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Bachelor thesis

Neural Habituation of Static Advertisements in Homo- and Heterogeneous Video-Environment

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All of these contributions are indivisible from the completion of this study.

Abstrakt

Název práce: Neurální habituace statických reklam v homo- a heterogennním video-prostředí

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Vedoucí práce: Kamila Lepková, M.Sc.

Počet stran: 66

Bakalářská práce se zaměřuje na teroretické rozpracování a empirický výzkum na téma habituace a percepce statických reklam v kyberprostředí během prohlížení videí. Teoretická část obsahuje souhrn teorie a výzkumu habituace, percepce reklam a vizuální percepce, také teoretický základ elektroencefalografie. Praktická část popisuje záměr, design, implementaci, výsledky výzkumu a jejich diskuzi.

Mezisubjektový design výzkumu je vytvořen za účelem napodobit reálný kyberprostor, kde se reklamy se stávájí šumem a distrakcí pro uživatele internetu. Cílem výzkumu je na základě sledování biologických signálů (s použitím elektroencefalografie) změřit habituaci mozku na opakované objevení reklam během prohlížení edukačních videí čili určit, jak se mozek učí zvykat/reagovat na reklamní podněty během prohlížení edukačních videí a jestli existuje rozdíl v mozkové reakci na homo- a heterogenní reklamní podněty. Nové experimentální paradigma bylo vytvořeno pro tento výzkum. Výzkumu se zúčastnilo 18 participantů, náhodně rozdělených do tří skupin: dvou experimentálních a jedné kontrolní skupiny. Do závěrečné analýzy se dostalo 15 participantů, s ohledem na technické nedostatky. Analýza byla provedená pomocí evokovaných potecniálů a dvou druhů spektrální analýzy. Výsledky poukazují na to, že homogenní reklamy míň narušují plynulost percepce prohlížejícího videa, než heterogenní, ale můžou vyžadovat výraznější diferenciaci.

Klíčová slova: Habituace, percepce reklam, vizuální percepce, homogeneita reklam, kongruence reklam, EEG, ERP, ERSP, PSA

Abstract

Title: Neural Habituation of Static Advertisements in Homo- and Heterogeneous Video-Environment

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This bachelor thesis focuses on theoretical elaboration and empirical research of the topic of habituation and perception of static advertisements in the cyberspace during video perception. The theoretical part contains a summary of the theory and research of habituation, perception of advertisements, and visual perception, as well as the theoretical basis of electroencephalography. The empirical part describes the intention, design, implementation, results of the research and their discussion.

The between-subject experimental design is constructed to mimic real cyberspace, where advertisements become noise and distractions to the Internet users. The study aims to measure the brain's habituation response to repeated advertisement presentation while viewing educational videos based on following biophysical signals (using electroencephalography), i.e., to determine how the brain learns to get used to /respond to advertising stimuli during educational video streaming and whether there is a difference in brain reaction to homo- and heterogeneous advertising stimuli. A new experimental paradigm was created for this research. 18 participants took part in the research, randomly divided into three groups: two experimental groups and one control group. 15 participants' data proceeded to the final analysis, due to technical deficiencies of signal processing. The analysis was performed using the following EEG methods: Event-Related Potentials, Event-Related Spectral Perturbation, and Power Spectral Analysis. The results indicate that homogeneous advertisements are less disruptive to the fluency of perception of the video viewer than heterogeneous ones, but may require more prominent differentiation.

Keywords: Habituation, perception of advertisements, visual perception, homogeneity of advertisements, ad-context congruency, EEG, ERP, ERSP, PSA

Contents

List of Abbreviations

APA	American Psychological Association
ASR	Artifact Subspace Reconstruction
CAR	Common Average Reference
CMS	Common Mode Sense electrode
CO	Control Group
CSP	Common Spatial Patterns
DRL	Driven Right Leg electrode
EEG	Electroencephalography
EPSP	Excitatory Post-Synaptic Potential
ERP	Event-Related Potentials
ERSP	Event-Related Spectral Perturbation
fMRI	Functional Magnetic Resonance Imaging
HE	Heterogeneous Advertisements Group
HO	Homogeneous Advertisements Group
ICA	Independent Component Analysis
IPSP	Inhibitory Post-Synaptic Potential
LGN	Lateral Geniculate Nucleus
LPP	Late Positive Potentials
LTD	Long Term Depression
LTP	Long Term Potentiation
PCA	Principle Component Analysis
PET	Positron Emission Tomography
PSA	Power Spectral Analysis
RAS	Reticular Activation System
SO	Stimulus Object
STD	Shot-Term Synaptic Depression
VEP	Visual Evoked Potential

1 Introduction

Prior studies in general psychology and neurology succeeded in describing the fundamental nature of neural habituation, the process of suppression of brain's reaction towards irrelevant stimuli. Still, not many researchers have paid attention to the role of this process in the perception of any stimuli in cyberspace, the environment most of us interact with daily. Habituation is not only the brain's attempt to identify and ignore minor distractions but also to develop an efficient cognitive response to every insignificant and significant stimulus appearing repetitively in one's environment. In other words, by habituation, we implicitly learn how to respond to all kinds of recurring factors in our environment, which means that understanding habituation in the context of equilibration of cyberspace stimuli is essential if we aim to build a coherent "map" of human cognition in cyberspace.

In the theoretical part, I describe the phenomenon of neural habituation to visual stimuli, map all acquired significant knowledge on this topic, including, for instance, a general review of the phenomenon, specific evoked potentials that are linked to habituation etc., and also introduces the reader to the theoretical basis of electroencephalography and its use in research.

In the empirical part, the experiment itself is depicted, starting with the methodology and proceeding to the process of its conduction and data analysis. The experimental data are also presented in the empirical part of this thesis.

The Main Research Question (MRQ) of the study is: How does the EEG habituation response differ between the perception of homogeneous and heterogeneous static visual advertisements?

Sub Research Questions (SRQ) are: How does the EEG habituation response differ between the perception of homogeneous and heterogeneous static visual advertisements between experimental groups in ERP? (SRQ1). How does the EEG habituation response differ between the perception of homogeneous and heterogeneous static visual advertisements between experimental groups in power spectrum and ERSP? (SRQ2).

This study aims to experimentally define neural habituation in the context of the perception of digital visual stimuli, particularly advertisements, and practically depict the difference in neural habituation patterns between the perception of homogeneous (congruent) and heterogeneous (incongruent) advertisements using electroencephalographic analysis. The experiment was conducted in the EEG laboratory in the faculty of Education at the University of South Bohemia in České Budějovice.

Theoretical part

2 Habituation

Habituation is a basic form of non-associative learning and perception, characterised primarily by a decrement in intensity of a response towards a certain stimulus or a group of stimuli. This process serves a significant role in determining the threshold of attention towards all categories of stimuli and its accentuation. It has been scientifically studied in the fields of neurology and psychology for over a century, so the basic theories of its functioning are established and differentiated in multiple contexts.

Still, as human informational field is expanding, as well as the daily ratio of cognitive tasks performed by our nervous systems, the nature of this process requires further investigation and differentiation in novel contexts.

2.1 Definition and history

The process of habituation is defined mainly in three contexts, all included in Corsini's The Dictionary of Psychology (Corsini, 2002): general psychological definition - *"the process of growing accustomed to a situation or pattern of behaviour"*, habituation as psychological habit formation in addiction - *"becoming psychologically dependent on the use of a particular drug but without the increasing tolerance and physiological dependence characteristic of addiction"*, and of course the core physiological definition - *"decreased attention to a stimulus as a result of repeated presentations"*.

All three definitions are significant, and most importantly, they show mutual support for one another.

The physiological definition describes the base of the process measured in this study with the help of EEG. General psychological, presenting long-term consequences of repeated habituation in a specific environment, is also an item of interest for this thesis. And last but not least the definition of the habituation process in the context of addiction, depicting its implications in cases of substance abuse or repeated exposition to other addictive stimuli, which is not covered in this study.

To operationalize the terms in use, I will primarily employ the physiological definition when referring to habituation during the immediate reaction to a repeatedly presented stimulus. Whenever describing the long-term implications of this recurring process, I will specify the use of the term to fit the nature of the aspect of habituation described.

2.2 History of Habituation Research

As stated in Thompson (2009), the history of habituation starts much earlier than when a scientist first addressed it. For instance, there is a recognisable description of this process in Aesop's Fables:

"A Fox who had never yet seen a Lion, when he fell in with him by a certain chance for the first time in the forest, was so frightened that he was near dying with fear. On his meeting with him for the second time, he was still much alarmed, but not to the same extent as at first. On

seeing him the third time, he so increased in boldness that he went up to him, and commenced a familiar conversation with him. Acquaintance softens prejudices."

Here, we see a poetic illustration of the general psychological definition of habituation. Still, even if a notion of habituation is at least 25 centuries old, it was first scientifically approached on the verge of the twentieth century, when many scientists showed interest in the phenomena of habituation for a variety of stimuli in a wide range of organisms. For instance, Jennings (1906) described some of its properties in lower organisms. It is unclear who was the first to use the term Habituation to describe the process in question. Nevertheless, the expression had already been widely spread and often utilised in the twentieth century.

A significant remark was made later by Humphrey (1933), that a range of terms: Acclimatization, Accommodation, Negative adaptation, and Fatigue have also been used to describe the phenomenon. Then the terms Extinction and Stimulatory inactivation were added to the list by Harris, who besides that made quite an essential note on that account: *"While none of the terms cited is especially appropriate to this type of response decrement, we shall use the term "habituation" throughout."* (Harris, 1943).

S.J. Holmes first studied the accompanying process to habituation called dishabituation (or dehabituation) in the sea urchin (Holmes, 1912). Other of his studies Humphrey (1933) provided a broader perspective on the phenomenon while studying human infants and lower vertebrates. The term majorly describes the extinction of habituation to a stimulus due to a particular change in the environment. The specifics of this process are presented in the next chapter (Chapter 2.3).

The substantial nature of the process was further generalised by Proser and Hunter (Thompson, 2009), who compared habituation (using, at that time, the term *'extinction'*) of the startle response in the intact rat and spinal reflexes in the spinal rat, presenting the apparent common qualities appearing in these phenomena. By this time, it was a consensus that habituation is indeed a central phenomenon, occurring at least within species with nervous systems, and that it is an essential element of elementary learning.

The later generation of the research on habituation starts with a very influential paper, written by Sharpless and Jasper (1956), which covered the habituation of arousal. The researchers used EEG to discover habituation and dishabituation of arousal caused by repeated tone generation. They have also shown that dishabituation may appear not only in the case of temporal extinction of habituation but also due to the presentation of differing stimuli, and more: that habituation can be generalised for stimuli which don't differ significantly in their nature. Further support for habituation of arousal (due to visual, tactile, and auditory stimulation), this time in humans, was shown by Sokolov in the year 1960 (Thompson, 2009).

After this essential research, a general interest in habituation as a fundamental form of behavioural plasticity was established. It became clear that it appears in virtually all behaviours throughout virtually all living species.

Following the spread of research on habituation, a list of nine essential characteristics of Habituation was compiled by Thompson and Spencer (1966). One more characteristic was added in 2009 by a collective of authors, who reviewed and re-evaluated the theory of habituation process accounting for the novel items in the scientific discourse around it during the 40 years that passed (Rankin et al., 2009). One of the original authors - Richard F. Thompson - also took part in the review. Rankin et al. (2009) describe the Ten Revised Characteristics of Habituation as follows in the Table 1, displayed on the page 13.

And just as importantly, the three main theories of neural habituation were introduced: Sokolov's Stimulus-Model Comparator Theory (Sokolov and Brazier, 1960), Wagner-Konorski Gnostic Unit Theory (Wagner, 1979), both accenting the long-term implications of the process, and the Groves and Thompson Dual Process Theory (Groves and Thompson, 1970), describing the theoretical structural nature of the physiological process of habituation. They are described in more detail in Section 2.4.

After the main theories and characteristics of the habituation process emerged, it was further researched in many fields and contexts. Some of the relevant more recent studies are, for instance: Castellucci and Kandel (1974); Mennemeier (1994); Plappert and Pilz (2005); Massa and O'Desky (2012), and many more.

2.3 Dishabituation

The companion phenomenon of *"dishabituation"* or *"dehabituation"*, the restoration of a habituated response by extraneous stimulation, was early studied by Holmes (1912) in the sea urchin. Humphrey (1933) provides an example with human infants: *"The phenomenon may easily and prettily be demonstrated on a young baby. The hands are clapped behind the child's back every two seconds; blinking occurs several times, but has generally died down by the sixth or seventh stimulation. Habituation has set in. The cradle is then given a sharp blow, and the hands are once more clapped, keeping the proper interval by counting. The child will be observed to blink again. The explanation seems to be that the blow on the cradle requires a new adjustment on the part of the organism which is inconsistent with that involved in effecting the habituation."* (Humphrey, 1933).

Humphrey provides the following explanation: *"The peculiar process involved in the establishment of equilibrium are thus nullified and habituation has to be re-established. Dehabituation by lapse of time and by another stimulus are thus fundamentally the same, for they involve each of them the derangement of an established state of equilibrium by altered conditions, the alteration being one of increase of environmental energy in the one case, of decrease in the other."*

2.4 Main Theories of Habituation

As previously stated in Chapter 2.2, there are three main theories of habituation. The theories describe the underlying neural processes as well as their behavioural outputs. I will briefly describe each of them in this hapter.

#1	Repeated application of a stimulus results in a progressive decrease in some parameter of a response to an asymptotic level. This change may include decreases in frequency and/or magnitude of the response. In many cases, the decrement is exponential, but it may also be linear; in addition, a response may show facilitation prior to decrementing because of (or presumably derived from) a simultaneous process of sensitization.
#2	If the stimulus is withheld after response decrement, the response recovers at least partially over the observation time (*"spontaneous recovery"*).
#3	After multiple series of stimulus repetitions and spontaneous recoveries, the response decrement becomes successively more rapid and/or more pronounced. This phenomenon can be called potentiation of habituation.
#4	Other things being equal, more frequent stimulation results in more rapid and/or more pronounced response decrement, and more rapid spontaneous recovery, if the decrement has reached asymptotic levels.
#5	Within a stimulus modality, the less intense the stimulus, the more rapid and/or more pronounced the behavioral response decrement. Very intense stimuli may yield no significant observable response decrement.
#6	The effects of repeated stimulation may continue to accumulate even after the response has reached an asymptotic level (which may or may not be zero, or no response). This effect of stimulation beyond asymptotic levels can alter subsequent behavior, for example, by delaying the onset of spontaneous recovery.
#7	Within the same stimulus modality, the response decrement shows some stimulus specificity. To test for stimulus specificity/stimulus generalization, a second, novel stimulus is presented and a comparison is made between the changes in the responses to the habituated stimulus and the novel stimulus. In many paradigms (e.g. developmental studies of language acquisition) this test has been improperly termed a dishabituation test rather than a stimulus generalization test, its proper name.
#8	Presentation of a different stimulus results in an increase of the decremented response to the original stimulus. This phenomenon is termed "dishabituation." It is important to note that the proper test for dishabituation is an increase in response to the original stimulus and not an increase in response to the dishabituating stimulus (see point #7 above). Indeed, the dishabituating stimulus by itself need not even trigger the response on its own.
#9	Upon repeated application of the dishabituating stimulus, the amount of dishabituation produced decreases (this phenomenon can be called habituation of dishabituation).
#10	Some stimulus repetition protocols may result in properties of the response decrement (e.g. more rapid rehabituation than baseline, smaller initial responses than baseline, smaller mean responses than baseline, less frequent responses than baseline) that last hours, days or weeks. This persistence of aspects of habituation is termed long-term habituation.

