University of West Bohemia
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# Master Thesis

# Detection of emotions in event related potentials

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# Declaration

I hereby declare that this master thesis is completely my own work and that I used only the cited sources.

Pilsen May 15, 2014

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# Abstract

This thesis explores measuring emotions using event-related potentials (ERP) and extends the idea to measure beer drinkability. The first part explains the background for the experiment - electroencephalography (EEG), event-related potentials (ERP), emotions, and summaries the similar experiments that were used as headstones for the final experiment. The crucial component should be late-positive potential (LPP) but it can omit earlier components too. The study uses also other ways to underlay the results from ERP. There are structured questionnaire Self-Assessment Manikin (SAM) and peripheral devices that record blood pulse and skin conductance. The practical part deals with creating of the scenario, data recording and processing. There is also described a subject preparation. The pictures from International Affective Picture System (IAPS) are projected to the subjects to bring emotions. Pictures are divided into four categories - positive, neutral, negative and not assigned (beer) pictures. The emotions are measured with the not assigned category.

# Abstrakt

Práce zkoumá měření emocí za použití evokovaných potenciálů a navazuje na myšlenku měření pitelnosti piva. V první části je vysvětleno pozadí experimentu - elektroencefalografie (EEG), evokované potenciály, emoce, a jsou zde podobné experimenty a jejich závěry, které byly použity jako základy pro vytvoření výsledného experimentu. Hlavní komponenta by měl být pozdní pozitivní potenciál, ale dřívější komponenty mohou také obsahovat emoční reakce. Studie využívá také další způsoby na podpoření výsledků z evokovaných potenciálů - strukturovaný dotazník Self-Assessment Manikin (SAM) a periferní zařízení pro měření pulsu srdce a vodivosti kůže. Praktická část se zabývá vytvořením scénáře, pořizováním a zpracováním dat. Také je zde postup pro přípavu měřených subjektů. Subjektům jsou promítány obrázky z mezinárodního emočního obrázkového systému (IAPS), které by u nich měly vyvolat emoce. Obrázky jsou rozděleny do 4 kategorií - pozitivní, neutrální, negativní a poslední skupinou jsou nezařazené (pivní) obrázky, u kterých se budou měřit reakce subjektů.

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# 1 Introduction

This thesis is focused on the exploration of human emotions. Emotions have been an integral part of human daily life for thousands (millions) of years. A better understanding of human emotions can help in many fields of interest, e.g. advertising. The main topic, human emotions, is going to be closely explained in background, see chapter 2.1.

Emotions are measurable. Because emotions are important and they can be measured, there are many ways to measure them. The easiest way are self-report (e.g. questionnaires), reading of the facial expression or vocal expression. However, these methods are easy to fake. More sophisticated methods comprise functional magnetic resonance imaging (fMRI), electroencephalography (EEG), event-related potentials (ERP) and bodily changes (skin conductance, muscle tension, hormone secretion, body temperature, electrocardiogram (EKG)).

The main importance is enclosed to electroencephalography (EEG) and event-related potentials (ERP). It will be accompanied by two peripheral devices, the first one records blood pulse and the second one measures skin conductance. The measured data will be also supported by a structured questionnaire Self-Assessment Manikin (SAM), it is standardized self-report questionnaire used in emotions measurements. The additional measurements done by peripheral devices and the SAM questionnaire should support the results obtained from the ERP.

The thesis derives knowledge from my bachelor thesis, see [21].

Chapter 3 contains several summaries of studies that explores similar topics. Most of the studies are related with event-related potentials (ERP) and electroencephalogram (EEG). The focused component in these studies is mostly late-positive potential (LPP) but there are studies that explores earlier components (0 - 300 ms) too. An important study is an International Affective Picture System (IAPS) that contains over a thousand evaluated pictures used in almost every experiment related to emotions. The pictures were provided for this experiment by the University of Florida. The studies serve as basics for building the experiment.

The actual experiment is described in detail in chapter 4. There is a short summary of important knowledge for the experiment extracted from

the studies. Then there is a section with instructions for subjects about the experiment. The chapter also describes the procedure of subject preparation. The whole experiment is situated in the university laboratory of neuroinformatics. It provides all the necessary equipment required for the experiment. Data measuring and processing section consists of three subsections. The first subsection mentions the creating of scenario in Presentation software. The second subsection is focused on recording EEG and peripheral data via BrainVision recorder. The last subsection describes the measured data processing in Matlab toolbox EEGLAB. Experiment results are presented in the last section in the 4th chapter.

The last chapter summarizes the experiment results and comes up with possible extensions and improvements of the experiment.

# 2 Background

## 2.1 Emotions

### 2.1.1 Definitions

There are several definitions that could be used when emotions are described. The basic definition is connected with feeling and it is used to express states as pleasure, sadness, anger, envy, fear etc.

The psychological demarcation of the concept emotions is difficult and its definition is impossible if the emotions are understood as a idiosyncratic and elementary experiences qualities. [29]

There can be found definitions in psychological dictionaries. 1. complex emotional state accompanied by characteristic motor and glandular, 2. complex behavior of an organism where visceral component are predominant. [29]

Other definitions - 1. mental state characterized by feeling and accompanied by motor symptoms that is connected to an object or external situation, 2. excited status of a mind that accompanies to target focused behavior, 3. affective state which is the consequence of an obstacle or postponement of the instinctive action, 4. dynamic instinct expression, 5. organism's disorganized response, 6. total act organized around autonomous controlled complex of behavior. [29]

Psychological meaning of the emotions concept according to D. Kreche and R.S. Crutchfeld is connected with the state of the organism's irritation that is expressed in three ways. [29]

1. emotional experience (experiences), i.e. feeling
2. emotional behavior
3. physiological changes in the organism

The conclusion from definitions is that emotions are phenomenally specific

and complex psychological phenomenons of situation or stimulation evaluation. To have an experience (feeling) component that is crucial because it constitutes in the unity with cognition of situation importance, a behavioral component and a somatic component. Emotions, as they are, are reactions to vitally important situations that also in addition to identification of their importance includes individual activation to adapt to given situations. [29]

### 2.1.2 Functions

**Evaluation** It is based on information selection, thinking and remembering. Identification of information meaning is important for life of an individual. Criterion of this evaluation are actual and permanent motives of activity, respectively gained rewards and punishments. [29]

**Integration** Emotions integrate partial psychic functions of recognition a motivation in unanimously working system of experiencing where the meanings of stimuli, situations and connected motivations are created on the base of this unity. E.g. situation is evaluated as dangerous and it concurrently initiates motive of escaping behavior and its possible realization. [29]

### 2.1.3 Emotions and physical functions

The sympathetic nervous system is characterized by postganglionic fibers that are quite lengthy, and which branch and divide as they make their way to specific target organs. This means that a single sympathetic fiber activates a number of different effectors, providing an anatomical substrate for Cannon's emergency reaction, which proposed a volley of responses – heart rate and blood pressure increases, electrodermal reactions, increase in respiration rate and depth, see figures 2.1, 2.2. [12]

One of the sources that explores the neural activity during affective processing is a measurement of electrophysiological signals on the scalp, event related potentials (ERP). ERP are changes of electric brain activity (or other parts of nervous system) after external targeted stimulation [28]. When the ERP is measured during affective picture viewing, the most common finding are connected with late positive potential (LPP). It appears around 300-1000

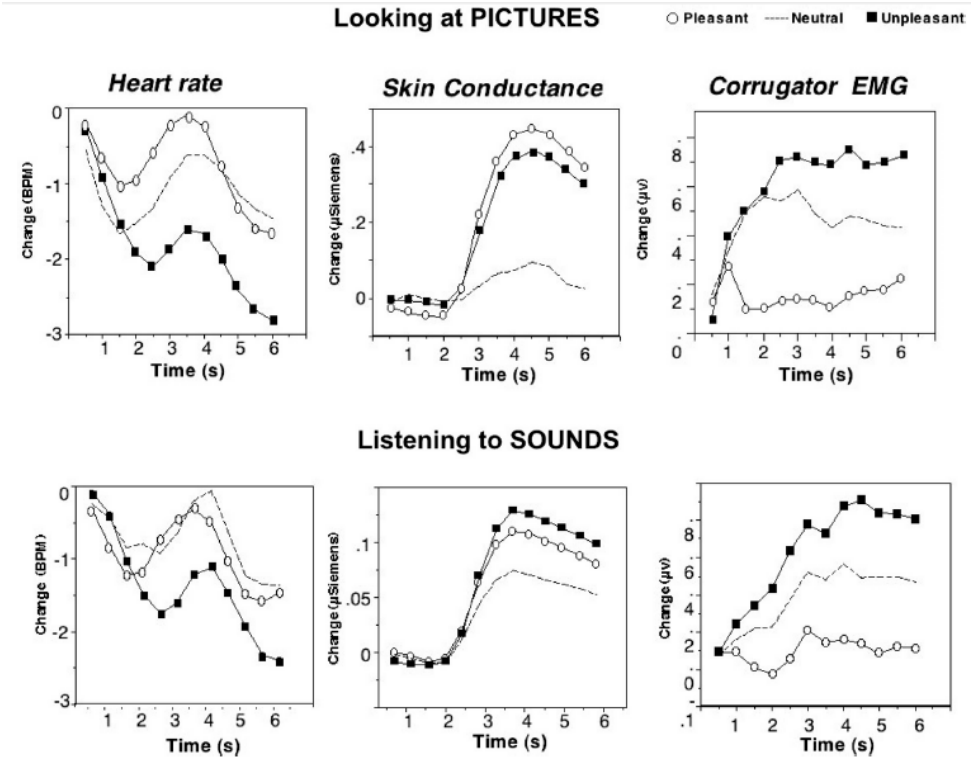


Figure 2.1: Comparison in subjects' reactions after watching set of pictures and listening to sounds. Stimuli are divided into three categories - pleasant, neutral and negative. The measured data are heart rate (s/BPM), skin conductance (s/$\mu$Siemens) and corrugator EMG (s/$\mu$V). [12]

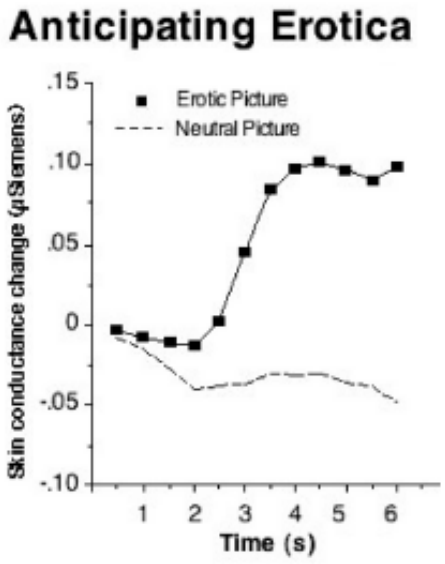


Figure 2.2: Skin conductance from anticipating the presentation of erotic and neutral pictures. Measured with skin conductance change in time (s/$\mu$Siemens). [12]

ms after the picture onset. The maximum LPP was found over centro-parietal sites [12].

The bigger response comes with emotional pictures (pleasant and unpleasant) rather than with neutral pictures. The largest LPP comes with pictures of erotica, mutilation and attack. But there are some studies that have found out modulation of earlier ERP components. For example, Cuthbert et al. (2000) found that pleasant pictures prompted greater positivity in a 200–300 ms time window following picture onset (at frontal, central, and parietal sites) and a similar pattern of greater positivity over parietal, central, and frontal sites for pleasant pictures in this time window was reported by Palomba, Angrilli, and Mini (1997) [12].

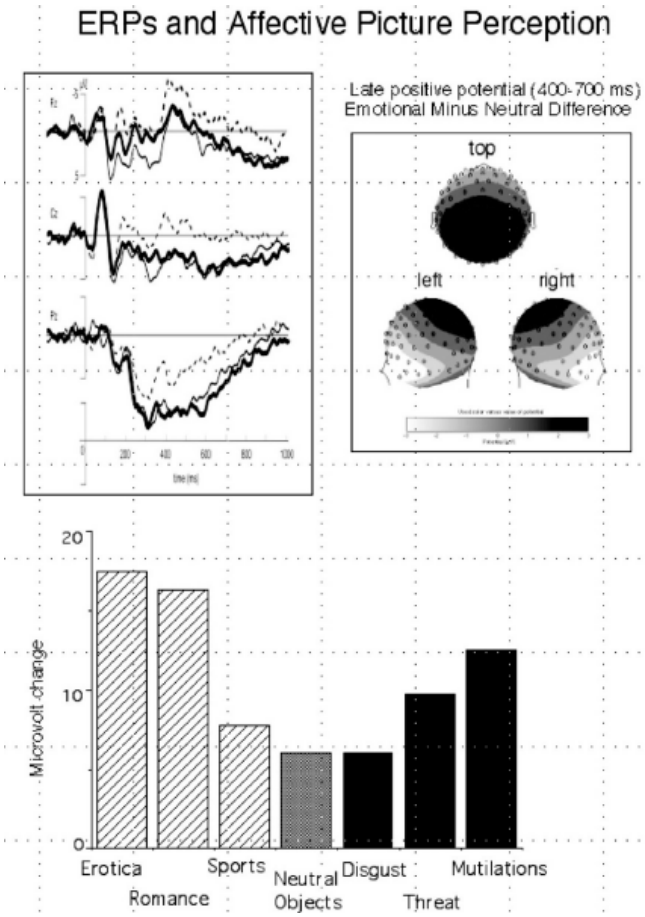


Figure 2.3: The late positive potential (LPP) elicited 300–1000 ms after picture onset. The first diagram shows the Fz, Cz and Pz components' averages in 1000 ms scale from -5 to +5 $\mu$V. The second diagram shows a distribution of emotional minus neutral reaction on a scalp in LPP. The last diagram displays the voltage changes ($\mu$V) in different picture categories. [12]

## 2.2 Neuroscience introduction

### 2.2.1 Late positive potential (LPP)

LPP is a positive-going event-related potential (ERP) that begins around 400 ms after the onset and lasting for few hundred milliseconds. Generally is largest over parietal scalp sites. [20]

It is an ERP that reflects attention to emotional stimuli. The magnitude of the LPP is greater when individuals view emotionally arousing compared to neutral pictures. [19]

### 2.2.2 P300

The P300 (P3) wave is a positive-going event-related potential (ERP) component elicited in the process of decision making. It peaks around 300 ms and it may vary in peak from 250-500 ms or later (depending on a task and a stimulus). It is divided into P3a and P3b. P3a has been associated with brain activity related to the engagement of attention. P3b has been used to study cognitive processes, especially psychology research on information processing. [31]

# 3 State of Art

## 3.1 Studies

In this chapter there are some case studies related to the experiment. The first study describes the International Affective Picture System database which is the most used picture database in studies and it is also used in the experiment. Study 2 focuses on emotions and ways to measure them. Components connected with emotions are examined in study 3. Study 4 investigated various ways to measure emotions using EEG and peripheral devices. Study 5 explores the problem with picture repetition in ERPs. Study 6 shows difference between emotionally affected and neutral pictures. Using event related potentials with focus on P300 for detection of beer drinkability in presented in study 7. Depressive states and cognitive aspects of aging and their influence on P300 was explored in study 8. Study 9 is addressed with the late positive potential and its application in emotional processing. Study 10 is an extension of study 7. It modifies and simplifies the experiment to get better results.

