0.06	1.40
C3 - PO3	0.72	0.21	3.51	0.02	0.05	1.40
P3 - PO4	-0.72	0.21	-3.49	0.02	-1.39	-0.04
P4 - Pz	0.71	0.21	3.45	0.03	0.04	1.38
F8 - Fz	-0.72	0.21	-3.44	0.03	-1.40	-0.04
	Mean difference	Std Error	*t*	*p*	Lower bound	Upper bound
III INTERVAL						
C3 - P4	-4.18	0.26	-15.86	<.001	-5.04	-3.32
C3 - PO3	-3.97	0.26	-15.05	<.001	-4.84	-3.11
C3 - PO4	-4.54	0.26	-17.26	<.001	-5.41	-3.68
C4 - P4	-3.44	0.26	-13.04	<.001	-4.30	-2.58
C4 - PO3	-3.23	0.26	-12.24	<.001	-4.09	-2.37
C4 - PO4	-3.80	0.26	-14.44	<.001	-4.66	-2.94
Cz - P3	-3.04	0.26	-11.61	<.001	-3.90	-2.19
Cz - P4	-4.37	0.26	-16.59	<.001	-5.23	-3.51
Cz - PO3	-4.16	0.26	-15.77	<.001	-5.02	-3.30
Cz - PO4	-4.73	0.26	-17.99	<.001	-5.59	-3.87
F7 - Oz	-3.31	0.27	-12.29	<.001	-4.19	-2.43
F7 - P3	-4.69	0.27	-17.49	<.001	-5.56	-3.81
F7 - P4	-6.01	0.27	-22.35	<.001	-6.89	-5.13
F7 - PO3	-5.80	0.27	-21.54	<.001	-6.68	-4.92
F7 - PO4	-6.37	0.27	-23.73	<.001	-7.25	-5.50
F7 - Pz	-4.27	0.27	-15.91	<.001	-5.14	-3.39
F8 - P4	-3.19	0.27	-11.90	<.001	-4.07	-2.32
F8 - PO4	-3.56	0.27	-13.27	<.001	-4.43	-2.68
Fz - P3	-3.53	0.26	-13.45	<.001	-4.39	-2.68
Fz - P4	-4.86	0.26	-18.43	<.001	-5.72	-3.99
Fz - PO3	-4.65	0.26	-17.61	<.001	-5.51	-3.79
Fz - PO4	-5.22	0.26	-19.83	<.001	-6.08	-4.36
Fz - Pz	-3.11	0.26	-11.84	<.001	-3.97	-2.25
Oz - PO4	-3.06	0.26	-11.57	<.001	-3.93	-2.20
F8 - PO3	-2.99	0.27	-11.11	<.001	-3.86	-2.11
C4 - F7	2.57	0.27	9.60	<.001	1.70	3.45
Cz - Pz	-2.62	0.26	-9.99	<.001	-3.48	-1.76
C3 - P3	-2.86	0.26	-10.88	<.001	-3.72	-2.00
Oz - P4	-2.70	0.26	-10.19	<.001	-3.57	-1.83
Oz - PO3	-2.50	0.27	-9.39	<.001	-3.36	-1.62
F7 - F8	-2.82	0.27	-10.33	<.001	-3.71	-1.93
C3 - Pz	-2.44	0.26	-9.27	<.001	-3.29	-1.58
Fz - Oz	-2.16	0.26	-8.17	<.001	-3.02	-1.29
C4 - P3	-2.12	0.26	-8.05	<.001	-2.97	-1.26
PO4 - Pz	2.11	0.26	8.01	<.001	1.25	2.97
F8 - P3	-1.87	0.27	-6.99	<.001	-2.74	-1.00
C3 - F7	1.83	0.27	6.82	<.001	0.95	2.71
P4 - Pz	1.75	0.26	6.63	<.001	0.88	2.61

C4 - Pz	-1.69	0.26	-6.44	<.001	-2.55	-0.83