Table 1: Ten Revised Characteristics of Habituation by Rankin et al.

2.4.1 Sokolov's Stimulus-Model Comparator Theory

In 1960, E. Sokolov presented an essential theory of habituation, the Stimulus-Model Comparator Theory, primarily describing his conclusions from observing the orienting response (manifesting as arousal) using EEG measurement.

The main concept is that a stimulus model is formed in the cerebral cortex after a stimulus is presented repetitively. When a novel stimulus is delivered, a large orienting response follows. The response is mediated by the amplifying system (identified with the ascending networks in Reticular Activating System (RAS)), which generally serves as a *"conditioner"* for behavioural output. The model is developed each time the stimulus is presented. Its development is accompanied by increasing inhibition in RAS via descending corticofugal activity, which causes habituation. When another novel or an altered stimulus is introduced, the strength of the response recovers due to inhibition withdrawal, allowing for the orienting response to take place (Sokolov and Brazier, 1960). The graphic interpretation of this model is presented in Figure 1.

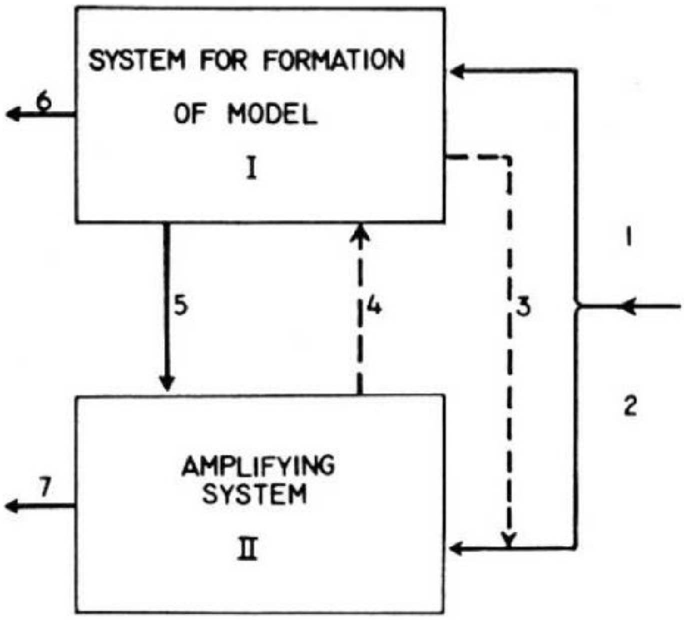

Figure 1: Sokolov's Stimulus-Model Comparator Theory graphic illustration. Source: Sokolov and Brazier (1960).

2.4.2 Wagner-Konorski Gnostic Unit Theory

This theory is based on Jerzy Konorski's insights (Konorski, 1967), which was very familiar to those presented by Sokolov, later elaborated by Allan Wagner (1979) with a greater accent on short-term memory and existing associative network significance.

In the final, Wagner's version of the model, the process of habituation took place in the following manner (graphically represented in Figure 2): a stimulus object (SO) is perceived by the receptor surface (REC. SURF.), processed by afferent fields, and further transmitted into the arousal system and to the Gnostic assembly, a memory system. Incoming repetitions of the stimulus cause the formation of a Gnostic Unit (G), a neural representation of the stimulus, a memory of the stimulus, which gets more precise as the number of repetitions increases. The development of the Gnostic Unit is followed by the activation of the inhibitory system, which suppresses the arousal system, thereby causing increasing habituation.

Wagner's contribution to the theory was the other two significant circuits influencing the formation of the stimulus' neural representation, the cyclical short-term memory circuit and the associative network. He accented explicitly that the associative network may activate the Gnostic System, memory, in a resonant context, therefore influencing the formation of the Gnostic Unit. Thus Wagner also implied the probability of context-specific long-term habituation for specific responses.

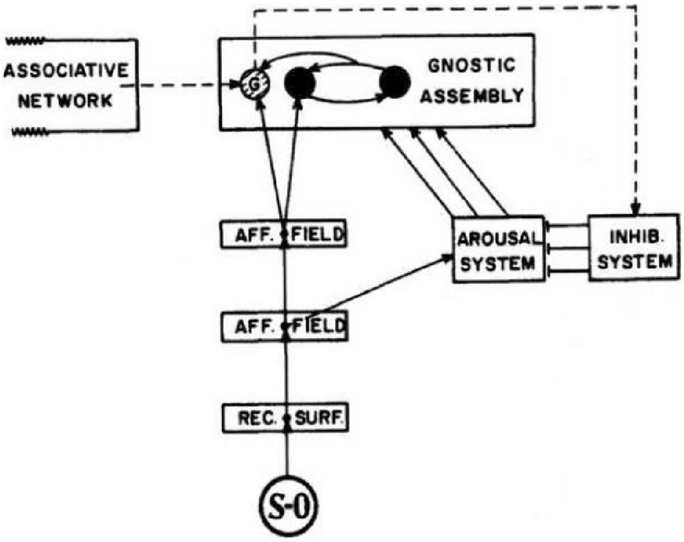

Figure 2: Wagner-Konorski Gnostic Unit Theory graphic illustration. Source: Wagner (1979).

2.4.3 Groves and Thompson Dual Process Theory

Groves and Thompson (Groves and Thompson, 1970) presented a theory based on their experiments in discrete muscle responses and concentrated on in-session measurements of short-term habituation. It emphasizes the observation that a reaction to any stimulus perceived will include two independent processes evoked in the nervous system: habituation, the decremental process, and sensitization, the incremental process. They assumed that habituation occurs in the stimulus-response pathway for every stimulus. In contrast, sensitization develops in a separate system. It then regulates the final behavioural outcome. Thompson states that the theory received strong support from research in spinal cord interneurons activity (Thompson, 2009). Figure 3 illustrates the basic notion of the theory and Figure 4, placed on the page 16, represents its neuronal model.

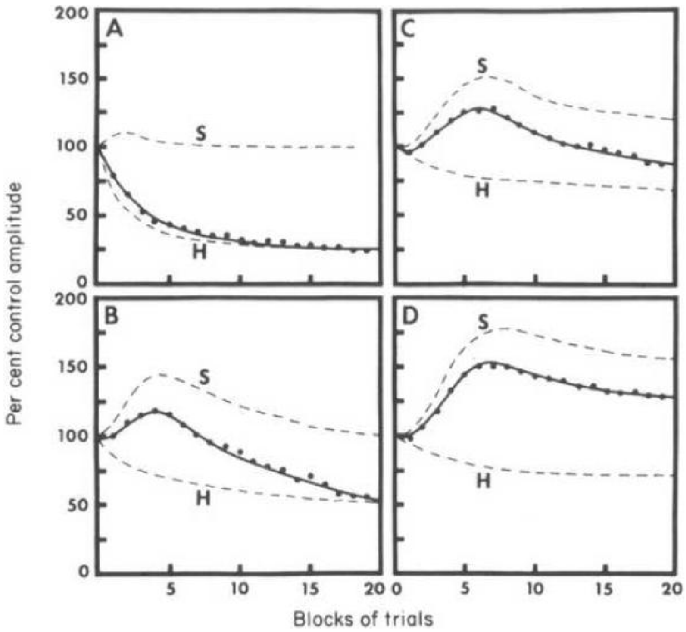

Figure 3: Basic notion of the Dual Process Theory of Habituation. Source: Groves and Thompson (1970).

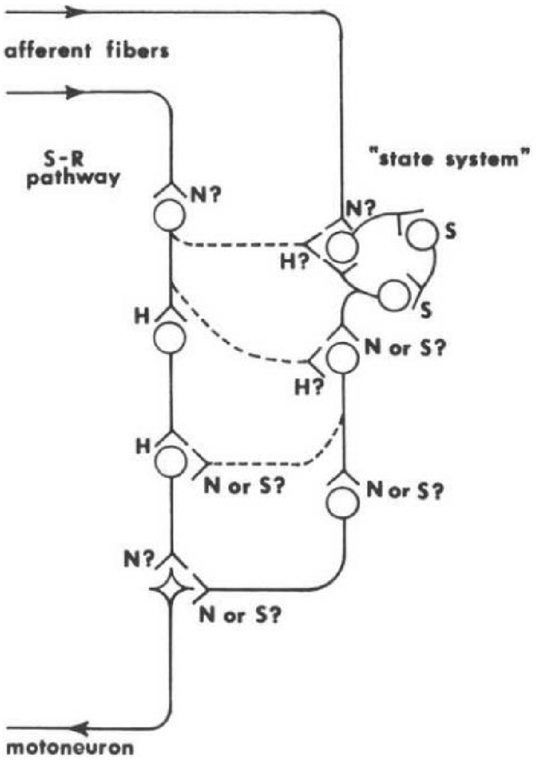

Figure 4: Neuronal model of the Dual Process Theory of Habituation. Source: Groves and Thompson (1970).

2.5 LTP, LTD, and Habituation

It is essential to mention the significant role of Long-Term Potentiation (LTP) and Long-Term Depression (LTD) as a long-term consequence of the process of habituation.

Long-Term Potentiation and Long-Term Depression, respectively, are thought to be the central phenomena in learning and memory (Takeuchi, 2014; Kandel et al., 2014). LTP is defined as persisting strengthening of synapses based on recent activity patterns, which induces a long-lasting increase in signal transmission between neurons. LTD is an opposite process, which results in a long-term decrease in the transmissive activity between neurons (Cooke and Bliss, 2006).

Based on accounting for all the qualities and characteristics of habituation as a neurophysiological process, it is safe to propose the following formulation. The process of habituation precedes both LTP and LTD. Facilitating categorisation of perceived objects as unimportant, it moderates those phenomena through repetitive Short-Term Depression (STD) of the elicited response. If the arousal was predominant in a series of stimulus presentations, LTP is enabled. LTD takes place, if the response was repetitively inhibited and further processing disabled, i.e., the response was habituated (Thompson and Spencer, 1966; Konorski, 1967). DeLiang Wang's Neural Model of Synaptic Plasticity supports this statement (Wang, 1993).

I believe the interconnection of these elements is crucial for understanding the nature of learning and memory, especially when examining the habituation of visual stimuli and their long-term consequences.

3 Visual Perception of Advertisements

Advertisements are a significant part of the human material culture. They have been filling our informational space since ancient times, almost all around the world. Still, whatever form they take, they remain sensory stimuli, although being quite a specific kind. The item of interest for this study is the visual perception of advertisements. In this chapter, and then in Chapter 5, I attempt to cover the main aspects of this item, including those concerning the experiment.

3.1 Perception of Visual Stimuli

Visual perception and association are two of the main ways for most animals to receive and process information about their surroundings, especially primates. It is brought on by our visual system, consisting of the sensory organ, the eye, and the processing circuits in the central nervous system.

In this subsection, I describe the Visual Neural Pathway, that facilitates visual perception. Electroencephalographical neural substrates of visual perception are described in Chapter 5, after introducing the reader to the EEG method.

3.1.1 Visual Neural Pathway

The neural circuits included in the visual neural pathway, the retinofugal projection, and those devoted to processing the visual information are listed and briefly described further.

The optic nerve, consisting of around one million axons, receives a signal extracted from the eye's retina. In the x-shaped optic chiasm, the axons from both eyes' nasal retinas cross to the opposite hemispheres, thus directing all the information from each hemifield to the opposite hemisphere. The signal in both hemispheres is then relayed through the optic tract to the lateral geniculate nucleus (LGN) in thalamus. The LGN then lets it proceed through the optical radiation to the functionally segmented visual cortex, where the signal is processed. The processed information is further relayed into all necessary cognitive, conative, and associative circuits (Bear et al., 2007).

3.2 Characteristics of Advertisements and Their Specific Qualities in Perception

An advertisement is defined in the American Psychological Association (APA) dictionary as *"a public announcement appearing in print, broadcast, or electronic media that is designed to bring individuals' attention to a particular item or service to encourage the purchase, consumption, or increased use of that item or service"* (APA, 2022).

Advertisements' general difference from normal stimuli is due to their instrumental function. Since the goal of the propagator is to draw customers' attention to the product, advertising stimuli often include elements which are the most prominent for human perception, such as public celebrities (Hayat et al., 2013; Osei-Frimpong et al., 2019), reactive human facial expressions (Giuliana and Vieira, 2020), prominent colours (Kyrousi and Panigyrakis, 2015), and other kinds of stimuli.

Due to the choice of characteristics aimed for the most potent persuasion effect, advertisements overall evoke a strong sensory response, stepping out of the environment, rendering this kind of stimulus as intrusive (Hairong et al., 2002; Krishna et al., 2016).

3.2.1 Research of Specific Qualities of Advertisements

Research suggests, that the interruption of ongoing cognitive processes by advertisements is neurally manifested in a drop of activity in the frontal and prefrontal cortical lobes affecting all frequency bands (see Chapter 4.3), primarily hindering the subject's concentration and thus lowering the degree of beta-band activity in the mentioned areas. The same study presents evidence for significant changes in the frontal and prefrontal asymmetry index, which differs in direction amongst individual subjects (Rejer and Jankowski, 2017).

The mentioned characteristics and qualities in perception of advertisements lead towards a clear need for an orienting response after the presentation of an advertising stimulus, including a habituative response to inhibit processing of redundant information.

3.3 Homogeneous and Heterogeneous Advertisements

The consistency of advertisements with the environment, where they are presented, is one of their significant characteristics. A number of studies have been conducted to describe its qualities and influence on individual's consumer behaviour. Some have paid attention the effect on individual's cognition.

In this section, I define the terms Homogeneous and Heterogeneous Advertisements and present some of the preceding research of this phenomena.

3.3.1 Operationalization of the Terms

The terms Homogeneous and Heterogeneous advertisements are used in the study to clearly mark consistency or inconsistency of the advertisement with the environment, where it is presented. Other researchers, who paid attention to the Same-Context, Different-Context advertisements, used the terms Thematic Congruence and Incongruence (Germelmann, 2020; Dahlén, 2008).

In this study, I used using an alternative dichotomy to better represent the fixed nature of the context, the manipulable nature of the target stimuli, and the overall innate quality of the perceived informational field. Additionally, to avoid interference with the other definitions of congruence, including those in marketing. They may be referring, for instance, to the thematic consistency of an advertisement with the product or business it propagates, consistency of the product with the audience and the influencers on social media (Belanche, 2021), sponsor-cause congruence (Roy, 2010), the marketing strategy congruence, or other differing definitions in a very close context.