### 3.1.1 International Affective Picture System (IAPS)

**Abstract** The study describes the international picture database which has been evolving for many years and it is used as a standardized set of pictures for experiments. The complete description is available in [24].

**Introduction** IAPS is a database that contains a big amount of emotionally evocative, internationally accessible, colour photographs. It has been developed by the NIMH Center for Emotion and Attention (CSEA) at the University of Florida. There are three big advantages of the database. The first is better experimental controlling in the selection of emotional stimuli. The second pro is the comparison of results with their database where every picture was evaluated using Self-Assessment Manikin (SAM) questionnaire (see next paragraph). Different studies can be easily compared even if they were not measured in the same laboratory. The last advantage is exact replications within and across research labs. [24]

The basic knowledge, that there are three major dimensions of the variance in emotional assesments, was grounded in Osgood's (Osgood, Suci & Tanenbaum, 1957) seminar work. The two primary dimensions were one of affective valence (ranging from pleasant to unpleasant) and one of arousal (ranging from calm to excited). The last dimension named *dominance* or *control*. [24]

**Self-Assessment Manikin (SAM)** is an affective rating system that was used to assess these three dimensions (pleasure, arousal and dominance). It was devised by Lang (1980). The system uses a graphic figure depicting values along each of the three dimensions on a continuously varying scale to indicate emotional reactions. 3.1 shows the paper-and-pencil version of SAM. The first line is a representation of valence dimension. The second line represents an arousal level and the dominance dimension is represented by the last line. Each dimension has nine options (five pictures and four spaces between pictures). [24]

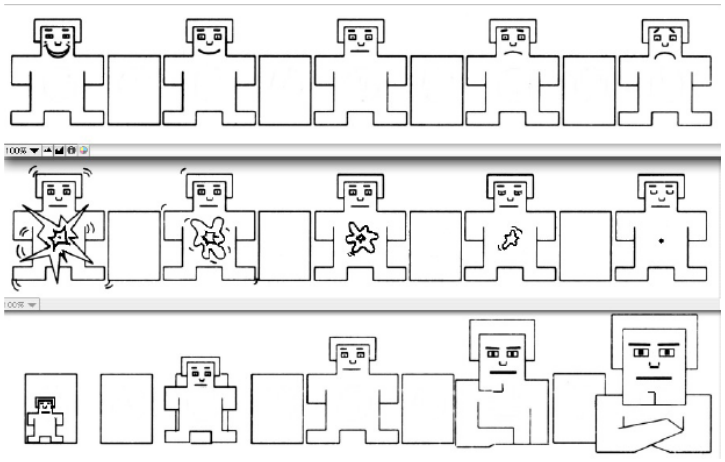

Figure 3.1: Paper and pencil version of SAM [24]

**Normative rating procedure for IAPS** There are 1196 pictures available. All of these pictures were rated in sets of 60 pictures. That means there were rated 20 picture sets of 60 pictures each. The collection has been tested for 13 years already.

Subjects were approximately 100 college students (half female). They were in groups ranging in size from 8 to 25, with the male:female ratio no

more than 1:2 (or 2:1) for any single group session. There were three to four different picture orders that balanced the position of a particular exemplar within the entire series of pictures. The three SAM dimensions served as a dependend measures [24]. The pictures followed these criteria:

- The entire affective space had to be covered by the picture selection.
- All pictures are in color.
- Pictures are selected to be easy to resolve, have clear figure - ground relationships, and communicate affective quality relatively quickly [24].

The paper-and-pencil version of SAM (Lang, 1980) in a booklet format was used to acquire affective ratings for Picture sets 1-6. Picture sets 7-20 used the computer-scorable ScanSAM sheet. Experimental sessions were conducted in a 20 ft x 35 ft room under similar lighting conditions. Subjects were seated in rows of 90 degree arcs facing the screen on which the slides were projected. The maximum size of the image projected on the screen was standardized at approximately 4 ft x 5 ft. The first slide was always just a preparation slide ("Get ready to rate next slide"). All the slides, except the preparations (5 seconds), were presented for 6 seconds. The rating was made immediately after the picture left the screen and there were 15 seconds to evaluate the picture. Kids had a bit different conditions, see page 4 in. The instructions for adult participants can be found in 4.3. They are similar to IAPS instructions except the EEG measuring part. [24]

The picture distribution to sets can be found on pages 13-61 in [24].

**Summary for experiment** The IAPS database will be used as a picture source for non-target stimuli in the experiment. Pictures will be chosen according to the IAPS statistics.

### 3.1.2 Emotion Assessment: Arousal Evaluation Using EEG and Peripheral Physiological Signals

**Abstract** There are two different physiological sources which could be used to assess the arousal dimension of human emotions (peripheral signals and

electroencephalography[1]) Results achieved in this study confirm the possibility of using EEG's to assess the arousal component of emotion. [14]

**Introduction** There are three viewpoints that Cornelius cites - the Darwinian, cognitive and Jamesian ones. The Darwinian theory suggests that emotions are selected by nature in term of their survival value. The cognitive theory states that the brain is the center of emotions. It particularly focuses on the direct and non reflective process, called appraisal [27], by which the brain judges a situation or an event as good or bad [33]. Finally, the Jamesian theory stipulates that emotions are only the perception of bodily changes such as heart rate or dermal responses. [14]

There are several channels which can express emotions. Facial expression or speech are the most common but also they are easy to be faked. More reliable emotion assessments can be reached by physiological signals.

Physiological signals can be divided into two categories: peripherals (heart rate, temperature, etc.) and those from the central nervous system (e.g. electroencephalograms).

### Data collection

**Emotion elicitation** There were used 700 evocative images from IAPS in this experiment. Each of these images has been extensively evaluated by participants, providing valence/arousal values. Means and variances values are also included. This is caused by the different experience of participants in the past. Therefore each participant self-assessment each image of valence/arousal.

**Acquisition protocol** There were four participants, three males and one female. The age range was from 28 to 49. One of the participants was left handed.

For EEG's they used a Biosemi Active Two device with 64 electrodes (plus 2 for reference). The other sensors used were a GSR sensor, a plethysmograph to measure blood pressure, a respiration belt to evaluate abdominal and

[1] EEG

thoracic movements, and a temperature sensor. All signals were sampled at a 1024 Hz rate.

First, there was dark screen for three seconds to rest and prepare the participant for the next image. Then the white cross appeared on the center of the screen for a random time from two to four seconds to attract user's attention and avoid accustoming. After this the IAPS image was shown for six seconds. Then participant self assess the valence and the arousal of his/her emotion using a simplified version of the Self Assessment Manikin (SAM) with 5 possible numerical judgments for each dimension (arousal and valence). There was no time limit to self assess the image so it allows subjects to rest between images.

There were 100 images used in the experiment, 50 high arousal and 50 low arousal (according to the IAPS evaluations). The image distribution of valence was relatively uniform.

**Conclusion** Measured results in the experiment showed that EEG can be used with other peripheral devices and the fusion can improves and support the final findings.

**Summary for experiment** The study brings a possibility to support the ERP results by other data (from peripheral devices). It can serve as an encouragement to the EEG/ERP and/or questionnaire answers. It could be an important data source for the results interpretation.

### 3.1.3 Emotion and attention: event-related brain potential studies

**Abstract** Pictures showing natural, pleasant and unpleasant scenes are associated with an increased early posterior negativity, late positive potential and sustained positive slow wave compared with neutral contents. These modulations are considered to index different stages of stimulus processing including perceptual encoding, stimulus representation in working memory, and elaborate stimulus evaluation. The are also discuss studies exploring the interaction of motivated attention with passive and active forms of attentional control in the review.[36]

**Introduction** People live in the world which could be represent as a continuous endless stream of stimuli. But only a small subset of information is consciously recognized. Passive attention is based on intensity, suddenness of onset, or novelty. In active attention, priority processing reflects the intentional effort to look for selected stimuli based on instructions, self-generated intentions, or associative learning. [36]

There are two distinct motivational subsystems. The self-preservative appetitive system (foraging, ingestion, copulation, and nurture of progeny) and the protective defensive system (withdrawal from and defense against nociceptive agents) associated with pleasant states and neutral states, respectively. [36]

**Early posterior negativity (EPN)** co-varied with the arousal level of the emotional pictures. Specifically, highly arousing picture contents of erotic scenes and mutilations elicited a more pronounced posterior negativity compared to less arousing categories of the same valence [36].

To examine the effects of color of the stimulus materials, Junghofer and colleagues (2001) included a control condition presenting the same materials as grayscale images. An almost identical affect modulated early posterior negativity was observed as for the corresponding color images showing that the early discrimination of emotional from neutral pictures did not depend on color [36].

**Late positive potential** It appears LPP corresponds with evolution. If there are two stimuli with the same valence but one is more evolutionary significant, the evolutionary more important one has enlarged LPP.[36]

**Summary for experiment** The experiment will be focused at LPP component but it will also consider other components. The components can be influenced not only by the basic distribution (positive, neutral, negative) but it can also differ in the same category.

### 3.1.4 Emotion Recognition System Using Brain and Peripheral Signals: Using Correlation Dimension to Improve the Results of EEG

**Abstract** The input signals were electroencephalogram, galvanic skin resistance, temperature, blood pressure and respiration, which can reflect the influence of emotion on the central nervous system and autonomic nervous system respectively. Experiment was focused on pictures divided into three specific areas of valence-arousal emotional space (positively excited, negatively excited and calm). Better results were achieved by EEG compared to other physiological signals.[22]

**Introduction** Emotion recognition is an interesting but difficult task. Previous studies have investigated the use of peripheral and brain signals separately but little attention has been paid so far to fusion between brain and peripheral signals.[22]

Emotions are known to be very dependent on past experience, so that one can never be sure whether in data collection the expected emotion is elicited or not. Furthermore about the way to elicit emotions, the subjective stimuli usually have better results than the objective one, audio visual stimuli seems to provide better results than only visual, especially the effect of music to elicit emotional state is well known.[22]

Picard and her group at MIT Media Laboratory developed pattern recognition algorithms which attained 78.4% classification accuracy for three categories of emotional states and using peripheral signals Galvanic Skin Resistance, Blood Pressure, Respiration, and Skin Temperature, the stimuli was a combination of music, story and showing images [16].

**Data acquisition** The database of this work is available in [34].

**Stimuli** To elicit the target emotions IAPS images were used as the stimuli. The images were divided into three emotional classes: calm, exciting positive and exciting negative (there were not used any erotic pictures in this experiment). Total amount of used pictures were 327 (106 calm, 71 positive and 150 negative).

Stimuli blocks were made of five pictures and each picture was displayed during 2.5 seconds (that means 12.5 s per block).

Five subjects participated the experiment. Everyone had 3 sessions, each session consisted of 30 trials.

**Subjects** There were five participants. All subjects were only right handed males. Age range was between 22 and 38 years. For each subject data are divided in three sets, one per session. Every session was divided into three categories: one concerns EEG and peripheral information, another concerns functional near-infrared spectroscopy (fNIRS) information and the last contains self-assessments of participants.

**Procedure** Due to occlusion from functional near-infrared spectroscopy (fNIRS) sensor arrangement, they had to remove the following ten frontal electrodes: F5, F8, AF7, AF8, AFz, Fpl, Fp2, Fpz, F7, and F6, which left us with 54 channels [27]. So EEG was recorded using 54 electrodes and peripheral sensors were Galvanic Skin Resistance (GSR), Respiration and Temperature. All signals were sampled at 1024 Hz.

### Physiological Metrics

**Galvanic Skin Resistance** GSR is a measure of the conductivity of the skin. Skin conductivity could change due some specific sweat glands and that results in the GSR. Located in the palms of the hands and soles of the feet, these sweat glands respond to psychological stimulation rather than simply to temperature changes in the body [35].

**Respiration** Respiration was recorded by using a respiration belt, providing the chest cavity expansion over time.[27]

**Blood Pressure** A plethysmograph was placed on the thumb of the participant to record blood volume pressure.[27]

**Temperature** Temperature was measured as skin temperature from the skin surface. Since muscles are tense under strain, the blood vessels will be contracted and therefore the temperature will decrease. [13]

**Electroencephalogram (EEG)** In this study, EEG is recorded using the Biosemi Active 2 acquisition system with 64 EEG channel. Due to occlusion from fNIRS sensor arrangement, the following ten frontal electrodes had to been removed: F5, F8, AF7, AF8, AFz, Fpl, Fp2, Fpz, F7, and F6. [27]

**Peripheral signals** To filter the noise from all signals was used a moving average filter. Filter parameters: length 512 for GSR, 128 for blood pressure, and 256 for respiration. Those different lengths were chosen to remove high frequencies without corrupting oscillations of interest [8]. The following features are extracted from GSR: Mean, Mean of derivative, standard deviation, the features extracted to consider the importance of average variation and deviation. The common features of temperature: Mean, Standard deviation, Minimum and Maximum of the whole trial. These features were extracted from Blood Pressure: Mean value over the whole trial is the feature which is extracted via this signal. At last to characterize the respiration, features below extracted from both the frequency and time domain; Mean, Mean of derivative, Standard deviation, Maximum values minus Minimum values and calculating the power in 10 frequency bands of .25 Hz to 2.75 Hz. [27]

**Brain signals** First, the signal need to be pre-processed to eliminate noise. There are several noise sources (environment - mainly 50Hz, muscles activity and fNIRS noise). Environmental noise is the easiest to remove with a band pass filter in the 4-45 Hz range. Muscles activity (e.g. eye blinks) devalue the signal with great artifacts. There is Laplacian Filter used to eliminate it. [27]

**Results and Discussion** According to the results there, EEG signals seem to perform the best results compare to other methods (peripheral or peripheral+EEG), see figure 3.2. But the results of fusion between EEG and peripheral devices are more complex than simple EEG or peripheral and they can serve to better further processing.

| EEG | *peripheral* | *EEG+peripheral* |
|---|---|---|
| 63.33% | *55%* | *61.8%* |

Figure 3.2: The match between results acquired by one subject with different methods compared to subject's evaluation. [27]

**Summary for experiment** This study explores the same area as [14]. The peripheral signals extend the pure EEG data and it can help with the further data processing. Even if the study's results seem to be the best as a raw EEG, the combined method can support the final decision more if the results from both, EEG and peripheral devices will correspond to each other.