P3 - PO4	-1.69	0.26	-6.41	<.001	-2.55	-0.83
Cz - Oz	-1.68	0.26	-6.32	<.001	-2.53	-0.81
F8 - Fz	1.66	0.27	6.22	<.001	0.79	2.54
Cz - F7	1.64	0.27	6.14	<.001	0.77	2.52
PO3 - Pz	1.54	0.26	5.83	<.001	0.68	2.40
C3 - Oz	-1.48	0.26	-5.61	<.001	-2.35	-0.62
F8 - Pz	-1.45	0.27	-5.41	<.001	-2.32	-0.57
C4 - Fz	1.42	0.26	5.40	<.001	0.56	2.28
Oz - P3	-1.38	0.26	-5.21	<.001	-2.24	-0.51
P3 - P4	-1.32	0.26	-5.02	<.001	-2.18	-0.46
Cz - F8	-1.17	0.27	-4.39	<.001	-2.05	-0.30
F7 - Fz	-1.15	0.27	-4.31	<.001	-2.03	-0.28
P3 - PO3	-1.11	0.26	-4.22	.001	-1.98	-0.25
C3 - F8	-0.99	0.27	-3.69	.01	-1.86	-0.11
Oz - Pz	-0.95	0.26	-3.61	.02	-1.82	-0.09
C4 - Cz	0.93	0.26	3.54	.02	0.07	1.79

Table 2

Post hoc results of emotion × electrode interactions with a significantly different mean electrocortical activity level.

	Mean difference	Std Error	*t*	*p*	Lower bound	Upper bound
II INTERVAL						
0. Disgust						
F8 – Oz	2.96	0.55	5.36	<.001	0.63	5.30
F8 – Pz	2.67	0.55	4.90	.002	0.37	4.98
Fz – Pz	2.46	0.55	4.48	.02	0.14	4.78
1. Surprise						
F7 – Fz	-3.21	0.56	-5.70	<.001	-5.60	-0.83
F8 – Fz	-2.42	0.56	-4.35	.03	-4.77	-0.07
F7 – PO4	-2.42	0.57	-4.27	.04	-4.81	-0.03
3. Anger						
F8 – Oz	4.29	0.56	7.65	<.001	1.92	6.66
Fz – Oz	3.81	0.54	6.94	<.001	1.49	6.12
F8 – P3	3.82	0.55	6.91	<.001	1.49	6.16
F8 – Pz	3.62	0.56	6.52	<.001	1.27	5.97
Fz – P3	3.34	0.54	6.18	<.001	1.05	5.62
Fz – Pz	3.13	0.54	5.78	<.001	0.84	5.43
F8 – PO4	3.05	0.56	5.48	<.001	0.70	5.41
Cz – Oz	2.82	0.55	5.16	.001	0.51	5.13
F7 – Oz	2.86	0.56	5.11	.001	0.50	5.23
F8 – PO3	2.76	0.56	4.92	.002	0.40	5.12
Fz – PO4	2.57	0.54	4.71	.007	0.26	4.87
Cz – P3	2.36	0.54	4.37	.03	0.08	4.63
C3 – Oz	2.38	0.55	4.35	.03	0.07	4.70
C4 – Oz	2.39	0.55	4.35	.03	0.07	4.71
F7 - P3	2.40	0.55	4.34	.03	0.06	4.73
4. Fear						
Fz – Oz	3.16	0.54	5.80	<.001	0.86	5.46
Fz – P3	2.50	0.54	4.63	.01	0.22	4.79
Fz – Pz	2.50	0.54	4.62	.01	0.21	4.78
Fz – F7	2.48	0.55	4.52	.02	0.16	4.79
5. Neutral						
Fz – Oz	3.19	0.54	5.90	<.001	0.90	5.48