At the same time, the dichotomy, chosen for this study, only interferes with a different close interpretation in case the homogeneity or heterogeneity used to describe the product itself. The latter does not concern marketing instruments of any kind; only the specific quality of the product to be interchangeable with alternative products of the same kind.

Due to the terms Thematic Congruence and Incongruence being the standard dichotomy used in the research of this item. I underlined its direct connection to the study's issue and the fact that the Homogeneous-Heterogeneous dichotomy refers directly to the same phenomenon as does the Thematic Congruence-Incongruence (in advertisement-context consistency).

3.3.2 Research of Advertisements' Homogeneity

Previous studies show that heterogeneous (incongruent) advertisements evoke stronger arousal in a sensory response to the stimulus, which also often results in a better brand and product recall (Dahlén, 2008; McCoy, 2007), but has a negative effect on fluency of perception (and therefore on *"downstream effect"*, as the authors describe it) and Persuasion Knowledge, which is key to the affective valence of brand perception, as opposed to the homogeneous (congruent) advertisements, which have a positive effect on perception fluency and Persuasion Knowledge, leading to a more positive brand attitude (Germelmann, 2020).

McCoy (2007) studied the issue by comparing heterogeneous and homogeneous advertisements placed in the context of internet sites. Testing the difference in brand recognition, they concluded that heterogeneous advertising stimuli were better recognised after the trials. Dahlén (2008) presented supporting evidence for the research by McCoy (2007) in a study of context-ad congruence (homogeneity) in printed magazines, including its significant effects on brand attitude (for familiar brands), ad attitude and brand association.

Germelmann (2020) observed the phenomenon in the experimental context of digital magazines, with the unpublished digital advertisements presented there during five separate studies, and supported the following hypotheses:

- Under more incidental in vivo exposure, consumers will be more aware of the incongruency versus the congruency tactic.
- Incongruency is more likely to evoke conscious thoughts, including persuasion knowledge thoughts, whereas congruence leads to more automatic processing that does not require conscious deliberation.
- A congruent ad–medium combination will produce largely positive effects on consumer evaluations and purchase intention.
- These positive effects are likely to operate through a fluency process.
- An incongruent ad–medium combination will lead to negative effects on evaluations and purchase intentions.
- The negative effects of ad–medium incongruence will be mediated by negative persuasion knowledge associated with the tactic.

Thus they presented evidence for the positive effect of homogeneous (congruent) stimuli on perception fluency, which is significant for the study, and supported the other effects and including a bidirectional influence between the homogeneity and Persuasion Knowledge.

4 Electroencephalography

Electroencephalography (EEG) is one of the most frequently used tools for brain analysis. It is often preferred due to approachable price, relative mobility and adequate measurement precision, especially in time domain. We use the term Electroencephalography to mark the whole method of analysis. The EEG record, or electroencephalogram, is obtained using an electroencephalograph - a device that measures electrical changes of brain activity by amplifying the signal from different types of electrodes that could be placed on the subject's head or deep inside the brain structure. An example of an EEG wave is presented in Figure 7 on the page 25.

EEG is a method, which is used for diagnosing many diseases, such as sleep disorder, epilepsy, etc.. It is also employed in research of cognitive processes, such as problem-solving, attention, evaluation, or habituation. It captures the temporal and frequential dynamics of bioelectrical changes in the brain.

It is important to note that the waves recorded by an electroencephalograph are produced by the activity of a large number of neural circuits, which is not just an activity summation of individual neural circuits, but the result of complex dynamics, taking place in the entire brain

(Kulišťák, 2003). Unlike other methods of brain activity analysis, EEG makes it possible to record direct brain activity (Tong and Thankor, 2009).

Compared to methods such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), EEG shows lower spatial accuracy but higher precision in time domain: it allows signals to be measured in milliseconds (Rektor et al., 2011). Another difference is the possibility to use both non-invasive and invasive methods in EEG analysis. We divide these methods according to the location of recording: non-invasive EEG, where the signal is recorded from the surface of the head using surface electrodes, and invasive EEG, where the subsurface needle electrodes are used to record the activity from the surface or the deep locations in the brain (Penhaker and Augustynek, 2013). Modern invasive methods include not only needle but also subdural (on the brain surface) and deep-brain (in the brain structure) electrodes. While non-invasive methods are more common, invasive techniques are used in the case that maximum accuracy is required. Such situations occur mainly in clinical practice: a frequent example is the examination of epileptic patients.

4.1 A Brief History of EEG

The discovery of the electrical properties of the brain is attributed to an English scientist named Richard Caton (1842–1926). He recorded electrical activity from animal brains using a sensitive galvanometer, then noting changes in activity while the animals were sleeping and the disappearance of electrical activity after their deaths. Ukrainian physiologist Vladimir Vladimirovich Pravdich-Neminsky (1879-1952) was the first researcher to publish a non-human EEG and the evoked potential of a mammalian (dog), both in 1912. The first man to record a human EEG was a German psychiatrist named Hans Berger (1873–1941), who made the recordings in 1924. Then in 1934, the first epileptiform spikes were demonstrated by two associate scientists - Fisher and Lowenback. Right after that, in 1935, Gibbs, Davis, and Lennox described interictal epileptiform discharges and 3-Hz spike-wave patterns during clinical seizures. Gibbs and Jasper then described focal interictal spikes in 1936. During the 1930s and 40s, the first clinical EEG laboratories started appearing in the United States. And finally, in 1947, the American EEG Society, later the American Clinical Neurophysiology Society, was founded (Britton, 2016; Brazier, 1984).

4.2 Neurophysiological Basis of EEG

Not only František Koukolík but probably every neuro- and any other scientist says the brain is the most complex structure in the known universe. It is studied continuously by researchers in many scientific disciplines, but neither one nor all of them can completely describe the principle of the brain's function. Physics, chemistry, and biology help us understand the basics the brain's anatomy and physiology, thus forming the essence of the neurological field. The first field that helped us scientifically connect brain structure and activity with the phenomena of its owners' experiences is neuropsychology, the genesis of which was preceded by fields such as neurology, philosophy, practical medicine and alike.

The human brain contains approximately 100 billion neurons that communicate dynamically with one another due to the ability of brain tissue to generate electrical activity and transmit signals through specialised chemical reactions at synapses. Neurons are the fundamental units of the brain and nervous system. The complex interconnection of the neurons thus creates large dynamic neural networks, able to adapt to an infinitely wide range of new conditions. Neuron structure is illustrated in Figure 5.

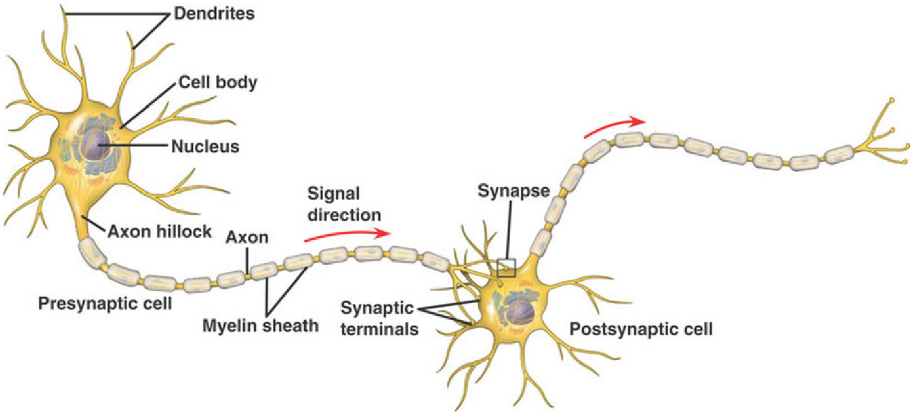

Figure 5: Functional structure of a neuron. Source: Redis (2014).

4.2.1 Action Potential and Postsynaptic Potentials

The electrical activity of neurons has two basic sources: action potential and postsynaptic potentials.

The action potential (see Figure 6) appears as a result of changes in membrane permeability to sodium Na^+ and potassium K^+ ions (Baldi, 1981). The resting membrane potential of neurons is approximately -70 mV.

The basis of the resting potential is the uneven distribution of ions within the cell in intracellular and extracellular fluids. Sodium and potassium ions are especially important, as well as chlorine Cl^-, particularly in their active transfer and following passive diffusion by the cell membrane. These changes cause polarization of the cell membrane: extracellular electrical positivity is weaker, intracellular electrical negativity is stronger, and that leads to a negative resting membrane potential (Čihák, 2016). As mentioned above, the action potential is created by means of changes in the membrane permeability towards ions. This is caused by a sufficiently strong irritation of the nerve cell by an electrical, chemical, or mechanical stimulus.

During the formation and spreading of the action potential, the rapid transfer of ions causes a change in the resting membrane potential from initially negative state towards zero. This way it exceeds the so-called threshold potential, which allows rapid transfer of the ions from extracellular into the intracellular fluid. The membrane potential is then shifted to zero (isoelectric

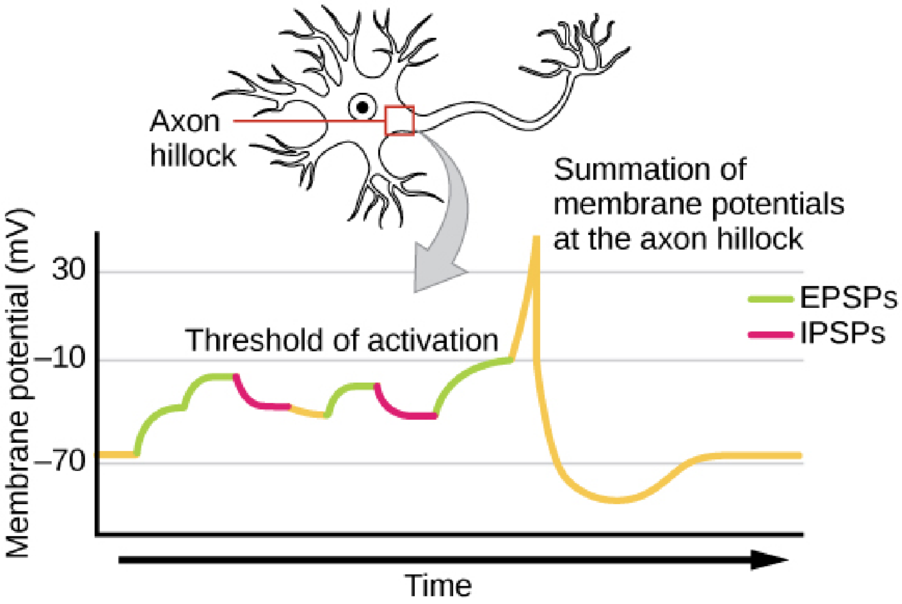

Figure 6: Illustration of the Excitatory, Inhibitory Post-Synaptic Potentials, and their summation, resulting in an Action Potential. Source: Furtak (2022).

line). Membrane depolarizaion will thus take place. In some cases, the potential exceeds zero, this is called *”an overshoot”*. Immediately, the membrane permeability to ions K^+ of the intra to extracellular fluid increases. This leads to the restoration of electronegativity within the cell, as well as the resting potential, i.e., this is how the membrane repolarization comes about. Sometimes, instead a short hyperpolarization, a short exceeding of the resting potential in the negative direction. This whole process lasts around 50 ms on a section sized tenths of a mm to 1.5 mm (for myelinated axons). Then, in the part of the neuron where the the action potential caused depolarization and repolarization, a refractory phase follows. A refractory phase is a short period when this particular part of the neuron is not irritable. This enables the action potential to spread unidirectionally from dendrites through perikaryon (neuron body) to axon and then to the synapse. The event can be repeated, therefore action potentials can arise rhythmically (Čihák, 2016).

Postsynaptic potentials (see Figure 6), in contrast to action potentials, appear on synapses. Under the influence of the action potential in the direction of the synapse, a mediator is released into the synaptic cleft. The mediator then diffuses to the postsynaptic membrane, where it induces changes in ion permeability for a maximum of 1ms. This causes partial depolarization (from -70 mV to approximately -50 mV) and subsequent repolarization.

The described process leads to the formation of an excitatory postsynaptic potential (EPSP), which, when strong enough, causes the formation of an action potential on another neuron in the direction of signal transmission. After these changes have occurred, the mediator is deactivated by the enzyme, and the whole process can occur again. The frequency of its occurrences makes up to a hundred times per second. The diffusion time of the mediator causes a synaptic delay. A synaptic delay is a time exceeding 0.5 ms from the action potential on the presynaptic membrane to the excitation of the postsynaptic potential.

However, if hyperpolarization of the postsynaptic membrane occurs under the action of a mediator instead of depolarization, an inhibitory postsynaptic potential (IPSP) arises. An inhibitory postsynaptic potential suppresses the activity of the affected neuron. Synapses with both excitation and inhibition potential can act on the same cell at the same time, then the numerical predominance of synapses of the first or second types decides whether or not the action potential will be evoked (Čihák, 2016).

This process is essential for bioelectrical neural activity, the multilayer wave projection, which we monitor with the help of EEG.

4.3 Brain Waves

As stated in Chapter 4.2, brain activity is oscillatory, therefore its function always manifests a certain frequency of wave oscillations read by EEG. Those frequencies are generally divided into five bands: alpha, beta, delta, theta, and gamma.

In Kulišťák (2003), the author states, that in adults, normal wave frequency in a state of vigil relaxation would lie in the alpha frequency band (8-13 Hz), during active engagement - in the beta spectrum (14-30 Hz). Author describes the delta (less than 4 Hz) and theta (4-8 Hz) bands as pathological, not mentioning the fact, that this is only true for the vigil states in adults. Delta and theta waves are very common during sleep. Theta wave may be present during daydreaming or drowsiness while awake (Abhang et al., 2016b).

Each band will be described from the fastest to the slowest in the following chapters.

4.3.1 Gamma

Waves from 30 to 100 Hz are typically categorised as Gamma waves. They are related to cognitive function, learning, memory, and basically all kinds of active information processing. Prominence of gamma activity leads to stress, anxiety, and high arousal; its suppression, on the other hand, may lead to ADHD, depression and learning disorders. In optimal conditions these waves bring out better attention, focus, more coherent sensory and mental processing, sharper perception and consciousness overall (Abhang et al., 2016b).

4.3.2 Beta

Beta waves are generally characterised as high-frequency, low-amplitude brainwaves, observed in an awaken state. They are related to thinking, conscious thought, and *"tend to have a stimulating effect"*. Optimal prominence of beta-waves is connected to a focused state. High prominence – to anxiety, inability to relax, high arousal, and stress, while suppression of this frequency band may can be connected to daydreaming, depression, ADHD, poor cognition. Beta waves are often divided into different domains by oscillation frequency, which may differ among sources. Abhang et al. (2016a) make a following categorisation. *"Beta one"* (12-15 Hz), associated with quiet concentration, *"beta two"* (15-20 Hz), associated with increases in energy and performance, but also anxiety; and *"beta three"* (18-40), associated with stress, anxiety, paranoia, and high arousal overall (Abhang et al., 2016b).

4.3.3 Alpha

Alpha is the wave domain for a calm, relaxed state of awaken functioning. It is also connected to the so-called *"flow"* state. It ranges between 8 and 13 Hz. High prominence may correlate with daydreaming, inability to focus; suppression – with anxiety, distress, and insomnia (Abhang et al., 2016b).