### 3.1.5 Repetition and Event-related Potentials: Distinguishing Early and Late Processes in Affective Picture Perception

**Abstract** Study explores an influence of repetition paradigm on the early and late components of the event related potentials during picture viewing. Participants passively viewed affective or neutral pictures. The pictures were repeated 90 times each. Both components, early and late, were modulated by emotional arousal. The reaction to pleasant and unpleasant pictures were different than reaction to neutral pictures. The repetition had different effect on the components. The data suggest that the early ERP primarily reflects obligatory perceptual processing that is facilitated by active short-term memory representations, whereas the late ERP reflects increased resource allocation due to the motivational relevance of affective cues. [15]

**Introduction** Affective picture elicit a larger, late positive potential (LPP) from about 300-600 msec over the centroparietal cortex compared with neutral pictures. In addition to the late positive potential, an earlier ERP component has been reported to vary with emotional arousal in a window from about 150-300 msec, with affective stimuli prompting significantly less negativity over frontal sites and less positivity over occipital sites compared with neutral pictures. [15]

There were used 15 pictures (five pleasant, five neutral, and five unpleasant). Each picture was repeated 90 times. The whole experiment was divided

into three phases. Every phase contained 450 pictures. The phases were separated by a short break interval which took two minutes. [15]

The participants repeated the whole experiment again after ten days with a new set of positive, neutral, and negative pictures. If early affective modulation of the ERP reflected a perceptual process triggered by the detection of object-relevant visual features, the expectation was that there would be less stability in this component, as the perceptual features and content of the pictures differ from one session to the next. On the other hand, because the new pictures in the second session continued to depict pleasant, neutral, and unpleasant content, there was an expectation of a higher correlation between sessions for the late ERP, which is presumed to reflect heightened attention to motivationally relevant material. [15]

There were 24 participants (12 male), age from 21 to 28, all students. Each participants joined two session in ten days. Each session contains 1800 pictures presented for one second. There were three habituation blocks (450 pictures) and one dishabituation block (450 pictures each). The same 15 pictures (5 pleasant, 5 neutral, 5 unpleasant) were presented in every of the three habituation blocks. There was a new set of 15 different pictures used in the dishabituation block. There was two minutes break between every block. [15]

**Results** Averaged ERP waveforms for pleasant, neutral, and unpleasant pictures can be seen in 3.3. They were averaged across the habituation and the novel phase for each sensor.

In early ERP interval (150-300 msec), there was indicated that repetition affected the magnitude of the early ERP component with-in a block of presentations. ERPs recorded over occipitotemporal sites showed a linear decrease in positivity across picture repetitions within a block [15].

In the late interval (300-600 msec) a block vs. subblock vs. region interaction indicated habituation of the late component across both blocks and subblocks of picture repetition [15].

In each session, picture repetition decreased the magnitude of the late positive potential (LPP). In both sessions, affective pictures prompted larger late potentials than neutral pictures did.

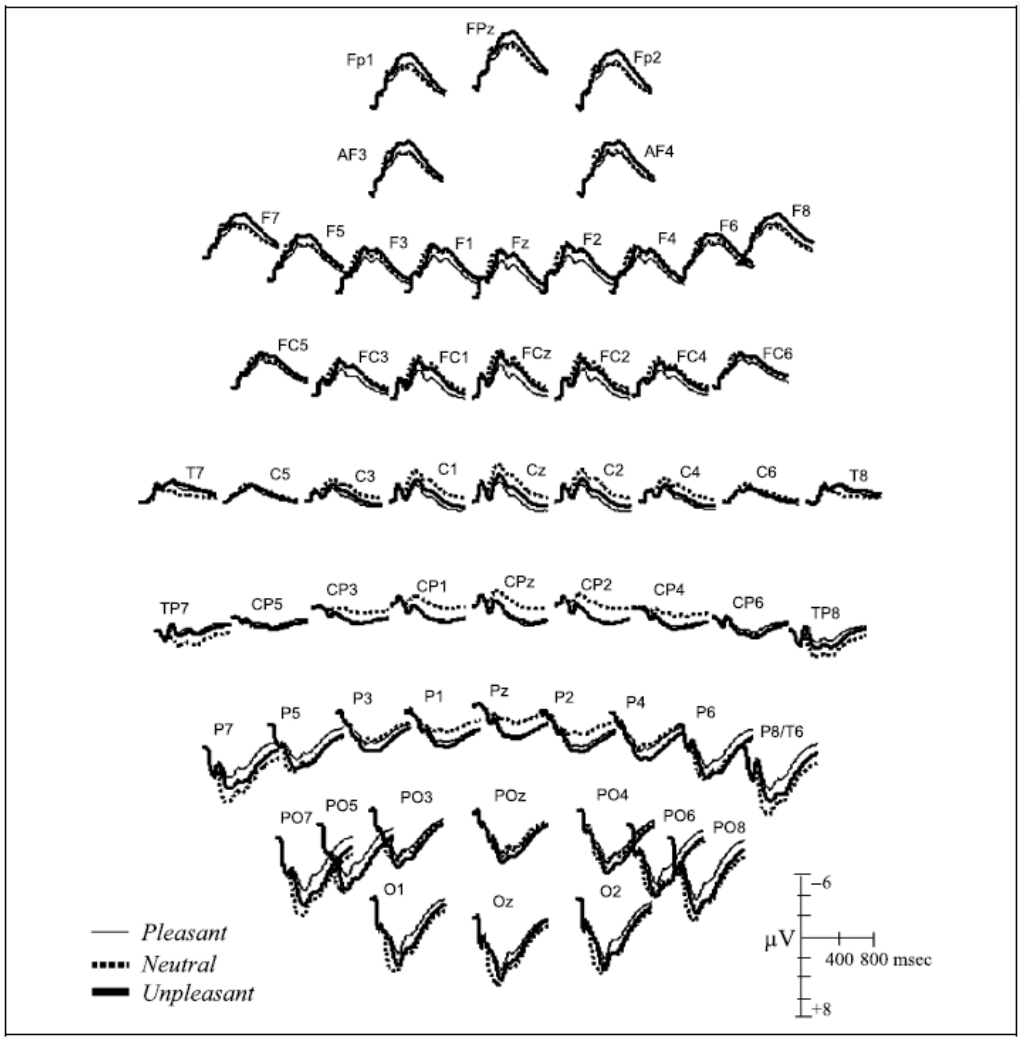


Figure 3.3: Grand-averaged ERPs [15]

**Summary for experiment** The study shows how pictures repetition can affect the response of a subject. The habituation process covers the whole spectrum from the early ERP interval (150-300) to late positive potential. To prevent that the habituation process will appear every picture will be repeated only three times. The repetition is necessary because of lack of the targeted pictures.

### 3.1.6 Brain potentials in affective picture processing: covariation with autonomic arousal and affective report

**Abstract** Significantly larger late, slow positive voltage change was observed for affective stimuli than for neutral stimuli. The beginning of the positive shift was 200-300 ms after picture onset. The maximum amplitude appeared approximately one second after picture onset, and was sustained for most of a six seconds picture presentation period. The results suggest that the late positive wave indicates a selective processing of emotional stimuli, reflecting the activation of motivational systems in the brain [16].

**Introduction** The aim of this experiment is assess the brain's reactivity to emotional pictures by recording event-related potentials and assessing their relationships to evaluative, somatic, and autonomic measures of affect [16]. According to Konorski (1967) the brain's appetitive motivation system is the center where pleasant affects are held. On the other hand, the unpleasant affects are associated with defensive motivation. [16]

**Experiment** There were taken 54 pictures from IAPS (18 positive, 18 negative and 18 neutral). The image was projected for six seconds. In order to promote a stable mental set, the participant was asked to try to maintain the image of the slide for a short period after its presentation (terminated by a soft tone). The participant was then asked to judge their emotional reactions while viewing the picture on bi-polar scales measuring affective valence and arousal. A variable interval (12–18 s) occurred between each trial. A one minute resting baseline was initiated at the beginning of the experiment to facilitate laboratory adaptation, and two neutral pictures served as practice trials [16].

The signals were recorded three seconds before slide onset until one second after the end of the post-picture period. Used electrodes were placed at F3, Fz, F4, C3, Cz, C4, P3, Pz, P4 and both mastoids [16].

### Results

**Autonomic, somatic and self-report measures** Emotional pictures, pleasant and unpleasant, did not differ in arousal reports, but were both judged to be significantly more arousing than neutral pictures. Unpleasant pictures occasioned significantly greater corrugator muscle activity and greater heart rate deceleration than other picture types. Both emotional types prompted significantly larger increases in skin conductance than did neutral pictures, and in this experiment, conductance responses to pleasant pictures were significantly larger than those to unpleasant images, see figure 3.4 .[16]

**ERP** Midline cortical response differences among picture contents began between 200 and 300 ms after picture onset, with significantly more positivity during pleasant relative to neutral pictures. For the subsequent P3 region of 300–400 ms,pleasant pictures continued to prompt the greatest positivity — significantly more than both neutral and unpleasant stimuli. From 400 to 700 ms, during the large fronto-central negative wave, the response to pleasant pictures was still significantly different from both neutral and unpleasant contents, but now unpleasant pictures also prompted a positive-going shift compared with neutral images. From 700 to 1000 ms, pleasant and unpleasant pictures were not different, and both showed significantly more positivity than neutral [16].

The interaction of emotion content and location was never significant. However, significant main effects of location were found for areas 200–300, 300–400, 400–700 and 700–1000 ms. For all area measures, the largest positivity was observed at Pz, intermediate at Cz, and least at Fz. [16]

**Covariation of brain potentials with intensity of emotional activation** The hypothesis was confirmed. Both emotional valence categories are more positive in the slow potentials for the more affectively intense pictures than for lower arousal pictures, see 3.5. [16]

Table 1
Means for valence and arousal ratings, corrugator response, skin conductance response, and heart rate change for pleasant, neutral, and unpleasant pictures[a]

| Measures | Pleasant pictures | Neutral pictures | Unpleasant pictures |
|---|---|---|---|
| Valence ratings | 16.1 (1.9) | 10.8 (1.4) | 5.9 (3.1) |
| Arousal ratings | 14.5[a] (2.8) | 6.6 (3.1) | 14.6[a] (2.6) |
| Corrugator EMG change (μV) | −0.16 (0.88) | 0.3 (0.66) | 0.54 (0.93) |
| Skin conductance response, log(μsiemens +1) | 0.08 (0.09) | 0.01 (0.03) | 0.05 (0.08) |
| Heart rate peak (bpm) | 3.9[a] (2.7) | 3.5[a] (2.6) | 2.2 (2.7) |

[a] Valence and arousal ratings were on a 0–20 scale. Values sharing a letter within a row do not differ significantly in a post-hoc comparison for that response ($P<0.05$). Standard deviations are presented in parentheses.

Figure 3.4: Result table [16]

Table 2
Mean difference responses (Δ score) of ratings, skin conductance, and EEG onset potentials for pictures high versus low in arousal, separately for pleasant and unpleasant pictures[a]

| Measures | Pleasant pictures | Unpleasant pictures |
|---|---|---|
| Arousal ratings (0–20 scale) | 3.1*** | 2.1*** |
| Valence ratings (0–20 scale) | 0.9* | −1.8** |
| Skin conductance response (μS) | 0.09*** | 0.025 |
| Averaged ERP amplitude (Fz, Cz, Pz), 400–700 ms (μV) | 5.9*** | 4.0*** |
| Averaged ERP amplitude (Fz, Cz, Pz), 700–1000 ms (μV) | 6.4*** | 4.6*** |

[a] The analyses were repeated using a matched subset of the pictures, such that arousal rating differences were maintained between high and low arousal pictures; however, high and low arousal pictures within pleasant and unpleasant categories did not differ in mean valence rating. The statistical results obtained with the valence-matched pictures were essentially the same as those shown.
* $P<0.05$.
** $P<0.01$.
*** $P<0.001$.

Figure 3.5: Result table 2 [16]

**Results** Nonaffective pictures have extensively reduced or even absent a late positive potential. These positive potentials are specifically enhanced for pictures that are more emotionally intense. [16]

**Summary for experiment** The important conclusion of this study is a comparison between affective and neutral stimuli. The studied areas covers the spectrum from 200 to 1000 ms. The peripheral signals were also included.

### 3.1.7 Using event related potentials method for detection of beer drinkability

**Abstract** The study explores the area of measuring the beer drinkability using event related potentials focusing on the P300 component. Study also describes the data processing and creating the experiment scenario. The full reference can be found in [21].

**Introduction** This thesis investigates the using event related potentials methods for detection of beer drinkability. The experiment cooperated with the Pilsner Urquell. There are summaries what EEG, ERP, P300 wave and artifacts are. As written before the P300 wave was used as the main component. The software EEGLAB, used to data processing, and Presentation software from Neurobs, that is used for scenario creation, are described here.

**Experiment** There were used two kinds of beers, both produced by company Pilsner Urquell: Gambrinus Premium and Pilsner Urquell. There were 13 participants, 10 males and 3 females. The averaged age was 27,5. There were 11 people right handed and 2 people were left handed.

