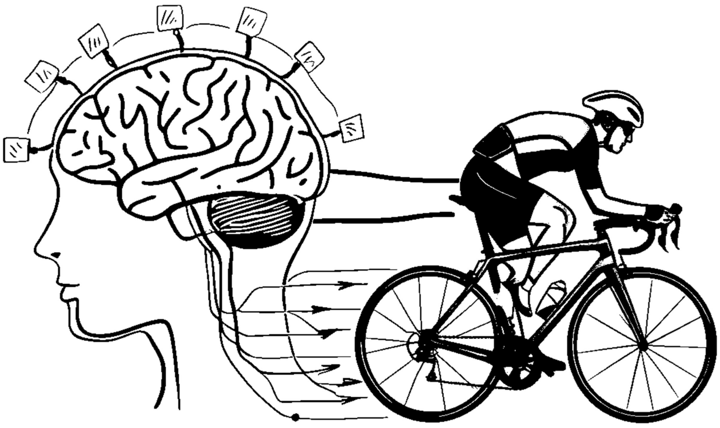

Impact of Mental Imagery Training on Amateur Cycling Athletes: Insights from Self-Assessments and EEG-Based Brain Activity Analysis

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December 11, 2024

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Abstract

Mental imagery training, or visualization, is a technique widely recognized for enhancing athletic performance by improving motor skills, attention, self-confidence, anxiety reduction, and muscle strength. Despite its broad application across sports, its impact on amateur cyclists, particularly in terms of brain activity, remains underexplored.

This study examines the effects of a seven-week mental imagery sprint training program on five male amateur cyclists, focusing on cognitive aspects such as attention, concentration, anxiety, and motor skills. EEG data were collected weekly to monitor neural changes, while pre- and post-program self-assessment questionnaires evaluated perceived improvements.

Findings indicate individual improvements in concentration and anxiety, though statistical significance was not achieved due to the small sample size. EEG trends revealed changes in brain activity linked to measured cognitive functions, suggesting potential benefits of mental imagery training on concentration and attention.

This research contributes to the understanding of mental imagery in cycling, highlighting EEG as a valuable tool for monitoring its effects. Further studies with larger sample sizes are necessary to validate these preliminary findings and refine mental imagery strategies for optimizing athletic performance.

Nomenclature

Abbreviations

BA	Breath Assignment
BCI	Brain Computer Interface
C	Central
EC	Eyes Closed
ECG	Electrocardiography
EEG	Electroencephalography
EO	Eyes Open
EOG	Electrooculogram
F	Front
FTP	Functional Threshold Power
GS	Guided Scenario
ICA	Independent Component Analysis
ID	Identification
IM	Imagery Training
MRI	Magnetic Resonance Imaging
O	Occipital
P	Parietal
PETTLEP	Physical; Environment; Task; Timing; Learning; Emotion; Perspective
PSD	Power Spectral Density
Q1	Upper Right Quadrant of the human brain
Q2	Bottom Right Quadrant of the human brain
Q3	Upper Left Quadrant of the human brain
Q4	Bottom Left Quadrant of the human brain
SMA	Supplementary Motor Area
SMR	Sensorimotor Rhythm
US	Unguided Scenario

Symbols

α	Alpha
β	Beta
θ	Theta
μ	Mu
σ	Sigma

Contents

1 Introduction

1.1 Motivation

In the world of sports, athletes are constantly seeking innovative methods to enhance their performance and gain a competitive advantage. One technique that has gained attention and recognition is mental imagery training, also known as, visualisation, imagery training or mental imagery. The terms mentioned are interchangeable. The concept involves mentally rehearsing and vividly imagining the execution of movements, providing athletes with a powerful tool to refine their skills beyond physical training. Research supports the efficacy of mental imagery training in improving performance across various sports, emphasizing its impact on motor skills, muscle strength, self-confidence, attention, concentration and anxiety reduction (Predoiu et al., 2020).

The use of imagery training has become an essential component for athletes across various sports disciplines. However, its development and application are more advanced in some sports than in others. Imagery training is defined as the process of mentally recreating movements through sensory experiences or mental execution of movement without any overt movement or muscle activation (Mizuguchi, Nakata, Uchida, & Kanosue, 2012). Mental imagery training offers athletes a unique opportunity to engage with their sport on a cognitive level. This is particularly crucial in top sports, where the margins of difference between competitors are often minimal. For example, while the body requires recovery time after physical exertion, the mind can be actively trained through imagery, contributing to an approach to optimizing athletic performance in tactical and technical aspects. The psychological benefits of mental imagery training are targeted at fostering confidence and self-belief, serving as a strategic approach to surmount performance anxiety and eliminate negative triggers (Dello Iacono, Ashcroft, & Zubac, 2021; Ekeocha, 2015).

1.2 Problem Statement

Optimal mental imagery training techniques encompass a multifaceted approach that draws upon insights from various studies. According to Predoiu et al. (2020) comprehensive mental imagery training should engage a vivid mental representation of the desired skill or performance. However, the optimal structure and duration of mental imagery training varies across studies. For example, Predoiu suggests a regimen of one hour per session over 6-10 days, while Weinberg (1981) advocates for sessions lasting at least one minute but not exceeding five minutes to avoid mental fatigue. However, all studies try to provide athletes with a structured framework to pursue their goals by fostering a more positive mindset with mental imagery training techniques (Birrer & Morgan, 2010). Within the research topics extended research is conducted in developing a suitable approach to train amateur cycling athletes with mental imagery training. First off, it is important to investigate how the brain reacts to such a training program. During mental imagery training certain parts of the brain become more active. Although research has been conducted on both; mental imagery training and brain activity, it's not entirely clear how or if the brain activity changes in athletes who practice mental imagery training techniques. Therefore, this graduation project will with the use of training amateur cycling athletes delve the changes of brain activity influenced by mental imagery training. The aim is to gain knowledge and to find out based on prior research what happens to the brain activity when someone actively trains on mental imagery techniques.

1.3 Research Questions

1. Do amateur cycling athletes experience progress in mental imagery training when practising their bunch sprint? And if so,

    a. In which aspects do they experience progress the most?

2. Does EEG reveal changes in brain activity following a seven-week imagery sprint training program among cyclists? And if so,

    a. In which brain regions can these differences be identified?

        i. What kind of trends are visible in the brain activity of these brain regions?

    b. Can one measure an individual's proficiency in mental imagery training?

   i. And if so, what are the observable indicators in the brain that correlate with proficiency?

3. How does imagery training for a bunch sprint influence the various brain regions involved in attention, concentration, anxiety, and motor skills?

Note: The outcome of gaining muscle strength and self-confidence will be accepted and assumed to be the case. Therefore, focusing on investigating the other four aspects (measurable with EEG): motor skills (only activation, not performance itself), attention, concentration, and anxiety.

2 Background

In this chapter, several critical aspects related to brain structure, imagery training and electroencephalography (EEG) will be extra clarified. The background is a chapter on its own which contains a lot of specific information. This chapter can be used to gain more information about a specific topic.
Firstly, the construction of the brain, examining its diverse regions and their respective functions will be discussed. Following this, an overview of EEG, elucidating its operational principles, its capacity to measure various frequencies of brain waves. Additionally, the intriguing phenomenon of Brain-Computer Interface (BCI) illiteracy will be discussed, discussing how some individuals may struggle to interface with EEG-based technologies.
Furthermore, the variability of EEG results among different individuals, considering factors such as hair colour, handedness, and other variables that can influence EEG recordings is examined. After this mental imagery training theory will be introduced explaining important areas where to focus on while conducting mental imagery training. Finally, the background of the data analysis methods for EEG will be explained.

2.1 Brain Regions

The human brain comprises two main parts, known as the left and right hemispheres, as can be seen in Figure 2.1. Each hemisphere can also be divided into two areas: the front and back area. These four areas are also referred to as quadrants, which can be useful for explaining a specific region of the brain. Each part of the brain serves its own function, as illustrated below in the schematic from Jama (2018). As depicted in Figure 2.2, the brain can alternatively be categorized into a frontal lobe, parietal lobe, temporal lobe, occipital lobe, and cerebellum. This offers an even more precise indication of where certain brain functions occur. The various brain areas have distinct functionalities, for example, there is one region for motor control, touch, and pressure, as well as vision. When one of these functionalities is activated, the neural signal becomes stronger in that specific area.