4.3.4 Theta

This particular frequency range (4-7 Hz) is involved in daydreaming and sleep. ADHD, depression, hyperactivity, impulsivity, and inattentiveness are observed when theta waves are prominent. If they are suppressed, anxiety, poor emotional awareness, and stress can be seen. In an optimal state, theta benefits creativity, experience of emotional connection, and relaxation. Optimal theta waves tend to improve creativity and experience of general ingenuity. Theta is also involved in restorative sleep (Abhang et al., 2016b).

4.3.5 Delta

Delta waves (0-3 Hz) are the slowest recorded brain waves in human beings. They are often found in infants and young children and are associated with the deepest levels of relaxation and restorative, healing sleep. Delta of high prominence is seen in brain injuries, cognitive dysfunctions, and severe ADHD. If this wave frequency is suppressed, it leads to an inability to rejuvenate the body and revitalize the brain and poor sleep. Adequate production of delta waves helps us feel completely rejuvenated and promotes the immune system, natural healing, and restorative/deep sleep (Abhang et al., 2016b).

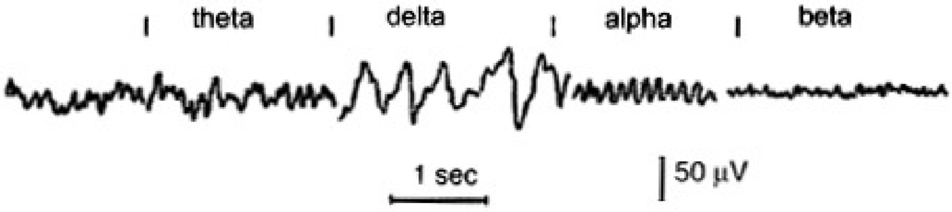

Figure 7: Brain wave samples with dominant frequencies belonging to theta, delta, alpha, and beta bands. Source: Abhang et al. (2016b).

4.4 Principle of EEG Measurement

The electrical activity measured by non-invasive electroencephalography is generated by groups of neurons, mainly those in the cerebral cortex, located closest to the skull at the dislocation of the electrodes. Each electrode collects at least about 6 cm^2 of synchronous cortical activity. The approximate coverage of the electrode varies significantly with the type and quality of the specific electrode set. Most of this activity is generated by groups of pyramidal neurons, located mainly in the third (Lamina pyramidalis externa) and fifth (Lamina pyramidalis interna) layers of the cerebral cortex (Britton, 2016; Junqueira et al., 1997). The electrical activity collected on the scalp represents the summation of excitatory and inhibitory postsynaptic potentials (not action ones - action potentials are too short to detect) of thousands of pyramid cells in the area of each recording electrode (Britton, 2016).

4.4.1 Electrode Placement

Non-invasive (scalp) EEG electrodes are placed on the scalp according to the international 10-20 Electrode Placement System (shown at Figure 8 on page 27). This system uses the distance between the bone landmarks on the surface of the head to create a system of lines. The recording electrodes are then placed at intervals of ten or twenty percent of the total length of these lines. The main advantage of using this proportional system is that it determines the same relative positions of the electrodes on the scalp regardless of the head volume (Britton, 2016).

To ensure the quality of the signal, the electrodes are pasted to the surface of the head. Special conductive gel or paste may be used as a conductor.

In the International 10-20 System, one universal method is used, where each electrode position is assigned a letter and a number. The letter stands for the position of the electrode on the scalp: Fp (frontopolar); F (frontal); C (central); T (temporal); P (parietal); O (occipital). The number rule is that over the left hemisphere, odd numbers are used, and even numbers over the right hemisphere. A midline position is indicated by a lowercase *"z"*. Within different EEG sets, as already mentioned, the number of electrodes may vary, changing only the proportional distances between electrodes as needed according to the 10-20 System. Also, sometimes it is sufficient to place additional surface electrodes at shorter distances according to the 10-20 System, as it provides more spacial precision in the analysis of the electrical activity produced by brain regions of interest. One example of such a case is the addition of special anterior temporal electrodes T1 and T2 for better detection of anterior temporal spike in a patient, which is not perfectly covered by the 10-20 System standard electrode arrangement. A1 and A2 electrodes, used for contralateral referencing of all electrodes, are another example of additional electrodes. (Britton, 2016).

The number of the electrodes varies significantly among individual EEG sets. It may start at only several electrodes for regular clinical measurements and go as far as 256 in complex experimental sets. Of course, the more electrodes are used to measure brain activity, the more

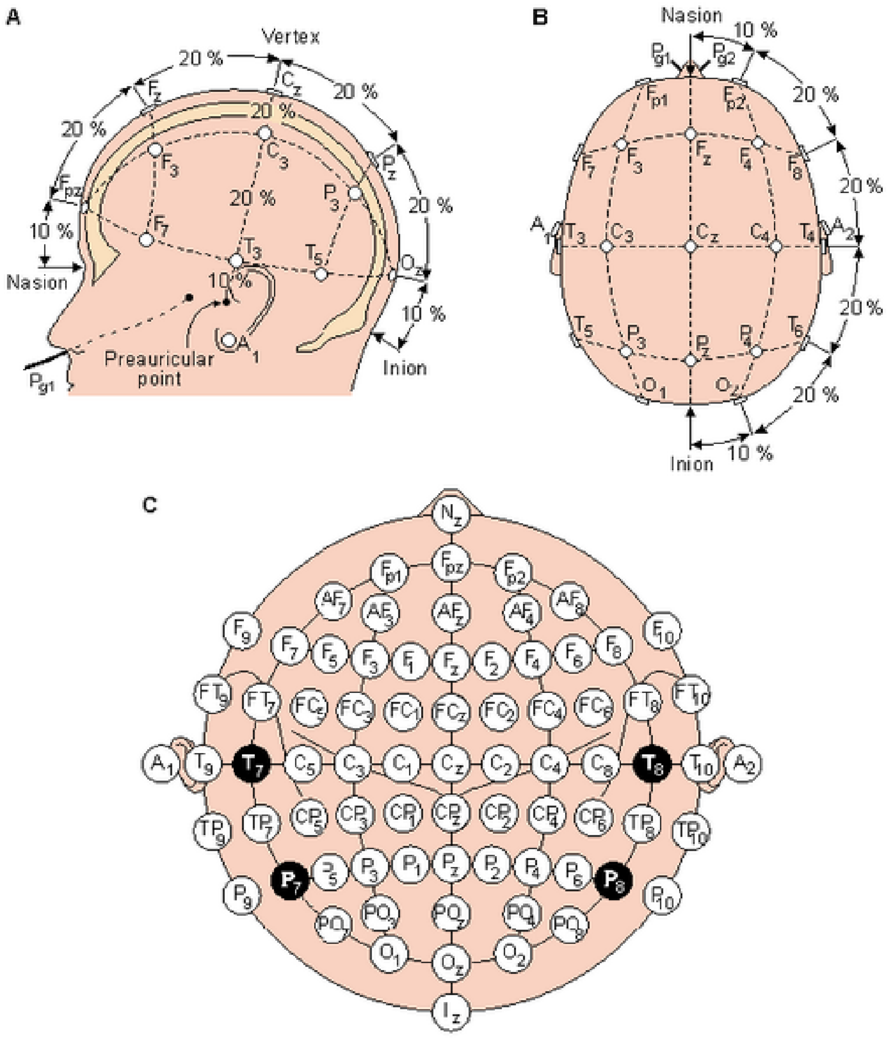

Figure 8: International 10-20 Electrode Placement System illustration. Source: NCAN (2019).

time-consuming the measurements are.

While more electrodes provide higher spacial precision during the measurements, it is often more efficient to use a simpler set of electrodes because of the stated limitation. For instance, Lau and his colleagues stated in their article (Lau et al., 2012), that *"as few as 35 channels may be sufficient to record the two most dominate electrical sources"*. In Britton (2016), the authors state, that the standard electrode set consists of the total of 22 electrodes, one of which is the ground electrode, also one channel for heart rate and eye movements tracking. In my study, a 32-channelled electroencephalograph is used.

4.4.2 Signal Recording

In order to record the relevant dynamics in EEG activity, differential amplifiers are used. The EEG amplifier is used for the data acquisition and it is responsible for amplifying and converting the analog electrical signals into a digital signal. Amplifiers measure the activity at the electrodes relatively to one another and eliminate much of the common activity between the electrodes, which is called Common Mode Rejection. Both biological and ambient artifacts are relatively similar around the head, thus they are largely eliminated by the Common Mode

Rejection principle (Britton, 2016).

Thus, once the signal is filtered by this *"cancelling out"*, we receive the recordings of the activity of interest, significantly improving the signal-to-noise ratio. The voltage increases due to the use of the amplifiers also allows us to visualise the recording. The sensitivity of the EEG is measured in microvolts per millimeters, being the ratio of the input voltage to the signal deflection. The common norm for the sensitivity is 7 μV/mm, still it can be adjusted in to ease the visualisation if needed (Britton, 2016).

For further analysis, the signal is recorded digitally thus being accessible for immediate display as well.

4.5 Artifacts

Generally, the term Artifacts is used to describe signals which are recorded by an electroencephalograph but are not generated by the brain. It is worthy of mentioning, that there are cases where the brain activity becomes an artifact itself, for instance, sensorimotor cortex activity induced by unwanted movements. Thus it may alter the recorded waves and confuse or prevent accurate interpretation of the electroencephalogram (Sazgar and Young, 2019).

Two types of artifacts - physiological (biological) and non-physiological - occur during EEG measurements.

Biological are the patient/participant-induced artifacts, which may be caused by ocular, muscle, cardiac activity, perspiration, respiration etc. The non-physiological are the ones not related to the participant's bodily activity, therefore induced by environmental irritants and other factors like loose electrodes, high impedance electrodes, power line artifacts etc. (Urigüen and Garcia-Zapirain, 2015; Sazgar and Young, 2019).

4.6 Signal Processing and Analysis

The signal, received during the recording, must be pre-processed before its analysis. The major objective of the pre-processing is to clean the data of the artifacts without damaging the relevant brain activity. This is necessary for all types of further analysis. Multiple pipelines for EEG signal processing exist, using different methods in different order (Cong et al., 2015).

4.6.1 Pre-processing of the Signal

The preprocessing is the step of signal processing, where signals are prepared for the further analysis, for instance, signals are filtered to remove the noise and artifacts.

During the pre-processing, some of the channels (electrodes) may be found to be especially noisy or contain a large amount of artifacts. In this case those channels may be removed or interpolated on the basis of the neighbouring channels activity. It is advised, that the number of interpolated electrodes does not exceed a tenth part of the initial set (Lakshmi et al., 2014).

Filtering is an important part of signal pre-processing. Various methods for signal filtration have been introduced. Low-frequency, high-frequency, and band filters are commonly used to select the waveforms in the most important range clearly and with minimal distortion. Low- and high frequency filters remove the amplitudes of the slow and the fast waves accordingly, while band-filter is used to reduce the activity of a certain frequency range, and the notch filter selectively reduces the amplitude of waves in a narrow frequency specifically to remove electrical line interference. For instance, in USA, the notch filter is set at 60 Hz, and at 50 Hz in Europe (Britton, 2016).

The signal is also downsampled during the pre-processing. It is done to save the space on the processing hardware and ease further signal processing. Downsampling is conducted according to the Nyquist-Shannon theory. The theory implies, that the minimal allowed sampling frequency must be at least two times higher than the high-point of the frequency range of interest. This minimal frequency is called the Nyquist frequency (Kipnis, 2016).

The data are also re-referenced repetitively on different stages of processing, meaning that their voltage is expressed relative to one or more electrodes, included in the set. Re-referencing the signals from all electrodes corrects the signal baseline to a common value, which is essential for the analysis. The signals from individual electrodes may be re-referenced to a certain electrode, that is relevant for the study (the electrode itself is removed in this case), a set of electrodes (for instance, mastoids) or the average value of all electrodes.

4.6.2 Analysis of EEG Signal

EEG signal may be analysed using various methods. Event-Related Potentials (ERP), Power Spectral Analysis (PSA) and Event-Related Spectral Perturbation (ERSP) are some of the main methods used in EEG applied research.

Many methods, which are often included in the pre-processing, may also categorised under the analytical part of EEG analysis. Those are algorithms for signal feature identification and dimensionality reduction. For instance, the widely used in neuropsychological studies Principle Component Analysis (PCA) and Independent Component Analysis (ICA). They are also utilised in this study. Lakshmi et al. (2014) mark the following methods as the most used in pre-processing and analysis of the signal throughout all disciplines: Common Average Referencing (CAR), Common Spatial Patterns (CSP), Adaptive Filtering, PCA, and ICA.

ERP analysis (Figure 9), sometimes referred to as analysis of Evoked Potentials, follows the specific EEG waveforms, elicited by a certain stimulus. The ERPs are measured in a range up to 1000 ms following stimulus presentation. Those waveforms form specific components. The components are primarily divided into early (under 250 ms after the stimulus presentation) and late ones (200-1000 ms after the stimulus presentation). Most prominent components are established and described in the ERP research and theory. Components, connected to visual attention, are described in Chapter 5 of this thesis.

The ERSP and PSA analysis methods enable the evaluation of the time-frequency domain of the singal.

The event-related Spectral Perturbation (illustrated in Figure 10) shows mean event-related changes in power spectrum at each frequency, at every moment in time during the epoch.

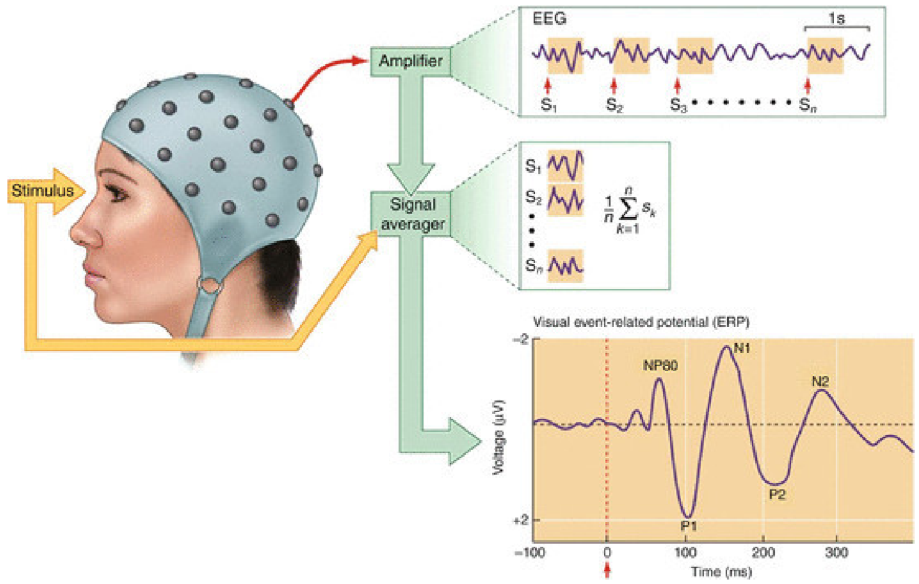

Figure 9: Illustration of the ERP analysis method. Source: Purves et al. (2009).

