PAVOL JOZEF ŠAFÁRIK UNIVERSITY IN KOŠICE
FACULTY OF SCIENCE

NEURAL CORRELATES OF AUDITORY SPATIAL ATTENTION

2022 **Mária VARGOVÁ**

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NEURAL CORRELATES OF AUDITORY SPATIAL ATTENTION
NEURÁLNE KORELÁTY SLUCHOVEJ PRIESTOROVEJ POZORNOSTI

BACHELOR THESIS

Field of Study:	Applied Informatics
Institute:	Institute of Computer Science
Supervisor:	doc. Ing. Norbert Kopčo, PhD.
Consultant:	Mgr. René Šebeňa, PhD.

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Thesis assignment

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Univerzita P. J. Šafárika v Košiciach
Prírodovedecká fakulta

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Názov: Neural correlates of auditory spatial attention

Názov SK: Neurálne koreláty sluchovej priestorovej pozornosti

Cieľ:
- Examine the mechanism by which automatic spatial attention affects spatial discriminability of auditory targets and its neural correlates.
- Design and perform a combined behavioral and electrophysiology experiment based on Kopco et al. (2021), in which automatic spatial attention is cued by two different types of auditory cue, while the eyes fixate a neutral location.
- Analyze the behavioral data to determine how the validity of the cue and the cue type influences discrimination accuracy,
- Analyze whether the cuing effect is modulated by congruency with the eye-sight direction and by blocking of the cue type,
- Analyze the EEG to identify neural correlates of the attentional modulation.

Literatúra:

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Kľúčové slová: spatial auditory perception, plasticity

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Abstract

When perceiving the space around us, we must constantly adapt to new realities. Auditory spatial perception helps us to better orient ourselves in space through hearing. Thanks to auditory perception, we can protect ourselves from danger, because we can identify in advance where it comes from. The main goal of the bachelor thesis is to examine how spatial attention affects the ability to distinguish spatial auditory targets and their neural correlations using two different types of auditory signals when the eyes fix the central place. We collected data on 10 subjects. Based on the analyzes I have performed on the data collected, we can assess that each subject probably has different hearing skills. As we can see, the best answers were with the cue presented on the left, whether it was a buzz or a white noise. If we look at the separate analyzes for blocks B1 and B2 and blocks B3 and B4, we do not notice a big difference in them. Therefore, we can assume that the cue modality does not have a large effect on auditory spatial attention. According to our results, we can assess that the place where the cue was presented has a greater influence on auditory spatial attention.

Key words: spatial auditory perception, plasticity

Abstrakt

Pri vnímaní priestoru okolo nás sa musíme neustále prispôsobovať novým skutočnostiam. Sluchové priestorové vnímanie nám pomáha lepšie sa zorientovať v priestore pomocou sluchu. Vďaka sluchovému vnímanie sa vieme chrániť pred nebezpečenstvom, pretože vieme vopred identifikovať odkiaľ k nám prichádza. Hlavným cieľom bakalárskej práce je preskúmať, ako priestorová pozornosť ovplyvňuje schopnosť rozlišovať priestorové sluchové ciele a ich nervové korelácie použitím dvoch rôznych typov sluchových signálov v prípade keď oči zafixujú centrálne miesto. Dáta sme zbierali na 10 subjektoch. Podľa analýz, ktoré som vykonala na zozbieraných údajoch, môžeme posúdiť, že každý subjekt má pravdepodobne iné sluchové schopnosti. Ako vidíme, najlepšie odpovede boli s cue prezentovanou naľavo, či už išlo o bzukot alebo biely šum. Ak sa pozrieme na samostatné analýzy pre bloky B1 a B2 a bloky B3 a B4, veľký rozdiel v nich nezbadáme. Preto môžeme predpokladať, že cue modalita nemá veľký vplyv na sluchovú priestorovú pozornosť. Podľa našich výsledkov môžeme zhodnotiť, že väčší vplyv na sluchovú priestorovú pozornosť má miesto, kde bola cue prezentovaná.

Kľúčové slová: priestorové sluchové vnímanie, plasticita

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List of Abbreviations

EEG	Electroencephalography
ITL	Interaural Time Differences
ILD	Interaural Level Differences
ERP	Event-related Potential

Introduction

The brain is an extremely important part of the human body. Knowing its functions requires extensive research, but despite all the research, it is still not fully researched. The brain is the center of all the functions of the human body, receiving important information from the sensory organs and sending them on. One of the most important senses is hearing. Hearing helps us to orient ourselves in space, it protects us from danger.

The thesis on the topic "Neural correlates of auditory spatial attention" will follow the research of 2021 Electrophysiological correlates of auditory and visual attentional cueing in fine-grained auditory spatial discrimination task. In this research, a behavioral experiment and an EEG were combined to find out how auditory spatial attention is affected if the eyes have to fix a place [1].

It is very important today to study the human brain. All the knowledge we gain helps us to better understand the functioning of our body.

At the beginning we will describe the theoretical knowledge about hearing, auditory spatial attention, EEG and neural correlates. This will be followed by a description of the experiment, and we will summarize the results at the end.

1 Goals

The main goal of the bachelor thesis is to examine how spatial attention affects the ability to distinguish spatial auditory targets and their neural correlations. We will use two different types of auditory signals and the eyes will fix the central place.

Individual goals of the thesis:

- Examine the mechanism by which automatic spatial attention affects spatial discriminability of auditory targets and its neural correlates.
- Design and perform a combined behavioral and electrophysiology experiment based on Kopco et al. (2021), in which automatic spatial attention is cued by two different types of auditory cue, while the eyes fixate a neutral location.
- Analyze the behavioral data to determine how the validity of the cue and the cue type influences discrimination accuracy,
- Analyze whether the cuing effect is modulated by congruency with the eyesight direction and by blocking of the cue type,
- Analyze the EEG to identify neural correlates of the attentional modulation.

2 Spatial hearing and attention

2.1 Hearing

Hearing is one of the five senses of man, it can be said that after sight it is the most important sense, as it protects us from impending danger. The human auditory organ is the ear, which consists of:

- Outer ear
- Middle ear
- Inner ear

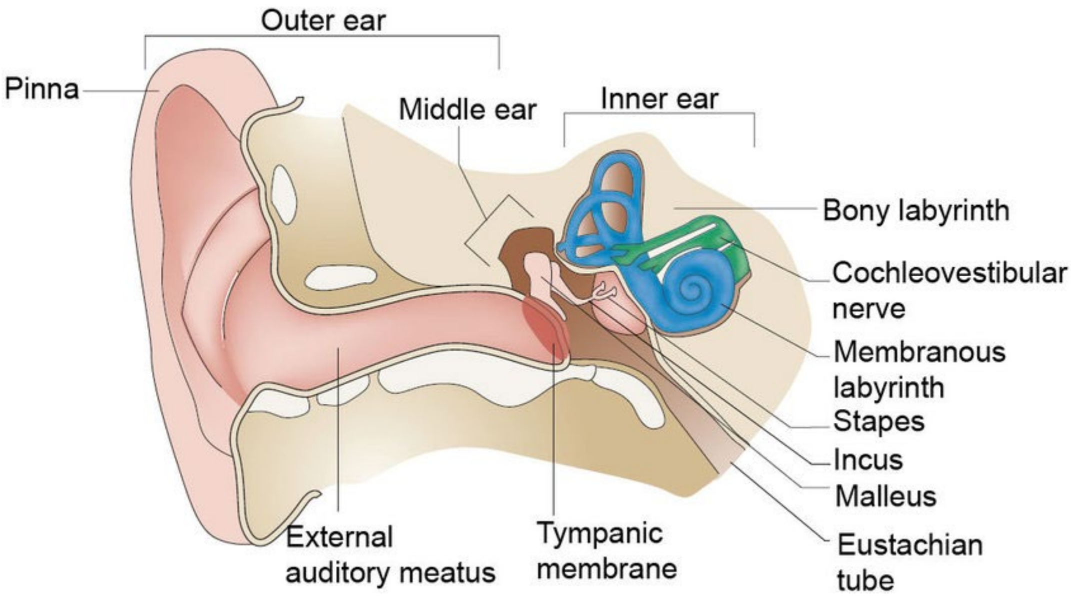

Figure 1 Ear anatomy[6]

The sound that a person hears first reaches the external auditory canal and vibrates the eardrum. Attached to its inner surface is the first of three auditory bones, the malleus. The auditory bones are connected to each other by joints. As a result of the vibrations transmitted by the eardrum, the auditory bones begin to move and transmit the vibrations to the fluid-filled screw[6].

Eventually, the vibrations become a stimulus in Corti's organ at the cochlea. From here, nerve signals are transmitted by the auditory nerve to the brain to the auditory center, where the sounds become conscious perception. Human hearing can be divided into several processes, the outer and middle ear picking up and transmitting sounds, while the inner ear converts these sounds into nerve signals that are transmitted by the auditory nerves[6].

2.2 Spatial hearing

Sounds plays a very important role in forming spatial orientation. Orientation reflex to sound contributes to the differentiation of fields of view, causes the head and body to rotate towards the sound. It is strange how we initially try to see the sound, i.e. we still turn towards the sound source. An increasingly complex set of time connections forms the basis of the associations that form in the brain between different objects and their sound properties. Based on these associations, a much more complex ability is created to determine the distance between a person and an external object by sound, the location of the object by sound, the direction of movement of sounds[7].

Recent studies have shown an undoubted link between auditory orientation in space and the movements of the human body (especially the rotation of the head) and, consequently, the corresponding muscle-joint sensations[7]. Therefore, it is not unexpected that disorders of auditory-spatial discrimination (mainly determining the direction of sound) are particularly severe in lesions of the temporo-parietal-occipital area as well as the lower parietal area of the cerebral cortex[8]. This means that auditory-spatial discrimination is based on a system of connections between hearing, muscle-joint sensations and spatial vision.