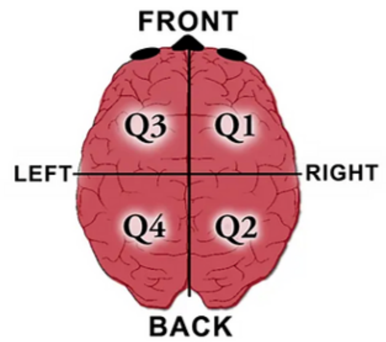

Figure 2.1: Schematic of the Human Brain
Source: Beyond Personality

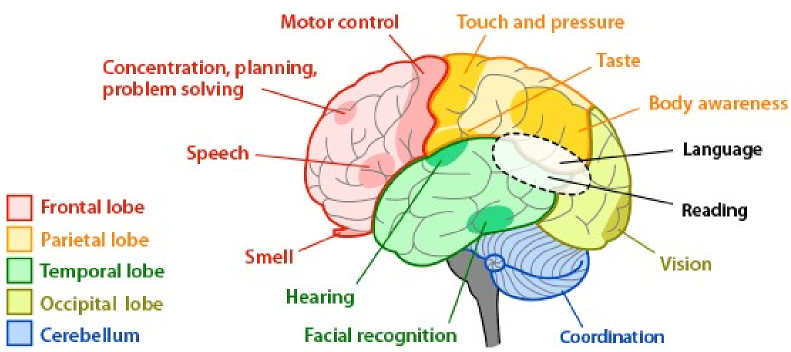

Figure 2.2: Detailed Schematic of the Human Brain.
Source: Jama (2018)

The papers discussing mental imagery training also touch upon the brain regions influenced by mental imagery training. In general, Predoiu et al. (2020) highlight a significant change in brain activity during mental imagery training, shifting from the left to the right hemisphere. The upper right quadrant (Q1), known for its strength in intuitive and imaginative tasks, emerges as crucial in the mental imagery training process. At the same time, the left hemisphere is linked to creative imagination, while its left quadrants (Q3) show associations with logical thinking, planning, and organization. Ekeocha (2015) emphasizes that activating the creative quadrant (Q3) of the brain during mental imagery training enhances visual imagery and consequently improves performance. However, these papers only mention the affected brain regions in relation to mental imagery training; they do not actually quantify the extent of the differences in brain activity with a measurement.

2.2 Brain Activity

Neural signals refer to the electrical activity generated by neurons in the brain, which are classified into five different frequency bands: alpha, beta, theta, delta, and gamma bands. In adults, these frequency bands and their approximate spectral boundaries are as follows: delta (1–3 Hz), theta (4–7 Hz), alpha (8–12 Hz), beta (13–30 Hz), and gamma (30–100 Hz) (Abo-Zahhad, Ahmed, & Seha, 2015; Saby & Marshall, 2012). The alpha band originates during periods of relaxation with eyes closed but while still awake. The beta band is associated with normal consciousness and active concentration. Theta waves are observed during some states of sleep and during quiet focus. Delta waves are the slowest EEG waves and are typically detected during deep, unconscious sleep. Finally, gamma waves exhibit stronger electrical signals in response to visual stimulation (Abo-Zahhad et al., 2015). An example of these frequency bands waves can be seen in Figure 2.3.

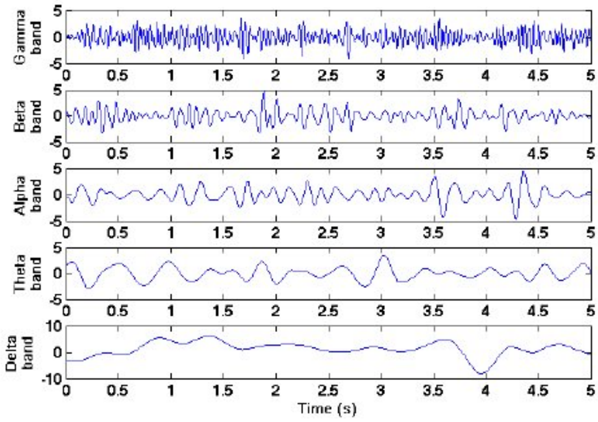

Figure 2.3: The five frequency bands of an EEG signal.
Source: Abo-Zahhad et al. (2015)

2.3 Electroencephalogram (EEG)

Electroencephalogram (EEG) is a device used to measure the electrical activity of the brain. It is capable of detecting waves at various frequency bands, providing valuable insights into brain function and activity. This non-invasive technique utilizes small electrodes placed on the scalp to record these electrical signals. Non-invasive means that there is no surgery required. EEG waves can be employed to detect a wide range of activities in the brain, including stress (TuerxunWaili, Alshebly, Sidek, & Johar, 2020). When considering EEG, it is important to note that different products offer varying numbers of channels. Typically, wet electrodes with gel are used, although they require more time to set up onto the head. Alternatively, dry electrodes are available, but they are more prone to movement artefacts and channel failure (di Fronso et al., 2019). The choice of product depends on which brain regions there is aimed to analyse, and which channels are required for the specific research or diagnostic needs. EEG channels are grouped according to the major cortical areas of the brain, such as frontal (F), central (C), parietal (P), and occipital (O), in both the left and right hemispheres. This grouping allows for a more precise analysis of brain activity, as different regions of the brain may exhibit distinct electrical patterns during various tasks or states. Understanding the organization of EEG channels is essential for accurately interpreting the data collected and drawing meaningful conclusions about brain function and activity (Prashad, Dedrick, & Filbey, 2018).

2.4 Differences Between People

It is important to select participants with similar characteristics to ensure accurate comparisons in research studies. Differences in factors such as handedness, caffeine intake, hair colour, gender, or age can introduce variability unrelated to the specific abilities or traits being studied. Therefore, when defining participant criteria, these factors should be carefully considered to minimize the impact of unrelated differences on the study's outcomes.

2.4.1 Handedness

As described in the previous section, while the brain generally operates according to specific areas, there are some differences among individuals. One of the main examples is handedness. Left-handedness is associated with differences in brain asymmetry related to working memory, language, hand control, and vision (Sha et al., 2021). For instance, in right-handed individuals, the left hemisphere controls the right hand, whereas in left-handed individuals, the right hemisphere controls the left hand. The same pattern applies to language: in right-handed individuals, the left hemisphere is more active, while in left-handed individuals, the right hemisphere is more active.

2.4.2 Caffeine Intake

Furthermore, caffeine intake plays a role in how the brain reacts. Research comparing rest phases among participants who monitored their caffeine intake shows that for the central channels (C3 and C4), the average alpha and beta power is lower in the caffeine group compared to the control or sugar group. However, this difference is not large enough to be statistically significant (Meng et al., 2017; Mundahl, John, Meng, Jianjun, He, Jeffrey, & He, Bin, 2016).

2.4.3 Hair

EEG works with electrodes that make contact with the scalp to measure brain activity from outside the scalp. However, good contact between the scalp and the electrode is necessary for accurate measurements. If participants have very thick hair, good contact may not be achieved, resulting in corrupt data (Spüler, 2017).

2.4.4 Gender and Age

There are also differences in how the human brain reacts between males and females and among people of different ages. For example, according to Hill et al. (2014), females tend to have higher brain activity in prefrontal regions compared to males.
Furthermore, older adults show slower peaks in alpha frequency compared to younger adults (Merkin et al., 2023). Because these differences are visible in EEG recordings, several machine learning models can predict the gender of a participant based on their EEG recording (Kaur, Singh, & Roy, 2019; Kaushik, Gupta, Roy, & Dogra, 2019).

2.4.5 Illiteracy

Around 15-30 percent of the people are unable to control BCIs accurately. This phenomenon is called BCI illiteracy (Becker, Dhindsa, Mousapour, & Dabagh, 2022). Due to different behaviour of the brain, many of the variations are still unknown to researchers. It is more likely that these individuals use different strategies than most people when performing mental imagery tasks (Becker et al., 2022; Dickhaus, Sannelli, Müller, Curio, & Blankertz, 2009).

2.5 Mental Imagery Training Theory

To organize the information about mental imagery training and explain the guidelines of Predoiu, Holmes and Collins, and Ekeocha, the structure from Predoiu's paper (2020) will be adopted and supplemented with research from Holmes and Collins, and Ekeocha. Resulting in covering the following aspects: Physical; Environment; Task; Timing; Learning; Emotion; Perspective (PETTLEP) and Senses, Relaxation, Learnability, Personality, Experience, Age, Time, Perspective, and Mindset.

2.6 PETTLEP and Senses

Enhancing sports performance relies on mental images that are vivid and realistic, evoke appropriate emotions, and remain under control (LeUnes, 2008). One system ensuring these criteria is the PETTLEP system developed by Holmes and Collins (2001), encompassing Physical, Environment, Task, Timing, Learning, Emotion, and Perspective. Incorporating all these elements enriches mental imagery by integrating stimulus-response and meaning propositions.

- **Physical:** Reflects the extent to which the physical aspects of the imagery mirror the actual movement, including body position, equipment, and clothing.

- **Environment:** Dictates that the imaged action should occur in the same environment as the actual action, both mentally and physically.
- **Task:** Requires that the imaged action closely corresponds to the actual action in terms of execution and expertise level.
- **Timing:** Perform the imagery in real time.
- **Learning:** The envisioned action should progress and refine as the skill is acquired.
- **Emotion:** Demands that the imaged action includes similar emotions and arousal levels as those experienced during the actual performance.
- **Perspective:** The chosen viewpoint for the imagined action should enable a focused emphasis on the necessary components of the action.

Additionally, Ekeocha (2015) argues in their paper that incorporating as many senses as possible can enhance the effectiveness of mental imagery. This is because utilizing all senses—smell, touch, hearing, taste, and sight—contributes to creating a fully coloured mental image. The concept is to ensure that the mental imagery training script includes sufficient details, aligning with the principles outlined in the Task component of the PETTLEP. An illustrative example of implementing this recommendation can be found in Figure 2.4, as presented in the paper by Predoiu (2020).