An epoch is a part of the dataset, that is cut out of the recording for further analysis. Epochs in ERSP may exceed 1000 ms used in ERP method, as it is often used for analysis of continuous changes during a short period of time (Delorme and Makeig, 2004).

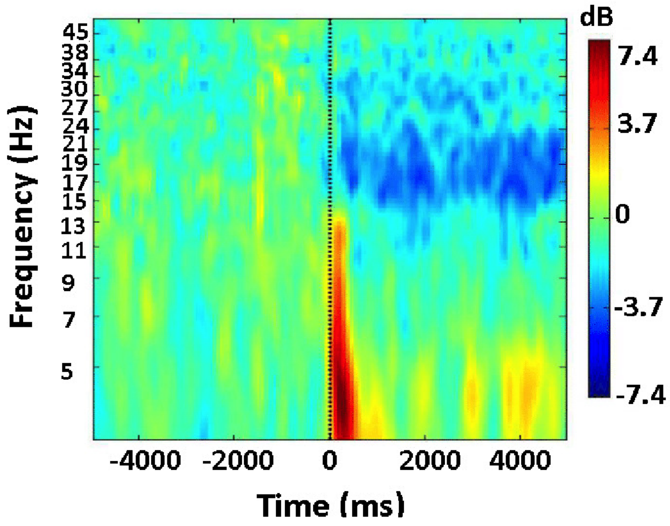

Figure 10: Illustration of the ERSP method. Source: Campus et al. (2011).

Power Spectral Analysis (illustrated in Figure 11) or just spectral analysis is one of the standard methods used for quantification of the EEG. It uses Fourier Transform to decompose individual frequencies from the main signal, in which multiple frequency ranges are mixed in different proportions. PSA allows to image the degree of power of individual frequencies present in the data and analyse it further (Delorme and Makeig, 2004).

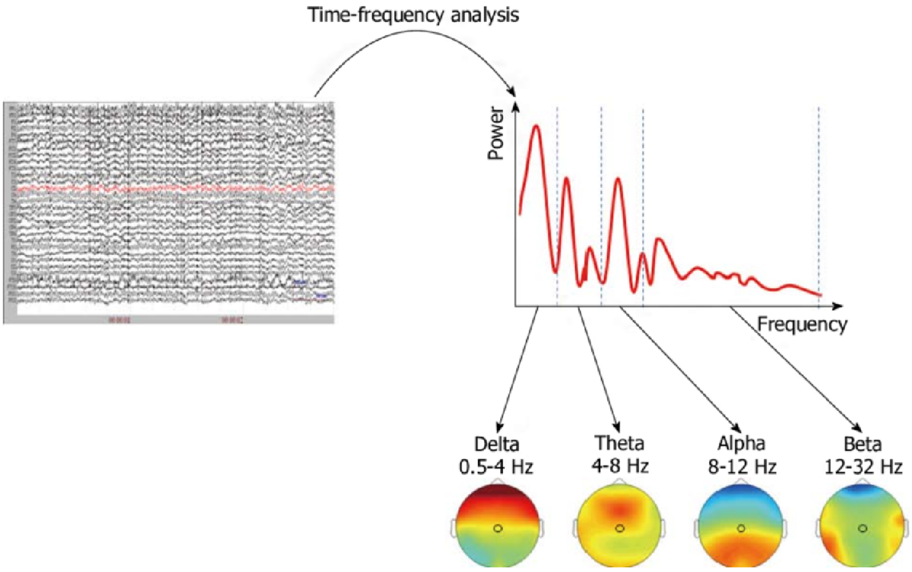

Figure 11: Illustration of the spectral analysis method. Source: Lelic et al. (2014).

5 EEG Substrates of Visual Perception

In this chapter, I present EEG correlates of visual perception and habituation to visual stimuli both in general and in context of perception of advertisements.

5.1 General EEG Correlates of Visual Perception

The primary visual signal processing in the brain is concentrated in the occipital lobe of the cerebral cortex. At the same time, it is also expanded to the parietal and temporal lobes. The accentuation of brain activity during visual processing can be observed through various imaging methods, including EEG (described in Chapter 4) and fMRI (Koukolík, 2012).

In EEG, visual perception is connected to dominant alpha-band activity (individual frequency bands of brain activity are described in Subchapter 4.3). In the mentioned regions, mainly occipital activity is induced by thalamocortical neurons projecting from the lateral geniculate nucleus to the visual cortex (Taylor and Thut, 2012; Mathewson, 2009). Experimental evidence also suggests that faster alpha frequency in the mentioned regions predicts more accurate temporal discrimination of stimuli (Samaha and Postle, 2015).

Visual perception is also defined in Event-Related Potentials (see Figure 12), or more precisely in ERP components, also collected using the EEG set. As described in Subsection 4.6.2, Event-Related Potentials are defined as slow brainwaves which are produced by neural circuits following some sensory or cognitive stimulation. The ERP technique enables a researcher to collect a clear representation of an immediate reaction to a stimulus through the repeated presentation of the stimuli. The individual ERP components received using the technique are divided by polarity of the amplitude, and time of onset, which refers to the latency of the wave. Multiple components may be observed in a single event-related potential (Martin, 1998).

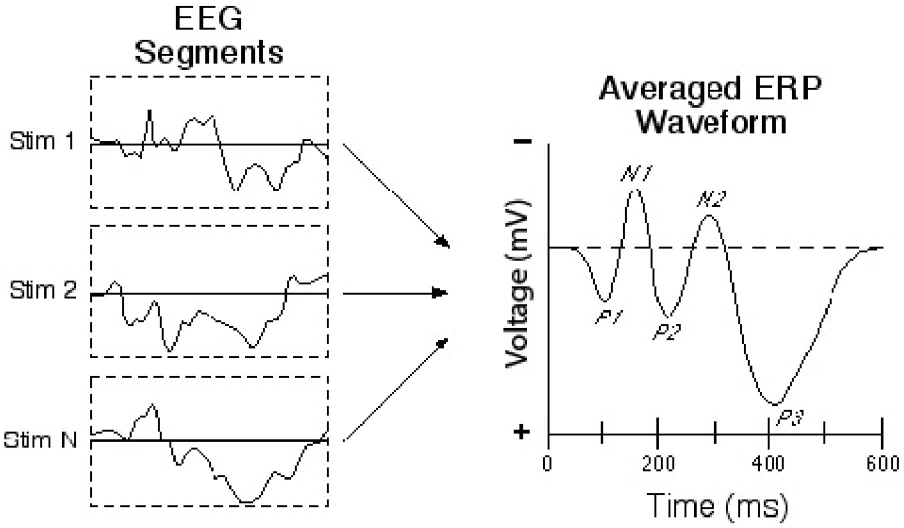

Figure 12: ERP components and averaging illustration. Source: Manhes and França (2011).

5.2 ERP Components of Visual Perception

ERP components are divided into the early and the later waves. Early components, such as P100 or N100 and P200 or N200, are thought to represent the initial neural response to the stimulus presentation, potentials that do not rely on cognitive processing but come as the sensation or perception of a sensory stimulus. Late components, especially P300, represent more complex, endogenous cognitive processing, such as response to stimulus uncertainty, context-updating and other phenomena (Martin, 1998).

One of the critical moments in fast habituation is selective attention. Saavedra and Bougran (Saavedra and Bougrain, 2012) describe specific characteristics of early ERP components associated with immediate, particular visual attention, visual evoked potentials (VEP) in the following way.

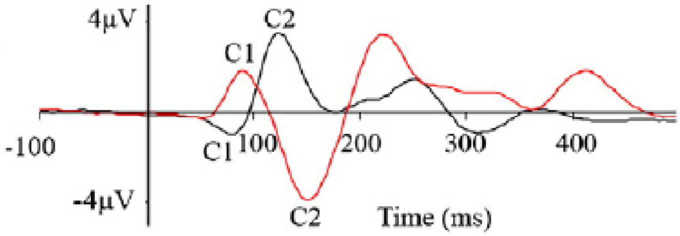

Figure 13: C1 and C2 components illustration. Source: Miller et al. (2014).

The first major visual evoked potential by latency is the C1 (illustrated in Figure 13), generated in the primary visual area *"V1"* (Martin, 1998) in the striate cortex, with the point of onset at approximately 50 ms and a peak at 90 ms. When the stimulus appears in the upper visual field, C1 has negative polarity, and the opposite: when perceiving a stimulus in the lower visual field, the positive polarity of C1 is manifested. For this reason, the component is not marked with the standard N or P nomenclature. C1 is sensitive to contrast in the visual field (Saavedra and Bougrain, 2012).

P1 (P100) is the first positive component, with an onset at 60-80 ms and a peak at 100-130 ms in the lateral occipital cortex. P1 overlaps with C1 in the early phase, complicating the identification of the time of its onset. It is a mandatory exogenous response to visual stimuli, showing influence by external factors such as luminance. The larger amplitude of P1 is evident during the perception of unpleasant stimuli, exampling a link between this component and affective processing (Saavedra and Bougrain, 2012). Luo and colleagues found a correlation between P100 and perception of facial expressions (Luo, 2009).

The visual N1 (N100) component is typically specified to differentiate it from the acoustic version. The manipulation of attention elicits it. Its peak is manifested at 100-150 ms, prominent in the lateral occipital cortex sensitive to the process of discrimination. N100 also represents lexical processing, with its amplitude increasing while reading pleasant words (Saavedra and Bougrain, 2012).

The following negative component, N170, is sensitive to face perception and familiar objects and words. The exact source of the component is still controversial. The latest evidence directed towards posterior superior temporal sulcus (Saavedra and Bougrain, 2012; Luck, 2005b).

N200 can be deconstructed into two subcomponents: the N2b, evoked by conscious attention to the stimulus, shown in visual discrimination tasks, and the N2c, arising in classification tasks. Also, an N2pc component is recognised (*"pc"* standing for *"posterior-contralateral"* cortex), showing when one specific object is being processed and the other ignored (Saavedra and Bougrain, 2012).

These studies describe the localisation, latency-polarity qualities of visual perception in different elements of reaction to visual stimuli in ERP. They example, that ERP can be used to infer the nature of visual phenomena observed with its help.

5.3 EEG Substrates of Habituation to Visual Stimuli

Grandstaff and Pribram (1972) have found the habituation process in the striate cortex's visual system to constitute a complex response pattern, sensitive to modality and the nature of neural structures involved in the processing. They also observed a consistent decrement in power in the optic nerve and LGN areas, happening in two stages: a sharp decline in amplitude over the first few trials and a slower gradual decline during a week of trials. The decrement in power occurred specifically at Gamma-band frequencies: 37-50 and 72-80 Hz.

Megela and Teyler (1979) present evidence for habituation of early visual N1 and P2 components between stimulus presentations, as well as the late visual P3 component. The authors accented the brightness dimensions of the visual stimuli, and the habituation proved to be present for both bright and dim stimuli. Dishabituation was observed separately at the N1 and P2 early visual components and the P3 late visual ERP component as well.

Verbaten with colleagues (1986) found the habituation effect of being most prominent in a decrease of latency of N1 between visual stimulus presentations (with long variable intervals) in orienting reaction, regardless of stimulus complexity. It was also present in the late P300 (especially P3b) component, with a significant effect over 12 trials, but habituation was slower in this case. The effect was followed at the frontal, vertex and parietal leads. More evidence of a significant effect of visual habituation in P300 is presented in Lammers and Badia's oddball paradigm research while analysing the data from the Cz electrode alone (see electrode placement in Chapter 4.4.1). They also followed a habituation effect in N200 in the same conditions and N100 when evaluating three electrodes: Fz, Cz, and Pz (Lammers and Badia, 1989).

There is also experimental evidence for habituation enhancing novelty detection through Short-Term Synaptic Depression (Jacob and Huber, 2019). The authors confirm the consistency of the habituation paradigm in predicting decrement in P100 (in visual object identification) and N170 (in lexical identification) ERP components as a consequence of stimulus repetition and visual priming for the stimulus. Authors also concluded that the neural habituation model lays the ground for the N400 semantic discrimination component but doesn't manifest itself in it.

Empirical part

6 Aim of the Research and Hypotheses

In this chapter, I describe the objective of this study based on the research problem. Research Questions and Hypotheses are also presented in this chapter.

6.1 Research Problem

Advertisements have a constant presence in our informational field, including cyberspace. As stated in Section 3.2, the primary advertising goal is to attract buyer's attention to the product. This brings us to a situation where many prominent heterogeneous and sometimes homogeneous stimuli fill our informational space and distract from the ongoing cognitive tasks, especially on the Internet. Most of the studies that paid attention to this issue looked upon it exclusively from the perspective of advertising effectiveness, with the effectiveness measure reduced to brand recognition, short-term, and long-term memory of the brand and product (Dahlén, 2008; McCoy, 2007).

Germelmann (2020) presents evidence of the effectiveness of homogeneous advertising, referring to the positive influence of the uninterrupted experience fluency on the propagated brand and product attitudes. Still, the study mainly concentrates on advertisement recall and after-trial verbal feedback about the perception experience. Therefore, the actual nature of the difference in cognition between these advertisement approaches remains unaddressed.

The habituation mechanism is used in the animal nervous system to ignore redundant short-term and long-term stimuli. It is by this mechanism, evoking synaptic depression (Jacob and Huber, 2019), that we can remain directed towards the relevant stimuli and not process the rest of the sensory field in depth, i.e., sustain selective attention (Buskirk, 2013; Saavedra and Bougrain, 2012) and identify novel stimuli in the field (Jacob and Huber, 2019). It is also evident that some stimuli naturally attract human and other animals' attention more due to both heritability and learning (Mather and Sutherland, 2011; D. Barrett, 2010), and those are the ones most manipulated in the advertisement business. Therefore, researching the habituating reaction to advertisements is the base for evaluating their meaningful interaction with human cognition, which seems to be especially significant in cyberspace.

This study aims to identify the habituating reaction to advertisements and evaluate the psychophysiological difference in their perception. Habituation is followed in a comparison of homogeneous and heterogeneous static visual advertisements. The advertisements appear on the presentation screen while the participants are watching informal educational video materials.

6.2 Research Questions

The following research questions were formed to fit the research purpose:

Main Research Question (MRQ):

MRQ: How does the EEG habituation response differ between the perception of homogeneous and heterogeneous static visual advertisements?

Sub Research Questions (SRQ):

SRQ1: How does the EEG habituation response differ between the perception of homogeneous and heterogeneous static visual advertisements between experimental groups in ERP?

SRQ2: How and does the EEG habituation response differ between the perception of homogeneous and heterogeneous static visual advertisements between experimental groups in power spectrum and ERSP?

6.3 Hypotheses

The experiment is designed to observe the phenomenon in an environment that does not go far from the actual in-video advertisement perception context on the Internet.