The subjects were watching a short video that was randomly interrupted by the instruction that they would drink a beer in ten seconds. It was the measured stimulus. The subject had no information about the beers. He or she only knew that there were two kinds of the beers. The experiment was divided into two parts. Every part had one video and one beer with ten stimuli. Then the second part was performed with the second beer. The total amount of the beer that subject drank was one liter.

After the experiment every participant also filled a questionnaire that asked about the beers. The used scale was from 1 (the best) to 5 (the worst).

The data were processed with EEGLAB. EEGLAB is an interactive Matlab toolbox for processing continuous and event-related EEG, MEG and other electrophysiological data incorporating independent component analysis (ICA), time/frequency analysis, artifact rejection, event-related statistics, and several useful modes of visualization of the averaged and single-trial data. [3]

**Results** The questionnaires showed that both beers were evaluated almost with the same points[2] and also the measured data revealed just a small differences.

The resultant data were not clear so that there could not be set any clear conclusion. It was caused because of the excessive similarity in results. The further researched with more distinct samples would be needed.

**Summary for experiment** The experiment brought the basis techniques for further scenario implementation and also knowledge of EEG and ERP. The data recording and processing are also mentioned there.

### 3.1.8 Correlation of the P300 evoked potential in depressive and cognitive aspects of aging

**Abstract** The P300 is a long-latency auditory evoked potential highly dependent on cognitive skills. It is believed that cognitive changes caused or not by depressive symptoms may interfere with the P300. [18]

**Introduction** The length of the human life has been extending. This brings an increase in organic, functional and psychosocial diseases and dysfunctions to the elderly. Deterioration of the auditory function, cognitive decline and depression symptoms, these are situations that can worsen the aging process. [18]

[2] 2,00 for Pilsner Urquell and 2,15 for Gambrinus Premium

The most common cognitive changes in depressed elderly are the executive functions, attention deficits and reduction in processing speed. The P300 Long Latency Auditory Evoked Potentials reflect the functional use the individual make of the auditory stimulus and among the evoked auditory potentials this is the one which better reflects mental functioning, being highly dependent on cognitive skills, e.g. attention and discrimination [18].

The process of aging causes the degenerating of the brainstem structures. This brings an increase of the absolute latencies of auditory evoked potentials. [18]

One of the problems of measuring elders is a difficulty of finding completely healthy person. Thus there can be sometimes paradoxical findings in the studies inclusive the population at this age range. [18]

To get better safety in the clinical and scientific use of the P300 in the elderly it is important to explore some factors that are usually seen in the elder population. Among these factors belong cognitive decline and depression symptoms. [18]

The hypothesis used as basis for the present study was that cognitive changes, whether generated or not by depression symptoms, my impact the P300 cognitive potential. This study is focused on exploring the influence of aging, cognitive aspects and depression symptoms in the P300 latency in elderly with hearing loss. [18]

**Experiment** The criteria for subjects selection:

- having symmetrical mild to moderately-severe bilateral sensorineural hearing loss
- not having overt neurological and/or psychiatric diseases
- not use any medication or drug which acts in the central nervous system that could alter the person's concentration or attention
- being 60 years old or older, in other words, be an elderly according to the National Statute of the Elderly (Brazil, 2003)

There were 60 subjects (20 males, 40 females) with moderately-severe sensorineural hearing loss. The age range was from 61 to 85 years (mean of 71.7 years, standard deviation of 6.1).

The subjects evaluated their cognitive and psychological aspects whether their performance is normal or abnormal. Then they were submitted to electrophysiological assessment. There were two sessions. The first session employed the cognitive and psychological assessment protocols. In the second one the subjects were submitted to electrophysiological testing.

The depression symptoms were tested with the abridged version of the Geriatric Depression Scale (GDS-15). It consists of 15 questions with 'yes' or 'no' answers. The results were evaluated by the score criteria suggested by Almeida & Almeida [17]. Result higher than five points was taken as an abnormal score. [18]

The individual was first asked concerning the use of medication in the 24 hours prior to the exam, doing extraneous mental or physical activities, smoking and/or ingestion of stimulants, i.e. tea, coffee or chocolate. All the participants answered "no" to these questions. [18]

Electrode positioning followed the International Electrode System (IES) 10-20 (Jasper20) standard, namely, in the front, (Fz) the ground electrode, in the midline of the cranial vertex, (Cz) the active electrode, and in the ear lobes (A1 = left ear and A2 = right ear) the reference electrode. [18]

The subjects were stimulated by a tone burst in the frequency of 500 Hz and 1000 Hz. These frequencies are the most preserved in individuals with hearing loss. [18]

**Results** It was noticed that P300 latency is not influenced by the education variable. But there was a positive correlation between the P300 latency and age, see figure 3.6.

It was observed that the latency might be dependent on the age. Older people had a bigger latency in reactions to stimuli, see figure 3.7.

The P300 latency was explored comparing to the hearing loss degree mean value in the frequencies of 500 and 4000 Hz. There was not found any influence of the degree of hearing loss in the P300 latency.

The advance of age caused an increase in P300 latency. Cognitive performance and depression symptoms, assessed by the MME[3], ADAS-Cog[4] and

[3]Mini-Mental Exam

[4]Alzheimer's Disease Assessment Scale-cognitive

P300 (ms) latency Spearman correlation coefficients with age and schooling.

| | Correlation coefficients |
|---|---|
| Age | r = 0.279 ($p$ = 0.031*) |
| Schooling | r = -0.024 ($p$ = 0.854) |

r: correlation coefficient of Spearman; * significant positive correlation.

Figure 3.6: Correlation between latency with P300 component and age, P300 component and education. It was used Spearman correlation (it is a nonparametric measure of statistical dependence between two variables). As could be seen in the correlation education level does not have any influence on P300 component. [18]

| Age range | n | Mean | Standard deviation | Lowest | Median | Highest |
|---|---|---|---|---|---|---|
| 60-69 | 24 | 342.1 | 45.0 | 289.2 | 337.0 | 500.0 |
| 70-79 | 29 | 368.9 | 58.1 | 272.7 | 358.2 | 500.0 |
| 80 ou + | 7 | 377.6 | 42.2 | 305.7 | 387.7 | 422.7 |
| Total | 60 | 359.2 | 52.7 | 272.7 | 348.0 | 500.0 |

Figure 3.7: Latency-descriptive statistics for latency (ms) per age range. The first column is age range of the subjects. Number of subjects stands for letter $n$. The latency values in ms are in the remaining columns. [18]

GDS[5] did not influence the P300 results in this population. [18]

### 3.1.9 Neural Substrate of the Late Positive Potential in Emotional Processing

**Abstract** The study describes the late positive potential (LPP) as a reliable electrophysiological index of emotional perception in humans. There were discovered three results. The found results may suggest that LPP is generated and modulated by an extensive brain network composed of both cortical and subcortical structures associated with visual and emotional processing and the degree of contribution by each of these structures to the LPP modulation is valence specific. [26]

**Introduction** The affective neuroscience widely uses the event-related potentials (ERP) method. Late positive potential (LPP) appears to be an ERP key component that is evoked by emotionally engaging stimuli. It is charecterized by an amplitude enhancement for pleasant and unpleasant stimuli, relative to neutral stimuli, and has a centroparietal maximum topography [26]. For affective picture viewing, LPP starts ∼300–400 ms after picture onset and is often sustained throughout the duration of picture presentation [16]. LPP amplitude has been shown to vary systematically with the experienced intensity of the affective picture content [35] and exhibit abnormal patterns in mood disorders and other psychiatric conditions [25]. Simultaneously functional magnetic resonance imaging (fMRI) has found that viewing of affective pictures is associated with increased blood oxygen level-dependent (BOLD) activity [32].

There were measured EEG-fMRI when the subjects passively viewed emotionally arousing and neutral pictures. The trial-by-trial LPP amplitude fluctuations were explored whether they are mediated by different neural generators during different affective states by examining the coupling between LPP amplitude and BOLD within each picture category (pleasant, neutral, unpleasant) [26].

**Materials and Methods** The experiment had 11 healthy volunteers. There were seven females. The average age was 20 years.

[5]Geriatric Depression Scale

The scenario set includes 60 pictures divided into three categories - pleasant, neutral and unpleasant (every category had a set of 20 pictures). All pictures were selected from the International Affective Picture System (IAPS) according to their normative valence and arousal levels.

The list of used pictures:

- pleasant: 4311, 4599, 4610, 4624, 4626, 4641, 4658, 4680, 4694, 4695, 2057, 2332, 2345, 8186, 8250, 2655, 4597, 4668, 4693, 8030
- neutral: 2398, 2032, 2036, 2037, 2102, 2191, 2305, 2374, 2377, 2411, 2499, 2635, 2347, 5600, 5700, 5781, 5814, 5900, 8034, 2387
- unpleasant: 1114, 1120, 1205, 1220, 1271, 1300, 1302, 1931, 3030, 3051, 3150, 6230, 6550, 9008, 9181, 9253, 9420, 9571, 3000, 3069

The pictures were selected to cover a wide range of contents and normative ratings. The pleasant pictures in general included sport scenes, romance, and erotic couples, whereas the unpleasant pictures incorporated threat, attack scenes, and bodily mutilations. The neutral pictures included landscapes and neutral human beings. The mean pleasure (valence) rating for pleasant, neutral, and unpleasant pictures was 7.0, 6.3, and 2.8, respectively. The pleasant and unpleasant pictures had similar mean arousal levels (pleasant, 5.8; unpleasant, 5.9), both being higher than neutral pictures (4.2). There were some rules that were followed when the pictures were selected - similar composition, matched in jpeg size across categories, and comparable in rated complexity, to minimize confounds. [26]

Subjects watched a centralized picture on a monitor for 3 seconds. Then there were a random interstimulus interval (2800 or 4300 ms). Every participant has five experimental sessions. Every session consisted of 60 pictures. In every session the pictures were showed in different random order. The random order differed not only across the sessions but also across the subjects. There was placed a cross at the center of the screen to help with the fixation. After the experiment was completed, the subjects were instructed to rate 12 representative pictures (4 pictures within each category) using the self-assessment manikin (SAM). These 12 pictures were not included in the experiment's picture set to prevent habituation for these pictures. [26]

**EEG data preprocessing** When the artifacts were removed from the data records, the low-pass filter was used with the cutoff set at 50 Hz, downsampled

to 250 Hz, and rereferenced to the average reference. These data were then exported to the EEGLAB. Second-order blind identification (SOBI)[6][10] was performed to further correct for eye blinking, residual cardioballistic, and movement-related artifacts. Recent work has shown that SOBI is effective in removing the residual cardioballistic artifact [38], as well as in separating EEG data into physiologically interpretable components [23]. The artifacts-corrected data were then epoched from -300 to 2000 ms with 0 ms being the onset of affective pictures. The prestimulus baseline was defined as -300 to 0 ms. [26]

**Results** The SAM evaluation after the experiment was finished suggested that subjects correctly distinguished the three categories of pictures (valence: pleasant, 6.5; neutral, 5.3; unpleasant, 2.6; arousal: pleasant, 4.7; neutral, 2.9; unpleasant, 4.0). Enhanced positivity for both pleasant and unpleasant pictures, relative to neutral pictures, in the grand average ERP at Pz, starting from 300 ms after picture onset. Since the time interval during which LPP reached a maximum was relatively broad, the LPP amplitude was measured by taking the mean within 300–600 ms, see figure 3.8. There was not found a significant difference between the pleasant and unpleasant stimuli. The ERP difference topography further confirmed that the positivity is strongest among parietal channels for both pleasant and unpleasant conditions. That corresponds with other studies of emotion and motivation. The enhanced positivity was sustained throughout the duration of picture presentation for both pleasant and unpleasant pictures. [26]

**Summary for experiment** The main idea found in the study is to focus on LPP component. A set of pictures can be created according to the rules that were used in the study to select the pictures. The idea to show the cross to aid the fixation is also one of the possibilities. It will be used as an inspiration for ERP data processing.

[6]SOBI is a Matlab extension for EEGLAB. Second Order Blind Identification by joint diagonalization of correlation matrices. THIS CODE ASSUMES TEMPORALLY CORRELATED SIGNALS, and uses correlations across times in performing the signal separation. Thus, estimated time delayed covariance matrices must be nonsingular for at least some time delays. [9]

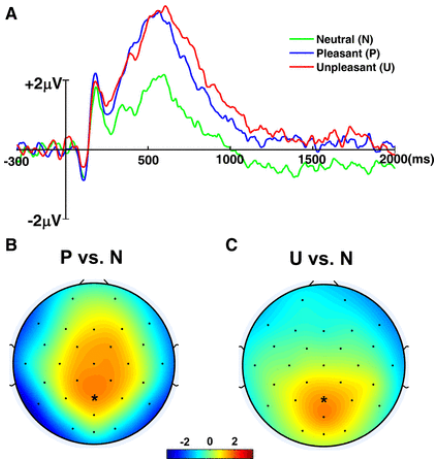


Figure 3.8: ERP analysis. A, Grand average (n = 11 subjects) ERP showing the LPP at Pz with time 0 set to the onset of pictures. B, The scalp topography showing the ERP difference between pleasant and neutral conditions. Here, ERP was averaged within the time interval from 300 to 600 ms. C, The scalp topography showing the ERP difference between unpleasant and neutral conditions. Here, ERP was averaged within the same interval. [26]

### 3.1.10 Using event related potentials method for detection of beer drinkability modification

**Abstract** The study was also focused on a beer drinkability using P300 component and tried to simplify the scenario from the previous experiment [21].

**Introduction** My bachelor thesis was focused on detection of beer drinkability using event related potentials method. Unfortunately even when the measured data delivered expected results, there were no meaningful conclusion from them. The outcome was too ambiguous. Therefore the experiment was modified.

**Experiment background** Ten students, seven males and three females, participated. Two of them were left handed.

Each participant got six beer cans, three cans of beer A and three cans of beer B. Every day he or she drunk one of the each beer. He or she was

drinking for three days. The fourth day the subject came to the lab and he or she was measured with EEG cap using Fz, Pz, Cz, O1 and O2 electrodes.