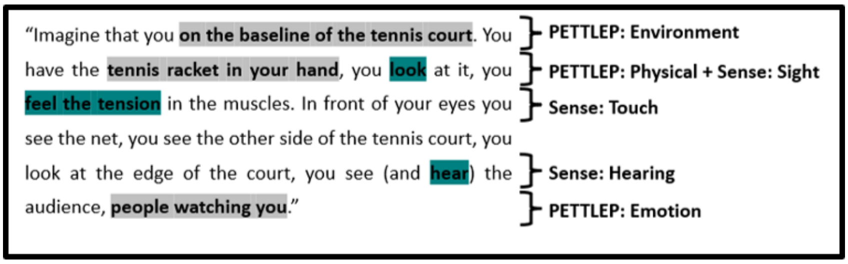

Figure 2.4: Imagery script example.
Text source: Predoiu (2020); Own figure

2.6.1 Relaxation

The initial aspect of many mental imagery training techniques is to start with relaxation, which aids in controlling imagery by eliminating disruptive factors and fostering a calmer state, enabling individuals to reconnect with an experience or performance (Ekeocha, 2015; Predoiu et al., 2020). Moreover, relaxation is one of the four primary mental techniques—imagery, goal setting, self-talk, and physical relaxation—predominantly employed in sports psychology. These techniques can be applied independently or in combination to manage focus on relevant processes during sporting activities (Birrer & Morgan, 2010). Additionally, relaxation techniques are not restricted to pre-sporting activities but can also be employed afterward to enhance recovery post-training or competition (Kellman et al., 2006, as cited in (Birrer & Morgan, 2010)).
However, not everyone can engage in mental imagery training due to various reasons. For instance, a relaxed mind may trigger flashbacks for individuals with post-traumatic stress disorder (Cooper & Strollings, 2009, cited in (Ekeocha, 2015)). Therefore, it is crucial to determine if participants are not affected by such conditions. To create a conducive environment for relaxation, certain guidelines should be followed. For instance, individuals performing mental imagery training should find a comfortable position and close their eyes. Opting for a quiet place is preferable to minimize distractions (Predoiu et al., 2020). Additionally, wearing comfortable clothing can contribute to the overall relaxation experience (Ekeocha, 2015). Other studies suggest that using competition-specific attire could also be beneficial, although this perspective is more related to the environment to make this more similar, this will be further explained in the subsequent section.

2.6.2 Learnable

Mental imagery training is not a one-time activity with immediate results; rather, it is a skill that requires learning and training. Practice and perseverance are essential, with some athletes dedicating months to mental rehearsal before achieving proficiency in mental imagery training (Cooley, Williams, Burns, & Cumming, 2013; Predoiu et al., 2020). Additionally, the ability to visualize varies among individuals, and not everyone can vividly imagine images in their minds. To assess an individual's mental imagery training ability, the Controllability of Motor Imagery Test (CMI) can be conducted (Cooley et al., 2013; Mizuguchi et al., 2012). This test involves presenting a sequence of six movements (e.g. step half a meter forwards) to the participant, who then selects the final body posture from five pictures. The CMI test is not the sole assessment tool; several other questionnaires have been developed, including the Vividness of Motor Imagery (VMI) test, the Vividness of Movement Imagery Questionnaire (VMIQ), the Sport Imagery Ability Questionnaire (SIAQ), the Florida Praxis Imagery Questionnaire (FPIQ), and the Movement Imagery Questionnaire (MIQ) (Mizuguchi et al., 2012). These different tests vary due to the specific purpose of the test, in example, the SIAQ focuses more of mental imagery training in sports whereas the CMI is more general and not sport specific. Furthermore, the fifth element in the PETTLEP model, underscores the significance of both learning and rehearsal. It also highlights the importance of enhancing the level of detail as the participant becomes more proficient. Failure to increase the level of detail could result in suboptimal outcomes in terms of imagery ability. Regarding learning, it is universally acknowledged in research that mental imagery training is a skill that must be acquired, with the duration of learning varying significantly within different papers. For example, Predoiu (2020) suggests one hour of daily mental training over 6-10 sessions, while other studies, such as Ekeocha (2015) and Mizuguchi (2012), propose 5-15 minutes for five consecutive days. Cooley (2013) addresses the variability in learning durations and methodologies in his paper on guided imagery interventions, comparing 20 interventions based on various criteria. He found that longer interventions and more time spent in imagery practice were associated with more successful outcomes. Successful interventions, defined in his paper as 'full change', typically require 6-7 weeks of training with 2-7 sessions, each lasting 3-10 minutes, emphasizing the need for a substantial time commitment to achieve tangible results.

2.6.3 Personality

The effectiveness of mental imagery training not only relies on the athlete's imaginative ability but also on their attitude and confidence in the technique's efficacy. This is connected to the rehearsal and training discussed in the last section, as well as the athlete's personality (Birrer & Morgan, 2010; Ekeocha, 2015). Some individuals are more receptive to mindfulness, while others are more convinced by physical training alone (Cooley et al., 2013). Given the importance of beginning with a fully relaxed mind, a person's innate disposition toward relaxation can be beneficial. A relaxed mind is, in turn, associated with a sense of control. Rotter (1966; cited in (Ekeocha, 2015)) terms this internal locus of control, reflecting individuals' beliefs in their ability to control events and determine their own rewards through their actions. In contrast, individuals with an external locus of control believe that their behaviour has little impact, and life's rewards are largely beyond their control. A robust internal locus of control is crucial for mental imagery training, as it contributes to an individual's overall well-being and performance. It is linked to higher levels of optimism, self-esteem, and the ability to endure pain, ambiguity, and stress (Naparstek, 2000; cited in (Ekeocha, 2015)). This aligns with the recommendation regarding mindset. If someone's natural disposition is to think more positively, it aids in mental imagery training, as the imagined components need to be positive as also described in Section 2.6.8 *Mindset*.

One validated method of assessing someone's personality is through the Big Five personality traits. These traits include Openness to Experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. Several questionnaires have been developed to gain insights into people's personalities. A commonly used tool in research is the International Personality Item Pool (IPIP), which was created by Lewis and Goldberg in 1999. This questionnaire comprises 3000 items organized into 250 scales based on these traits and can be found in Appendix E.

2.6.4 Experience

Certain studies suggest that as athletes accumulate more experience in a specific sport, the advantages of employing mental imagery training techniques become more pronounced (Howe, 1991; cited in (Predoiu et al., 2020)). This phenomenon may be attributed to the fact that individuals with a deeper understanding of the required movements find it easier to visualize those specific actions. For instance, in speed skating, mental imagery training is frequently utilized to fine-tune technique (TWST Consulting, 2016). Professional athletes, having a heightened awareness of areas for optimization in their technique, can pinpoint specific aspects to focus on compared to novice athletes.

2.6.5 Age

Concerning age, it is commonly believed that senior athletes excel in utilizing mental imagery training techniques (Predoiu et al., 2020). However, certain studies indicate that even children between the ages of 8 and 11 can derive benefits from mental imagery training (Partington, as cited in (Predoiu et al., 2020)). Conversely, younger children at the age of five may not possess the ability to utilize imagery, as this skill seems to develop during the elementary school age, around seven years (Molina et al., 2007; cited in (Mizuguchi et al., 2012)). Oppositely, Mulder (2007; cited in (Mizuguchi et al., 2012)) assessed the Vividness of Movement Imagery Questionnaire (VMIQ) and found that the imagery ability of the elderly was less than that of young adults. Therefore, when comparing mental imagery training progress, age must be considered as it can also influence the results.

2.6.6 Time

Mental rehearsal is recommended to follow a correct time sequence, with the understanding that mental imagery training in slow motion or at very high speeds, especially concerning motor skills, is not very effective (Bull, 2011; (Mizuguchi et al., 2012)). This notion aligns with the concept of mental chronometry, which refers to the time it takes for mental movements or actions (Mizuguchi et al., 2012). An example highlighting the impact of imagery training on performance is seen in a video featuring Erben Wennemars, ex-professional speedskater athlete, where he attributes a time difference of a few tenths of a second on his 500m to the regular use of imagery training (TWST Consulting, 2016). This suggests that Wennemars is considered proficient in utilizing mental rehearsal techniques. Moreover, the second "T" in PETTLEP stands for Timing, emphasizing the importance of performing imagery in real-time. This underlines the significance of aligning the mental rehearsal with the actual timing of the desired actions or movements (Cooley et al., 2013).

2.6.7 Perspective

When discussing perspectives in mental imagery training, there are two distinct viewpoints: the first perspective, also known as the internal perspective, and the third perspective, also referred to as the external perspective. The first perspective involves seeing things through one's own eyes, while the external perspective is akin to observing oneself as a bird or an outsider from the sidelines. Numerous authors (Hinshaw, 1991; Whelan et al., 1991; Suinn, 1997; as cited in (Predoiu et al., 2020)) emphasize the superiority of internal mental imagery training over external mental imagery training. In other words, mentally rehearsing motor actions or skills from an inner perspective, as if experiencing them through one's own eyes, is considered preferable (Mizuguchi et al., 2012). This preference is further underscored by the Perspective from the PETTLEP model (Cooley et al., 2013).