Fz – Pz	2.82	0.54	5.22	.001	0.54	5.10
Fz – P3	2.74	0.54	5.05	.001	0.45	5.03
Fz – PO3	2.69	0.54	4.95	.002	0.39	4.99
Fz – Oz	2.33	0.55	4.27	.04	0.03	4.64
6. Happy						
F8 – Oz	3.31	0.56	5.89	<.001	0.94	5.69
Fz – Oz	3.24	0.55	5.85	<.001	0.90	5.58
Cz – Oz	2.96	0.55	5.36	<.001	0.63	5.30
C4 – Oz	2.85	0.55	5.16	.001	0.51	5.19
C3 – Oz	2.82	0.55	5.10	.001	0.49	5.16
III INTERVAL						
0. Disgust						
Fz – P4	-5.0	0.70	-7.14	<.001	-7.94	-2.04
Fz – PO4	-4.97	0.70	-7.14	<.001	-7.92	-2.03
F7 – P4	-4.56	0.71	-6.40	<.001	-7.58	-1.55
F7 – PO4	-4.55	0.71	-6.38	<.001	-7.55	-1.54
Cz – P4	-4.45	0.70	-6.38	<.001	-7.39	-1.50
Cz – PO4	-4.43	0.70	-6.38	<.001	-7.37	-1.49
Fz – PO3	-4.11	0.70	-6.38	<.001	-7.05	-1.16
C3 – P4	-4.07	0.70	-5.89	<.001	-7.02	-1.12
C3 – PO4	-4.05	0.70	-5.83	<.001	-6.99	-1.11
Fz – P3	-4.04	0.70	-5.82	<.001	-6.98	-1.10
F7 – PO3	-3.68	0.70	-5.16	<.001	-6.69	-1.10
Cz – PO3	-3.56	0.70	-5.12	<.001	-6.50	-0.67
F7 – P3	-3.61	0.71	-5.08	<.001	-6.62	-0.62
Cz – P3	-3.50	0.70	-5.04	.001	-6.43	-0.61
C4 – P4	-3.50	0.70	-5.02	.002	-6.46	-0.57
C4 – PO4	-3.49	0.70	-5.01	.002	-6.43	-0.55
Fz – Pz	-3.29	0.70	-4.73	.006	-6.23	-0.54
C3 – PO3	-3.18	0.70	-4.57	.01	-6.13	-0.35
C3 – P3	-3.12	0.70	-4.49	.02	-6.06	-0.24
1. Surprise						
F7 – PO4	-8.90	0.74	-12.04	<.001	-12.02	-5.78
C3 – PO4	-6.20	0.70	-8.87	<.001	-9.16	-3.25
F8 – PO4	-7.19	0.72	-9.98	<.001	-10.24	-4.15
F8 – P4	-6.28	0.73	-8.66	<.001	-9.35	-3.22
Cz – PO4	-6.60	0.70	-9.44	<.001	-9.55	-3.64
F7 – P4	-7.99	0.74	-10.75	<.001	-11.13	-4.85
Fz – PO4	-6.45	0.70	-9.28	<.001	-9.40	-3.51
F7 – Pz	-6.24	0.74	-8.45	<.001	-9.37	-3.12
F7 – PO3	-7.50	0.75	-10.05	<.001	-10.65	-4.34
F7 – P3	-6.13	0.74	-8.30	<.001	-9.26	-3.01
Cz – P4	-5.69	0.70	-8.08	<.001	-8.66	-2.71
F8 – PO3	-5.79	0.73	-7.95	<.001	-8.87	-2.71
Fz – P4	-5.54	0.70	-7.92	<.001	-8.50	-2.58
C3 – P4	-5.29	0.70	-7.52	<.001	-8.26	-2.32
Cz – PO3	-5.20	0.70	-7.35	<.001	-8.19	-2.21
F7 – Oz	-5.43	0.74	-8.56	<.001	-8.56	-2.29
Fz – PO3	-5.05	0.70	-8.03	<.001	-8.03	-2.08