**Experiment scenario** The measurement was divided into two main parts. In the first part the subject was watching a black screen. There were four pictures used as stimuli (Beer A, Beer B, Water, no label) with probability of 10%, 10%, 10% and 70%. The target stimuli were Beer A, Beer B and Water. The participant had no further instructions.

The second part of the experiment was the same as the first one only the subject was instructed to concentrate on the favourite beer. There was an assumption, due to this concentration, that the favourite beer had to elicit greater reaction. This reaction should be found primarily in P300 wave.

**Conclusion** The measured data differed in every subject. There were no clear reaction in investigated components (mainly P300) after processing. Bigger sample would be needed to measure but better way was to modified the whole experiment.

# 4 Experiment

## 4.1 Summary from studies

Amount of participants was usually between 4 and 15 in EEG/ERP experiments.

Visual or auditory stimuli were used to elicit the emotions. Most of the experiments examined the visual stimuli.

Every studied experiment focused on emotions elicited by visual stimuli used standardized self-report SAM questionnaire. Emotional experiments often used peripheral devices as a supplement for EEG/ERP data (mostly GSR, blood pulse, body temperature and respiration).

The selected pictures amount was ordinarily in range between 20 and 100 pictures. The pictures were divided into three categories: pleasant, neutral and unpleasant. The IAPS database served as a picture source in all investigated studies.

Most of the time, the measured component was LPP. Some studies were focused on earlier components.

## 4.2 Experiment basic design

The experiment was based on visual stimuli. The IAPS database was selected as a non-target stimuli pictures source because it contains detailed statistics from SAM to every picture. Target stimuli were downloaded from different commercial or free sources.

The EEG/ERP recordings were extended by two more peripheral devices - blood pulse and skin conductance. It was not possible to use more peripheral devices because the recording device has only two peripheral ports.

There were 80 pictures selected. They were divided into four categories: 20 pleasant pictures, 20 neutral pictures, 20 negative pictures and 20 target pictures. Every picture would be repeated three times.

The target pictures are composed of beer photos. The photo cannot contain anything that can distract attention from the beer (e.g. focused human face or animals).

Late positive potential was chosen as a main component but earlier components were also taken into account.

The scenario lasts for 60 minutes.

## 4.3 Instructions for subjects

The followed instructions will be translated to the Czech language and it will be given to the subjects. Before start, please fill the questionnaire. The important points are labeled with the *. The experiment consists of two parts. Both parts will be done simultaneously.

The first part is pictures evaluating. You will be watching different pictures projected on the screen in front of you. You will rate each picture in terms of how you felt while viewing it. The pictures are divided into three categories - positive, neutral and negative. Pictures will be selected and projected randomly. You will watch each picture only once. There are no right or wrong answers, so simply respond as honestly as you can.

There are 3 sets of 5 figures on the second screen next to you, see figure 4.1. You will be using these figures, that are called SAM, to rate how you felt while viewing each picture. You will make all three ratings for each picture that you observe. SAM shows three different kinds of feelings: Happy vs. Unhappy, Excited vs. Calm, and Controlled vs. In-control.[24]

The first SAM scale is the happy-unhappy scale. If you felt completely happy while viewing the picture, select the figure at the left. The other end of the scale is when you felt completely unhappy, annoyed, unsatisfied, melancholic, despaired, bored. The figures also allow you to describe intermediate feelings by clicking on any of the other pictures. If your feeling falls between two of the pictures, then click between the figures. This permits you to make more finely graded ratings of how you feel in reaction to the pictures. [24]

Other two scales are rated in the same way. For excited vs. calm scale, if you are stimulated, excited, frenzied, jittery, wide-awake, aroused, mark the figure at the left of the row. The opposite side is when you felt completely

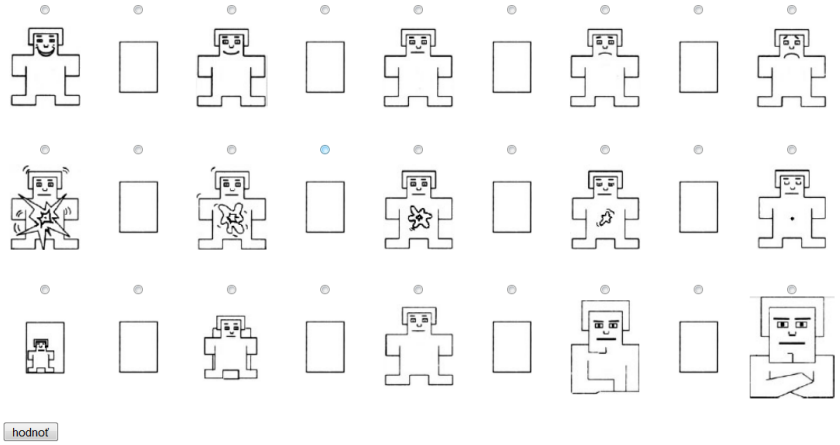


Figure 4.1: SAM online form

relaxed, calm, sluggish, dull, sleepy, unaroused. The last scale's (controlled vs. in-control) left end of the row is when you were completely controlled, influenced, cared-for, awed, submissive, guided. On the other hand, select the right end of the row when you felt completely controlling, influential, in control, important, dominant, autonomous. Note that when the figure is large, you feel important and influential. When it will be very small, you feel controlled and guided [24].

Some of the pictures may prompt emotional experiences. Others may seem relatively neutral. Your rating of each picture should reflect your immediate personal experience. Important is to rate each picture as you actually felt while you watched the picture! [24]

The procedure will be as follows. There will be a warning slide that will inform you that the picture will be shown. It is important that your eyes will be directed towards the screen when the picture is shown [24]. There are two seconds to watch the picture. It is important to view the picture for the entire time and make your rating right after the picture disappears. Another warning slide will be shown before another picture is shown. Warning slides will be shown for two seconds. If, for any reason, you miss viewing any picture, please leave that rating row blank.

The time to evaluate the picture is accompanied by a slide that informs you to rate the picture on all three dimensions. Rate every picture in a short time because the time to evaluate is limited. Also it is important to express the first feeling or emotion that was invoked by the picture.

The second part contains EEG measurement. When you will be watching the pictures you will also wear an EEG cap. It is important to reduce eye-blinking to minimum when the rated picture is shown.

## 4.4 Subject preparation

After the subject was instructed with the experiment, subject preparation starts.

The first thing that needs to be done is the skin spots cleaning where the ground and reference EEG channels will be placed. The next step is to place the EEG cap and stick the reference and ground channels. The last point is minimization of skin impedance. It is done by application of a conductance gel and it is controlled by the brainvision recorder software, more about the software in section 4.6.2.

When the subject is ready for the experiment, he or she is moved into special soundproof chamber, see figure 4.2. It also helps to limit the influence of electrical devices on measured EEG signal.

The approximate time to prepare one subject was around one hour (up to two hours with the laboratory preparation).

## 4.5 Time consuming

Time spent in a laboratory per one subject is approximately three hours (it includes an experiments itself, subject preparation, laboratory preparation and paperwork[1]).

Data processing of one subject took about two hours.

The biggest problem appeared to be finding test subjects. Their reliability to come to the experiment was another big problem.

[1] the employment agreement, collecting personal data etc.

Figure 4.2: Subject preparation

## 4.6 Data measuring and processing

### 4.6.1 Presentation

The experiment scenario was written using software Presentation from Neurobehavioral Systems [4]. It allows users to deliver stimuli codes to measuring software and to write various kinds of scenarios.

It has its own language to create a scenario. The language consists of two parts - SDL (Scenario Definition Language) and PCL (Presentation Control Language). A scenario description can be divided into 3 parts: an SDL header section, an SDL section, and a PCL section (optional) [37].

The part of the scenario file:

```
# SDL header part
scenario = "emotions";
active_buttons = 1;
# zapis kodu stimulu na vystupni port
write_codes = true;
# sirka pulzu na paralelnim portu v ms
```

```
pulse_width = 100;
...

begin;

# SDL part
picture {bitmap { filename = "..\\1463.jpg"; }; x = 0; y = 0;}p1;
...

begin_pcl;

# PCL part

pictures.shuffle();

int size = pictures.count();
loop
int i = 1
until
i > size
begin
pictures[i].present();
blackclear.present();
i = i+1;
end;
```

In the first part, there is a SDL header part. It contains the scenario name, number of active buttons[2]. There is an information whether the code is send to parallel port. It is important. The recording software cannot recognize when the stimulus came without it. The constant sets the width of pulse send to parallel port.

The second part is SDL part. There are created picture objects that will be used in the scenario.

The last part contains PCL code. It operates the whole scenario. It shuffles the pictures and it displays and hides the pictures.

[2]Buttons used to control the scenario

**SLD** is a function specifying scenario objects and definitions. It is the main part of the scenario. The SDL part of scenario is processed before the scenario even starts.

**PCL** is a programming language. The PCL is compiled into an intermediate form, and then Presentation executes those instructions when the scenario runs. A PCL program has access to all the scenario objects defined in SDL and can manipulate them. Since PCL is a real programming language, there can be implemented almost any kind of experimental behavior (e.g. visual or audio stimuli). [21]

### 4.6.2 BrainVision recorder

It is a multifunctional software tool to record the EEG signals and to set the EEG cap. The peripheral devices can be recorded too. The acquired data can be displayed in multiple ways and the channel montages (original, bipolar and average) can be switched on the fly, to adjust the channel view to the specific experiment's needs [11].

**Setting up a workspace** Firstly, a new workspace for the experiment has to be created. EEG files storage, amplifier parameters and more data are set there.

**EEG cap preparation** Before the experiment is started, the device must be correctly prepared. It means that the EEG cap impedance must be set to the minimum. There is a special menu item for this named **Impedance check**. It shows a symbolic representation of a head, as shown in figure 4.3. The channel by channel impedance check is extremely simple. Each electrode is placed at the topographic position and its impedance value is displayed with a fully selectable color coding [11].

The experiment also uses two more peripheral devices. The first one measures the blood pulse and the second one records the changes in skin resistance. Both are recorded by the BrainVision recorder.

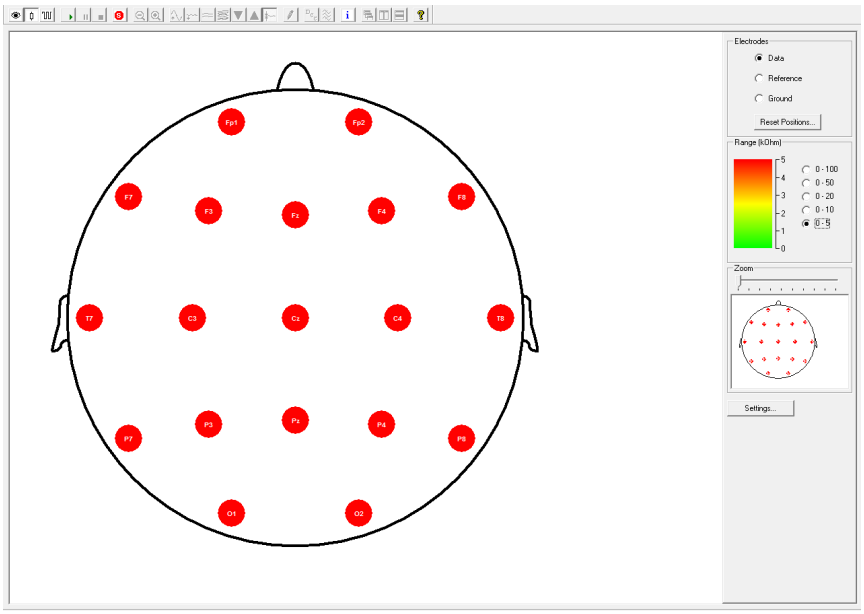


Figure 4.3: BrainVision channels impedance check

**Data recording** The experiment can be started after the subject is fully connected and all the channels impedances are set to the minimum. Then the scenario is launched from the Presentation software. The Presentation software sends stimuli to parallel port and they are recorded in BrainVision recorder. The process can be watched in BrainVision monitoring screen. The monitor is divided into two parts. The first part shows the immediate EEG and in the second part there are averages of the channels for all used stimuli, see figure 4.4.

### 4.6.3 EEGLAB and ERPLAB

When the data are collected, they have to be processed. A great processing tool is EEGLAB from SCCN (Swartz Center for Computational Neuroscience)[3]. It is distributed in two main versions. The first version is fully self-sufficient and it does not need any other programs to cooperate with (it is the biggest advantage of this version). However, there is a big disadvantage because it cannot use other plugins. The second version has been used for this reason. It requires the Matlab software tool installed on the computer. However, it allows to use additional plugins. They are needed to process the data fully.

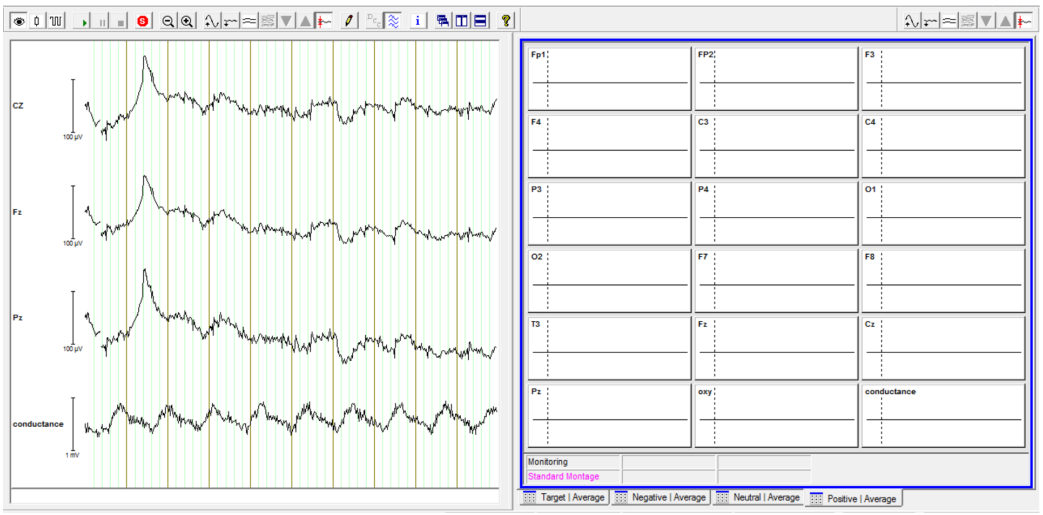


Figure 4.4: BrainVision monitoring screen

The used plugin is called ERPLAB[5] and it is developed at the UC-Davis Center for Mind & Brain. It extends the EEGLAB functions.