Of course, hearing comes first in this associative system. The sound lies in the pair work of the cerebral hemispheres. It is clear that such pair work is a unification, a synthesis of the sound-discriminating work of the brain end of each of the hemispheres. In other words, spatial-auditory discrimination is the latest and most complex formation of the sound-discriminating activity of the brain[8]. Peripheral mechanisms of auditory-spatial discrimination are the pathways of both auditory nerves, each of which enters in its parts into each of the hemispheres[7]. As a result, each of the brain ends of the auditory analyzer regulates the operation of both ears in some specific function. The qualitative originality of binaural hearing was discovered only in a special study of the role of binaural hearing in the perception of the direction of sound. It turned out that it is in this spatial discrimination that the qualitative originality of the joint work of both auditory receptors lies.

A study of the process of recognizing the direction of sound with both ears has shown that there is some dependence on the time of arrival of the sound signal in one ear and the other. The greater the difference between the time the sound arrives in each of the ears, the greater the ability to distinguish direction. Both auditory nerves transmit nerve impulses that coincide with the frequency of sound, the difference in the time of arrival in the cortex is the main condition for auditory reflection of space[7].

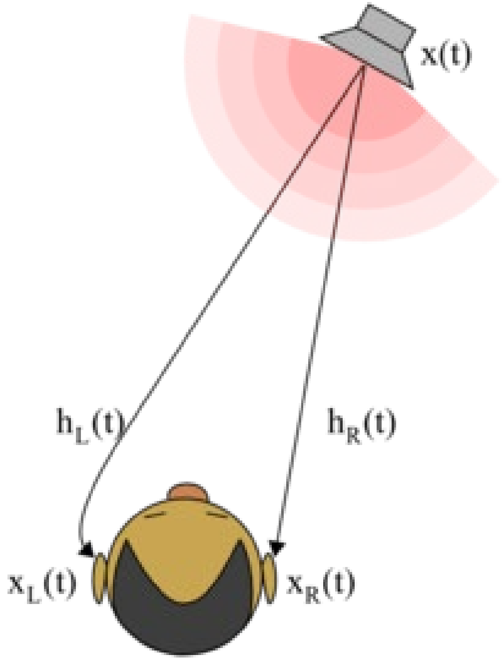

Figure 2 Spatial sound localization

When sound propagates from a source (such as a speaker) to our ears, it transforms by interacting with the environment, our head, shoulders, ears, and auditory canal. This transformation will cause the sound we hear to actually differ from the one coming from the source. In addition, the sound we hear with the left and right ears differs. The sound coming from the side arrives in one ear sooner than in the other and, moreover, with a higher intensity. The brain analyzes these differences and tries to calculate where the sound came from. We then only realize that we heard the sound, and that came e.g. from the right[8].

2.2.1 Interaural Time Differences (ITD)

The difference in the distance of the source from the left and right ear causes a difference in the time when the signal reaches the ears. We call these differences

Interaural Time Differences (ITD). They are approximately constant for a given azimuth. ITD does not depend on frequency[8].

2.2.2 Interaural Level Differences (ILD)

Interaural Level Differences (ILD) are differences in the intensity with which sound reaches the left and right ears. People are sensitive to differences around 0.5 dB. ILD are caused by the head creating an "acoustic shadow", so the sound reaches one ear at a higher intensity than the other. ILD are frequency dependent, increasing with frequency[8].

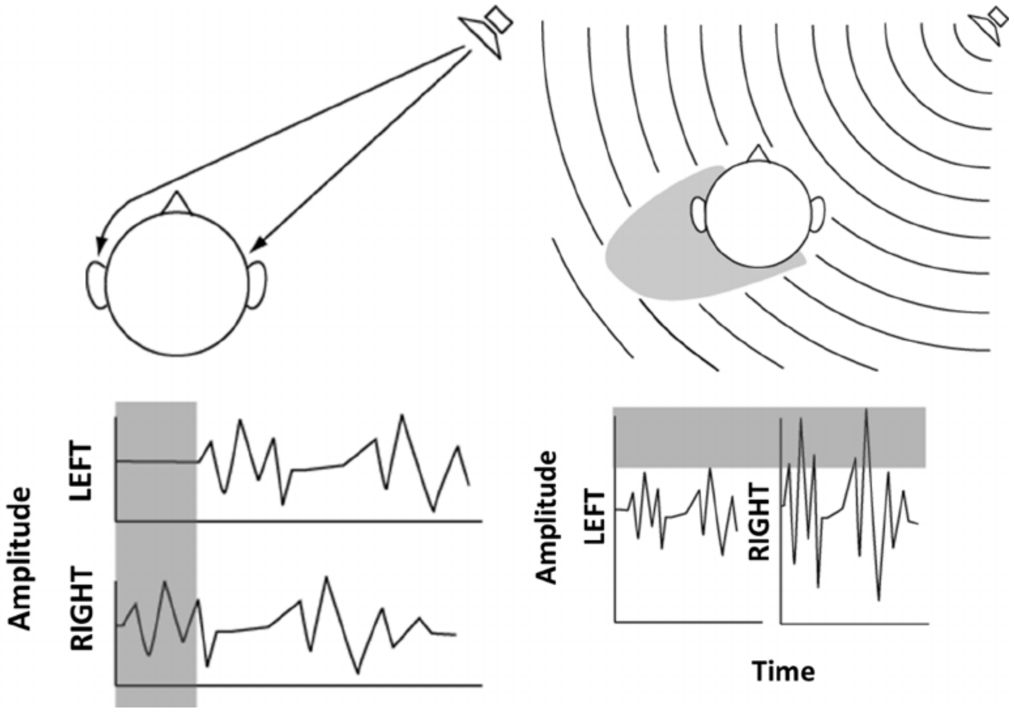

Figure 3 ITD and ILD[8]

Despite the important role of interaural differences (ILD and ITD) in determining the position of a sound source, they are only one part of the perception system. How the position of a sound source is perceived depends, for example, on the position and orientation of the listener's head, on visual perceptions and, in large part, on the listener being able to know the sound sources in his/her surroundings and to orient himself/herself accordingly[8].

2.3 Attention

There are a number of definitions of the term attention: *Attention is the mental concentration (focusing) on sensory or mental events* (Dana Murphy), or *the activation of mechanisms that allow for uninterrupted cognitive activity focused on the object of attention* (David Somers). [5]

However, questions arise as to whether the concept of attention is meaningful, that is, whether there is attention or is only part of the brain functions in which we observe it. Scientists Johnston and Dark have expressed concern that the study of attention is "ultimately futile." [5]. We can also look at attention as a filter of incoming stimuli, which helps us to select only those that are important to us and ignore the irrelevant. Attention works as a stage spotlight, i.e. what is illuminated on the stage is cognitively processed, what is not is ignored. The basic characteristics of attention are *limitedness* and *selectivity*. Attention is limited because we can't pay attention to a large number of stimuli at once. Selectivity lies in the fact that we can consciously focus on sensory stimuli, information in memory (recollection), or motor responses [5]. Other properties of attention are intensity, division, extent, and stability.

Attention intensity indicates the strength of concentration, if we pay attention to several objects at once, then the concentration on individual objects decreases. We can divide attention in some activities, e.g. cook and make a phone call at the same time, but we can't solve two mathematical equations at the same time. By extent is meant the number of stimuli that a person is able to capture, and stability is the time we can focus on one and the same object.

2.4 Electroencephalography

Electroencephalography is a field that deals with the recording and interpretation of electroencephalograms[4]. Electroencephalography (EEG) is a non-invasive method - EEG is recorded by applying surface electrodes to the scalp, so this method has many limitations, for example, there are difficulties in locating potentials. Those waves, brain rhythms that we can see on the graph are just differences in electrical potentials that show how they have changed over time[4].

In electroencephalography, the overall level of electrical activity is recorded continuously and a graph is compiled based on this data, reflecting the change in activity over time[3]. Certain areas of the brain can also be stimulated, for example to determine which part of the brain is responsible for the motor activity of the arms, legs, etc. In addition to the electrodes, it is also possible to stimulate with a strong magnetic impulse[3].

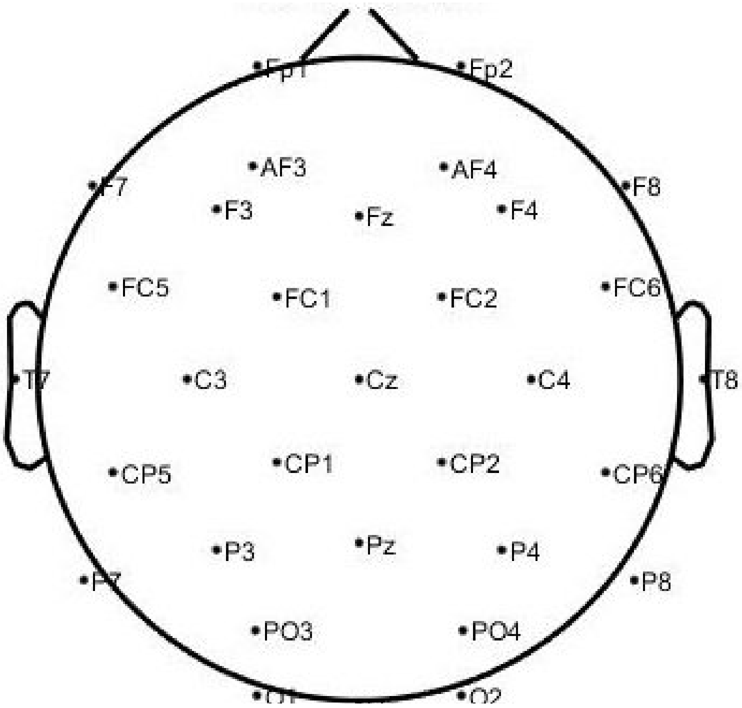

Figure 4 32 channel location map for EEG recording

2.5 Neural correlates

Neurons are cells of the nervous system that can accumulate action potentials and form complex connections. Neurons have processes - dendrites, which are very numerous and each of them branches, which allows it to connect with thousands of other nerve cells[9].

In addition to dendrites, a neuron has one axon - a long process along which a signal usually comes from a cell[5]. The axon is often covered with a myelin sheath, for higher speed of electrical impulse transmission.