For this reason, it could not contain the number of stimuli (advertisements) presentations needed for a standard ERP paradigm experiment, with a standard minimum count of stimulus presentations starting around 30 events (Thigpen et al., 2017; 2018). The optimal number varies with the experimental design. This experiment counts 15 stimulus presentations (trials) per participant with a significant period between the presentations. The period is taking place while the videos were perceived, or the participant's attention to the contents of the videos is assessed with a questionnaire.

The standard minimum count of trials in ERP varies. Number of stimuli used in an ERP study depends on the observed phenomenon's nature, the group's size, and the expected difference in power between conditions. For the studies where a relatively small difference in power is expected, the minimal number of stimulus presentations for a single condition starts around 30 (Thigpen et al., 2017; Boudewyn, 2018). According to the same authors, 18 participants are sufficient for an ERP study, making around the minimal amount of subjects for valid results. At the same time, the effect of habituation in real-time visual perception was not yet observed using Power Spectrum Analysis or Event-Related Spectral Perturbations methods, so the study must rely on both plains of assessment.

When conducting an EEG ERP study, researchers do not work with the standard hypotheses, predicting a certain dependency between two variables. Instead, they use so-called Effect-Specific Hypotheses (or Effect-Unspecific Hypotheses respectively) (Handy, 2005).

The term Effect-Specific Hypothesis refers to a hypothetical prediction of a specific change in both amplitude and latency domains of a certain ERP feature (or component) between conditions. The term Effect-Unspecific Hypothesis describes a hypothetical prediction where only the presence of the difference between conditions is accounted for, and the precise characteristics of the difference are omitted. This way, while an effect-specific hypothesis allows for a more valid conclusion from the results, an Effect-Unspecific Hypothesis leaves more freedom for post hoc analysis and theoretical interpretation, which is often questionable. Still, in some research, it is hard or impossible to rely on an Effect-Specific Hypothesis due to its broad nature of the absence of previous evidence of a specific effect in the employed research domain. In this case, it requires follow-up research to confirm the preceding conclusion based on an observation following an effect-unspecific hypothesis (Handy, 2005).

Due to the nature of the study and the prevailing absence of concrete ground for specific predictions, both approaches are used to construct satisfactory hypotheses for the study.

The following hypotheses are formulated based on the previously presented research questions.

H1: The homogeneous advertisements require a less prominent habituation response than the heterogeneous ones, manifested in a smaller amplitude of the Early Visual Event-Related Potential occurring after the stimulus presentation.

H2: The homogeneous advertisements require a less prominent habituation response than the heterogeneous ones, manifested in less intense Power Spectral changes after the stimulus presentation.

7 Methodology of the Study

In this section, I describe the approach, which was utilised during the construction and conduction of the study.

7.1 Experimental Design

As previously mentioned in the Chapter 6.3, the experiment was designed to measure the phenomenon in an environment, that does not differ significantly from real cyberspace, where advertisement perception during video-watching occurs. It was adjusted to the conditions of the measurements accounting for the use of the EEG data collection. A novel experimental paradigm was created to fit the purpose since no other was available.

The experimental paradigm was created in the OpenSesame 3.3.1 program (https://osdoc.cogsci.nl/). The program itself required significant adjustments due to the software inconsistencies on the computer where it was installed.

The paradigm consists of six informational videos in Czech language, which are presented to every participant in the same order. The videos were chosen by the following criteria: 3-7 minutes of length, relatively high informational value, quality of 720p or higher, minimal visual and auditory prominent noises.

Two to three self-made advertisements were placed in each video with randomly chosen intervals between them. Each advertisement is displayed for 6 seconds, corresponding with the minimal advertisement presentation time on the YouTube platform. The time of target stimuli presentation in the videos was the same for both experimental groups. The moments of advertisement presentations were set in the time areas of their probable occurrence in the videos on the YouTube service, that is around the middle of a video of the chosen length and then on fairly even intervals closer to its ending.

To ensure the direction of participants' attention towards the videos, six small questionnaires were compiled and printed out on paper, one set for each video. An example of a questionnaire is presented in Appendix. Participants were provided with a pen to answer the questions. Every questionnaire contained three questions about the video contents and two questions about its quality. The participants were instructed to answer one questionnaire after each video. The participants were not initially informed about the advertisement presentations.

The experiment was conducted in a following order:

1. Hardware and software are prepared for the assessment.
2. The participant is acquainted with the upcoming process.
3. An informed consent undersigned by the participant.
4. A basic state form filled out by the participant.
5. The participant is led to Faraday's cage, where the hardware and the EEG set are installed.
6. The best-fitting EEG cap is fixed on the participant's head, and the electrodes are placed, using conductive gel.
7. The experiment is started, and the signal recording is activated.
   (a) A short instruction is again presented to the participant before the first video.
   (b) The first video is presented to the participant, with the stimuli appearing at 129120-135140 and 246000-252000 ms for both experimental groups.
   (c) An unlimited amount of time is offered to the participant in order to fill out the questionnaire.
   (d) Once the participant notifies the researcher of their readiness to proceed, the next video is started.
8. The experimental cycle takes place six times, with the advertisements always presented at a fixed moment for every participant (all of the times of target stimuli presentations are included into Table 2).
9. After the presentations are concluded, the data recording is stopped, the electrodes and the cap are uninstalled from the participant's head.
10. The participant is presented with a short set of qualitative questions for the control of more specific possible intervening variables (for instance, the amount of regular exposition to video-contents and attitude towards advertisements).
11. The experiment is concluded.

Time of target stimulus presentation from the start of the video in ms			
Video 1	129120-135140	246000-252000	X
Video 2	121120-127120	242070-248080	X
Video 3	174160-180160	300090-306090	380110-386110
Video 4	169020-175030	292070-298070	380020-386020
Video 5	115250-121260	222120-228120	X
Video 6	135130-141130	242170-248170	308150-314150

Table 2: Time of target stimuli presentations from the start of the each environment stimulus in ms. *X* stands for the planned absence of a third advertisement presentation in the video.

7.2 Data Collection

The experiment was conducted in the EEG laboratory on Faculty of Education of the University of South Bohemia from February to April of the year 2022. As stated in the Chapter 7.1, the measurements took place in Faraday's cage, where the equipment was installed, including an EEG set, a screen, and speakers.

A Biosemi ActiveTwo EEG with a 32-electrode set was used in the experiment. The electrodes were of the Ag-AgCl active type, and the electrode placement corresponded with the standard 10-20 Electrode Placement System (see Subsection 4.4.1). The EEG cap was chosen from three size options (S/M/L), according to the participant's head size, and centred relative to the high-middle point of the participant's head (Cz electrode). The placement of the electrodes took approximately 20 minutes. The presentation process took around 40 minutes. The session, including electrode installation and displacement, paradigm presentation, and completion of the questionnaires, lasted for 1 hour and 30 minutes in average.

For the presentation of the paradigm, described in the Chapter 7.1, its synchronisation, and time-triggers installation, the Open Sesame 3.3.1 software was used. The experiment was transmitted to the screen in a Faraday's cage from the personal computer 1 (PC1), where the experimental software was installed. The data from the EEG set was transmitted through the parallel port to personal computer 2 (PC2), where the signal reading software, BiosemiLabView, was installed. The signal reading software on PC2 received information about the event time triggers from the PC1 through the parallel port. The data were recorded at the sampling rate of 2048 Hz and saved on the PC2.

7.3 Participants

The experimental sample consisted of eighteen participants, nine males and nine females aged 18-26, making a minimal satisfactory number of partakers for a study (Boudewyn, 2018; Thigpen et al., 2017). All participants were University of South Bohemia students from the Faculty of Education and the Faculty of Arts. The participants were randomly divided into three groups: two experimental and one control group. Each group contained an equal number of both genders. None of the participants had a significant visual impairment. Two participants (one male, one female) were left-handed and sixteen right-handed. All of them had a satisfactory amount of sleep hours the day before the study.

All of the participants were informed about the process of the experiment. The experiment's aim and specifics of the stimuli nature were not shared with the participants before the experiment took place. All participants were asked to reduce the amount of the carried metal objects and objects with metal elements before entering Faraday's cage and remain as still as possible during the measurements.

7.4 Ethics of the Study

All of the participants received and signed informed consent, formulated in the following way (originally in the Czech language):

"I agree with voluntary participation in this study without a reward claim entitlement. You have a right to exit the study at any given moment, without any reason. Your personal information only serves the purpose of data processing in the study. The collected information is not provided to third parties, and your recordings are anonymous."

All participants were informed about the general nature of the experimental process, including the general nature of the videos, serving the role of an active environment for the presentation of the target stimuli, and the technicalities of electroencephalographic analysis, which may concern the participant. Every participant was allowed to provide an e-mail address to receive the study results once it is concluded.

7.5 Stimuli

The stimuli, used in the study, may be primarily divided into two categories: environment and target stimulus. The videos served as the environment and the advertisements played the role of target stimuli. The videos were chosen by the criteria, mentioned in the Chapter 7.1, in order for them to satisfy the quality norm, the requirement of a relatively high informational value, and the necessity to avoid overstimulation and exhaustion.

Due to the proven priming effect of brand familiarity (Kim, 2016; Lin, 2014), most of the advertisements (11 out of 15) were created by hand (see examples in Appendix), the other were of brands, either not present or not widely recognised in Czech Republic. The advertisements were full-coloured. All of them contained a mild amount of semantic information, some contained human faces or postures.

The participants' possible acquaintance with the advertisements and the videos was assessed after the presentation. The number of familiar stimuli is minimal among participants and ranges from 0 to 2 (out of 21 stimuli of both kinds).

7.6 Data Preprocessing

In this section, I describe data pre-processing steps, taken to ensure a good quality of the signal before its analysis.

7.6.1 Dataset Import

MATLAB R2022a with an EEGLAB plugin (Delorme and Makeig, 2004) and two signal processing add-ons were used in the research for data preprocessing. The EEG recordings were saved and uploaded into MATLAB in the .bdf format.

Firstly, the imported signal, received from one experimental session, is labelled for the later identification in the following order: initials, ID-number, ID-number in group, group. Then, channel (electrode) locations of the 32 used electrodes are imported from the same file. The channel locations are recorded in three-dimensional Cartesian coordinates. Identifying the positions of individual electrodes enables the two- and three-dimensional mapping of the electrical activity in the brain. Just as the physical electrode placement, the digital localisation is based on the 10-20 Electrode Placement System (see example on Figure 8).

7.6.2 Signal Cleaning

After the channel locations are imported, the data recordings must be cleaned from the multiple kinds of artifacts, appearing in the recordings (see types of artifacts in the Chapter 4.5). Multiple levels and methods of afrtifact cleaning are used to receive a satisfactory quality of the signal. In this study, several automatic artifact cleaning methods were used.

Automatic cleaning algorithms allow for the recording parts affected by artifacts to be adjusted, and not rejected. For this reason, only this kind of algorithms was used to clean the data recorded during this experiment.

The cleaning of the data started with the review of the overall condition of the data, recorded by individual electrodes and rejecting or interpolating up to 10 percent of the electrodes if needed. The following elements were cleaned from the data: line noise, multiple kinds of eye and muscle artifacts, artifacts caused by malfunctioning electrodes. Electrodes, which exampled a strong derivation in power spectrum from the average value on the Channel spectra and maps instrument in EEGLAB, were interpolated or rejected. The individual channels for rejection were chosen with the help of the channel spectra and maps instrument and visual evaluation of the signal quality using the channel data imaging instrument. In case the critically affected electrodes were not positioned closely to one another, they were interpolated (replaced with an approximation of the signal on the electrode in question based on the activity of the neighbouring electrodes), instead of being rejected completely.

The second artifact cleaning step was taken after the re-sampling of the signal (see Subsection 7.6.3).

After the data were downsampled, it was processed with the CleanLine automatic afrifact cleaning algorithm. A significant function of the CleanLine algorithm is reducing the 50 Hz noise, which is caused by the activity of Common Mode Sense (CMS) and Driven Right Leg (DRL) electrodes in the Biosemi EEG set. After the CleanLine algorithm was applied, the signal was again re-referenced relative to the average signal value.

Then, as the last artifact cleaning measure, the signal was also processed by the Artifact Subspace Reconstruction (ASR) algorithm, which adjusted the signal in the locations of specific highly prominent artifacts (Mullen, 2013). A re-referencing again followed.

7.6.3 Signal Filtering

After the critically affected electrodes were removed or interpolated, the signal was filtered with a 0,5 Hz high-pass and 45 Hz low-pass. This high-pass was chosen due to the frequencies below 0,5 Hz not being useful for the research. I also accounted for the probability of a higher filter affecting the late positive potentials (LPP) (Hajcak, 2012), such as the P3 wave component (Luck, 2005a), which could serve as subsequent evidence of the process of habituation (see Chapter 5.3). The 45 Hz lowpass was chosen after primary pre-processing to improve data quality and reject 50 Hz line noise. Afterwards, the signal was re-referenced relative to the average value of all channel signals.

After this, the data were re-sampled from initial 2048 Hz to 512 Hz sampling rate, ensuring a smaller file size of the data and conserving a maximal needed quality of the signal. This re-sampling rate was chosen based on the research showing, that lower sampling rates may distort the data (Jing and Takigawa, 2000).

The described procedure was initially performed with 18 data recordings, collected from the participants' brain activity during the measurements. Two of the datasets (one in the Heterogeneous group, one in the Control group) were too damaged to recover readable data, as the spectral power presented critical abnormal repetitive spikes in all frequencies, and therefore were rejected. One participant with the lowest signal quality (the highest amount of noise, malfunctions, and artifacts) was rejected from the Homogeneous group due to an equal number of subjects requirement in the EEGLAB between-group analysis.

After the signal was fully processed and reached a significantly better quality composure, the 15 epochs (the time sections, where the target stimuli presentations take place), were extracted for the further grouping and analysis.

7.7 Data Analysis

To analyse the data and extract the features, needed for hypothesis testing, the data epochs were arranged into a study, which was created in the EEGlab MATLAB plugin. Every participant's dataset, containing all epochs from one recording session, was identified by the number of the participant (for instance, S12, *S* standing for *Subject*) and group ID (HE, HO, CO). Since every participant's data were recorded in a single run during a single session, the *"run"* and *"session"* categories were not utilised.

Before the testing, the data were decomposed by Independent Component Analysis. Components including muscle and eye artifacts were automatically flagged and removed by ICA, if the probability of the component being being artifactual exceeded 0.9.

The comparisons were statistically tested using permutation statistics with FDR correction for both paired tests and multiple comparisons. Using permutation statistics for the data comparison is advised for plotting the final results in EEGLAB due to most statistics in the plugin relying on surrogate methods which are not sensitive to the data probability distribution (Grandchamp and Delorme, 2011).

The comparisons were performed between each pair of the groups. The following signal comparison designs were therefore formed for all methods of analysis:

- Heterogeneous advertisements (HE) and Control group (CO)
- Homogeneous advertisements group (HO) and Control group (CO)
- Heterogeneous advertisements (HE) and Homogeneous advertisements group (HO)

The baseline was set to -500 to 0 ms, which is a widely used baseline latency, advised to avoid data distortion, which may appear when using a baseline under 200 ms of duration. The frequency range for Spectral Analysis and Event-Related Spectral Perturbation was set to 0.5 to 45 Hz, regarding previous filtering. The latency range for Event-Related Potentials and ERSP was set to -200 to 1200 ms interval.