Both toolboxes are distributed as open-sources for free.

**Data filtration** There are three types of filters in ERPLAB: IIR Butterworth, FIR and Parks-McClellan Notch. The IIR Butterworth was selected because Parks-McClellan Notch does not allow to set high and low pass filters and FIR filter can produce artificial oscillations in the filtered data.

High-pass filter usually filters out slow artifact, such as electrogalvanic signals and movement artifacts. Typical values are between 0.5 and 1 Hz. [30] The recommended values from ERPLAB manual[6] are 0.1 Hz or lower. Therefore the value was set to 0.1 Hz.

Low-pass filter filters out high-frequency artifacts, such as electromyographic signals. Typical setting is from 35 to 75 Hz.[30] The recommended values from ERPLAB manual[6] are 20 Hz or higher. The used value was set to 40 Hz.

**Extracting epochs** The epoch extraction of ERP signal and peripheral devices' signal is different in time interval.

The ERP signal epoch is extracted from -500 ms prior the stimulus onset to 1000 ms after the stimulus onset. The interval 0-1000 ms was selected because of positive late potential (LPP) which appears between 300 and 1000 ms. The interval prior stimulus onset serves to baseline correction. Baseline correction removes the mean of the recorded baseline. The interval is prior stimulus because it is desirable to have a time range where one can reasonably assume that the brain is not producing any stimulus related activity [7].

The skin conductance and blood pulse signals were extracted in interval 0-6000 ms. The interval was selected according to similar studies using these peripheral devices.

**Artifacts removing** ERPLAB has a tool for automatic artifact detection. The voltage treshold, the difference between the largest and smallest values, was set to 100 $\mu$V. It removed most of the artifacts. The rest of the artifacts had to be removed manually. Lower values tend to remove too many epochs (more than 60 %).

## 4.7 Results

### 4.7.1 Tested sample

The final sample, which was processed, consists of 14 subjects. There were seven male and seven female subjects. The age of subjects was between 20 and 34 years, average age was 26 years with 4 years standard deviation. All subjects were right handed and in perfect physical and health condition. All subjects are or used to be university students.

Total amount of the experiments, including tuning of the experiment, was over 30.

### 4.7.2 Subjects' feelings

It was a first experience with this kind of experiment for every tested subject and they described it as an interesting experience.

Because the experiment was in a special dark room, most of the subjects felt tired at the end of the experiment. It influenced the recorded data, but the influence was noticed only in the frequency of eye blinking. Therefore the later data contained more artifacts. The quality of measured data remained stable for the whole experiment.

The subjects complained about filling the questionnaire. They lost a concentration because of it and they found out hard to concentrate back again.

Some of the subjects were influenced by the negative pictures so much that they were afraid of the next picture before it even appeared. On the contrary some, of the subjects did not have any special feelings at all during the session. Also there was a small group that perceived pictures from the art view but the results did not differ from the results of rest subjects so the data were included in the final processing.

### 4.7.3 ERPs and Peripherals

The data were divided into several categories:

1. All subjects
2. Males only
3. Females only
4. Subjects that like beer (STLB)
5. Subjects that do not like beer (STDNLB)

There was no subject that would have not positive or negative attitude to beer.

**ERPs** The **all subjects** group has the biggest activity across all channels from 200 ms to 600 ms. The occipitals (O1 and O2) and parietals (P3, P4 and Pz) channels also have a big activity between 50 and 150 ms with a peak at 100 ms, see figure 4.6. The amplitude is between 6 and 9 $\mu$V in occipitals and between 2 and 7 $\mu$V in parietals. The Cz channel has the early activity

shifted and it starts at 150 ms and ends at 220 ms with peak around 190 ms with the amplitude in range from -1 to 3 $\mu$V, see figure 4.5.

The other groups waves have the similar waves with the peaks in time that correspond with the **all subjects** group.

The early response, around 200 ms, is in the average more uniform in latency in the comparison between **all subjects** and **STLB**, see figures 4.5 vs. figure 4.7 and 4.6 vs. 4.8. Also the target wave of **STLB** group differs less from the other waves in the late positive potential (300ms and later). There is difference only 7 $\mu$V in the peak at 450 ms (STBL) in compare to 11 $\mu$V in **all subjects** group.

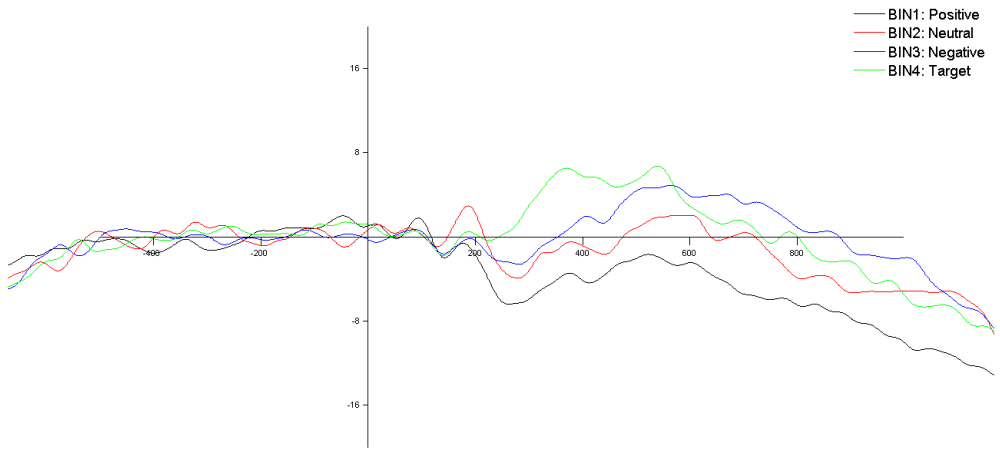


Figure 4.5: Grand average across all subject, Cz channel

Comparison between **STLB** and **STDNLB** shows in early response across the channels similar characteristics. In **STLB** group the positive and target waves are close together (difference less then 1 $\mu$V at a peak in 120 ms with approximately 8 $\mu$V amplitude in occipitals which have the biggest reaction in early response). On the contrary, the target and negative waves are close to each other in the **STDNLB** group (both reach 6 $\mu$V at a peak in 120 ms), see figures 4.9 and 4.10. **STLB** has target waves closest to negative in late positive potential in all measured channels. Target waves of **STDNLB** differs from the other non-target waves and the **STDNLB** group has a perceptible deviation in amplitude of target in late positive potential over all measured channels (it differs up to 16 $\mu$V in the biggest spread).

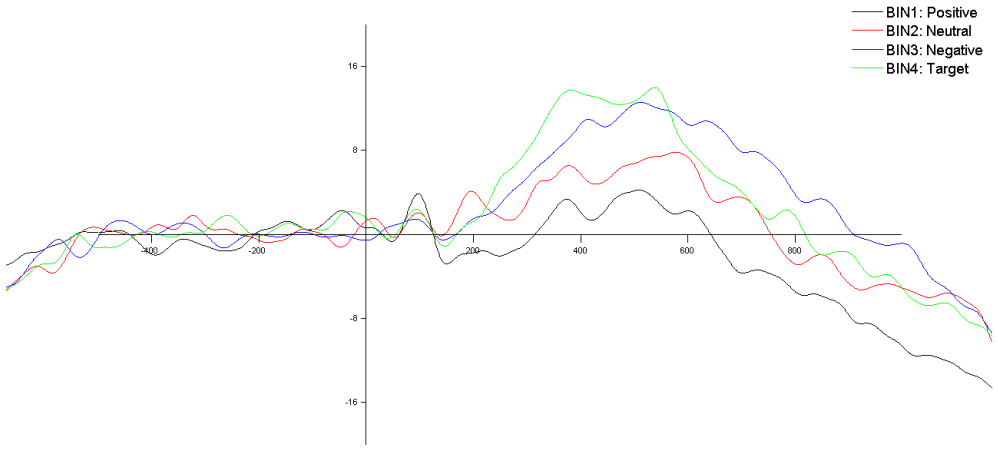


Figure 4.6: Grand average across all subject, Pz channel

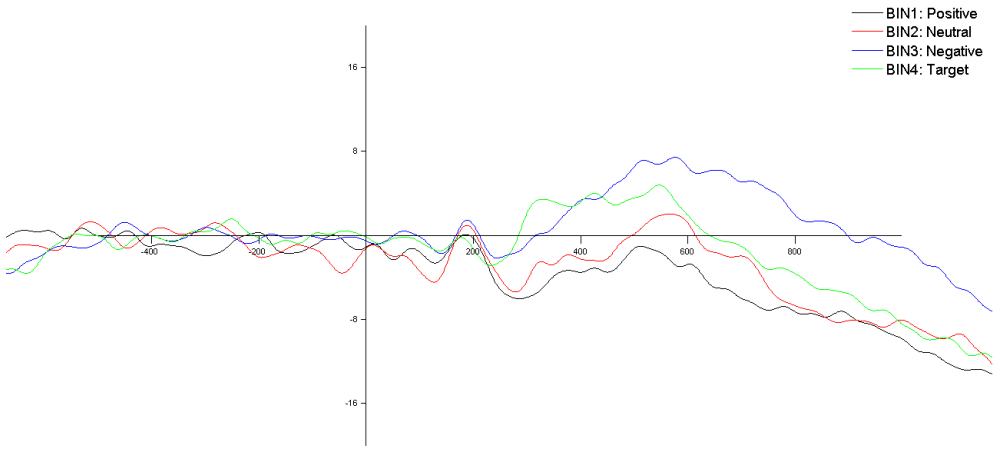


Figure 4.7: Grand average across all STLB, Cz channel

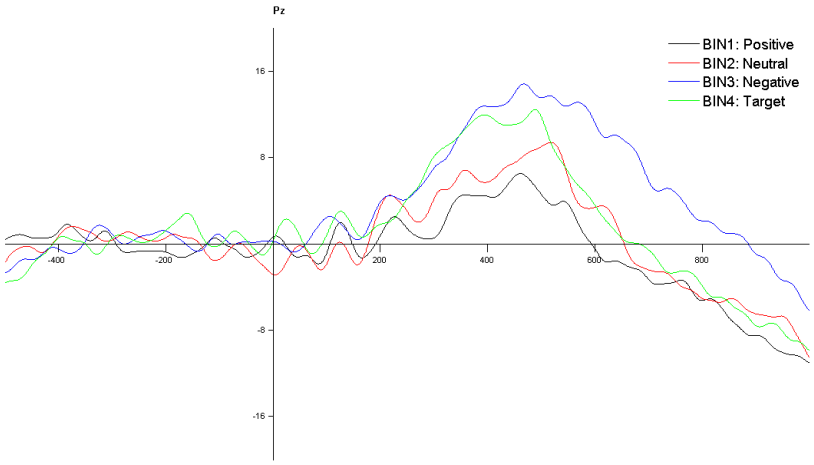


Figure 4.8: Grand average across all STLB, Pz channel

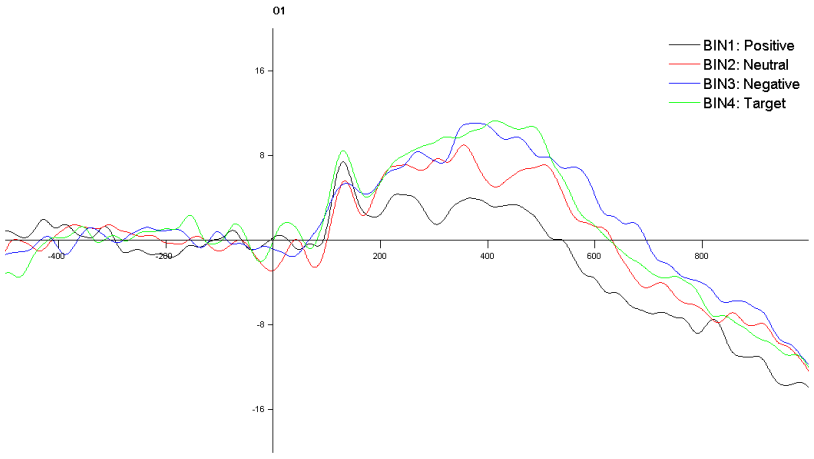


Figure 4.9: Grand average across all STLB, O1 channel

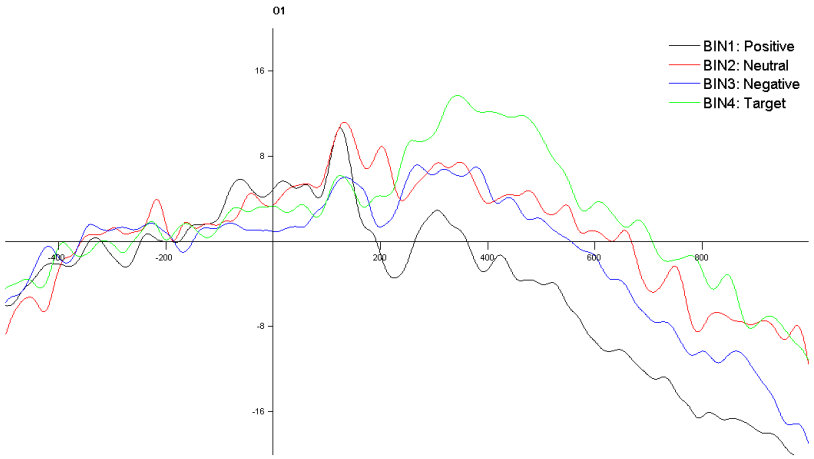


Figure 4.10: Grand average across all STLB, O1 channel

The **males only** and **females only** groups are mixed from both categories - **STLB** and **STDNLB**. **Males only** group has no stimulus in great deviation from others in early response time and target stimulus is close to the negative stimulus in late positive potential between 300 and 500 ms over all channels (the difference between target and negative did not outreached 4 $\mu$V compare to difference up to 8 $\mu$V between target and neutral or positive). **Females only** group has different positions and similarities across the channels in early response time and closest to the neutral or negative stimuli in late positive potential.

