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EXPERIMENTAL DESIGN TO MAP BRAIN AREAS INVOLVED IN SOUND RECOGNITION PROCESS

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ABSTRACT

This contribution aims to explore the sound stimuli recognition steps and create an overview of the involved brain processes. When the human auditory system detects sound it recognises stimuli according to features of the sound ,e.g., noise or speech, before the sound is characterised into a certain category ,e.g., a language or music. This process is likely to involve our working memory. Therefore, the study will measure the involved processes while the participants are exposed to sound samples, like traffic noise, quietness or music, in regard to psychoacoustic metrics such as sharpness and tonality, and their working memory is being occupied. As sounds can be assessed emotionally ,e.g., as safe or hazardous, the recognition process is highly important for our psychophysiological state and therefore health. The effects of the different sound samples and the resulting sound recognition process steps will be measured using a combination of electroencephalography and electrodermal activity measurements to demonstrate the brain areas involved in sound sorting decision making. As a result, a map of the involved brain areas will be created, which can be used for the evaluation of sound characteristics and consequently noise protection or acoustic design.

Keywords: *sound recognition, psychoacoustic experiment, auditory recognition*

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1. INTRODUCTION

Noise can have short and long-term impacts on the physical and mental health. Therefore, it is important to assess the consequences of noise exposure on the wellbeing. Investigating our physiological and mental processing that leads to the perception of sounds is therefore key. The perception of sounds is subjective and can hence be different among individuals as for its experience is based on previous experiences with sounds and its processing [1, 2]. After a sound was detected by our auditory system, there is a step of sound recognition that identifies the sound as ,e.g., music or noise, before the next processing step of further discriminating the sound happens. This sound recognition process helps to filter out important and less important information before we might become consciously aware of the sound as ,e.g. a spoken word. We develop an experimental setup to investigate the sound recognition processing steps in the human brain, which are necessary to identify a stimulus as ,e.g., music, speech or just noise.

2. METHODS

The participants are supposed to execute a task that occupies their working memory while simultaneously being presented with a sound sample that changes from white noise to a traffic noise sample with different intensities of predefined psychoacoustic features, like sharpness or tonality. Electroencephalography (EEG) and electro dermal activity (EDA) measurements will be performed to investigate the physiological reactions to this sound exposure under cognitive load. An EEG measures the voltage fluctuations between certain pairs of electrodes placed around the head. This non-invasive research method shows the sum of electrical events in and around the head and is therefore an indirect measure of neural activity [3]. For placing the electrodes the international 10-20-method will be used as a standardized way to place the 21 electrodes in certain distances relatively to each other and based on certain landmarks on the scalp [4]. As for movements can impact the measurements done with an EEG, especially eye movements, the participants will be instructed not to move during the testing. Furthermore, eye-tracking will be used as a method to correct for eye-movement artifacts. The EEG will be used to measure auditory event-related potentials (AERP) with regards to the psychoacoustic features of the traffic noise sound samples in comparison to the white noise [5]. The resulting AERPs will then be further analyzed to find commonalities and patterns with regard to the psychoacoustic features.

Furthermore, EDA measurements will be performed to measure the reactivity to the auditory stimuli. EDA measurements show changes in the skin's electricity conductance. As for sweat glands increase their production during arousal and stress, the skin conductance shows the activity of the sympathetic nervous system. It is usually measured with two electrodes placed on the palm of the participants non-dominant hand. As for hand movements can cause artefacts in the measurements, the participants will be asked to keep their hand on the desk in front of them with the hand facing palm-up [6, 7]. The combination of EEG measurements and EDA measurements will show the activity and arousal state during the time intervals of interest. The aim of conducting these measurements is to find patterns or common, distinct features and similarities for the sound recognition process in regards to certain psychoacoustic features.

3. EXPERIMENTAL SETUP

For this experimental setup the participants will need to be physically fit and mentally healthy. They should not take psychotropic medication, nor have a history of neurological and cardiovascular diseases nor mental disorders. Participants will be recruited through internet and physical platforms for students at different universities in Graz, Austria, through university mailing lists, word of mouth, and social media channels. Therefore, the age of the participants is expected to be between 20 to 60 years old. To goal for the recruitment phase will be to get at 50%-50% representation of female and male participants.

Before the experiment starts the participants will be led individually into a room where they will sign an informed consent form, a data protection form and get information about the experimental procedure and the experimental task. The experimental procedure includes the physiological measurements taken and the equipment being used as well as the order in which the instruments are being applied and taken off again. An audiometry prior to the experiment will test the hearing abilities of the participants. Generally, we aim at normal-hearing participants. The participants will have the chance to familiarize themselves with the testing location and the equipment that is being used for taking the measurements. After this instruction phase the participants will sit down in the testing location to put on the measurement equipment.