All modelled comparisons were performed with an alpha-value of 0.05. This threshold of significance ensures a higher validity, despite the analyses employing correction by repeated measurements being prone to second-type errors (Mrhálek, 2019).

8 Results

The results are presented in a form of differential comparisons between the three groups: Homogeneous advertisements group, Heterogeneous advertisements group, and the Control group, where the triggers are placed on the exact same time, as in the other groups, but no advertisements are shown and the video perception continues uninterrupted.

The changes were followed using three methods: ERP, ERSP, and Power Spectral Analysis, all included in the EEGLAB plugin. Electrodes Fp1, Fp2, Cz, paired T7 and T8, and paired O1 and O2 were chosen as target electrodes for ERP analysis, according to the previous research, underlining the significance of their positioning in estimating neural substrates of visual perception and habituation (see Chapters 2, 3.1, 5.3). These electrode positions cover the activity of the prefrontal cortex, visual neural pathway areas, and the primary visual cortex, most relevant for the item of interest. General averages of all electrodes were also included into the analysis, primarily for ERSP and Power Spectral Analysis.

The results are presented here in three comparisons of the listed electrodes between the groups of participants, each done by three methods.

8.1 HE and CO Groups Comparison

The first comparison was between HE and CO groups. ERP, ERSP and power spectrum values are presented below.

8.1.1 HE and CO Groups ERP

Comparison of ERP in the activity of Fp1 electrode (Figures 14 and 15) showed a small significant difference in the late negative N400 component, which becomes more prominent as the heterogeneous advertisements are presented.

Similar dynamics can be seen in the Fp2 paired comparison, but the effect was rendered insignificant in this case.

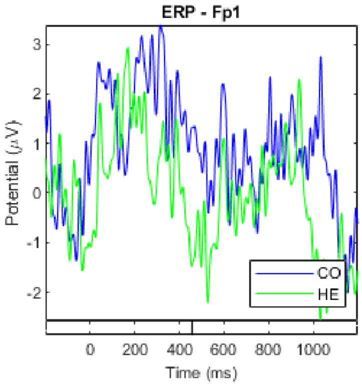

Figure 14: ERP comparison of HE and CO group averaged activity on Fp1.

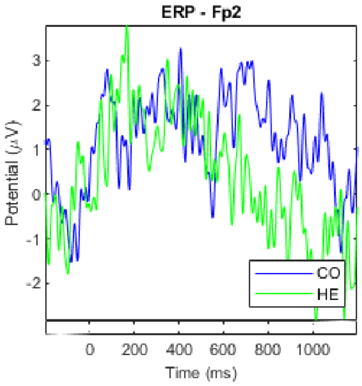

Figure 15: ERP comparison of HE and CO group averaged activity on Fp2.

On the Cz electrode location (Figure 16), there is a significant difference in activity present in a late 700-800 ms negative potential with the more prominent negativity manifested again in the HE group.

The comparison of the T7 and T8 channels average value (Figure 17) showed a difference in activity emerging around 1000 ms after the stimulus presentation (stimuli were being presented for 6000 ms). A more prominent positive potential is present in the HE group.

O1 and O2 average comparisons did not show significant difference in the signals.

8.1.2 HE and CO Groups ERSP

Event-Related Spectral Perturbation of average means for all electrodes show significant difference across most of the frequency spectrum during the whole 1200 ms period after presentation. A prominent suppression and the following arousal of the alpha and theta-band activity is seen in the case of heterogeneous ad presentation (Figure 18). Beta and Gamma frequency domains were also significantly affected.

8.1.3 HE and CO Groups Power Spectrum

Despite the prominent changes in the ERSP, no significant difference in overall average power spectrum was found in the period of the whole epoch (-500 to 6000 ms), as it may be seen in

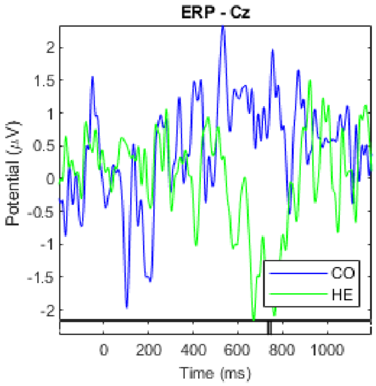

Figure 16: ERP comparison of HE and CO group averaged activity on Cz.

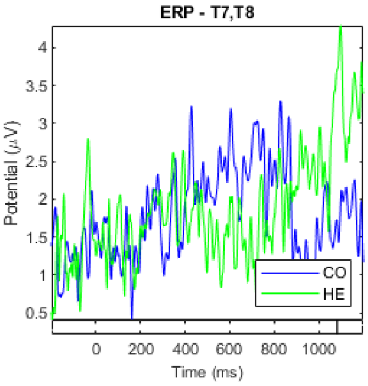

Figure 17: ERP comparison of HE and CO group averaged activity on averaged T7 and T8.

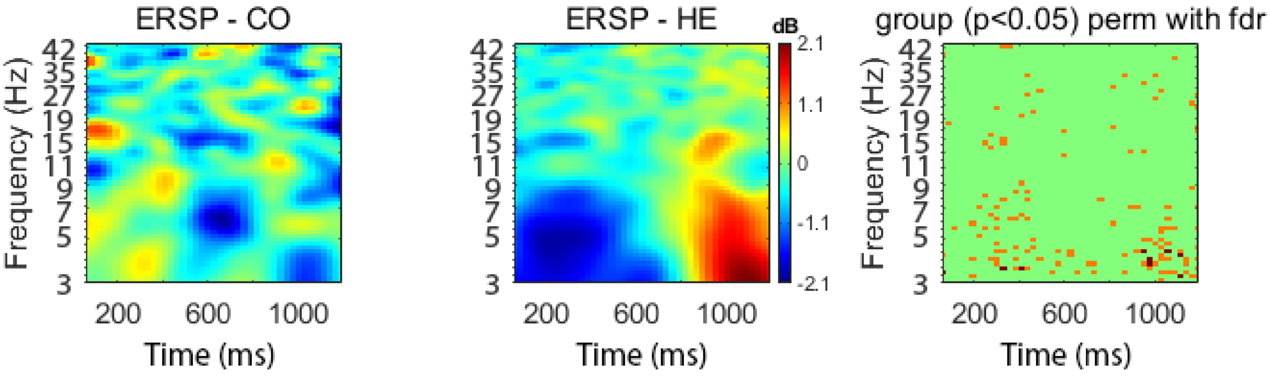

Figure 18: Average ERSP value for all electrodes comparison in HE and CO groups.

Figure 19.

8.2 HO and CO Groups Comparison

The second comparison was between HO and CO groups. ERP, ERSP and power spectrum values are presented below.

8.2.1 HO and CO Groups ERP

Comparison of ERPs in the activity of Fp1 electrode (Figures 14 and 15) showed a small significant difference in the late negative N400 and N700 components, which are more prominent in the case of heterogeneous advertisement presentation, compared to the continuous video perception.

A higher HO group overall signal volatility can be noticed on Fp2 compared to the CO

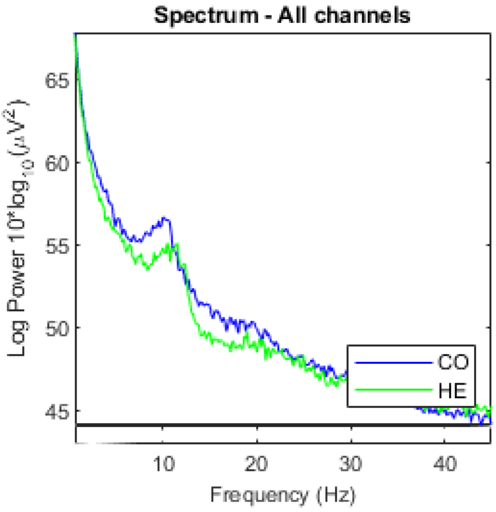

Figure 19: Average Power Spectrum value for all electrodes comparison in HE and CO groups.

signal, but the effect was rendered insignificant.

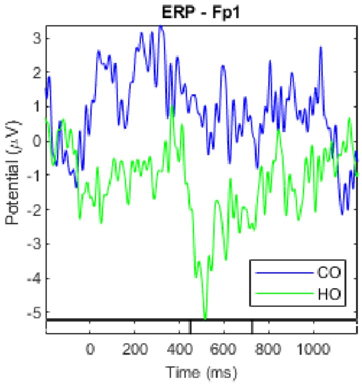

Figure 20: ERP comparison of HO and CO group averaged activity on Fp1.

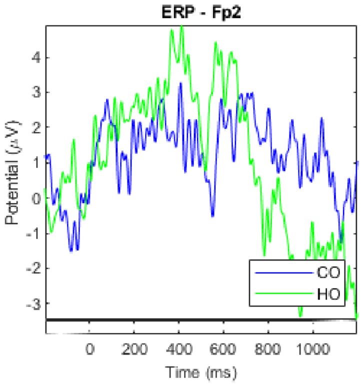

Figure 21: ERP comparison of HO and CO group averaged activity on Fp2.

On the Cz electrode location (Figure 22), there is a statistical significance differentiated in activity present in a late 800-900 ms negative component with the more prominent negativity manifested again in the HO group. More prominent earlier late negative components can be seen, that were not categorised as statistically significant.

The comparison of the O1 and O2 channels average value (Figure 23) showed a difference in activity emerging at 800 ms after the stimulus presentation. The activity in the HO group manifests a positive peak, exceeding that of fluent perception in CO group.

T7 and T8 average comparisons did not show significant difference in the signals in this case.

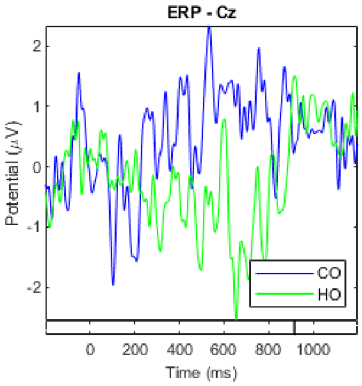

Figure 22: ERP comparison of HO and CO group averaged activity on Cz.

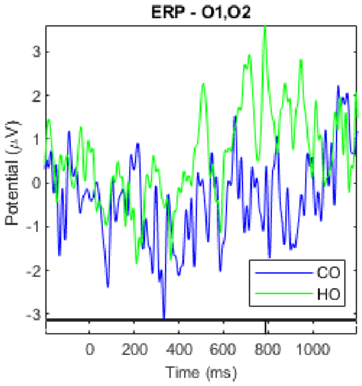

Figure 23: ERP comparison of HO and CO group averaged activity on averaged O1 and O2.

8.2.2 HO and CO Groups ERSP

Event-Related Spectral Perturbation of average means for all electrodes show significant difference across the theta and a minor difference in alpha-band activity. Like the HE group in comparison with CO group (Section 8.1.2), HO shows prominent suppression in the first 500 ms after stimulus presentation and further activation in the later period of 700-1200 ms. Still, with the the spectra in the HO group being much more consistent with the fluent perception state, than the HE group (Figure 24).

8.2.3 HO and CO Groups Power Spectrum

No significant difference in overall average power spectrum was found in the period of the whole epoch (-500 to 6000 ms), and neither in any of the individual electrodes (Figure 25).

8.3 HE and HO Groups Comparison

The third comparison was between HE and HO groups. ERP, ERSP and power spectrum values are presented below.

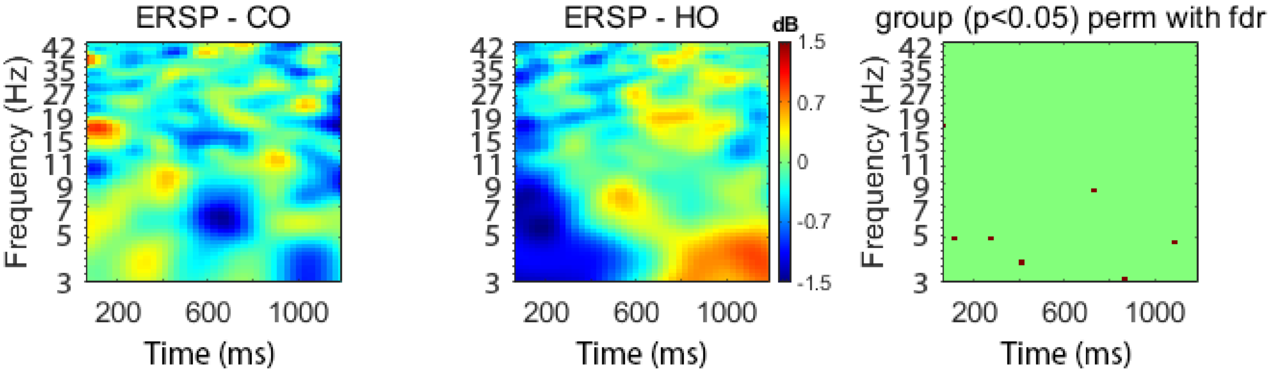

Figure 24: Average ERSP value for all electrodes comparison in HO and CO groups.

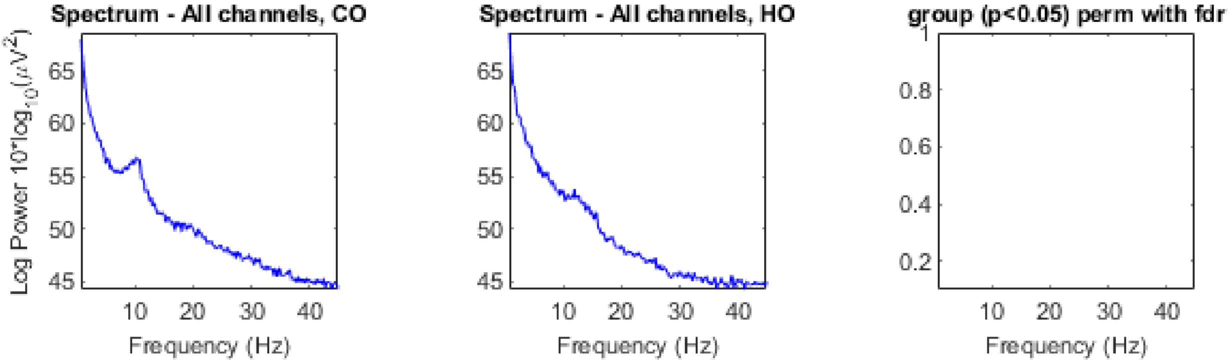

Figure 25: Average Power Spectrum value for all electrodes comparison in HO and CO groups.

8.3.1 HE and HO Groups ERP

Comparison of ERP in the activity of Fp1 electrode (Figures 26 and 27) showed a small significant difference in the late negative N400 component, which is more prominent in the case of homogeneous advertisement presentation, compared to the heterogeneous.

No significant difference was found in the activity of the Fp2 electrode.

No statistical difference in activity between HE and HO groups was found on the Cz electrode location (Figure 28).

The comparison of the O1 and O2 channels average value (Figure 29) showed no difference in activity as well.

T7 and T8 average comparisons did not show significant difference in the signals.