The myelin sheath is white, so there are few such axons in the gray matter, which means that gray matter neurons communicate mainly with their neighbors[9]. This means that it is myelination that determines the division into white and gray matter. Signal transmission is performed electrically and chemically. The dendrites and axons of different neurons are always interconnected by synapses. Electrical impulses flow along dendrites and axons, while synapses are electrical and chemical and there are more of the latter[9].

We can study individual neurons quite well. Their general structure in humans and molluscs is very similar. Conscious and unconscious processes take place in our brain at the same time[9]. Unconsciousness is what we do not mean, which takes place automatically, although we can also transfer some of these processes to consciousness. Conscious are such processes we do through consciousness. The neurons that respond first to changing impulses are the neural correlates of consciousness.

3 Previous study

Previous studies that have looked at something similar have found an improvement in auditory spatial attention when the subject's gaze has been focused on the auditory stimulus. However, better performance was found for visual stimuli than for auditory stimuli, especially when the auditory stimulus was directed from a non-congruent place [2]. Analysis of the results in the shorter interval did not reveal any association with correlates of attention processing, but in the longer interval the potentials changed for different combinations of hemispheric laterality, position and signal validity [2]. These results suggest that the sound cue causes modulation of attention in the occipital areas [2].

It was also found by a behavioral experiment that subjects performed better with valid cues than with invalid cues, as well as better performances at greater cue distances from the stimulus [1]. ERP analysis examined the evoked response to auditory cues, which was reported to be a correlate of attention processing. The auditory stimulus has been found to modulate attention. These results show the interactions between the two modalities independent of eye position and movement [1].

4 Experiment

4.1 Description of the experiment

The experiment involved 10 subjects (4 men, aged 20-26 years). All participants were subjected to an audiogram, which did not reveal any hearing defects in any of them. Before collecting the data themselves, each of the participants also took part in a test, where they tested variants of experimental conditions. Each participant signed a written informed consent to data collection for the university.

Auditory stimuli were generated using Matlab. The experiment was generated using Matlab with the Psychtoolbox extension. Auditory stimuli were presented using headphones connected to the Datapixx system. During the experiment, subjects sat in a soundproof booth. The experiment consisted of tests of auditory stimuli. In each experiment, the target consisted of two sounds presented from slightly different locations, and the listeners' task was to distinguish the direction of change of the target position.

The auditory stimulus tests consisted of two consecutive sounds. The subject had to fix a neutral spot (0°) marked with a white dot on the computer screen and listen to the sounds in the headphones. The first sound was cue, at 0°, +25° or -25°, followed by a double sound, the target, which was also at 0°, +25° or -25°, and at the same time moved slightly by +/-4.2° for the middle position, or +/-8.4° for the side positions. The subject had to determine in which direction the double sound was moving, if moving to the left he had to press 1, if it was moving to the right he had to press 2. Subjects were instructed before the experiment to pay all attention to the stimulus, expect a target stimulus, and respond in the same way.

In "identical" experiments (33.3%), stimuli and target stimuli were presented in the same place. In "discordant" experiments (66.6%), auditory stimuli and target stimuli were presented from another place. Auditory stimuli were divided into 2 versions, namely white noise and buzz. Both of these stimuli were represented in equal numbers.

Each subject completed 48 blocks, in each block all 36 conditions were presented. The 48 blocks consisted of 12 quad blocks that were randomly generated. Each quad block was randomly generated from 4 blocks: the first block was presented first with randomly generated cue buzz conditions, followed by white noise; the second block was the opposite of the first, i.e., the randomly generated cue white noise conditions were presented first, followed immediately by buzz; the third and fourth blocks were randomly generated from all conditions regardless of whether it was cue buzz or white noise.

4.2 Data analysis

The obtained data were analyzed as follows. The data were grouped by stimulus type (buzz / white noise), by cue presentation site (left / center / right), by target presentation site (left / center / right) and also by shift (left / right).

The arithmetic mean was determined for each of the conditions of all subjects and of course the subjects separately. We also analyzed the answers according to whether they came from blocks B1 and B2 or from blocks B3 and B4.

In block B1, the buzz cue were presented first, followed by white noise cue. In block B2, the white noise cue was presented first, followed by the buzz cue. And in blocks B3 and B4, cues from both buzz and white noise were randomly shuffled in equal amounts.

4.2.1 Analysis of all conditions

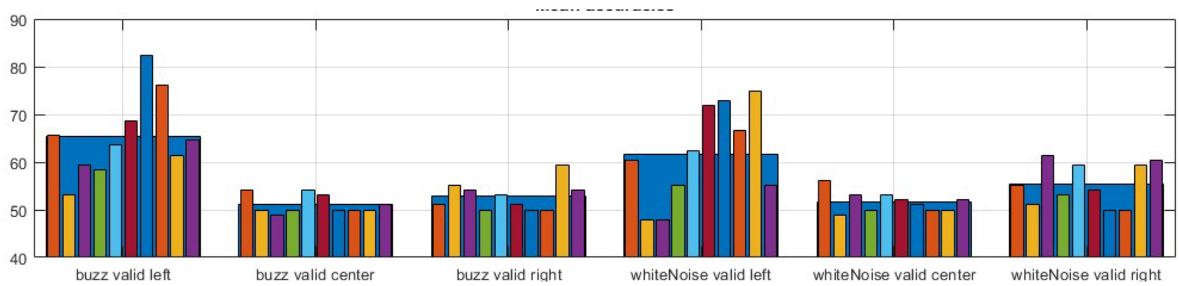

Figure 5 Valid cue and target values

In the figure we can observe the average of the responses of the subjects, as well as the responses of the individual subjects in the case if the cue was valid, ie it was also presented from the same place as the target. As we can see, it seems that if the cue was presented from the left, then the subjects had more accurate answers, ie it was more recognizable than in the center or on the right. The difference between a cue buzz or white noise is noticeably better for a cue on the left than a buzz if it was in the center or on the right, these are almost comparable results.

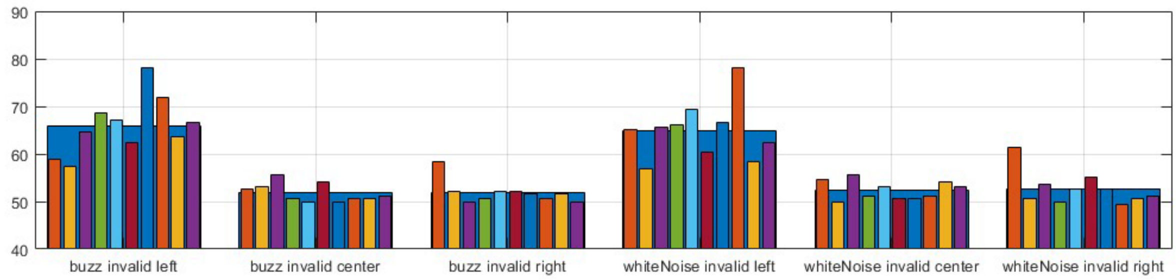

Figure 6 Invalid cue and target values

In the figure we can observe the average of the responses of the subjects, as well as the responses of the individual subjects in the case if the cue was invalid, ie it was not presented from the same place as the target. As we can see, if the cue was presented from the left, the subjects had more accurate answers, ie it was more recognizable than in the center or on the right, exactly as with valid answers. The difference between whether the cue was buzz or white noise is not recognizable, so the results are quite comparable for both types of cue.

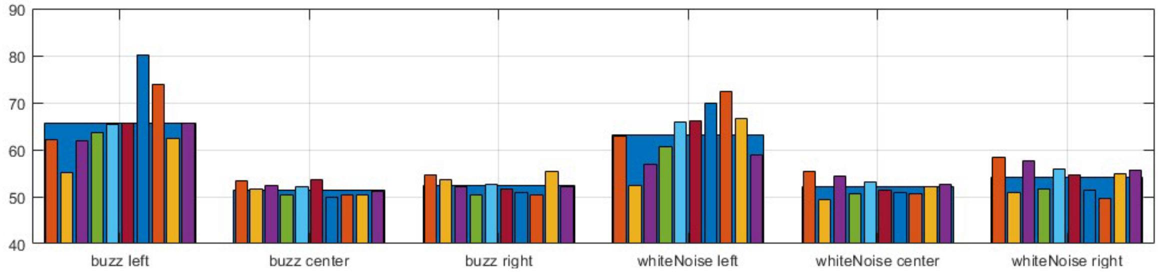

Figure 7 Average valid and invalid values

In the figure, we can observe the average of the responses of subjects, as well as the responses of individual subjects in the case of the average of cue values when it was valid and invalid, ie all responses sorted by cue type and cue presentation location. We can see that if the cue was presented from the left, the subjects had more accurate answers, ie it was better recognizable than in the middle or right. The difference between whether the cue was a buzz or a white noise is not discernible, so the results are quite comparable for both types of cue.

A cue type analysis will now follow. First we look at buzz, we look at the averages of individual conditions according to shift, then when we neglect shift. And we will also look at the results according to whether they were presented from blocks B1 and B2 or B3 and B4. Then we look at the same thing when the cue is white noise.