C4 – PO4	-4.97	0.70	-7.91	<.001	-7.91	-2.02
C3 – PO3	-4.80	0.71	-7.80	<.001	-7.80	-1.81
F8 – Pz	-4.54	0.72	-7.58	<.001	-7.58	-1.49
F8 – P3	-4.43	0.72	-7.47	<.001	-7.47	-1.38
C4 – P4	-4.06	0.70	-7.02	<.001	-7.02	-1.09
Cz – Pz	-3.94	0.70	-6.90	<.001	-6.90	-0.99
Cz – P3	-3.83	0.70	-6.79	<.001	-6.79	-0.88
Fz – Pz	-3.80	0.70	-5.47	<.001	-6.74	-0.86
C4 – F7	3.93	0.74	5.33	<.001	0.81	7.05
Fz – P3	-3.69	0.70	-5.30	<.001	-6.63	-0.75
F8 – Oz	-3.72	0.72	-5.14	<.001	-6.78	-0.66
C3 – Pz	-3.55	0.70	-5.08	<.001	-6.50	-0.59
C4 – PO3	-3.57	0.71	-5.06	.001	-6.55	-0.59
Oz – PO4	-3.47	0.70	-4.95	.002	-6.44	-0.51
C3 – P3	-3.44	0.70	-4.92	.003	-6.39	-0.48
Cz – Oz	-3.12	0.70	-4.45	.02	-6.09	-0.16
Fz – Oz	-2.98	0.70	-4.26	.04	-5.94	-0.03
2. Sadness						
F7 - PO4	-5.07	0.70	-7.23	<.001	-8.03	-2.10
F7 - P4	-5.04	0.70	-7.18	<.001	-8.00	-2.07
F7 - PO3	-4.79	0.70	-6.82	<.001	-7.76	-1.82
Cz - P4	-4.44	0.70	-6.42	<.001	-7.37	-1.52
C3 - PO4	-4.31	0.70	-6.21	<.001	-7.24	-1.37
Fz - PO4	-4.30	0.70	-6.20	<.001	-7.24	-1.37
C3 - P4	-4.28	0.69	-7.21	<.001	-7.21	-1.34
Fz - P4	-4.27	0.69	-7.21	<.001	-7.21	-1.34
Cz - PO3	-4.20	0.69	-7.13	<.001	-7.13	-1.26
F7 - P3	-4.18	0.70	-7.15	<.001	-7.15	-1.21
C3 - PO3	-4.03	0.70	-6.97	<.001	-6.97	-1.09
Fz - PO3	-4.03	0.70	-6.97	<.001	-6.97	-1.09
C4 - PO4	-3.68	0.69	-6.61	<.001	-6.61	-0.74
C4 - P4	-3.64	0.69	-6.58	<.001	-6.58	-0.71
Cz - P3	-3.59	0.69	-6.52	<.001	-6.52	-0.65
C3 - P3	-3.42	0.70	-4.92	.003	-6.36	-0.48
Fz - P3	-3.42	0.70	-4.91	.003	-6.36	-0.48
C4 - PO3	-3.40	0.70	-4.88	.003	-6.34	-0.46
F7 - Pz	-3.19	0.70	-4.57	.01	-6.14	-0.24
3. Anger						
F7 - P4	-4.59	0.71	-6.49	<.001	-7.58	-1.60

F7 - PO4	-4.57	0.71	-6.47	<.001	-7.56	-1.59
Fz - P4	-4.02	0.70	-5.76	<.001	-6.96	-1.07
Fz - PO4	-4.00	0.70	-5.74	<.001	-6.94	-1.05
F7 - PO3	-4.04	0.71	-5.70	<.001	-7.04	-1.04
C3 - P4	-3.79	0.70	-5.46	<.001	-6.73	-0.86
Cz - P4	-3.79	0.70	-5.45	<.001	-6.73	-0.85
C3 - PO4	-3.78	0.70	-5.44	<.001	-6.71	-0.84
Cz - PO4	-3.77	0.70	-5.43	<.001	-6.70	-0.84