All the figures can be found on the attached DVD.

**Peripherals** The skin conductance was processed as a grand average across the subjects according to studied experiments, see [12]. It was also evaluated by a simple eye checking of the single subject raw signal, see [16].

There was a problem because both peripheral devices were attached to hands which were in constant movement. It was caused because of the SAM evaluation. That probably caused the big differences among single stimuli and also among the subjects. The grand averages differs up to hundreds of percent, see figures 4.12, 4.13 and 4.13. When the signal was evaluated as a function in time, there was not also determined any valuable conclusion, see example in figure 4.11. The same problem was with the blood pulse.

Therefore it is inappropriate to include the results from the peripheral devices into the final results.

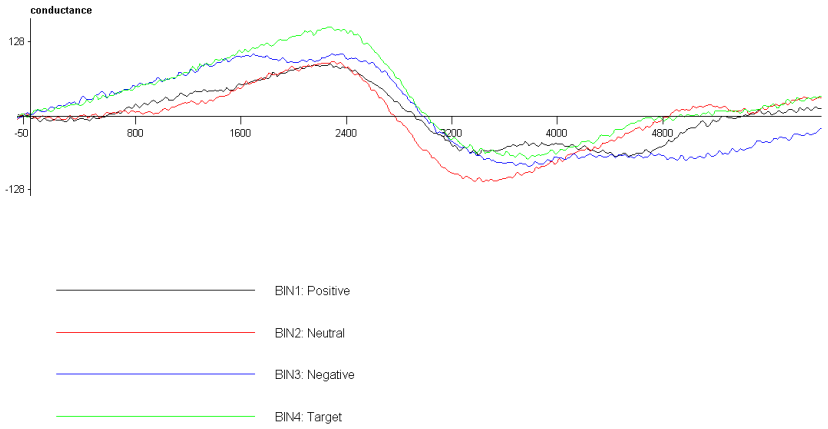


Figure 4.11: Skin conductance of a single subject. The horizontal axe is a time interval from 0 ms to 6000 ms. The vertical axe represent $\mu$Siemens$\cdot 10^{-3}$.

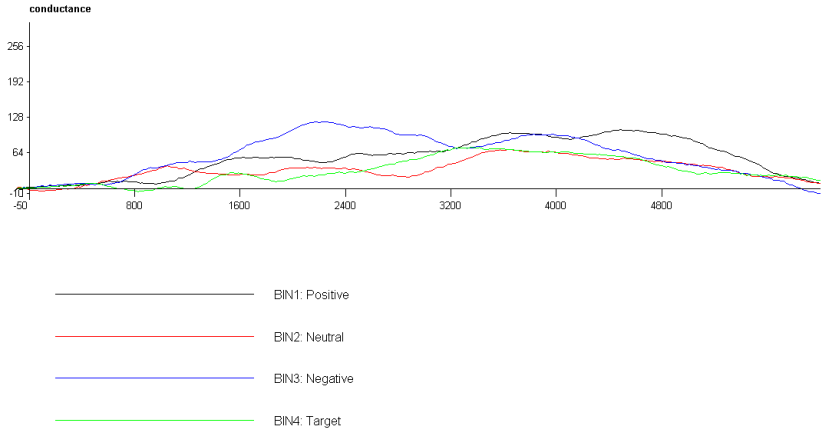


Figure 4.12: Grand average across all subjects, skin conductance. The horizontal axe is a time interval from 0 ms to 6000 ms. The vertical axe represent $\mu$Siemens$\cdot 10^{-3}$

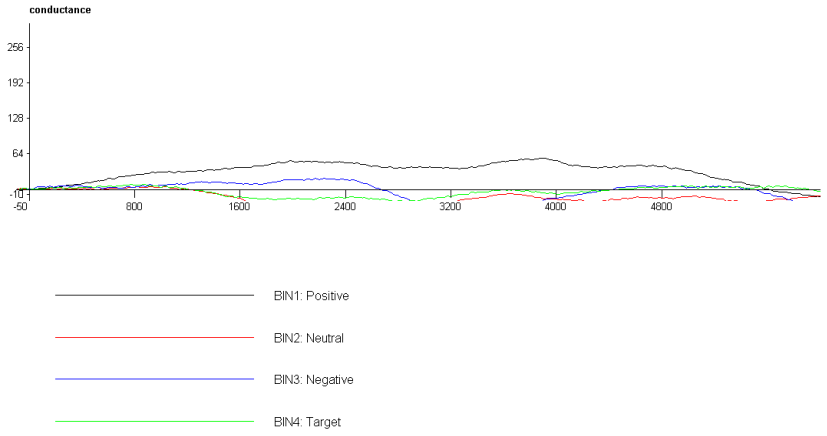


Figure 4.13: Grand average across all STLB, skin conductance. The horizontal axe is a time interval from 0 ms to 6000 ms. The vertical axe represent $\mu$Siemens$\cdot 10^{-3}$

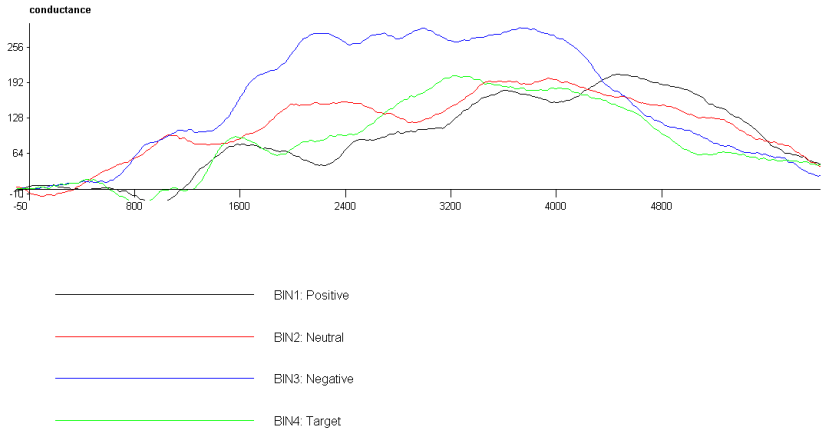


Figure 4.14: Grand average across all STDNLB, skin conductance. The horizontal axe is a time interval from 0 ms to 6000 ms. The vertical axe represent $\mu$Siemens$\cdot 10^{-3}$

### 4.7.4 Questionnaire

The SAM results correspond with the IAPS standard measurements, see figure 4.15.

According to figure 4.16, the biggest conformity in the SAM results was observed between target and neutral stimuli (over 83 %, 68 % and 94 % match in valence, arousal and dominance scale respectively). The **STLB** indicates a bigger shift to positive stimuli than **STDNLB** (79,5 % vs. 61 % and 93,2 % vs. 82,3 % match in valence and dominance scale respectively) and **STDNLB** are closer to negative response than **STLB** (53,5 % vs. 39 % and 76 % vs. 64,7 % match in valence and dominance respectively). But the average is still closest to the neutral.

| VALENCE | All subjects | Subjects that like beer | Subjects that do not like beer | Males only | Females only |
|---|---|---|---|---|---|
| positive | 7,65 | 7,49 | 7,82 | 7,53 | 7,76 |
| neutral | 5,07 | 4,98 | 5,15 | 5,16 | 4,97 |
| negative | 2,43 | 2,33 | 2,52 | 2,51 | 2,35 |
| target | 5,45 | 5,96 | 4,77 | 5,8 | 5,14 |
| | | | | | |
| AROUSAL | All subjects | Subjects that like beer | Subjects that do not like beer | Males only | Females only |
| positive | 5,41 | 5,32 | 5,55 | 5,34 | 5,48 |
| neutral | 3,07 | 2,82 | 3,23 | 2,94 | 3,18 |
| negative | 5,6 | 5,42 | 5,78 | 5,38 | 5,81 |
| target | 4,02 | 4,13 | 3,88 | 4,08 | 3,95 |
| | | | | | |
| DOMINANCE | All subjects | Subjects that like beer | Subjects that do not like beer | Males only | Females only |
| positive | 6,4 | 6,32 | 6,57 | 6,36 | 6,48 |
| neutral | 5,55 | 5,65 | 5,45 | 5,37 | 5,73 |
| negative | 4,02 | 3,81 | 4,11 | 3,93 | 4,08 |
| target | 5,6 | 5,89 | 5,41 | 5,71 | 5,5 |

Figure 4.15: SAM results in valence, arousal and dominance scale

| Valence | All subjects | STLB | STDNLB | Males only | Females only |
|---|---|---|---|---|---|
| target vs. positive | 71,24183007 | 79,57276368 | 60,99744246 | 77,0252324 | 66,2371134 |
| target vs. neutral | 93,02752294 | 83,55704698 | 92,62135922 | 88,96551724 | 96,692607 |
| target vs. negative | 44,58715596 | 39,09395973 | 53,4591195 | 43,27586207 | 45,71984436 |
| | | | | | |
| Arousal | All subjects | STLB | STDNLB | Males only | Females only |
| target vs. positive | 74,30683919 | 77,63157895 | 69,90990991 | 76,40449438 | 72,08029197 |
| target vs. neutral | 76,3681592 | 68,28087167 | 83,24742268 | 72,05882353 | 80,50632911 |
| target vs. negative | 79,44664032 | 76,19926199 | 67,12802768 | 75,83643123 | 67,98623064 |
| Dominance | All subjects | STLB | STDNLB | Males only | Females only |
| target vs. positive | 87,5 | 93,19620253 | 82,34398782 | 89,77987421 | 84,87654321 |
| target vs. neutral | 99,10714286 | 95,92529711 | 99,26605505 | 94,04553415 | 95,98603839 |
| target vs. negative | 71,78571429 | 64,68590832 | 75,97042514 | 68,82661996 | 74,18181818 |

Figure 4.16: SAM percentage match between target and non-target stimuli in valence, arousal and dominance scale

# 5 Conclusion

The experiment was several times modified because the measured data did not correspond with expected assumption. In the final experiment, there were 14 subjects (without subjects that were used to test the designed experiment). The results from SAM questionnaire corresponds with the IAPS measurements. According to SAM results, the tested sample has response for the target stimuli almost equal to neutral stimuli (85 % vs. 95,8 % in conformity of STLB, STDNLB respectively, between target and neutral value in valence scale). Subjects that like beer (STLB) have it also in the neutral area but it is more shifted to positive (79,5 % vs. 61 % in conformity of STLB, STDNLB respectively, between target and positive value in valence scale) and subjects that do not like beer (STDNLB) have it moved to negative (39 % vs. 52 % in conformity of STLB, STDNLB respectively, between target and negative value in valence scale).

The results from event related potentials imply that subjects that like the beer have target closer to the positive in late positive potential and subjects that do not like beer have it near to the negative wave in LPP. It may support the small variance to negative or positive in the SAM results.

The data from the peripheral devices were too distorted. A necessity of subjects almost constant movements during the experiment could be the reason. The cabin where the experiment was performed only has amplifier available that cannot work with peripheral devices. The amplifier that works with peripheral devices was always pinched in a cabin door. There can be a link interruption during amplifier displacement.

The improvement are:

1. Increase a test sample (tens of subjects) - by measuring a small group of subjects there is always great risk of data distortion. Unfortunately, these studies are very time consuming and even the model studies used only a small samples.

2. Skip the peripheral devices - subjects can feel uncomfortable with wearing so many devices and wires and it can also influence the acquired data.

3. Change the times in the experiment - make the picture projection

shorter or longer and also the pause between the picture can be changed.

4. Make the experiment in two sessions. The first session will be focused only on ERP and the second session will focus on SAM. Or vice versa. Then the subjects can remain concentrated for the whole experiment. There is also advantage that the movement will be reduced to minimum so the peripheral devices could be used.

5. Do not repeat the already shown pictures.

6. Change the amount of pictures. Some studies used only small sets (e.g. 20 pictures), other had a big picture sets containing hundreds of pictures.

7. Extend the cabin hardware to allow plugging in the peripheral devices.

# List of abbreviations

| | |
|---|---|
| BOLD | Blood oxygen level-dependent |
| EEG | Electroencephalography |
| ERP | Event-related potential |
| fMRI | Functional magnetic resonance imaging |
| fNIRS | functional near-infrared spectroscopy |
| GA | Grand average |
| GSR | Galvanic Skin Response |
| IAPS | International Affective Picture System |
| LPP | Late positive potential |
| MEG | Magnetoencephalography |
| PCL | Presentation Control Language |
| SAM | Self-Assessment Manikin |
| SD | Standard deviation |
| SDL | Scenario Definition Language |
| STLB | Subjects that like beer |
| STDNLB | Subjects that do not like beer |

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# Attachment A

## Scenario guide translation

Experiment sestává ze 2 měření, která probíhají současně. Měření se zopakuje třikrát.

První částí je hodnocení obrázků. Budete sledovat různé obrázky promítané na monitor před vámi a budete hodnotit každý obrázek podle toho, jak na vás působil, když jste ho viděli. Obrázky jsou rozděleny do tří kategorií - pozitivní, neutrální a negativní. Obrázky jsou vybírány a promítány v náhodném pořadí. Každý obrázek se vám zobrazí v každém měření pouze jednou (celkem tedy třikrát). Nejsou zde správné nebo špatné odpovědi, takže odpovězte tak, jak to opravdu cítíte.

Pro hodnocení budete používat SAM, což je dotazník sestávající ze 3 hodnotících škál, které jsou rozděleny na 9 stupňů. Pro každý obrázek budete vybírat z každé škály jednu možnost. Jednotlivé škály jsou - veselý vs. smutný, vzrušený vs. klidný a kontrolovaný vs. kontrolující, viz obr. 3.

První škála je veselý vs. smutný. Pokud se cítíte úplně šťastní, vyberte obrázek nalevo. Druhý konec vyberte, pokud se cítíte zcela nešťastný,naštvaný, nespokojený, melancholický, zoufalý, znuděný. Máte také možnost vybrat mezistupně v celém rozsahu škály. Můžete vybrat i obdélníček mezi dvěma postavičkami.

Další 2 škály se hodnotí stejným způsobem.