4.2.2 Analysis of buzz conditions

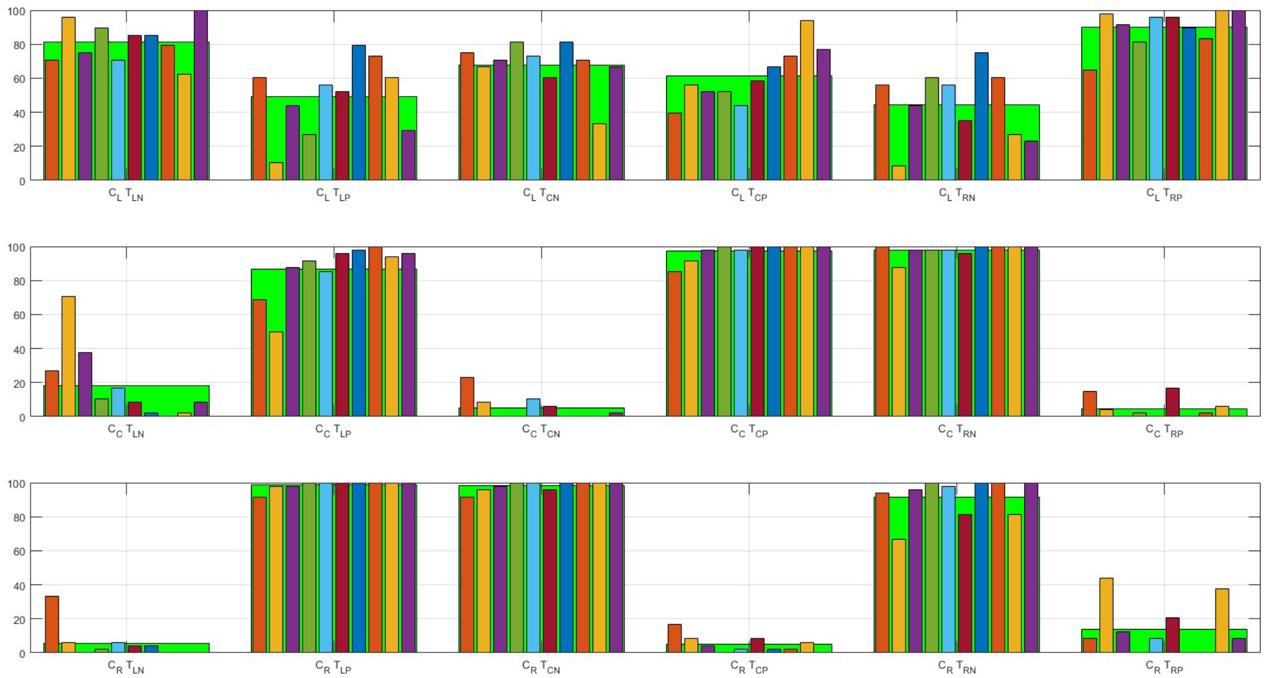

Figure 8 Cue, target and shift division

Legend: C indicates the location of the cue, T indicates the location of the target, both of these stimuli can be from the left, center or right. In the case of a target, there is also the designation N or P, ie the designation of the shift, ie negative or positive, ie on the left or right.

In the first line we have the average values of the answers and the answers from each subject, if the cue was presented from the left. As we can see, there is a difference between the answers depending on whether the target was from the left, the center or the right. And also look at the difference between shifting to the left or right.

In the second line, we have the average values of the answers as well as the answers from each subject, if the cue was presented from the center. As we can see, there is not a big difference in the direction of the target, but there is a big difference in the direction of the shift.

In the third line, we have the average values of the responses as well as the responses from each subject, if the cue was presented from the right. As we can see, as with the center, there is not much difference in the direction of the target, but there is a big difference in the direction of the shift.

According to this analysis, we can assess that the subjects were probably not able to distinguish very well whether the shift shifted to the left or to the right. They probably merged into one.

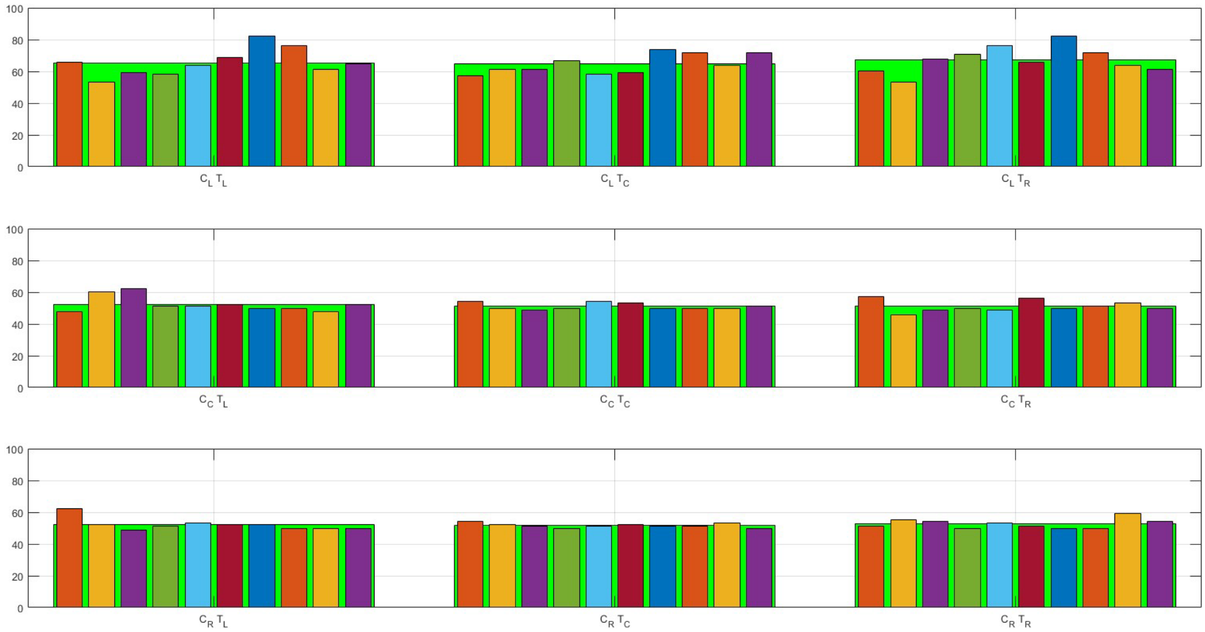

Figure 10 Cue and target division

In this case, we neglected the shift values in the analysis, and averaged the responses only by cue and target. As we can see, we have better results again with the cue presented from the left, but the results for the cue from the center or from the right no longer look so bad.

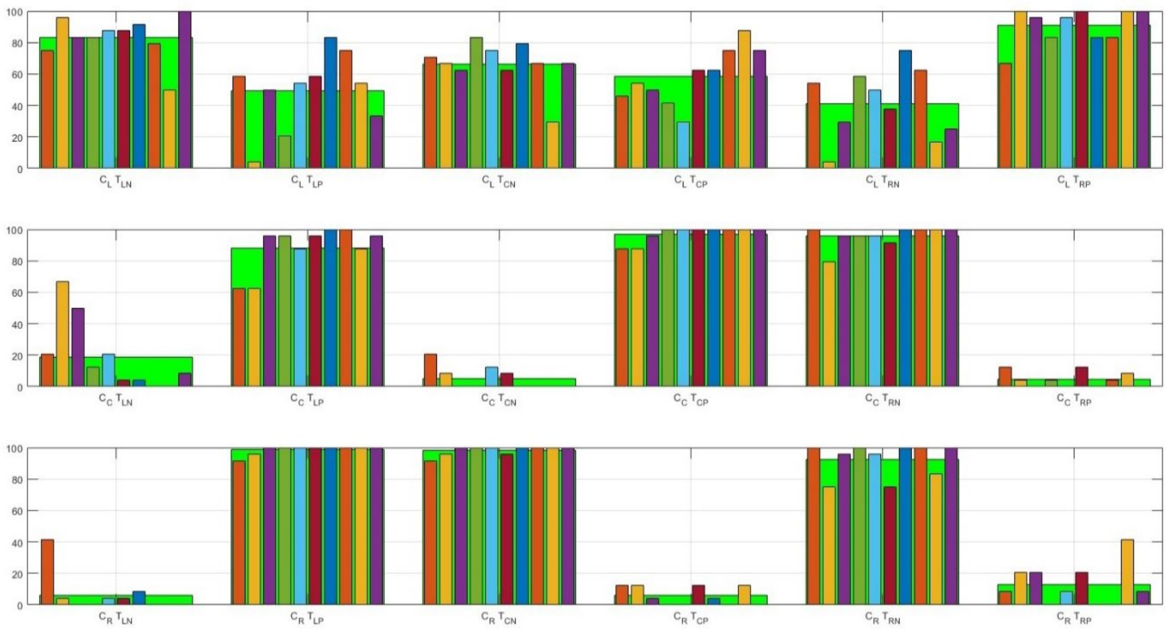

Figure 9 Cue, target and shift division B1B2

In this analysis, we looked at the division by blocks, specifically this is the analysis of B1B2 blocks, ie when one type of cue was presented first and then the second type.

In the first line we have the average values of the answers and the answers from each subject, if the cue was presented from the left. As we can see, there is a difference between the answers depending on whether the target was from the left, the center or the right. And also look at the difference between shifting to the left or right.

In the second line, we have the average values of the answers as well as the answers from each subject, if the cue was presented from the center. As we can see, there is not a big difference in the direction of the target, but there is a big difference in the direction of the shift.

In the third line, we have the average values of the answers as well as the answers from each subject, if the cue was presented from the right. As we can see, as with the center, there is not much difference in the direction of the target, but there is a big difference in the direction of the shift.

According to this analysis, and at the same time looking at the previous one, we can assess that some subjects had better answers when they were first presented with one type of cue and then the other type. However, you still notice a big difference between shifting left and right.

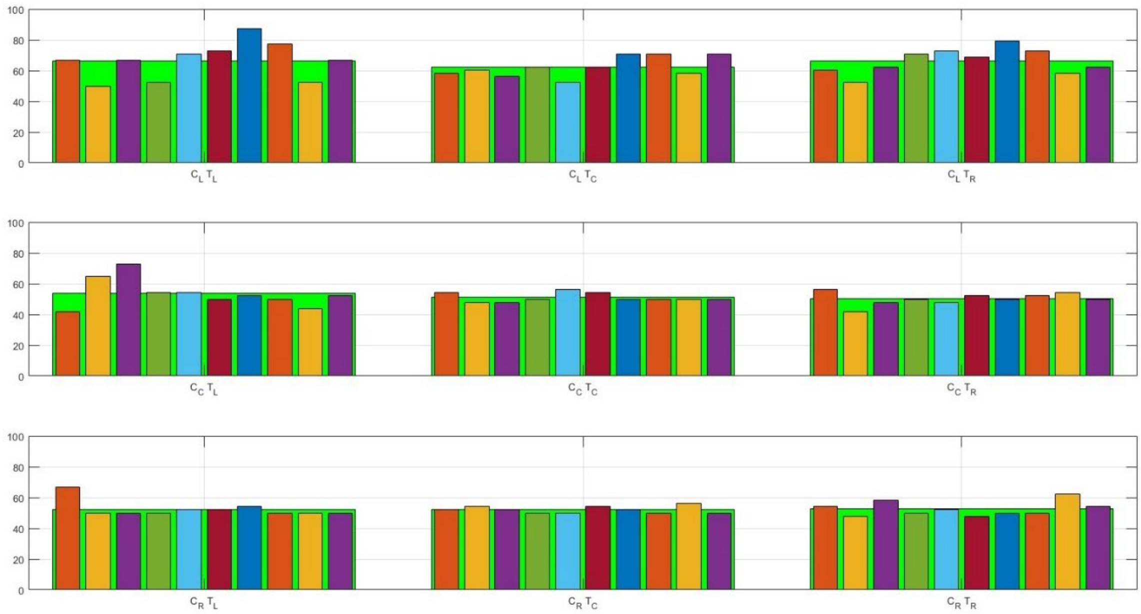

Figure 11 Cue and target division B1B2

In this analysis, we have neglected the shift values, and averaged the responses only by cue and target. As we can see, we have better values again for the left cue, but some subjects responded for these blocks in other cue locations as well.