The testing location will be an anechoic acoustic chamber in a room-in-room setup. The stimuli sound presentation will be done via loudspeakers into this acoustic chamber. This way the ears are kept free and it prevents additional cabling and effort as well as a negative influence on the participants and the measurements. The participants will sit in the chamber facing its window and door to reduce the cramped visual impression due to the acoustic chambers appearance. The view through this window will be onto a neutral-coloured tarpaulin as background. The set-up for the measuring equipment will be behind the participant to reduce further distractions and directly in front of the participant will be a monitor on a table to visually present the experimental task and allow for the hands to be placed on.

Firstly, the EEG with an electrode cap using the international 10-20-method will be put on. Therefore, an electrode gel for good conductivity between the electrodes and the skin will be applied with regards to the 10-20-method. The electrode positioning with the reference electrode, the mass electrode and the skin contact will be checked and a control measurement will be done. Secondly, the electrodes for the EDA measurement will be applied on the non-dominant hand with a gel on the electrodes and a sticky band to ensure the electrodes are properly fixed.

While the participant performs the task that is meant to occupy their working memory, they will be exposed to sound samples that change between white noise and a synthesized signal resembling traffic noise (train pass-by, fly-over or street noise) that will be played with different intensities of psychoacoustic features but will be loudness-normalized. The white noise and the synthesized signal will be played repetitively to measure the AERPs with the EEG [8]. The sound exposure and experimental task interval will be between 5 to 7 minutes for the measurements and the samples will be played with equal loudness of about 70 dB(A). Subsequently there will be a short break for the participants before the next measuring interval starts. The total experiment duration shall not exceed 1 hour.

After the conduction of the experiment the participants will get the opportunity to wash and dry their hair as for the EEG measurements require a gel for conduction that should be removed after the testing. After the participants are done they will fill out a form to get further sociodemographic, socioecological and experiment-relevant information for statistical analysis [9]. The form will be filled out after the experiment to avoid the participants becoming emotionally aroused about the questions before the experiment starts.

4. DISCUSSION

While the pre-selection of participants makes sense in terms of comparability, it is more adequate for the selection of a control group rather than to be seen as representative. For a bigger study that includes also neurodiverse participants or participants in different development stages some aspects of the study might have to be adjusted. The cognitive load task, the loudness setting, the time for instructions and the application of the measuring equipment need further investigation from the authors to allow an adequate representation.

The testing equipment of the EDA measurements offers the opportunity to click a button to signalize that the EDA measurement ,e.g., begins, ends, or is interrupted. While such a feature can be very helpful for analyzing the time series, the click sound of the button could be possibly interfering with the measurements being taken. A possibility to avoid that would be if the testing would be done with active noise canceling earphones instead of a loudspeaker to play the sound samples. This would create an additional application effort and could be potentially uncomfortable for the participants if they are not already used to it. Furthermore, such a device could enhance the focus on the noise instead of the experimental task.

The complexity of the measurement set-up with two different measuring devices adds additional effort for combining the measurements. Additionally it poses a potential source of distress for the participants as for there are a lot of cables. On the other hand the cables could serve as a reminder for the participants to overall restrict movements to not interfere with the measurements like EEG measurements or EDA. Electrical interferences, bad connections between skin and electrodes or muscle movements can cause artifacts in EEG measurements. These need to be checked upfront and the participants instructed to remain still during the experiment.

For the EEG measurements the 10-10-method using 74 electrodes instead of 21 at the international 10-20-method would deliver a better resolution due to the higher electrode density [10]. This higher resolution comes along with a longer time for the equipment application phase as for the putting on of the electrode cap would take more time. Furthermore, while EEG measurements offer a high temporal resolution, its spatial resolution is limited. Functional magnetic resonance imaging (fMRI) measurements offer a better spatial resolution. In comparison they are limited in temporal resolution and can be challenging for hearing experiments as for the relatively loud environment of the fMRI scanner itself. For future experiments a set-up combination of fMRI and EEG could be of interest, if the fMRI can be paused during the sound exposure and turned on immediately afterwards. Such a combination could be a good compromise of temporal and spatial resolution to measure the brain activity after sound exposure but it could also potentially add further artifacts and requires further consideration of the authors.

5. SUMMARY

This experimental setup aims to investigate the sound recognition processing steps in the human brain which are necessary to identify a stimulus as ,e.g., noise. By using EEG and EDA measurements the participants reaction to a sound sample that alternates between white noise and a traffic noise sample will be measured while they conduct a task that occupies their working memory. The resulting EEG and EDA measurements will then further be analyzed to find patterns in the recognition processing steps.

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