F7 - F8	-3.79	0.73	-5.21	<.001	-6.86	-0.71
Oz - P4	-3.54	0.70	-5.05	.001	-6.50	-0.58
Oz - PO4	-3.52	0.70	-5.03	.001	-6.48	-0.56
Fz - PO3	-3.47	0.70	-4.96	.002	-6.23	-0.51
C3 - PO3	-3.24	0.70	-4.66	.009	-6.19	-0.30
Cz - PO3	-3.24	0.70	-4.65	.009	-6.18	-0.30
C4 - P4	-3.22	0.70	-4.62	.01	-6.16	-0.27
C4 - PO4	-3.20	0.70	-4.60	.01	-6.14	-0.26
F8 - Fz	3.22	0.72	4.48	.02	0.18	6.25
Oz - PO3	-2.99	0.70	-4.26	.04	-5.96	-0.02
4. Fear						
F7 - PO3	-8.09	0.71	-11.42	<.001	-11.08	-5.09
F7 - PO4	-8.91	0.70	-12.65	<.001	-11.89	-5.93
F7 - P4	-7.85	0.70	-11.15	<.001	-10.83	-4.88
F7 - P3	-6.34	0.70	-9.01	<.001	-9.31	-3.37
Fz - PO4	-6.20	0.69	-8.94	<.001	-9.13	-3.27
Cz - PO4	-6.02	0.69	-8.69	<.001	-8.95	-3.09
C3 - PO4	-5.78	0.69	-8.32	<.001	-8.71	-2.84
F7 - Pz	-5.81	0.70	-8.25	<.001	-8.79	-2.84
F7 - Oz	-5.68	0.70	-8.05	<.001	-8.67	-2.70
Fz - PO3	-5.37	0.70	-7.71	<.001	-8.32	-2.43
Cz - PO3	-5.20	0.70	-7.46	<.001	-8.14	-2.25
Fz - P4	-5.14	0.69	-7.42	<.001	-8.07	-2.21
F8 - PO4	-5.18	0.70	-7.37	<.001	-8.15	-2.21
Cz - P4	-4.97	0.69	-7.16	<.001	-7.90	-2.04
C3 - PO3	-4.95	0.70	-7.10	<.001	-7.90	-2.00
C4 - PO4	-4.75	0.69	-6.88	<.001	-7.67	-1.83
C3 - P4	-4.72	0.69	-6.80	<.001	-7.65	-1.78
F8 - PO3	-4.35	0.71	-6.17	<.001	-7.34	-1.37
C4 - F7	4.16	0.70	5.93	<.001	1.19	7.13
F8 - P4	-4.12	0.70	-5.87	<.001	-7.09	-1.15
C4 - PO3	-3.92	0.69	-5.65	<.001	-6.86	-0.99
C4 - P4	-3.69	0.69	-5.34	<.001	-6.61	-0.77
Fz - P3	-3.63	0.69	-5.24	<.001	-6.55	-0.70
F7 - F8	-3.73	0.71	-5.23	<.001	-6.75	-0.71
Cz - 4,P3	-3.45	0.69	-4.99	.001	-6.37	-0.53
Oz - PO4	-3.23	0.69	-4.65	.009	-6.17	-0.29
C3 - P3	-3.20	0.69	-4.62	.01	-6.13	-0.27
Fz - Pz	-3.10	0.69	-4.47	.02	-6.03	-0.17
PO4 - Pz	3.10	0.69	4.47	.02	0.17	6.03
C3 - F7	3.14	0.71	4.45	.02	0.15	6.12
Fz - Oz	-2.97	0.69	-4.28	.04	-5.91	-0.04
5. Neutral						
F7 - PO4	-5.91	0.70	-8.47	<.001	-8.85	-2.96
F7 - PO3	-5.29	0.70	-7.56	<.001	-8.24	-2.33
F7 - P4	-5.24	0.70	-7.50	<.001	-8.19	-2.28
Fz - PO4	-4.72	0.69	-6.83	<.001	-7.64	-1.80