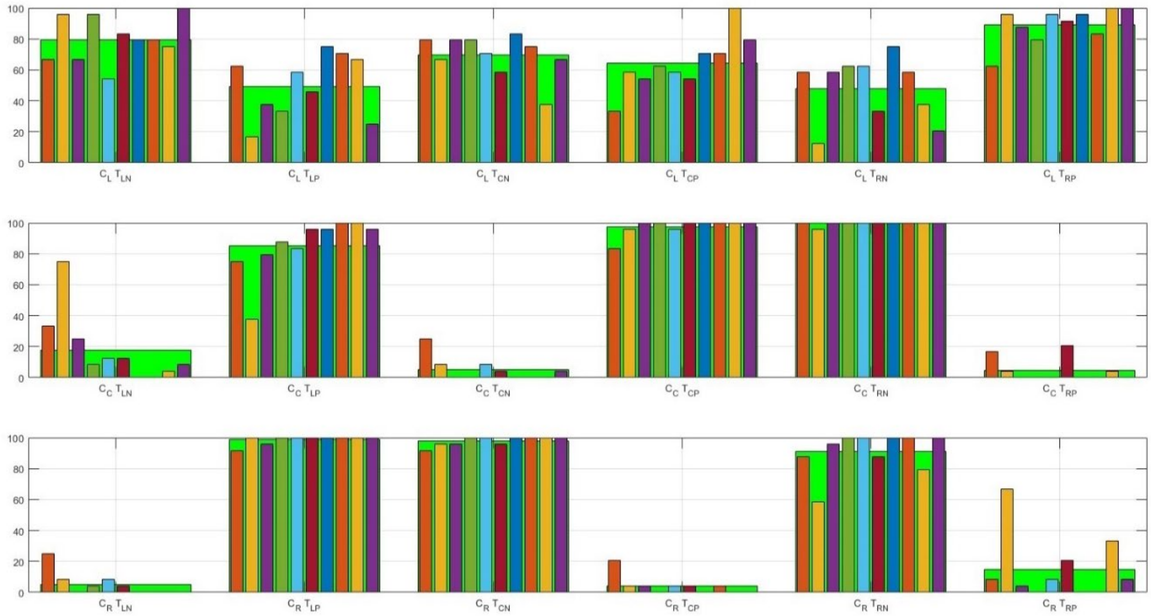

Figure 12 Cue, target and shift division B3B4

In this analysis, we looked at the division by blocks, specifically this is the analysis of B3B4 blocks, so the cues were randomly generated from both types of the same number.

In the first line we have the average values of the answers and the answers from each subject, if the cue was presented from the left. As we can see, there is a difference between the answers depending on whether the target was from the left, the center or the right. And also look at the difference between shifting to the left or right.

In the second line, we have the average values of the answers as well as the answers from each subject, if the cue was presented from the center. As we can see, there is not a big difference in the direction of the target, but there is a big difference in the direction of the shift.

In the third line, we have the average values of the answers as well as the answers from each subject, if the cue was presented from the right. As we can see, as with the center, there is not much difference in the direction of the target, but there is a big difference in the direction of the shift.

According to this analysis, and at the same time looking at the previous ones, we can evaluate that, for example, subject 2 did significantly better at mixed cue values than when they were first of the type first and then the other.

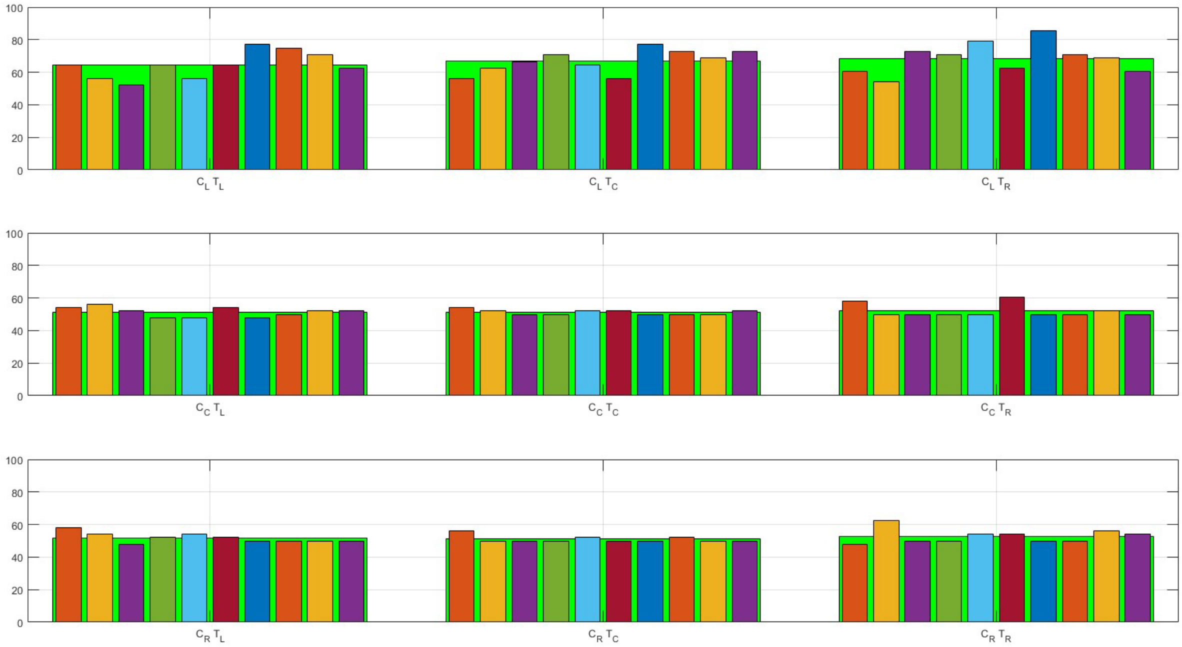

Figure 13 Cue and target division B3B4

In this analysis, we neglected the shift values, and averaged the responses by cue and target only. Again, we can observe better values for the left cue, but some subjects responded better for these blocks and for other cue locations.

4.2.3 Analysis of white noise condition

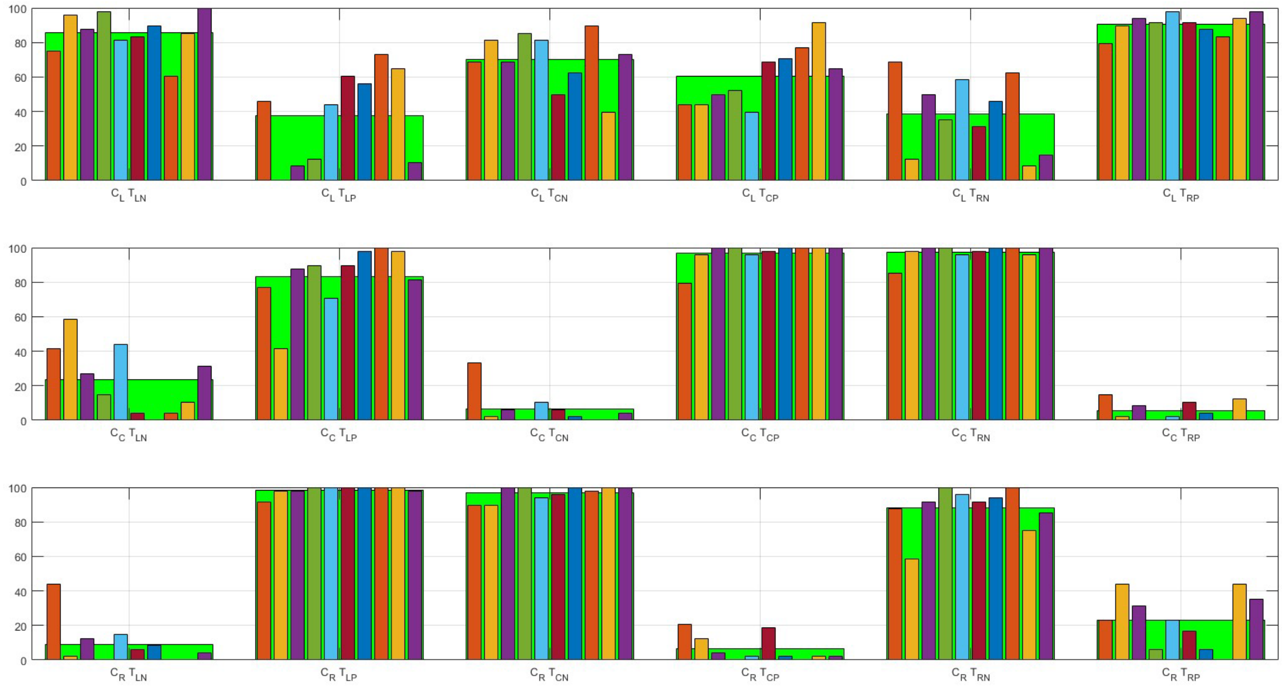

Figure 14 Cue, target and shift division

In this analysis, we looked at the distribution by conditions, we sorted them by cue, target, and shift.