2.6.8 Mindset

The final recommendation emphasizes the importance of maintaining positive mental images. In essence, it is advantageous for athletes to envision themselves performing well mentally. This is because if mental rehearsal includes negative aspects, such as errors in execution, it can contribute to creating conditions for sports failure (Birrer & Morgan, 2010; Predoiu et al., 2020). Moreover, positive affirmations such as "I can do it" have been shown to increase pain tolerance and reduce the sensation of pain (Flor, 2009; cited in (Birrer & Morgan, 2010)). These positive affirmations are also known as self-talk and are also one of the four mental techniques that were mentioned in Section 2.6.8 *Relaxation.*

2.7 EEG Data Analysis

2.7.1 Data Cleaning

Cleaning the data is essential to improve the quality of recorded brain signals by removing unwanted noise and artefacts, allowing for more accurate analysis. EEG signals can be contaminated by various sources of noise, such as eye blinks, coughs, heartbeats, and powerline interference. Without proper cleaning, these artefacts can obscure or distort the brain activity being studied, making it difficult to interpret the data.

Eyeblinks can be identified with a Electrooculogram (EOG) signal. This technique specifically targets eye-related artefacts. By recording signals from electrodes placed near the eyes, it is possible to identify and subtract these artefacts from the EEG data. For setting up the EOG channel electrode channels that are in the front region are used. This because the frontal area it is most likely to capture eye blinks. Furthermore, vascular noise can be identified using Electrocardiography (ECG). Since heartbeats are repetitive and regularly occurred waveform can this artefact clearly be identified in an EEG signal. For the ECG channel the mean of all channels can be used.
Another tool that can be used is Independent Component Analysis (ICA), ICA is a mathematical tool that can be used to process and clean signals by separating independent sources from a mixed signal. In the context of EEG, it can also isolate components related to artefacts such as eye blinks, heartbeats or muscle activity. Once identified, these components can be removed from the data, leaving a cleaner EEG signal. Although it is not necessary to use EOG and ECG signals in combination with ICA it can make it easier to identify and confirm the components related to eyeblinks or heartbeats.
Applying frequency filters (e.g., high-pass, low-pass, band-pass, or notch filters) are also to remove noise outside the range of interest. For example, the notch filter at 50 Hz can remove power line noise. Whereas a band-pass filter allows a specific range of frequency (e.g. alpha band) to pass while removing others.

2.7.2 Visualising the Data

Visual Noise Inspection

The data of an event can also be visualised to be able to visually inspect the data for noise. Really high peaks can be related to noise. With use of these plots the data can be cropped down to suitable parts or channels that contains a lot of noise can be excluded for further analysis. In Figure 2.5 below an example of such a plot is shown. A suitable part for further analysis can be between 649s – 652s as this data does not contain strange fluctuations. Another option could be to disregard the channel Oz (dark red) as this channel shows a lot of unexpected fluctuations.

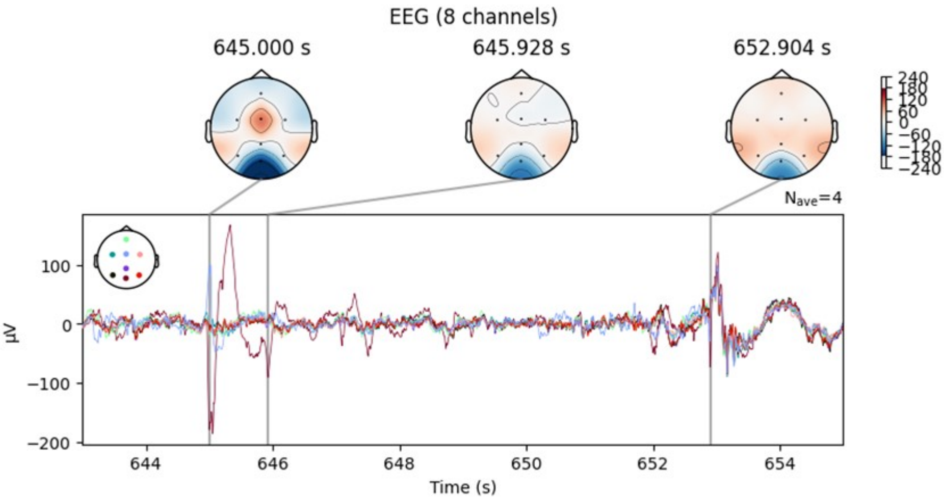

Figure 2.5: Plot of pilot EEG data. Channel Oz shows a high peak around 645s which is likely to be noise.
Source: Own figure

Topomaps

To find out where changes occur in the brain activity Topomaps can be created. This are visual representations of data distributed across the scalp, They depict spatial distributions of electrical activity measured by EEG electrodes. This can be created for each event or certain timeframe. Additonally, if you compare Topomaps of the same event over different weeks they can also illustrate differences over weeks. These visual representations can help distinguish between effective and ineffective mental imagery training of brain activity. Topomaps provide a clear and intuitive way to compare the spatial distribution of EEG signals, highlighting regions with significant changes in activity. This can be particularly useful in monitoring progress, assessing interventions, and understanding neural dynamics. By analysing these maps, researchers could identify patterns.

Frequency Bands

Looking at the different channels is just as important as looking at the different frequencies within the channels. This can be shown with Power (μV) on the y-axis and Time (s) on the x-axis. Just to get an idea of how the frequencies are within that specific channel, see Figure 2.6. Another more insightful graph is a PSD graph that shows the Power Spectral Density (dB) on the y-axis and the Frequency (Hz) on the x-axis. In these graphs you can see which frequency bands are the most present during the EEG recording and for which channels there are peaks in certain frequency bands (see Figure 2.7).

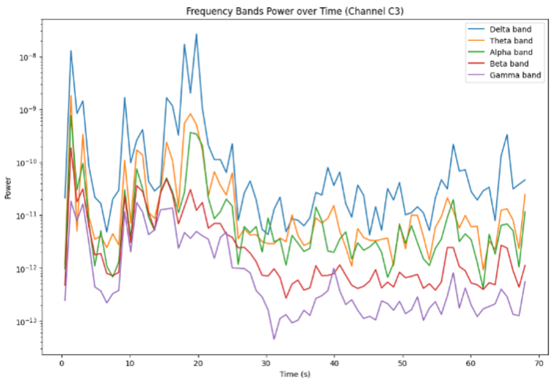

Figure 2.6: Graph of frequency power of channel C3 over time to illustrate the different behaviour of frequencies within a channel. *Source: Own figure*

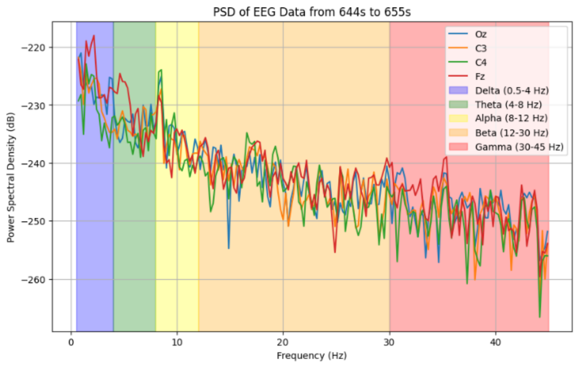

Figure 2.7: PSD Graph of the 'Unguided Scenario' from the pilot experiment. *Source: Own figure*

3 Related Work

3.1 What is Mental Imagery Training?

Mental imagery training is defined as the process of mentally recreating movements through sensory experiences or mentally executing movements without any overt movement or muscle activation (Mizuguchi et al., 2012). It is not a one-time activity with immediate results; rather, it is a skill that requires learning and training. Practice and perseverance are essential, with some athletes dedicating months to mental rehearsal before achieving proficiency in mental imagery training (Cooley et al., 2013; Predoiu et al., 2020).
For example, consider an athlete preparing for an 800-meter run. They would visualize the entire experience: knowing the distance, being aware of their own strength to execute a negative split, hearing the crowd cheering, and anticipating the intense muscle pain at the end of the race. Through such detailed mental rehearsal, athletes can enhance their performance by preparing themselves for the actual event.

3.2 How to Achieve the Best Results?

Mental imagery training is not a one-time practice, so how does one achieve the best results? It can be helpful to create a structured imagery script, including a detailed scenario of the event, such as an athlete preparing for an 800-meter run. This script should be practised until the athlete knows every detail and possible deviation. The mental imagery training script should be systematic, goal-oriented, planned, controlled, and evaluated (Birrer & Morgan, 2010).
To obtain an optimal script, several aspects must be considered. Predoiu (2020) provides a guideline of nine aspects to achieve good results with mental imagery training. Another system is PETTLEP, an acronym for Physical, Environment, Task, Timing, Learning, Emotion, and Perspective, created by Holmes & Collins (2001). This system covers similar areas to Predoiu's guideline and also helps integrate the human senses in mental imagery training which is also preferred (Ekeocha, 2015). It is recommended to incorporate these guidelines as thoroughly as possible when designing an imagery script for optimal results. An extended explanation of these guidelines can be found in Chapter 2.5 *Mental Imagery Training Theory.*

3.3 EEG and Mental Imagery Training

The question arises: what occurs in the brain during mental imagery training? The brain directs the muscles on how to move by sending neural signals towards them. The strength of these neural patterns correlates with the clarity and strength of the movement. Previous Magnetic Resonance Imaging (MRI) brain research has discovered that mental imagery training strengthens these neural signals, leading to positive effects, as mentioned in Chapter 1.1 *Motivation* of this report (Newmark, 2012; cited in (Ekeocha, 2015)). It was learned that mental imagery training enhances motor skills, self-confidence, attention, and concentration, and reduces anxiety (Predoiu et al., 2020). Except for muscle strength, all these aspects can be associated with the brain. Therefore, the focus in the following section will be on these five aspects when exploring the brain. Furthermore, it would be important that these aspects could to be studied using EEG, as this forms the basis of the initial research plan to analyse the neural impact of mental imagery training. However, it is not yet known whether these specific aspects can be effectively investigated with EEG, highlighting the exploratory nature of this study.