C3 - PO4	-4.45	0.69	-6.41	<.001	-7.38	-1.52
F7 - P3	-4.34	0.70	-6.22	<.001	-7.29	-1.39
Cz - PO4	-4.11	0.69	-5.95	<.001	-7.03	-1.19
Fz - PO3	-4.10	0.69	-5.91	<.001	-7.03	-1.17
Fz - 5,P4	-4.05	0.69	-5.85	<.001	-6.98	-1.12
F7 - 5,Pz	-3.98	0.69	-5.74	<.001	-6.92	-1.05
C4 - PO4	-3.87	0.69	-5.59	<.001	-6.80	-0.94
C3 - PO3	-3.83	0.70	-5.50	<.001	-6.77	-0.89
C3 - P4	-3.78	0.70	-5.44	<.001	-6.72	-0.84
F8 - PO4	-3.66	0.70	-5.25	<.001	-6.61	-0.71
Cz - PO3	-3.49	0.69	-5.04	.001	-6.42	-0.56
Cz - P4	-3.44	0.69	-4.97	.002	-6.36	-0.52
C4 - PO3	-3.25	0.69	-4.68	.008	-6.18	-0.31
C4 - P4	-3.20	0.69	-4.61	.01	-6.13	-0.27
Fz - P3	-3.16	0.69	-4.56	.01	-6.08	-0.23
F7 - Oz	-3.12	0.70	-4.48	.02	-6.06	-0.17
F8 - PO3	-3.04	0.70	-4.35	.03	-5.99	-0.08
F8 - P4	-2.99	0.70	-4.28	.04	-5.94	-0.04
6. Happy						
F7 - P4	-6.81	0.71	-9.58	<.001	-9.82	-3.81
F7 - PO3	-7.24	0.71	-10.21	<.001	-10.24	-4.24
F7 - PO4	-6.72	0.71	-9.42	<.001	-9.73	-3.70
Fz - P4	-5.98	0.70	-8.49	<.001	-8.95	-3.00
Fz - PO3	-6.41	0.70	-9.12	<.001	-9.38	-3.44
Fz - PO4	-5.88	0.71	-8.33	<.001	-8.87	-2.90
F7 - P3	-5.38	0.71	-7.61	<.001	-8.36	-2.39
F7 - Pz	-4.89	0.71	-6.90	<.001	-7.88	-1.89
Fz - P3	-4.54	0.70	-6.49	<.001	-7.50	-1.59
Cz - PO3	-4.23	0.70	-6.04	<.001	-7.19	-1.27
Fz - Pz	-4.06	0.70	-5.78	<.001	-7.02	-1.09
C4 - F7	4.46	0.71	5.72	<.001	1.06	7.06
F7 - F8	-3.97	0.72	-5.52	<.001	-7.01	-0.93
Cz - P4	-3.80	0.70	-5.41	<.001	-6.76	-0.83
C3 - PO3	-3.78	0.70	-5.39	<.001	-6.74	-0.81
Cz - PO4	-3.70	0.70	-5.27	<.001	-6.68	-0.73
F7 - Oz	-3.66	0.71	-5.12	<.001	-6.68	-0.64
Oz - PO3	-3.59	0.71	-5.06	.001	-6.58	-0.59
C3 - 6,F7	3.47	0.71	4.90	.003	0.48	6.45
C3 - 6,P4	-3.35	0.70	-4.76	.005	-6.32	-0.38
C3 - PO4	-3.25	0.70	-4.62	.01	-6.22	-0.27
C4 - Fz	3.22	0.70	4.59	.01	0.25	6.19
F8 - PO3	-3.27	0.71	-4.59	.01	-6.29	-0.25
C4 - PO3	-3.19	0.70	-4.53	.01	-6.16	-0.21
Oz - P4	-3.16	0.71	-4.44	.02	-6.16	-0.15
F8 - Fz	3.14	0.71	4.41	.02	0.13	6.15
Oz - PO4	-3.06	0.71	-4.30	.04	-6.07	-0.05
Cz - F7	3.01	0.71	4.27	.04	0.03	6.00