In the first line we have the average values of the answers and the answers from each subject, if the cue was presented from the left. It is obvious that there is a difference between the answers depending on whether the target was from the left, the center or from the right. And also look at the difference between shifting to the left or right.

In the second line, we have the average values of the answers as well as the answers from each subject, if the cue was presented from the center. As we can see, there is not a big difference in the direction of the target, but there is a big difference in the direction of the shift.

In the third line, we have the average values of the answers as well as the answers from each subject, if the cue was presented from the right. We observe, as with the center, that there is not a large difference in the direction of the target, but there is a large difference in the direction of the shift.

According to this analysis, we can assess that if the cue was presented from the left, the subjects had better answers than the others, so it follows that if the cue was presented from the left, it was best for the subjects.

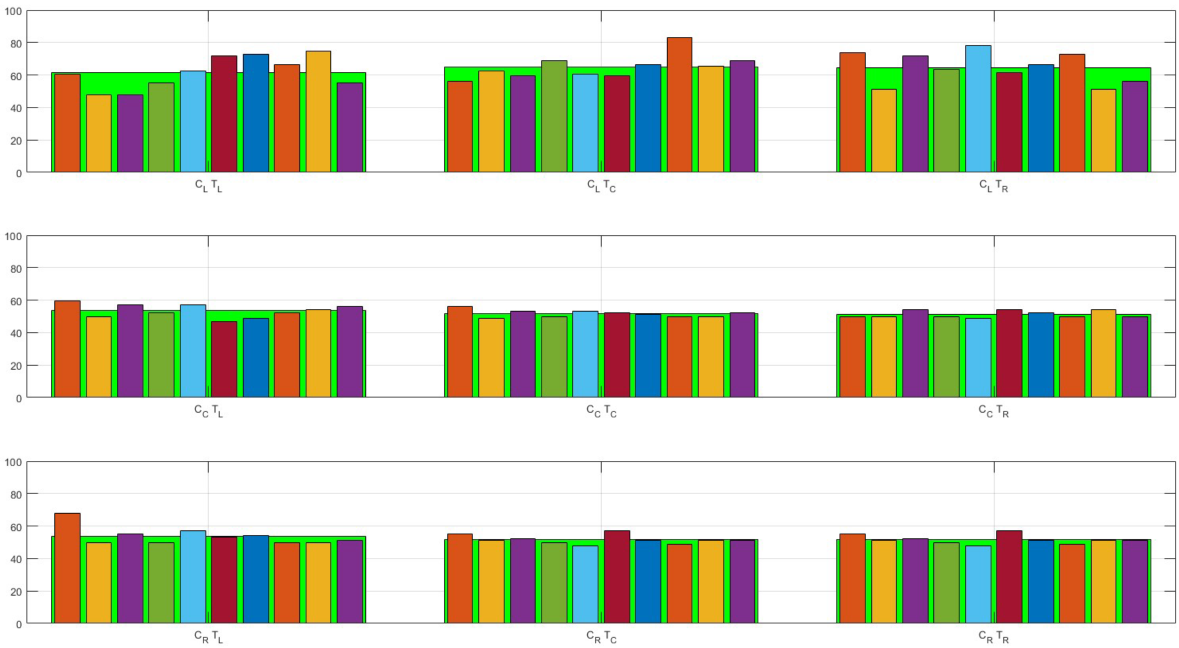

Figure 15 Cue and target division

If we average these values only according to the cue and target and neglect the shift, then we see that there are no significant differences. However, there are still better values for the cue presented from the left. However, there are also subjects who had better answers in other cue directions.

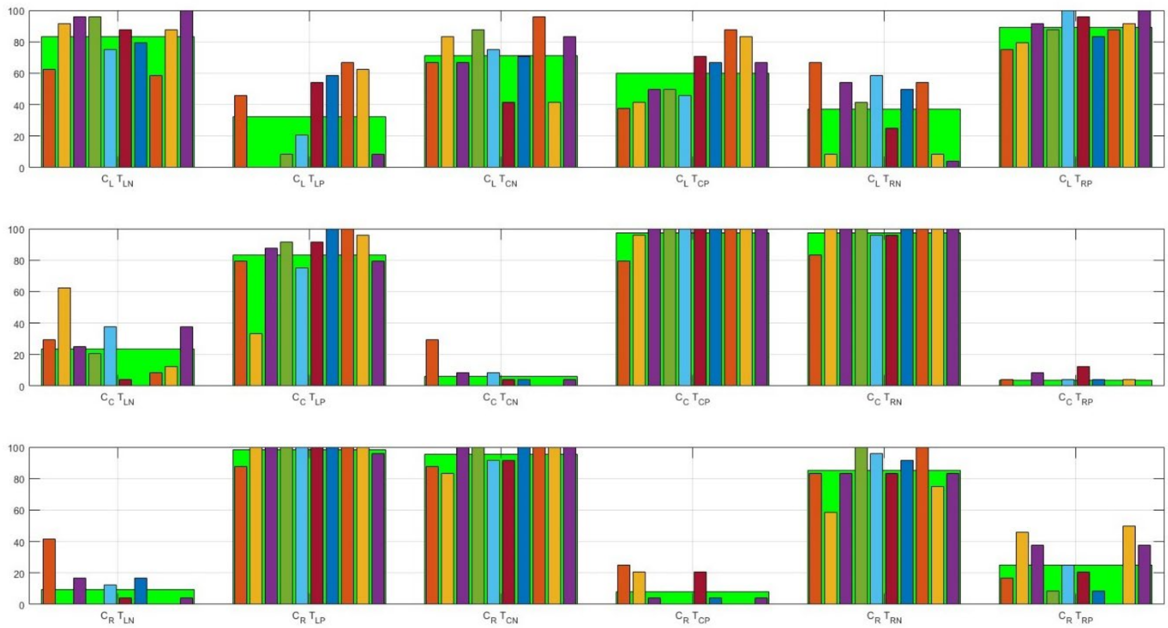

Figure 16 Cue, target and shift division B1B2

In this analysis, we looked at the distribution according to conditions and blocks B1 and B2, we divided them according to cue, target and shift.

In the first line we have the average values of the answers and the answers from each subject, if the cue was presented from the left. It is clear that there is a difference between the answers depending on whether the target was from the left, center or right. And also look at the difference between shifting to the left or right.

In the second line, we have the average values of the answers as well as the answers from each subject, if the cue was presented from the center. As we can see, there is not a big difference in the direction of the target, but there is a big difference in the direction of the shift.

In the third line, we have the average values of the answers as well as the answers from each subject, if the cue was presented from the right. We observe, as with the center, that there is not a large difference in the direction of the target, but there is a large difference in the direction of the shift.

In this analysis, the conditions of one type of cue were presented first and then the other. When we look at this analysis and at the same time the previous one we see almost comparable results.

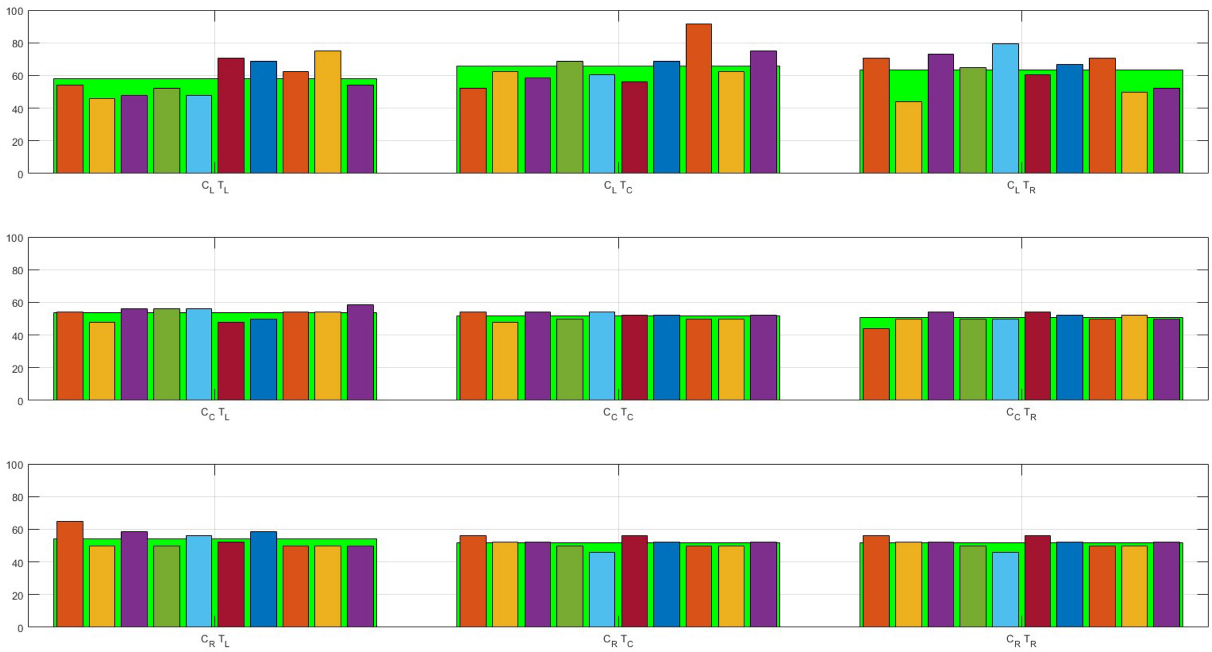

Figure 17 Cue and target division B1B2

The figure shows already averaged values according to cue and target, here we neglected the direction of shift. It can be seen that if shift is neglected, all subjects have almost identical responses for all cue and target options.