3.3.1 Motor Skills

Motor skills are essential for various activities, and their measurement involves multiple brain regions, including the cerebellum, motor cortex, basal ganglia, and brainstem. The motor cortex can be in particular be assessed using EEG (Baladron, Vitay, Fietzek, & Hamker, 2023). Additionally, the Supplementary Motor Area (SMA) plays a role in higher-order motor planning and coordination processes. It is involved in internally generated movement planning, motor preparation, and the execution of tasks that require synchronization and anticipation. The SMA also contributes to learning new motor skills and integrating sensory information to refine movement strategies. During motor tasks, occipital regions are activated due to visual feedback and processing. Beta activity, as observed in studies by Laufs et al. (2003) and Cheron et al. (2016) (cited in (Tamburro, Stone, & Comani, 2019)), provides valuable

insights into motor binding, and fatigue as typically, an increase in beta activity is associated with the preparation and execution of motor tasks, while a decrease can indicate motor inhibition or fatigue. Therefore, studying beta activity can provide valuable insights into how the brain coordinates motor actions and how fatigue might disrupt motor performance.
EEG channels that are associated with brain activity in the motor cortex are C3, Cz and C4 (Yahya, Musa, Ong, & Elamvazuthi, 2019). The more SMA-related channel that is involved in higher-order motor planning and coordination processes is FCz.

3.3.2 Self-confidence

Self-confidence can be measured deep inside the brain, in the hippocampus. However, it's important to note that the hippocampus is located too deep within the brain to be measured using EEG (Fahimi Hnazaee et al., 2020; Lu, Li, Wang, Song, & Liu, 2018). Because it cannot be researched using EEG, this aspect will be further investigated with the use of self-assessment questionnaires. The location of the hippocampus inside the brain can be seen in Figure 3.1 below.

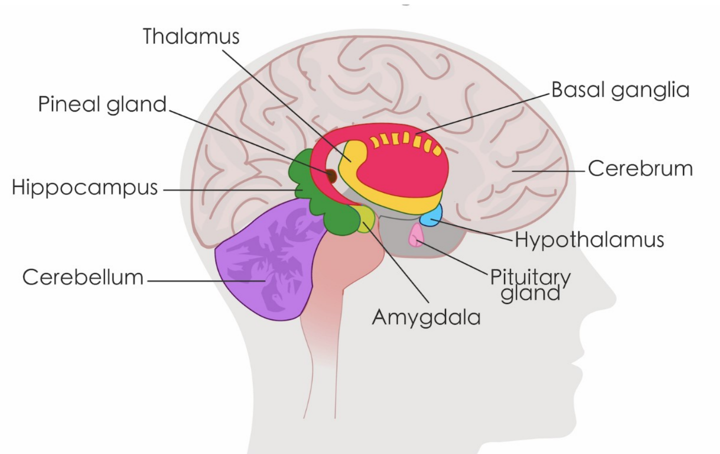

Figure 3.1: Schematic of the limbic system to highlight the location of the hippocampus.
Source: Ruscio (2024)

3.3.3 Attention

Attention, also referred to as alertness, has been studied extensively in laboratory research on attention deficits. Gola et al. (2013) discovered that the beta band power of EEG signals recorded over the occipital region correlates with visual attention. This was evident from an increase in beta power before correct responses and a lack of beta activity changes preceding erroneous responses (Ko, Komarov, Hairston, Jung, & Lin, 2017). Channels that correlate with the occipital regions are PO7, PO8, Pz, Oz. Additionally, attention as part of the cognitive process of concentration can be measured in the frontal lobe, in channel Fz, using Sensorimotor Rhythm (SMR) waves. SMR waves, which fall within the frequency range of 12–15 Hz, encompass both alpha and beta waves. This frequency range is well-known to be associated with attention (Y. Choi, Kim, & Chun, 2019). Both the alpha and beta bands indicate processes related to alertness/attention and motor binding/fatigue (Tamburro et al., 2019; Vine & Wilson, 2011).

3.3.4 Concentration

Concentration in the frontal lobe has been studied by Choi. According to Choi et al. (2014), there is a notable increase in the concentration index in frontal lobe locations and can be measured with the Fz channel. Generally, it has been observed that beta waves increase while theta waves decrease during concentration. The power ratio between beta and theta bands has been utilized as a parameter to determine the state of concentration (T. J. Choi et al., 2014).

$$\text{Concentration Index} = \frac{\text{power of } (\beta + \text{SMR})}{\text{power of } \theta} \tag{3.1}$$

3.3.5 Anxiety

The prefrontal cortex is linked to anxiety, with asymmetry occurring in frontal alpha power (Davidson, 2004). Anxiety can be observed in the alpha and theta frequency bands and has been associated with the relative right-sided frontal part of the brain (Thibodeau, Jorgensen, & Kim, 2006). Another study using quantitative EEG on patients with anxiety showed decreased alpha, beta, and theta activity, especially in the central and middle cerebral regions (Wang et al., 2016). Channels that correlated with these channels are Fz, Cz, C3 and C4. Additionally, Wang (2016) found basal instability in cortical arousal[1], which increases wakefulness, vigilance, muscle tone, heart rate, and minute ventilation (Kent, 2006). Furthermore, anxiety and stress are related (Mucci et al., 2016): an increase in beta power and a decrease in alpha power in the frontal region measured with Fz seem to indicate stress (TuerxunWaili et al., 2020). TuerxunWaili (2020) uses in its study, therefore, the ratio beta over alpha. If the ratio value increases the higher stress is indicated.

$$\text{Stress ratio} = \frac{\text{power of } \beta}{\text{power of } \alpha} \tag{3.2}$$

Table 3.1: Summarizing table: Brain Region Functions and Associated EEG Features

	Brain Regions	**Quadrant/Regions**	**Frequency Bands**	**Channels**
Motor Skills	Motor Cortex, Supplementary Motor Area	Central	Beta increases	C3, Cz, C4
Attention	*Visual attention:* Occipital Regions *Cognitive alertness:* Frontal Lobe	*Visual attention:* Parietal, Occipital *Cognitive alertness:* Frontal	*Visual attention:* Beta increases *Cognitive alertness:* SMR waves (alpha and beta) increases	*Visual attention:* PO7, PO8, Pz, Oz *Cognitive alertness:* Fz
Concentration	Frontal Lobe	Frontal	Beta increases Theta decreases	Fz
Anxiety	Prefrontal Cortex, Cerebral Middle and Central Regions	Frontal, Central	*Theorem Wang:* Alpha, Beta and Theta decreases *Theorem TuerxunWaili:* Increase in Beta and decrease in Alpha	*Theorem Wang:* Fz, Cz, C3, C4 *Theorem TuerxunWaili:* Fz

[1]Cortical arousal refers to the activation of the network of nerve cells and fibers in the brainstem, also known as the reticular formation, which connects the brain to the spinal cord and is essential for regulating unconscious bodily functions, such as breathing and heart rate.

4 Methodology

4.1 Goal of the Study

This study aims to answer the three research questions provided in Chapter 1.3. The first research question addresses if amateur cycling athletes experience progress themselves in practising mental imagery training for their bunch sprint. This is a subjective question that requires qualitative input from the participants - if the participants themselves are convinced, they improved in their mental imagery ability skills and additionally where they experience progress in the most. Furthermore, to answer research questions two and three, which address how the brain of the participants reacts to practising mental imagery training, there is looked for any observable changes in the brain activity after practising mental imagery training over six weeks. Additionally, it aims to determine which brain regions exhibit these changes.

4.2 Method

In order to answer the research questions, the following protocol is designed: Five participants attended a seven-week imagery training program. The first week was dedicated solely to EEG baseline measurements without any beforehand practice. Additionally, a personality questionnaire and sports imagery ability questionnaire were executed to gain information about the mindset of participants that were attending this study as is suggested in Section 2.6.8 *Mindset* and about the baseline of their imagery abilities.
During the next six weeks, participants practised sport imagery training several times a week to become proficient in this skill. As the weeks went by, the sessions' difficulty level increased to keep challenging as was suggested in Section 2.6.2 *Learnable*. The brain activity will be measured once every week. The results from these EEG recordings will be evaluated for both within-subject and between-subject differences. The analysis results will be visualized using figures and graphs to illustrate the findings of the experiment. These analyses will help determine if there are changes in the brain activity of the participants. Due to the small participant group, significant changes may not be evident, but potential trends in certain directions could be observed. Additionally, in the last week, the Sport Imagery Ability Questionnaire was executed again to gain insight in the self-assessment of the participants if they are convinced if they improved their imagery ability.
The outcomes of both, the questionnaires and the EEG results, will answer the research questions that are provided in Chapter 1.3 *Research Questions*, and any unexpected findings not previously included in the research questions will be discussed.