Škála vzrušený vs. klidný - pokud se cítíte stimulovaně, vzrušeně, zběsile, nervózně, zcela probuzeně vyberte postavičku úplně vlevo. Opačnou stranu stupnice vyberte, pokud se cítíte zcela zrelaxovaně, klidně, netečně, ospale,

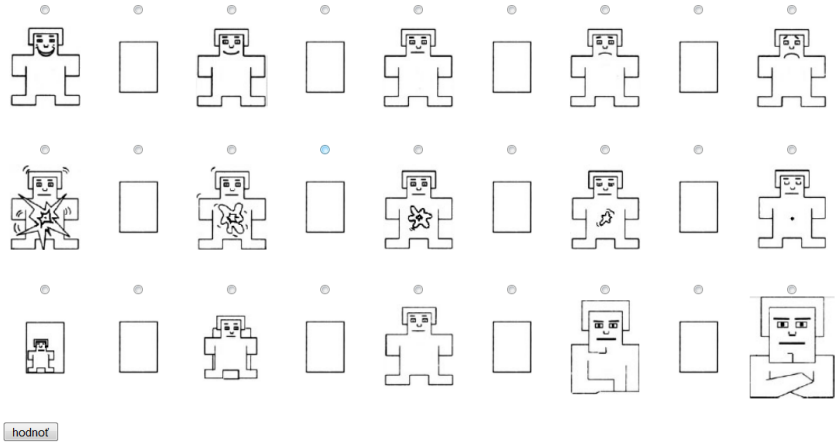


Figure 1: SAM online verze

nevzrušeně.

Poslední hodnocení je řízený vs. řídící. Máte-li pocit, že se cítíte úplně řízeně, ovlivněně, starajícně, ohromeně, submisivně, vyberte figurku úplně vlevo. Druhou stranu zvole cítíte-li se zcele řídící, vlivně, důležitě, dominantně, nezávisle. Poznámka - když je figurka veliká, tak se cítíte důležitě a vlivně, pokud je malá cítíte se řízeně a submisivně.

Některé obrázky mohou vyvolávat emoce, některé mohou vypadat relativně neutrálně. Vaše hodnocení každého obrázku by mělo odrážet vaše okamžité osobní zkušenosti. Důležité je hodnotit každý obrázek tak, jak jste se v daný okamžik cítil/a.

Postup bude následující. Před každým obrázkem bude zobrazen slide, který informuje, že se zobrazí obrázek. Informující slide bude zobrazen po dobu 2 vteřin. Je důležité koukat se na přímo monitor, když je obrázek zobrazen. Obrázek bude možné sledovat po dobu 2 vteřin. Je důležité sledovat obrázek po celou dobu a ihned po zmizení jej ohodnotit. Jestliže z jakéhokoli důvodu nestihnete obrázek ohodnotit, nechtě hodnocení prázdné.

Čas na hodnocení je doprovázen slidem, jenž vás informuje k ohodnocení všech 3 stupnic. Jelikož je na hodnocení jenom omezené množství času, neváhejte s hodnocením. Je také důležité, abyste vyjádřil/a první emoce, které to ve vás vyvolalo.

Jestliže máte jakékoli otázky, tak se neváhejte zeptat. Pro připomenutí,

použijte veškerý čas na sledování obrázku a poté se pokuste co nejrychleji tento obrázek ohodnotit a buďte připraveni sledovat další obrázek. Pamatujte si, že zde nejsou špatné či správné odpovědi. Hodnoťte všechny 3 škály.

Druhá součást měření je snímání mozkové aktivity. Během celého experimentu budete mít na hlavě speciální čepici, která vám bude snímat EEG a ještě 2 další senzory, které budou snímat odpor kůže a váš tep. Je důležité redukovat mrkání na minimum, když je zobrazen obrázek, který máte hodnotit.

# Attachment B

## Photos

All the photos are on the attached DVD. There are only examples from each category. All non-target stimuli are from the IAPS database [24].

Figure 2: Experiment photo - positive 1 [24]

Figure 3: Experiment photo - positive 2 [24]

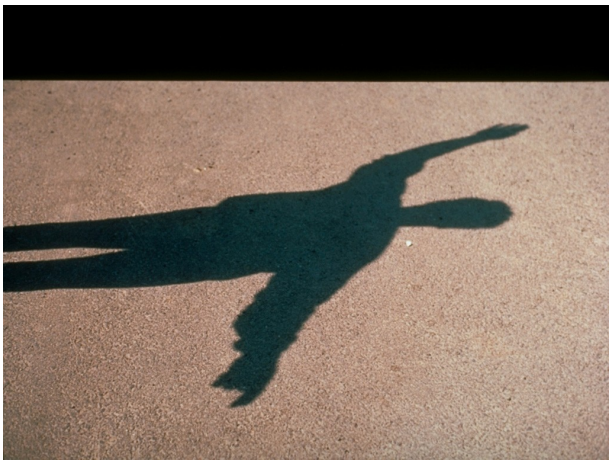

Figure 4: Experiment photo - neutral 1 [24]

Figure 5: Experiment photo - neutral 2 [24]

Figure 6: Experiment photo - negative 1 [24]

Figure 7: Experiment photo - negative 2 [24]

Figure 8: Experiment photo - target 1 [1]

Figure 9: Experiment photo - target 2 [2]

# Attachment C

## EEGLAB and ERPLAB manual

**Data process instruction** The first step is to import the recorded data. It is done by *File→Import data→Using EEGLAB functions and plugins→From Brain Vis. Rec. .vhdr file.* The *Load a Brain Vision Data Exchange format dataset* window allows to choose the interval and channels. It loads all the intervals and channels when no values are filled. The possibility to name the dataset pop-up in with next window. It is not required but recommended because orientation among the datasets is easier.

The next step is signal filtration. It is located in *ERPLAB→Filter & Frequency tools→Filters for EEG data*, see figure 10. The important values to set are *Filter type* - IIR Butterworth, *Cutoff frequencies* - High-Pass = 0.1 Hz and Low-pass = 40.0 Hz. With these setting it is ready to apply.

The next step is creating an event list, *ERPLAB→EventList→Create EEG eventlist.* Select the option **Advanced** in the pop-up window. Then fill up the *Event Info* and *Bin Info* fields with the stimuli codes and names, see figure 11.

Once the data are filtered and the event list is created, they are ready to epoch extraction, *ERPLAB→Extract bin-based epochs.* Choose the epoch time range (it is dependent on the component that is looked for). It was set -500 1000 for ERP signal and 0 6000 for peripheral devices' signal, see figure 12. Baseline Correction was set as *Pre.*

Currently there are only the stimuli in selected range (-500 1000 ms, 0 6000 ms respectively). These data need to be devoid of the artifacts, e.g. eye-blinks. It can be done manually or there are various automated filters. *Simple*

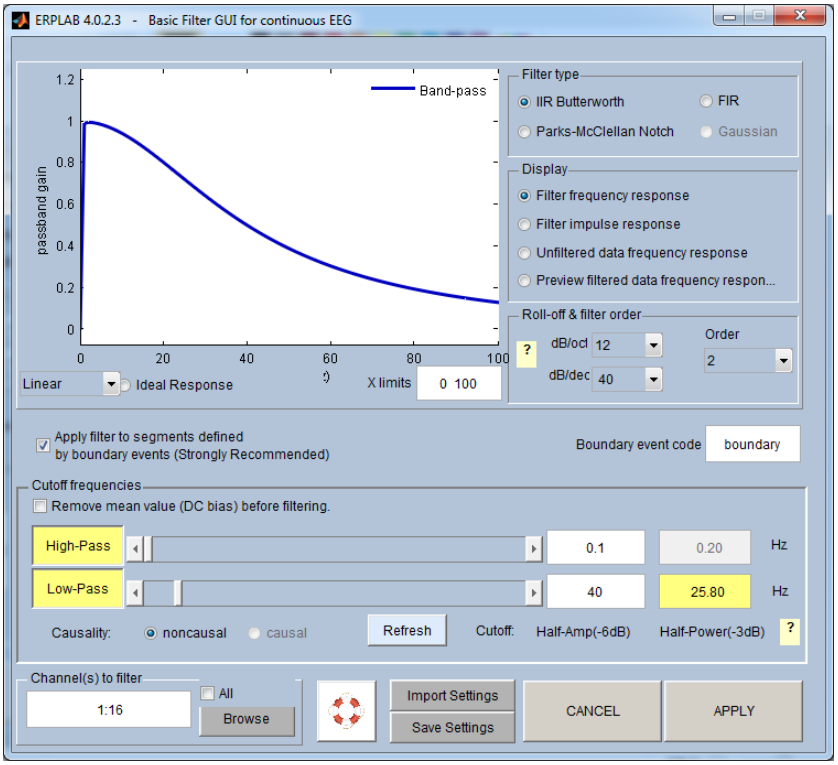


Figure 10: ERPLAB data filtration window. There are various filter options. It is used to remove noise from the signal.

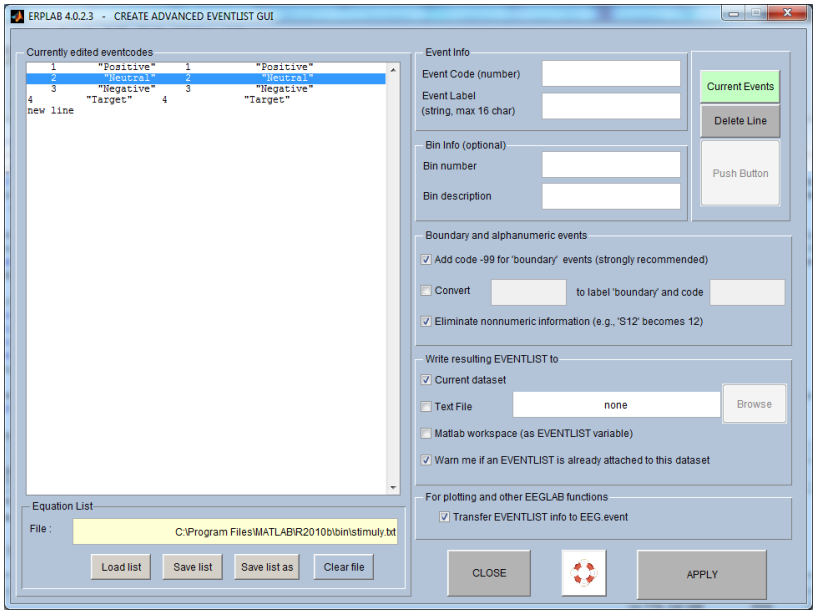


Figure 11: ERPLAB Event List

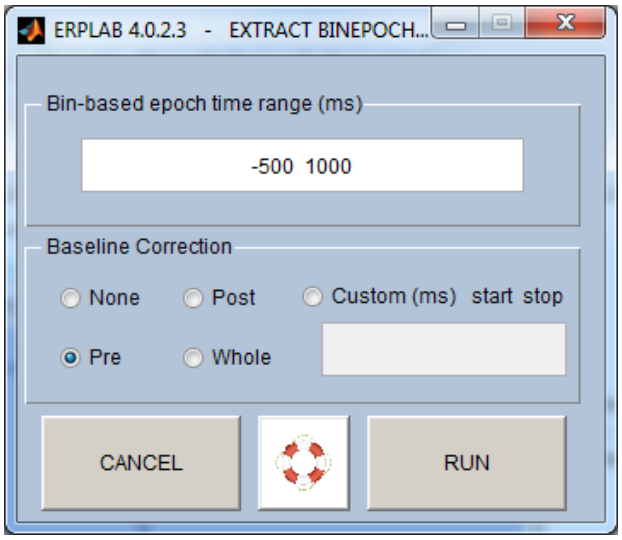


Figure 12: ERPLAB epoch extraction

*voltage threshold* filter was used, *ERPLAB→Artifact detection in epoched data→Simple voltage threshold*. *Test period* was set to -500 999 ms, *Voltage limits* to 100 $\mu$ and the chosen *Channels* were 9 10 14:16 (it can be selected manually in the *Channel list*), see figure 13. When the artifacts filter is applied, it marks the epochs that do not fit the filled criteria. *Plot→Channel data (scroll)* menu item shows those marked epochs. There is possibility to delete them with the *REJECT* button. Also it is possible to manually check the unmarked epochs whether they also do not contain artifacts or any other kind of interference.

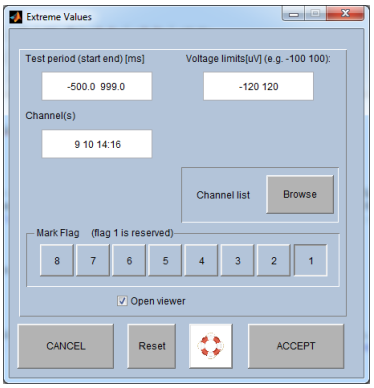


Figure 13: ERPLAB artifacts detection

Result data contain only epochs that can be processed to the resultant

average, *ERPLAB→Compute averaged ERPs*. It creates a final ERPset with averaged stimuli.

These averages can be plot via *ERPLAB→Plot ERP→Plot ERP waveform*. There are many possible options to set. *Bins to plot* offers which stimuli will be shown (in this case all of them). *Channels to plot* menu contains all the channels, ERP and peripherals. Because these channels differ in the scale, it is good separate ERP channels into one group and every peripheral channel into single group. The *Scales* options need to be changed too. *Time range* cannot be bigger then the extracted epochs (-500 999 ms) and *Y range* should not be bigger than 50 with reasonable ticks.

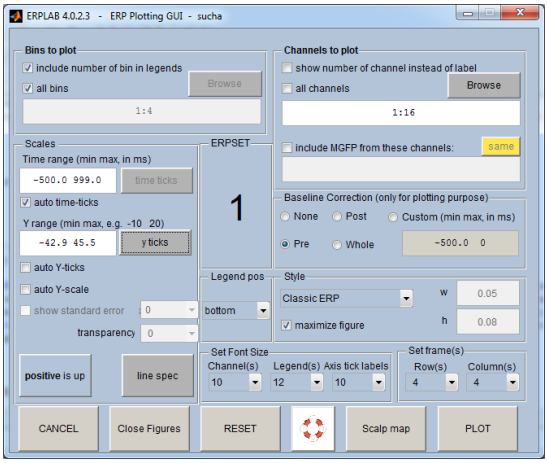


Figure 14: ERPLAB plot ERP waveforms