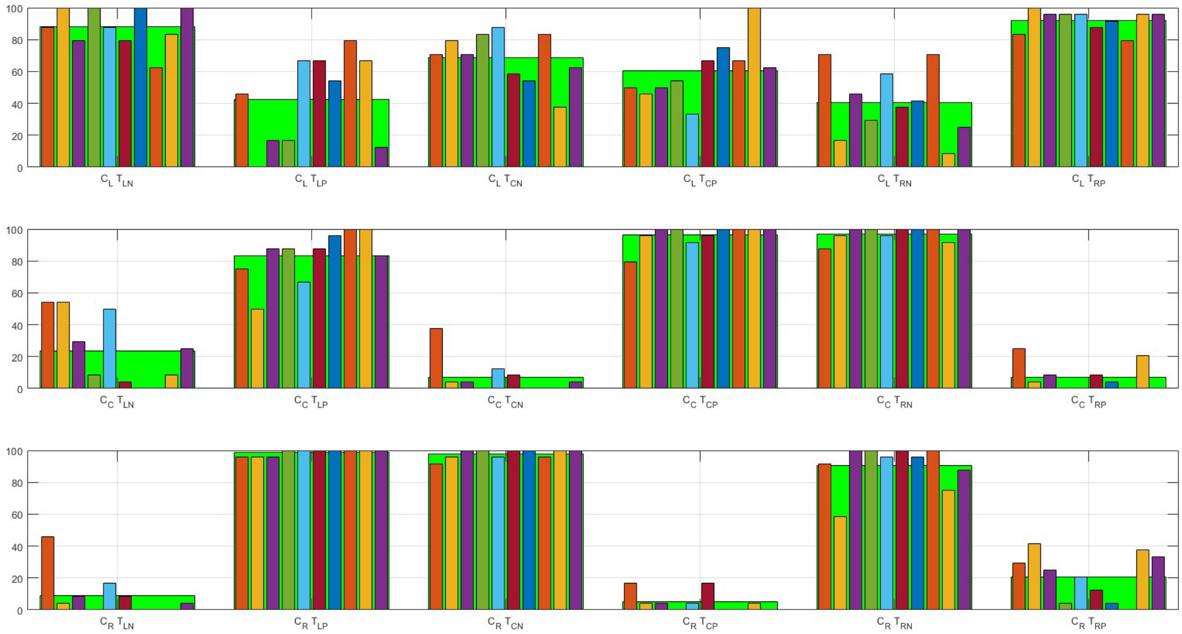

Figure 18 Cue, target and shift division B3B4

In this analysis, we looked at the distribution by conditions and blocks B3 and B4, we sorted them by cue, target, and shift.

In the first line we have the average values of the answers and the answers from each subject, if the cue was presented from the left. It is clear that there is a difference between the answers depending on whether the target was from the left, center or right. And it is also possible to see the difference whether there was a shift to the left or to the right.

In the second line, we have the average values of the answers as well as the answers from each subject, if the cue was presented from the center. As we can see, there is not a big difference in the direction of the target, but there is a big difference in the direction of the shift.

In the third line, we have the average values of the answers as well as the answers from each subject, if the cue was presented from the right. We observe, as with the center, that there is not a large difference in the direction of the target, but there is a large difference in the direction of the shift.

In this analysis, randomly generated conditions from one type of cue and another were presented, with the same number. When we look at this analysis and at the same time the previous ones we see almost comparable results.

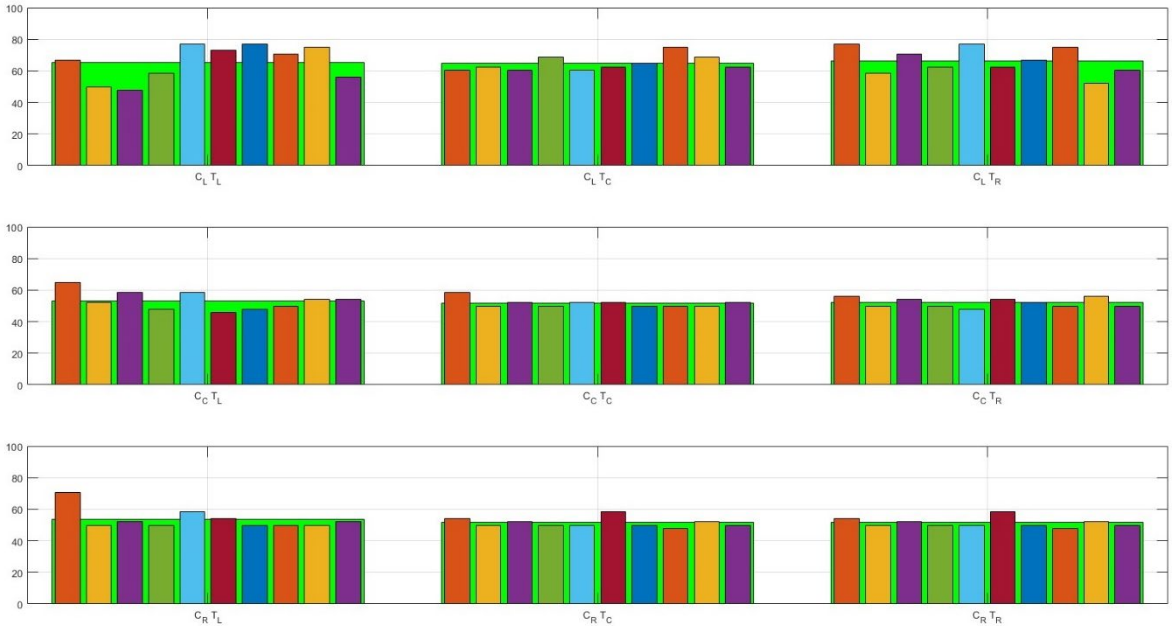

Figure 19 Cue and target division B3B4

The figure shows already averaged values according to cue and target, here we neglected the direction of shift. It is clear that if shift is neglected, all subjects have almost identical answers for all cue and target options, but some subjects with better values were also found.

Conslusion

Experiments have shown that the study of auditory spatial attention evoked by auditory stimuli is not easy. After studying and elaborating the previous research concerning auditory spatial attention, I prepared an experimental setup and based on the existing MATLAB scripts I programmed an experimental procedure for data collection. 10 subjects participated in data collection. The task of the subjects was to locate in which direction the target sound moved.

According to the analyzes I performed on the collected data, we can assess that each subject probably has different hearing skills. As we can see, the best answers were with the cue presented on the left, whether it was cue buzz or white noise. If we look at the separate analyzes for blocks B1 and B2 and blocks B3 and B4, we do not notice a big difference in them. Therefore, we can assume that the cue modality does not have a large effect on auditory spatial attention. According to our results, we can assess that the place where the cue was presented has a greater influence on auditory spatial attention.

However, according to our assumptions, the results should have been significantly better when the cue was presented from the center than from the left or right. So we can assume that the task was probably misunderstood, or that an error still occurred in the experimental code.

However, the question remains whether the subjects really paid attention when answering. After a large number of presentations of the complaint, it could happen that the subjects processed and evaluated it only mechanically. Some people know how to concentrate more, some less. Some are better at localization (they can quickly create a map of the environment), some less so. The observed large inequality between some conditions between subjects may be due to this.

Resumé

Mozog je nesmierne dôležitou časťou ľudského tela. Spoznávanie jeho funkcií si vyžaduje náročné výskumy, avšak napriek všetkým výskumom ešte stále nie je celkom prebádaný. Mozog je centrom všetkých funkcií ľudského tela, prijíma dôležité informácie zo zmyslových orgánov a posiela ich ďalej. Jeden z najdôležitejších zmyslov je aj sluch. Sluch nám pomáha orientovať sa v priestore, chráni nás pred nebezpečenstvom. Hlavným cieľom bakalárskej práce je preskúmať ako priestorová pozornosť ovplyvňuje schopnosť rozlíšiť priestorové sluchové ciele a ich nervové korelácie. Budeme využívať dva rôzne typy sluchových signálov a oči budú fixovať centrálne miesto[6].

Sluch je jedným z piatich zmyslov človeka, dá sa povedať že po zraku je najdôležitejším zmyslom, nakoľko nás chráni pred blížiacim sa nebezpečenstvom. Sluchovým orgánom u človeka je ucho, ktoré sa skladá z:

- vonkajšieho ucha
- stredného ucha
- vnútorného ucha

Zvuk, ktorý človek počuje sa dostane najprv k vonkajšiemu zvukovodu a rozvibruje bubienok. K jeho vnútornému povrchu je pripevnená prva z troch sluchových kostičiek, kladivo. Sluchové kosti sú navzájom spojené kĺbmi. V dôsledku vibrácií prenášaných ušným bubienkom sa sluchové kosti začnú hýbať a prenášajú vibrácie na závitovku naplnenú tekutinou. Nakoniec sa vibrácie stanú stimulom v Cortiho orgáne u slimáka. Odtiaľto sú nervové signály prenášané sluchovým nervom do mozgu do sluchového centra, kde sa zvuky stanú vedomým vnímaním[6]. Ľudský sluch môžeme rozdeliť do viacerých procesov, vonkajšie aj stredné ucho zachytávajú a prenášajú zvuky, zatiaľ čo vnútorné ucho tieto zvuky premieňa na nervové signály, ktoré prenášajú sluchové nervy. Pri formovaní orientácie v priestore má zvuk veľmi dôležitú úlohu. Orientačný reflex na zvuk prispieva k rozlišovaní zorných polí, spôsobuje otáčanie hlavy a tela smerom k zvuku. Je zvláštne ako sa spočiatku snažíme zvuk vidieť, t.j. stále sa otočíme za zdrojom zvuku. Čoraz zložitejší súbor časových spojení tvorí základ asociácií, ktoré sa vytvárajú v mozgu medzi rôznymi predmetmi a ich zvukovými vlastnosťami. Na základe týchto asociácií sa vytvára oveľa komplexnejšia schopnosť určiť vzdialenosť medzi človekom a vonkajším objektom zvukom,