4.3 Participant Selection

During the process of recruiting the participants the interested people will receive a participant letter that contains more information, this letter can be found in Appendix A. In this letter the whole procedure that is relevant for the participant is explained. If the possible participant decides that it wants to attend the experiment, they will be asked to sign the form of consent which is in the attachment of the participant letter. The form of consent that is provided to them can be found in Appendix B. The participants are all recruited from personal network via a message in several group chats on WhatsApp.

For this experiment there are five male participants recruited (n=5). These participants are all experienced cyclists and have some experience with the proposed sprinting scenario that will be trained during the imagery training sessions. The participants all have approximately the same age and are between 20-30 years old. They are all right-handed and did not experience trauma that could be triggered with mental imagery training. These participant criteria are created based on the information that is provided in Chapter 2.4 *Differences Between People* and Sections 2.6.4 *Experience* and 2.6.5 *Age*. The checklist of the participant criteria can be found in Appendix C. Within Table 4.1 and 4.2 the demographics of the participants are provided.

Table 4.1: Participant Demographics Detail

ID	Age	Occupation	Degree	Sex	Nationality	Handedness	Hair Thickness	Cycling Trainings a Week	FTP (Watt)	Weight (kg)	Watt/ kg
P01	22	Technical University Student	Bachelor	M	Dutch	Right	Thick	2	250	77	3.25
P02	24	Technical University Student	Master	M	Dutch	Right	Intermediate	2	290	75	3.87
P03	26	Technical University Employee	PhD	M	Dutch	Right	Intermediate	3	265	77	3.44
P04	24	Technical University Student	Master	M	Dutch	Right	Thick	5	356	67	5.31
P05	23	Technical University Student	Master	M	Dutch	Right	Intermediate	6	305	76	4.01

Table 4.2: Participant Demographics Summary

Variable	Category	N	Percentage (%)
Gender/Sex	Male	5	100
Age	20-30	5	100
	Mean	**SD**	
	23.8	1.48	
Occupation	Technical University Student	4	80
	Technical University Employee	1	20
Degree	Bachelor	1	20
	Master	3	60
	PhD	1	20
Nationality	Dutch	5	100
Handedness	Right	5	100
Hair Thickness	Intermediate	3	60
	Thick	2	40
Watt/kg	**Mean**	**SD**	
	3.98	0.81	

4.4 Procedure

The whole experiment will consist of seven weeks. The proposed schedule can be found below in Table 4.3.

Note: The weeks within this table start on Saturday, the reason for this is to have all the trainings of one 'imagery trainings week' within one row.

Table 4.3: Experiment Schedule

Date	Week	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
31 – 6 Sept.	0			PQ			BM S0	
7 – 13 Sept.	1	UMT W1S1	UMT W1S2		UMT W1S3	UMT W1S4		MT S1
14 – 20 Sept.	2	UMT W2S1	UMT W2S2		UMT W2S3	UMT W2S4	MT S2	
21 – 27 Sept.	3	UMT W3S1	UMT W3S2		UMT W3S3	UMT W3S4	MT S3	
28 – 4 Oct.	4	UMT W4S1	UMT W4S2		UMT W4S3	UMT W4S4	MT S4	
5 – 11 Oct.	5	UMT W5S1	UMT W5S2		UMT W5S3	UMT W5S4	MT S5	
12 – 18 Oct.	6	UMT W6S1	UMT W6S2		UMT W6S3	UMT W6S4	MT S6	

List of abbreviations of Table 4.3:

- PQ = Pre-Questionnaires
- BM = Baseline Measurement
- UMT = Unmonitored Training
- MT = Monitored Training
- W = Week
- S = Session

On Monday 2 September, the pre-questionnaires are send to the participants. They need to have filled this out before the baseline measurement on 5 September. The goal of the pre-questionnaires is to gain information about the participant which can be of influence during the EEG sessions further in the experiment. Information about the participants personality, experience in sports and their mental imagery training capabilities. The questionnaires can be found in Appendix E, F and G.
On 5 September the first measurement will be executed. Within this session the participant will perform a mental imagery training scenario for the first time. Without practising this scenario before. The results of this EEG session show the baseline of the brain activity of the participant. The procedure of these Thursday sessions can be found in Appendix H. The scenarios that are created for these 'Monitored Sessions' can be found in Appendix I. These scenarios will be more extended and detailed over the weeks to increase the level of difficulty. The goal of these Thursday sessions is to measure each week the possible differences in brain activity over the weeks. Possibly a clear difference can be seen between the baseline measurement and the measurement of week six.
From 7 September on, will the participant also practised the scenario of that week at home on the dates that are indicated in the schedule. Such a session will take up maximum five minutes per day.
A schematic overview of the experiment is shown below in Figure 4.1. After MT S6 the participant will also be asked to fill out the SIAQ questionnaire again. This way the results can also be compared to the results of 2 September. This will indicate if the participant has the feeling that his mental imagery training skills have improved compared to the first week.

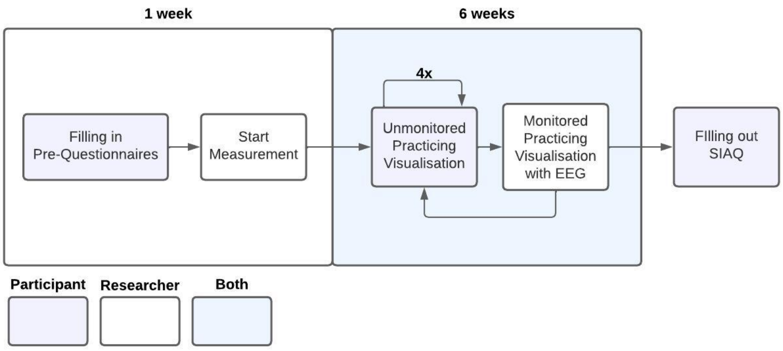

Figure 4.1: Schematic Overview of Experiment

4.5 Conditions

The monitored sessions will be conducted in the EHealthHouse-room at the University of Twente on every Thursday. The following criteria are taken into consideration: the room it is a quiet room, in a quiet area and is comfortable. This to avoid unnecessary noise in the recording. Furthermore, there is a camera setup present to be able to track the timeline of the experiment. The room will be on room temperature, approximately 20 degrees Celsius. A picture of the EHealthHouse setup is shown in Figure 4.2.

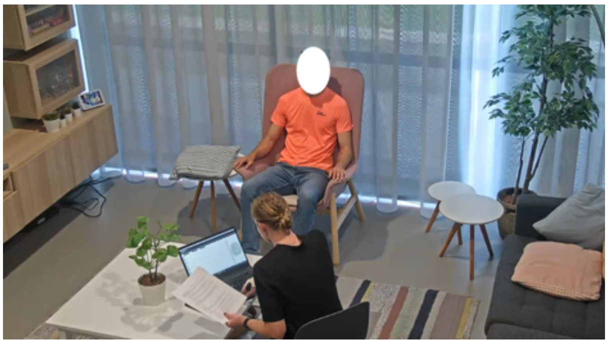

Figure 4.2: EHealthHouse Setup

The guidelines from Baxter (2015) for experiments involving human participants are taken into consideration in the study, examples are, emphasizing the importance of clearly explaining the purpose, procedures, potential risks, and benefits of the study. It is also essential to ensure that participants voluntarily agree to participate and sign a consent form, which is provided in Appendix B. Furthermore, participants' identities and personal information must be protected through anonymization techniques, in this case, providing the participants with a unique code.

4.6 Equipment

4.6.1 Unicorn Hybrid Black

The Unicorn Hybrid Black is an eight-channel wearable EEG headset with 24 Bit resolution produced by g.tec, suitable for both dry and wet measurements. The capability for dry measurements significantly reduces the time required for preparation. It measures brain activity from the following eight channels: Fz, C3, Cz, C4, Pz, PO7, Oz, and PO8. The setup protocol for the Unicorn Hybrid Black can be found in Appendix J. For the experiment capsize L (58-62 cm) will be used because all participants measured a head size of at least 58cm.

The data is stored in CSV format. The headset continuously estimates the band powers for delta (1-4 Hz), theta (4-8 Hz), alpha (8-12 Hz), beta (12-30 Hz), and gamma (30-60 Hz). The sampling rate per channel is 250 Hz.

4.6.2 Data Analysis Program

For the data analysis, Python will be used within the Jupyter Notebook and Visual Study Code environment. The MNE library, an open-source library renowned for its capabilities in handling EEG data, will be employed to clean and analyse the recordings. This approach allows for efficient processing, mental imagery training, and interpretation of the EEG data collected from the Unicorn Hybrid Black headset. By utilizing the tools available in MNE.

4.6.3 Questionnaires

Personal Information Questionnaire

The Personal Information Questionnaire can be found in Appendix C. The Personal Information Questionnaire is used to gather information about the participant. This includes the participant selection criteria and some personal questions about the participant. The first five questions are created to define the participants in this research.

The first question that involves personal information about the participant is about the hair thickness of the participant. Knowing the thickness of the hair can be of interest when there is more noise found in the data afterwards than expected. Thicker hair can make it more challenging for the EEG cap to connect with the scalp. Therefore, the researcher needs to take more attention when applying the cap on someone that has thick hair. The other two questions assess the participant's cycling experience. A higher FTP (Functional Threshold Power) indicates a stronger cyclist (Sørensen, Aune, Rangul, & Dalen, 2019). By dividing the FTP value by the participant's weight, we can determine how many watts they can push per kilogram of body weight. This information is valuable, as more trained cyclists—those with higher watts per kilogram—are likely to have more cycling experience and may be better at mental imagery training tasks (Kelley, 2021).