A significant difference was shown in the grand average ERP comparison between the groups. The HO group manifested higher overall positivity in the area between 600 and 700 ms (Figure 30).

8.3.2 HE and HO Groups ERSP

Event-Related Spectral Perturbation of average means for all electrodes show significant difference across the whole frequency spectrum from 0.5 to 45 Hz., with the spectral changes being

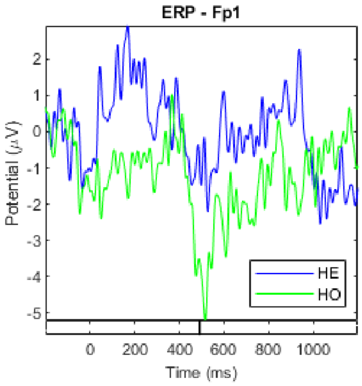

Figure 26: ERP comparison of HE and HO group averaged activity on Fp1.

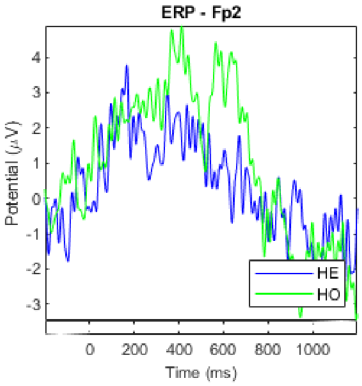

Figure 27: ERP comparison of HE and HO group averaged activity on Fp2.

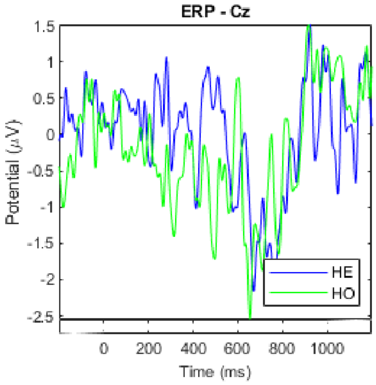

Figure 28: ERP comparison of HE and HO group averaged activity on Cz.

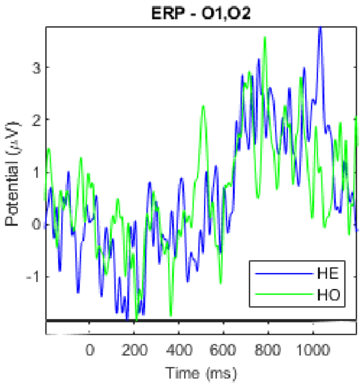

Figure 29: ERP comparison of HE and HO group averaged activity on averaged O1 and O2.

more prominent in the HE group (Figure 31).

8.3.3 HE and HO Groups Power Spectrum

No significant difference in overall average power spectrum was found in the period of the whole epoch (-500 to 6000 ms), and neither in any of the individual electrodes (Figure 32).

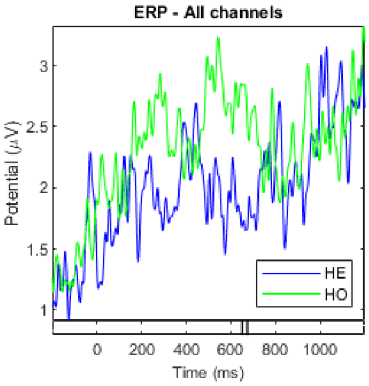

Figure 30: Average ERP value for all electrodes comparison in HE and HO groups.

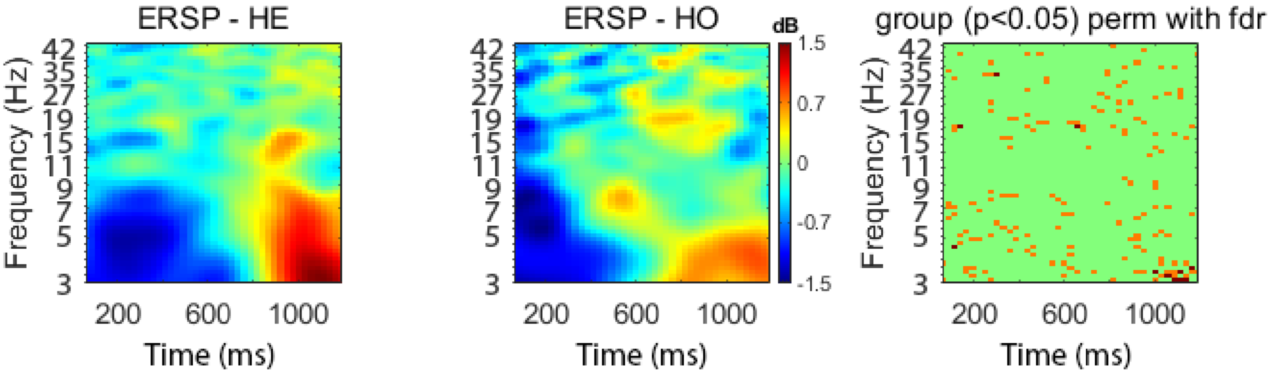

Figure 31: Average ERSP value for all electrodes comparison in HE and HO groups.

8.4 Interpretation

Based on the performed analysis, it can be inferred, that presentation of both homogeneous and heterogeneous advertisements during active video perception evoke a visible arousal-to-habituation response, which can be monitored with ERP and ERSP electroencephalographic methods. The difference in ERP can be seen mainly in the late components. HO group showed consistently higher positive and negative amplitudes on relevant electrodes.

ERSP showed the highest degree of significant difference in alpha and theta domains, coherent with the theory of visual perception, during the period of 1200 ms after stimulus presentation. Heterogeneous advertisements evoked a more prominent change in frequential dynamics. Significant difference was also seen in the beta and gamma domains, showing more consistence of HO group activity with the CO group, and HE group showing a more significant disruption. In the experimental conditions of this study, homogeneous stimuli evoked more prominent changes in both positive and negative amplitudes across different components, than the heterogeneous

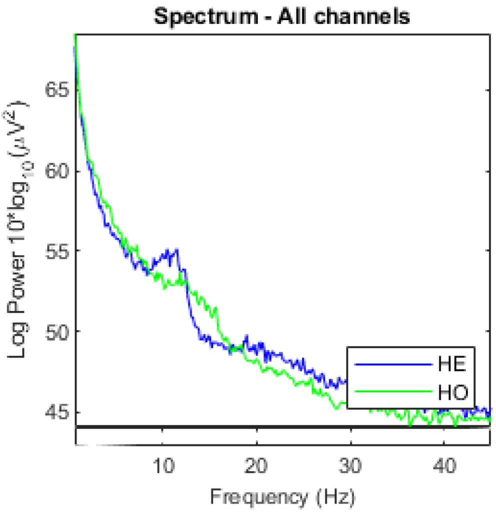

Figure 32: Average Power Spectrum value for all electrodes comparison in HE and HO groups.

ones.

According to these conclusions, the established hypotheses may be evaluated in the following way:

H1: The homogeneous advertisements require a less prominent habituation response than the heterogeneous ones, manifested in a smaller amplitude of the Early Visual Event-Related Potential occurring after the stimulus presentation. - **Rejected**

H2: The homogeneous advertisements require a less prominent habituation response than the heterogeneous ones, manifested in a less intense Power Spectrum after the stimulus presentation. - **Not Rejected**

Therefore it may be concluded, that homogeneous advertisements are likely to be less disruptive in the frequency domain, than heterogeneous advertisements, but may still have a higher effect on the amplitude of the evoked reaction. Thus, the ERSP analysis shows evidence, that homogeneous advertisements require less habituation, but the ERP analysis does not support this statement as suspected.

Also, the standard ERP characteristics of habituation, which are commonly described in between-trial within-subject comparisons, were not observed in the between-subjects analysis in this study, as the evoked potentials appeared mainly in the late components. This serves as an additional reason for rejecting H1.

9 Limitations of the Study

Though the experiment was controlled for many potential intervening variables, it must still be taken into account, that the results may have been influenced by multiple aspects of the process. Those include a relatively small number of participants, author's inexperience, which took effect even under a steady guidance of the supervisor, and a number of technical and general contextual complications, which emerged during the year of the study implementation.

Another limitation was a relatively small number of stimulus presentations in the paradigm, which would not be sufficient for a standard ERP study. That may have influenced validity of conclusions from the ERP between-group analysis.

To improve the approach and minimise the possibility of unwanted influences, the further steps should be implemented:

- The hardware and software used for the conduction of the experiment must be fully tested accounting for all the aspects of the processing and prepared for the experimental conduction.
- The design of the experimental paradigm must be in complete coherence with the signal processing software, so that no excessive steps are needed during the processing of the data.
- The number of participants should account for possible loss of data during the processing, in order for the data quality to be sufficient in that case.
- A paradigm should be constructed to fit both the requirements of the study objective and all methods of analysis, that are to be used.

10 Discussion

Habituation to novel and dynamic stimuli has been researched widely in the context of immediate reactions, and has been followed in multiple commonly researched ERP components, such as N1, P2, N170, P300, and other (see Chapters 2.2, 5.3).

In this research, it is visible, that the reaction to the changing visual stimulus in the context of active perception of complex stimuli may be active far in the late components of the evoked potentials. An abrupt change of context, containing complex stimuli, such as advertisements, evokes a full process of orienting evaluation before being habituated. The processing, connected to late potentials, is linked to stimulus categorisation, episodic memory, associative learning, semantic processing (see Chapter 3.1; Johansson and Mecklinger, 2003). Those processes are included into reaction to novelty and therefore will show habituation, when adapting to the novel stimulus during this reaction.

The first major implication of this study is that when a complex stimulus is presented in a similarly complex and dynamic environment, habituation (as moderation of synaptic depression a decrease following the reactive arousal) would appear only after the identification of an unexpected change of context. This orienting reaction in this case is not as rapid, as the identification of a simple prominent stimulus, appearing in a calm and stable environment. The suggestion would be, that this is a consequence of the predictive nature of perception (L. Barrett, 2017), i.e., since the environment contains a large amount of objects, and is constantly changing, the changes themselves are predicted to be dynamic, and therefore it takes more time to identify a specific change, that differs by nature, and integrate it into the perception of environment.

This implies, that the process of categorisation of stimuli as unimportant and formation of the reversable habit to ignore them can be researched out the context of primary non-associative information processing. The described approach has been so far predominant in the research of habituation. Further research of habituation to complex stimuli may allow better structuralization of implicit contextual learning and long-term consequences of repetitive perception of our surroundings.

The second major implication is that dynamics in domains of amplitude and frequency in EEG reaction to a stimulus may significantly differ. Since this proved to be the case, it is possible, that combination and comparison of these domains may provide additional information about the qualities of the reaction to the stimulus, the qualities of the stimulus itself, and the nature of its effect on perception.

In the context of advertisements, this implies, that further multi-perspective research of the qualities of advertisements is likely to allow designing and placing the advertising stimuli the way, that would at the same time be sufficient for the product propagation, and have a minimal disruptive effect on the individual's perception.

The third major implication concerns the reaction to homogeneity and heterogeneity of the stimuli, which were the main subject of this research. The results, received with the ERSP analysis, show, that homogeneous advertisements presentation allows to preserve most of the high-frequency (beta- and gamma-band) dynamics, taking place during video perception. HO group also presented less disruption in the alpha and theta domains, than HE group.

Thus it can be said, that the homogeneous stimuli habituate significantly better in the frequency domain, than the heterogeneous stimuli.

This implies, that choosing the same context for the presentation of advertisements is likely to be less disruptive for the fluency of perception.

The results from ERP analysis showed slightly more prominent positive and negative potentials in the HO group, than the HE group on the Fp1 electrode and on average. These prominent potentials, appearing in the late components, imply, that homogeneity of the stimuli requires more complex differentiation, processed in the prefrontal cortex. Accentuation on the left frontal lobe is evident. Despite a relatively small number of stimulus presentations, HE and HO groups show high consistency in response on the main electrodes, connected to visual perception, which serves as support for the validity of results.

As the electrodes, monitoring the visual neural pathway and primary visual cortex showed no significant difference between the experimental groups, the effect is likely to only be present in the more complicated associative processing of the signal.

11 Conclusion

In this study, I present a review of theory and research of the habituation process, as well as a review of Electroencephalography, its technical and neural basis, and processing methods.

With the help of the Supervisor and consultations of other academic professionals, it was possible to construct and conduct an experiment, using the theory to better understand the nature of habituation and overall perception of advertisements.

The experiment has shown, primarily, that advertisements evoke a significant response, disrupting the fluent perception of the environment, or, in this case, educational videos. The disruption, caused by the advertisement presentation, shows a need for normalising habituation reaction, which follows the elicited response. The arousal and the following habituation are observed in combination due to the processes being subsequent in the momentary physiological response.

The central item of interest for the experiment in this study was the observation of the difference in the nature of habituation of heterogeneous and homogeneous advertisements. The comparison using ERP and ERSP methods showed a significant difference in the response.

The hypothesis, that heterogeneous advertisements would be more disruptive and thus require a more prominent habituation response in the frequency domain was strongly supported by the data from ERSP analysis of average value of all electrodes. This implies, that the homogeneous advertisements have a less disruptive effect on the individual's perception.

ERP analysis has shown a smaller specific effect in the amplitude of the evoked potential for the Fp1 and average sum of activity, not supporting the hypothesis in relation to ERP. As it was mentioned in the method description, the number of presentations in this paradigm did not fully satisfy the requirements for a valid standard ERP analysis, so the relults, obtained through the ERSP method are likely to be more valid. Still, the high coherence of ERP responses on electrodes, monitoring the visual brain system, supports the validity of the ERP analysis.

Overall Power Spectral Analysis did not show significant difference in the summation of power in the frequency spectra in all three comparisons.

The results also imply, that further research of habituation to complex stimuli with different qualities, such as hetero- and homogeneity, may allow us to better understand short-term and long-term consequences of perception and cognitive processing of our environment. Especially in cyberspace, where we face enormous amounts of prominent changes in the environment during our interaction with it.

List of Figures

List of Tables

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Appendices

Otázky

Video 1

Sekce 1

1. Jakým bodům se autoři videa v něm věnovali? (zaškrtněte jednou nebo víc správných variant).
    - a. Vznik vesmíru
    - b. Čas
    - c. Rychlost světla
    - d. Mars
    - e. Kvazary
    - f. Komunikace s mimozemšťany
2. Jak dlouho letí světlo ze Slunce na Zemi?
    - a. 3 hodiny
    - b. 8 hodin
    - c. 3 minuty
    - d. 8 minut
3. Jak daleko ve světelném čase jsou od našeho systému nejbližší hvězdy? (přibližně)
    - a. Několik světelných hodin
    - b. Několik světelných dnů
    - c. Několik světelných měsíců
    - d. Několik světelných roků

Sekce 2

1. Jak na Vás z hlediska kvality video působilo?
    1. vážně frustračně
    2. mírně frustračně
    3. obyčejně
    4. příjemně
    5. velice příjemně
2. Viděl(a) jste to video předtím? – Ano/Ne (podtrhněte)

Figure .1: An example of a target stimulus.

Figure .2: An example of a target stimulus.