umiestnenie objektu zvukom, smer pohybu zvukov[7]. Najnovšie štúdie preukázali nepochybnú súvislosť medzi sluchovou orientáciou v priestore a pohybmi ľudského tela (najmä otáčaním hlavy) a následne zodpovedajúcimi svalovo-kĺbovými vnemami. Preto nie je neočakávané, že poruchy sluchovo-priestorovej diskriminácie (hlavne určujúce smer zvuku) sú obzvlášť závažné pri léziách temporo-parietálno-okcipitálnej oblasti, ako aj dolnej parietálnej oblasti mozgovej kôry[8]. Znamená to, že sluchovo-priestorové rozlišovanie je založené na systéme prepojení medzi sluchom, svalovo-kĺbovými vnemami a priestorovým videním. Samozrejme, sluch je v tomto asociatívnom systéme na prvom mieste. Zvuku spočíva v párovej práci mozgových hemisfér. Je jasné, že takáto párová práca je zjednotením, syntézou zvukovo rozlišovacej práce mozgového konca každej z hemisfér. Inými slovami, priestorovo-sluchové rozlišovanie je najnovšie a komplexné formovanie zvukovo-rozlišovacej činnosti mozgu[8]. Periférne mechanizmy sluchovo-priestorovej diskriminácie sú dráhy oboch sluchových nervov, z ktorých každý vstupuje vo svojich častiach do každej z hemisfér. V dôsledku toho každý z mozgových koncov sluchového analyzátora reguluje činnosť oboch uší v nejakej špecifickej funkcii. Keď sa zvuk šíri od zdroja (napr. reproduktora) do našich uší, transformuje sa interakciou s prostredím, našou hlavou, plecami, ušnicami a sluchovým kanálom[8]. Táto transformácia spôsobí, že zvuk, ktorý počujeme, sa v skutočnosti líši od toho, aký vyšiel zo zdroja. Naviac, líši sa aj to, aký zvuk počujeme ľavým a pravým uchom. Zvuk prichádzajúci zo strany dorazí do jedného ucha skôr ako do druhého a navyše aj s vyššou intenzitou. Mozog analyzuje tieto rozdiely a snaží sa vypočítať, odkiaľ zvuk prišiel. My si potom uvedomujeme len to, že sme počuli zvuk, a že prišiel napr. sprava.

Existuje množstvo definícií pojmu pozornosť: *Pozornosť je mentálne koncentrovanie sa (sústredenie sa) na senzorické (vnemové), alebo mentálne udalosti* (Dana Murphy), alebo *aktivácia mechanizmov, ktoré umožňujú neprerušenú kognitívnu aktivitu zameranú na objekt*

pozornosti (David Somers). [5] Prichádzajú sa však otázky, či je koncept pozornosti zmysluplný, teda či existuje pozornosť alebo je len súčasťou mozgových funkcií, v ktorých ju pozorujeme. Vedci Johnston a Dark vyjadrili obavy, že štúdium pozornosti je „ultimately futile“, teda naveky márne [5]. Na pozornosť môžeme pozerať aj ako na filter prichádzajúcich podnetov, ktorý nám pomáha k tomu, aby sme z nich vybrali len tie, ktoré sú pre nás dôležité [6] a odignorovať nepodstatné. Pozornosť funguje ako pódiový reflektor (angl. spotlight), t.j. to, čo je na pódiu osvetlené, sa kognitívne spracuje, to čo nie, sa ignoruje. Základnými vlastnosťami pozornosti sú *obmedzenosť* a *selektívnosť*. Pozornosť je obmedzená, pretože nedokážeme venovať pozornosť veľkému množstvu podnetov naraz. Selektívnosť spočíva v tom, že pozornosť môžeme vedome zamerať na senzorické podnety, informácie v pamäti (rozpamätávanie sa), alebo motorické odozvy [5]. Ďalšími vlastnosťami pozornosti sú intenzita, rozdelenie, rozsah a stálosť [6]. Intenzita pozornosti udáva silu sústredenia, ak venujeme pozornosť viacerým objektom naraz, potom koncentrácia na jednotlivé objekty klesá. Pozornosť u niektorých činností môžeme rozdeliť, napr. variť a zároveň telefonovať, ale nemôžme riešiť súčasne dve matematické rovnice. Rozsahom sa myslí množstvo podnetov, ktoré je človek schopný zachytiť a stálosťou doba, po ktorú sa dokážeme sústrediť na jeden a ten istý objekt.

Elektroencefalografia je odbor, ktorý sa zaoberá záznamom a interpretáciou elektroencefalogramu[4]. Elektroencefalografia (EEG) je neinvazívna metóda - EEG sa zaznamenáva priložením povrchových elektród na pokožku hlavy. Tie vlny, mozgové rytmy, ktoré môžeme pozorovať na grafe, sú len rozdiely v elektrických potenciáloch, ktoré ukazujú, ako sa menili v priebehu času[3]. Pri elektroencefalografii sa priebežne zaznamenáva celková úroveň elektrickej aktivity a na základe týchto údajov sa zostaví graf, ktorý odráža zmenu aktivity v čase[3].

Predchádzajúce štúdie, ktoré sa zaoberali niečím podobným, zistili zlepšenie schopnosti sluchovej priestorovej pozornosti, ak bol pohľad subjektu nasmerovaný na sluchový podnet. Avšak zistil sa lepší výkon pri vizuálnych podnetoch ako pri sluchových, hlavne ak bol sluchový podnet smerovaný z nekongruentného miesta[2]. Analýza výsledkov v kratšom intervale nezistila žiadne spojenie s korelátmi spracovania pozornosti, avšak na dlhšom intervale sa potenciály menili pre rôzne kombinácie hemisferickej laterality, polohy aj platnosti signálu[2]. Z týchto výsledkov vyplýva, že zvuková narážka spôsobuje moduláciu pozornosti v okcipitálnych oblastiach[2]. Tak isto sa zistilo pomocou behaviorálneho experimentu, že subjekty podávali lepší výkon s platnými narážkami ako s neplatnými, a tak isto lepšie výkony pri väčšej vzdialenosti narážky od podnetu[1]. Analýza ERP skúmala vyvolanú odozvu k sluchovej narážke, ktorá bola uvedená ako korelát spracovania pozornosti. Zistilo sa, že sluchový podnet spôsobuje moduláciu pozornosti. Tieto výsledky zobrazujú interakcie medzi dvoma modalitami nezávisle od polohy a pohybu očí[1].

Experimentu sa zúčastnilo 10 subjektov (4 muži, vo veku 20 – 26 rokov). Všetci účastníci boli podrobený audiogramu, ktorý u nikoho z nich nezistil žiadne nedostatky v sluchu. Pred zberom samotných dát sa každý z účastníkov zúčastnil aj testovanie, kde si odskúšali varianty experimentálnych podmienok. Každý z účastníkov podpísal písomný informovaný súhlas na zber dát pre univerzitu. Sluchové podnety boli generované pomocou Matlab. Experiment bol generovaný pomocou Matlabu s rozšírením Psychtoolbox. Sluchové podnety boli prezentované pomocou slúchadiel pripojených k systému Datapixx. Počas experimentu subjekty sedeli v odzvučenej kabínke. Experiment bol zložený zo skúšok sluchových podnetov. V každom pokuse bol cieľ pozostávajúci z dvoch zvukov prezentovaných z mierne odlišných miest a úlohou poslucháčov bolo rozlíšiť smer zmeny cieľovej polohy. Skúšky sluchového podnetu pozostávali z dvoch po sebe nasledujúcich zvukov. Subjekt mal na obrazovke počítača fixovať neutrálne miesto (0°) označené bielou bodkou a počúvať zvuky v slúchadlách. Prvý zvuk bol cue, na pozícii 0°, +25° alebo -25°, po ňom nasledoval dvojitý zvuk, target, ktorý bol tak isto na pozíciach 0°, +25° alebo -25°, a zároveň sa mierne posúval o +/-4,2° pre strednú pozíciu, alebo o +/-8,4° pre bočné pozície. Subjekt mal určiť ktorým smerom sa posúval dvojitý zvuk, ak sa pohol do ľava mal stlačiť na klávesnici 1, ak sa pohol do prava, mal stlačiť 2. Subjekty boli pred začatím experimentu poučené, aby venovali všetku svoju pozornosť podnetu, očakávali cieľový stimul a reagovali rovnakým spôsobom. V „zhodných“ pokusoch (33,3 %) boli podnety a cieľové stimuly prezentované na rovnakom mieste. V „nezhodných“ pokusoch (66,6 %) boli sluchové podnety a cieľové stimuly prezentované z iného miesta. Sluchové podnety sa delili na 2 verzie, a to biely šum a bzukot. Obe tieto podnety boli zastúpené v rovnakom množstve. Experimenty ukázali, že štúdium sluchovej priestorovej pozornosti vyvolanej sluchovými podnetmi nie je jednoduché.

Po preštudovaní a rozpracovaní predchádzajúceho výskumu týkajúceho sa sluchovej priestorovej pozornosti som pripravila experimentálnu zostavu a na základe existujúcich skriptov MATLABu som naprogramovala experimentálny kód zberu dát. Na zbere údajov sa zúčastnilo 10 subjektov. Úlohou subjektov bolo lokalizovať, ktorým smerom sa cieľový zvuk pohyboval. Podľa analýz, ktoré som vykonala na zozbieraných údajoch, môžeme posúdiť, že každý subjekt má pravdepodobne iné sluchové schopnosti. Ako vidíme, najlepšie odpovede boli s cue prezentovanou naľavo, či už išlo o bzukot alebo biely šum. Ak sa pozrieme na samostatné analýzy pre bloky B1 a B2 a bloky B3 a B4, veľký rozdiel v nich nezbadáme. Preto môžeme predpokladať, že cue modalita nemá veľký vplyv na sluchovú priestorovú pozornosť. Podľa našich výsledkov môžeme zhodnotiť, že väčší vplyv na sluchovú priestorovú pozornosť má miesto, kde bola cue prezentovaná. Podľa našich predpokladov však mali byť výsledky výrazne lepšie, keď bola cue prezentovaná zo stredu ako zľava alebo sprava. Môžeme teda predpokladať, že úloha bola pravdepodobne zle pochopená, alebo sa v experimentálnom kóde vyskytla chyba. Otázkou však zostáva, či subjekty pri odpovedi naozaj dávali pozor. Po veľkom počte prezentácií podnetu sa mohlo stať, že subjekty už odpovedali iba mechanicky. Niekto sa vie sústrediť viac, niekto menej. Niektorí sú na tom lepšie s lokalizáciou, niektorí menej. Pozorovaná veľká rozdielnosť medzi subjektmi môže byť spôsobená práve týmto.

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Attachments

Attachment A – User manual