IPIP-NEO-120 Personality Questionnaire

The IPIP-NEO-120 Personality Questionnaire is used to gather information about the personality traits of the participant. People with a more positive outlook on life are expected to be better at mental imagery training. Therefore, this questionnaire is being conducted to determine the personality traits of the participants. The primary value of interest obtained from the questionnaire is 'Neuroticism.' neuroticism is a personality trait associated with negative emotions (Cassiello-Robbins, Wilner, & Sauer-Zavala, 2017). If a person scores higher on this scale, they are more likely to experience feelings such as anxiety, worry, and anger. Therefore, it is expected that people with lower neuroticism scores will be better at mental imagery training. The questionnaire used is the IPIP-NEO-120, which is a 120-item questionnaire and can be found in Appendix E.

Sport Imagery Ability Questionnaire (SIAQ)

The Sport Imagery Ability Questionnaire (SIAQ) is used to gather information about how proficient the participant already is with imagery. This 15-item imagery questionnaire was chosen because it is known as a reliable questionnaire (Rahman, 2022). Furthermore, the SIAQ has good internal reliability and temporal stability (Budnik-Przybylska & Karasiewicz, 2020; Chow, Li, & Ma, 2021). Additionally, this questionnaire is specific to sports, making it the best choice between the other questionnaires that were mentioned within the research topics that were not necessarily meant for sport imagery tasks. This questionnaire will be administered in week 0 before the first EEG session and in the final week of the experiment, after the last EEG session. It is possible that the results will differ within participants over the weeks. The hypothesis is that participants' imagery ability will become stronger and therefore obtain a higher outcome in the questionnaire after the experiment compared to the results that are obtained in week 0. The SIAQ can be found in Appendix F.

Weekly Debriefing Questionnaire

The 'Debriefing Questionnaire' is created to receive information the thought process, tactical and technical insights of the participant. This is a 6-item questionnaire that can be found in Appendix G. The first two questions are about the sense of time and distance. Whereas the next two questions gain information about the tactical and technical focus points of the participant. The last two questions are about the confidence of the participants. This questionnaire will be executed after each weekly EEG session.

4.7 Task and Stimuli

During the EEG part of the experiment, the EEG will first be calibrated. The participant will be asked to sit still with their eyes open for two minutes, followed by sitting still with their eyes closed for two minutes. Additionally, the participant will perform a breathing exercise to relax before starting the mental imagery training task (Birrer & Morgan, 2010; Ekeocha, 2015; Predoiu et al., 2020). The mental imagery training task involves completing the scenario twice. For the first round, the experimenter will read the scenario out loud while the participant listens with their eyes closed. Since brain activity occurs while listening, the participant will then be asked to perform the scenario a second time on their own. This approach is important because in imagery, the timing should align with the real duration of the task (Cooley et al., 2013; Mizuguchi et al., 2012). When reading out loud, a timing offset is introduced. However, the initial guidance helps the participant focus on the task. The Unguided Scenario is intended to observe only the brain signals related to imagination, without interference from listening or guidance. All the scenarios created for the entire experiment of every week are provided in Appendix I. The decision to focus on sprinting scenarios is due to the short duration of the task and its specific technical and tactical elements. Sprinting has a clear goal but allows for different tactical approaches to achieve it.

4.8 Methodology Self-Assessment Analysis

The self-assessment methodology aimed to evaluate participants' sports imagery ability and gather qualitative feedback on their experiences. This was conducted through two primary approaches: the Sports Imagery Ability Questionnaire (SIAQ) and Debriefing sessions.

Sports Imagery Ability Questionnaire

The Sports Imagery Ability Questionnaire (SIAQ) was administered at two key points during the study: at the baseline (Week 0) and at the conclusion of the training period (Week 6). During Week 0, participants filled out the SIAQ to establish a baseline measurement of their perceived sports imagery abilities. After the six-week training intervention, participants completed the questionnaire again, with sufficient time elapsed to minimize recall bias from their initial responses. This design aimed to ensure honest and independent answers during the post-intervention evaluation. The data from both instances were analyzed and compared to assess changes in participants' sports imagery abilities over time. By plotting the results, insights were obtained into whether the intervention influenced participants' self-perceived qualities related to sports imagery.

Debriefing

Weekly debriefing sessions provided an opportunity to collect qualitative observations about participants' experiences throughout the training. While participant feedback on their weekly experiences occasionally arose organically during informal discussions, it was not a structured component of these interim debriefings.

The final debriefing, however, was conducted as a semi-structured interview designed to capture participants' comprehensive reflections on the six-week training program. Open-ended questions, such as *"How did you experience the past weeks?"*, were used to initiate conversations, allowing participants to freely share their impressions, takeaways, and potential doubts about the training. Follow-up questions explored whether participants anticipated applying the skills learned in future scenarios and whether they noticed progressive development over the training period. These qualitative responses were documented and integrated into the study's results in Table 5.1 to provide a nuanced understanding of participants' experiences and perceptions of the mental imagery training program.

4.9 Methodology EEG Analysis

The EEG data obtained during the experiment must first be pre-processed before it can be analysed. The data must be formatted and cleaned. This is important because, for example, disconnections can occur between the electrodes and the head during recording, or external noise may affect the data. Figure 4.3 below shows an example of a artefact caused by such a disconnection. This kind of artefact may appear briefly in one or more channels. However, it is also possible that an electrode lacks a strong connection for the entire recording period. In that case, data from this electrode cannot be considered reliable. All artefacts and bad channels must be excluded to ensure a trustworthy recording for analysis.

MNE suggests three things that a procedure must contain to ensure a reliable recording: identify bad channels, apply filters to set the desired bandpass, and suppress artefacts. This approach is used as guideline. The flowchart in Figure 4.4 provides a schematic overview of the methodology that is used during the preprocessing phase of this study.

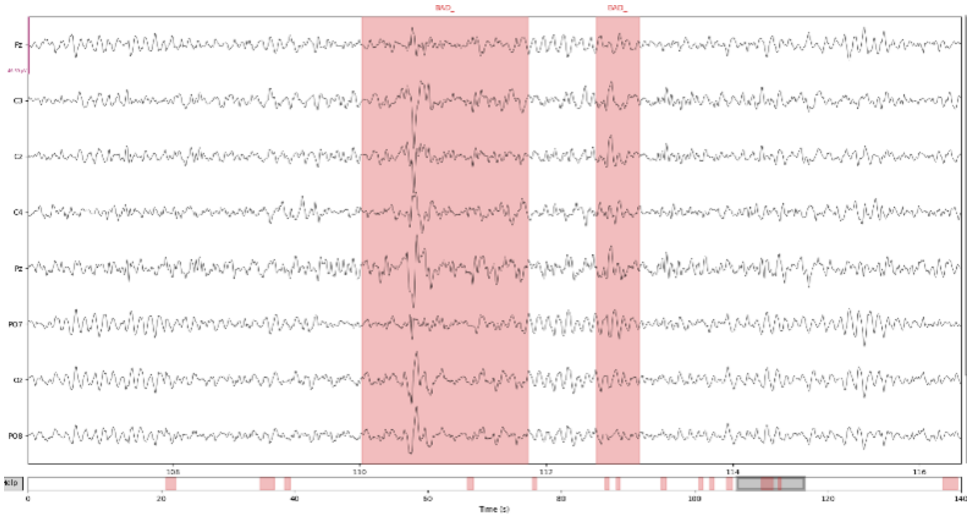

Figure 4.3: EEG data with artefacts
Source: Own figure

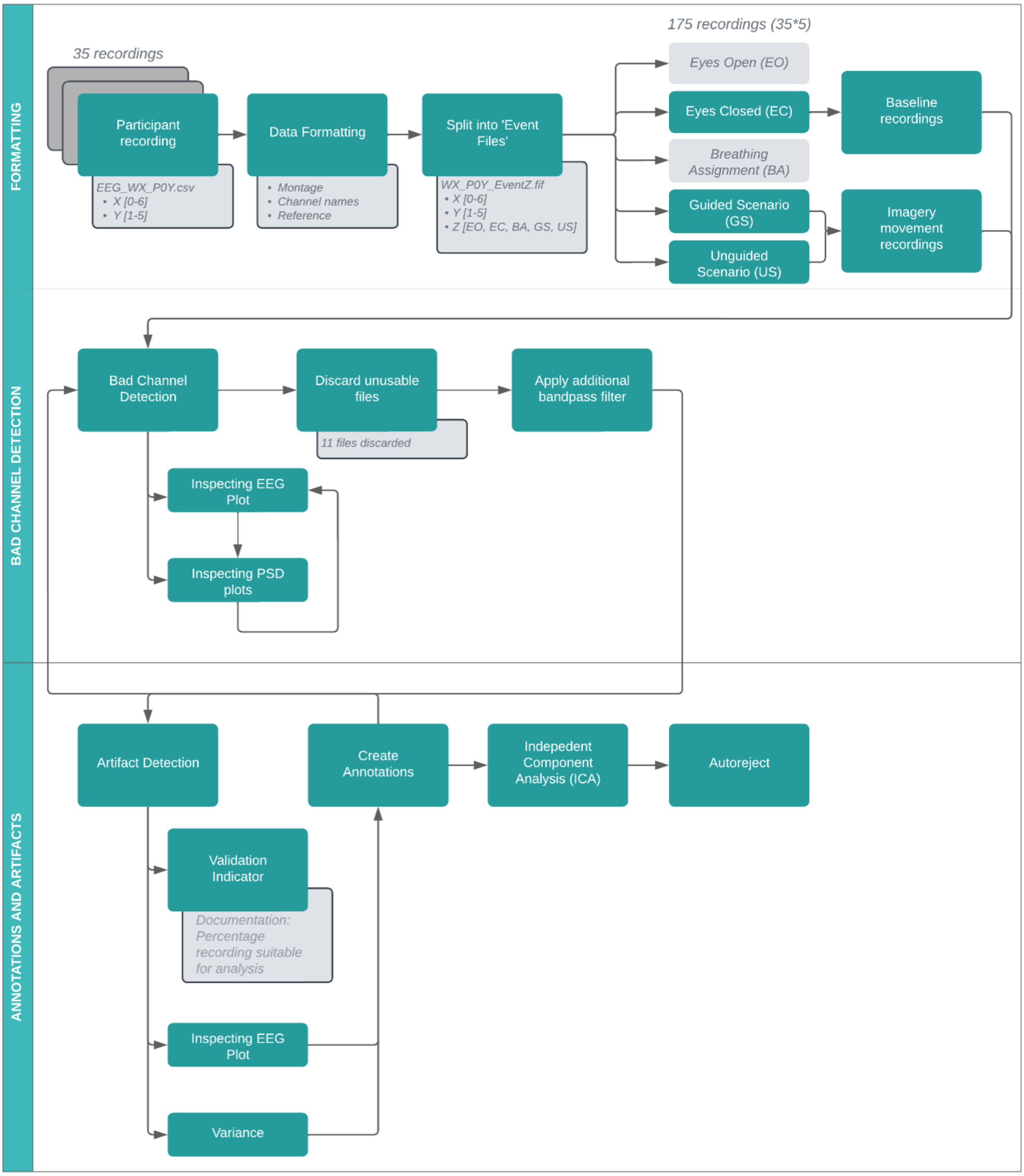

Figure 4.4: Schematic Overview Inspired by MNE

4.9.1 Data Formatting

The first step is to correctly label the EEG data and ensure all settings are properly configured. Data is recorded for five participants (P01-P05) over seven weeks (W0-W6), resulting in 35 recordings. Each recording includes five distinct events: Eyes Open (EO), Eyes Closed (EC), Breathing Assignment (BA), Guided Scenario (GS), and Unguided Scenario (US). To mark the start of each event, video recordings are made of the participants during the experiment. These videos help segment the recording into five separate files, one for each event. A table with the event timeframes is available in Appendix P.
The montage will be set to map EEG channels onto a standardized layout that indicates electrode

placement. This study uses the international 10-20 system, a method based on anatomical landmarks to standardize electrode positioning. The montage is important because it provides a consistent reference for analysing brain regions. Additionally, the Unicorn Hybrid headset records data as EEG 1-8, Gyroscope XYZ, Accelerometer XYZ, Battery Level, Counter, and Validation Indicator. The EEG columns, labelled with standard Unicorn Hybrid names, will be converted to names from the 10-20 system.
Each electrode label reflects the brain region it covers: F (Frontal), C (Central), T (Temporal), P (Parietal), and O (Occipital). The 'z' indicates the midline, while numbers denote hemisphere—odd for the left, even for the right—and their distance from the midline (TMSi, 2024).
Since the participant remains seated during the experiment and does not make large movements, the Gyroscope and Accelerometer data are not relevant and are therefore can be excluded from analysis, this along with the battery level information from the Unicorn Hybrid headset.
The counter channel plays a key role in converting the EEG signal into the time domain. By incrementing with each recorded sample, the counter acts as a timestamp reference, enabling an accurate time axis to be established for the EEG data. With a sampling rate of 250 Hz, each sample represents an interval of 4 milliseconds (ms) (1/250 seconds). Multiplying the counter value by this interval provides the exact timestamp for each data point in the recording. For example, a counter value of 1000 corresponds to:

$$1000 * 0.004 \text{ seconds} = 4 \text{ seconds}$$

This approach creates a continuous time axis across all recorded EEG data. Additionally, the Validation Indicator offers information about signal quality: it displays a 0 when the connection is lost and a 1 when the connection is stable, as monitored by the Unicorn Hybrid headset. This indicator aids in assessing the quality of the signals which is shown to be helpful in detecting the poorer recordings. When assessing the recordings only one recording showed issues in more than 10 percent of the recording as can be seen in Table 4.4. The complete list per file can be found in Appendix K.

Table 4.4: Validation Indicator

Variable	Category	N	Percentage (%)
CSV Files	Total	35	100
Bad Quality Validation Indictor Percentage (%)	0.00%	29	82.86
	00.01-01.00%	4	11.43
	01.00-02.00%	1	2.86
	10.00-11.00%	1	2.86

The data is recorded in microvolts (μV), but Python expects values in volts. Therefore, the microvolt values will be divided by $1e6$ to convert them to volts. The sampling frequency is set to 250 Hz, representing the number of samples taken per second.
Upon inspecting the recording, it is clear that many electrical devices introduce peaks in the higher frequencies of the data. To filter out powerline noise, a notch filter can be applied at 50 Hz. However, since most relevant signals for this experiment are expected within the alpha and beta frequency bands—and given that higher frequencies are often affected by electronic noise—a bandpass filter between 1-40 Hz will also be applied to reduce noise even further.

4.9.2 Bad Channel Detection

To investigate whether the recording had bad channels, several approaches were used. There are two manual inspection approaches used that both showed to be useful. These approaches had often the same channels marked as bad using a different strategy. However, manual inspection is a subjective strategy and leaves a lot to decide for the researcher also several automatic detection methods were tried to find the bad channels to be able to reproduce the detection. However, when utilizing the automatic detection, it was found that manual inspection currently was superior due to the automatic detection misses a lot of channels or that it marked too many channels. Therefore, it did not behave as expected. First, both manual methods were executed separately from each other. But in the end was decided to combine the approach and first iterate over all EEG plots and mark obvious channels as bad. Secondly, iterate over all Power Spectrum plots and mark the left-over bad channels as bad.

Manual inspection
1. Inspecting the EEG plot
Iterate over all files and exclude channels that seem to behave differently. Files that were found to be unusable for further analysis are here excluded. The list of excluded files can be found in Appendix L.

2. Inspecting the Powerspectrum plots
Iterate over all files and exclude the left-over channels that seem to behave differently. A table that is created which indicates all bad channels after inspecting the EEG plot and PSD plot can be found in Appendix M.

EEG Plot
Within the EEG plots, the following can be seen: the channels and if they are of good quality, voltage fluctuations, noise pattern, artefacts. By iterating over all files can the biggest source of noise be eliminated. If the noise is a pattern, this can later be removed with the help of ICA. The scale of the EEG plots for this experiment is within 50 microvolts (μV) if there is a peak higher then these boundaries it is likely that this is a noise artefact.

Power Spectral Density (PSD) Plots
PSD plots show the distribution of the frequency within the recording. The plots show in which frequency bands the power is bigger. Powerspectrum plots in resting face with eyes open are approximately the same for all humans (Sommer, Mount, Weigelt, Werkle-Bergner, & Sander, 2022). Expected is that in that in the alpha band is a peak for all individuals. Within the dataset that is obtained in this experiment is also data recorded with the participant that has his eyes closed. This recording will for that specific week be the baseline. When inspecting the powerspectrum plots only a peak in the alpha band was expected for all channels. However, some channels where all over the place indicating that something went wrong with recording for that channel, and these channels were excluded. Furthermore, there were some more unexpected peaks in some of the recordings. If this was the case after the artefact exclusion of next section, then that part was interpolated. The choice to exclude this later was because these peaks could also be triggered by very strong artefacts. Excluding these artefacts first seemed therefore the most promising order.

4.9.3 Artefacts

Artefacts refer to noise. In EEG signals this can be eye movement, cardiac interference or muscle contractions. A good rule of thumb is that the artefact amplitudes should be orders of magnitude larger than your signal of interest, and there should be several occurrences of such an event. Eye movement artefact is in the low-frequency range of around 0.5-3 Hz and are the most prominent in the frontal channels. Noise from cardiac interference is mostly between 1-2 Hz and is matching the heartrate (therefore, around 60-100 bpm) (Clinic, 2024). To filter out those artefacts it is decided to put a bandpass filter on the data from 4-40 Hz to filter out this noise. However, muscle contractions are more difficult. An example of muscle contractions is shown below and occur when the participant is tense throughout the experiment. This can be over the whole recording or for several time frames. This occurs in a broad range of 20-40 Hz and after bandpass filtering still present in the data (Yilmaz, Ungan, Sebik, Uginčius, & Türker, 2014).

Autoreject
Autoreject is a cleaning function which can be used to find excessively noisy parts in the data that can occur when the participants make sudden movements. These movements can create artefacts in the data. These artefacts are often bigger than eyeblinks. It is a computationally intensive function and therefore requires a lot of computational time.

Independent Component Analysis (ICA)
ICA is good at capturing features that explain the most variance. Variance is the deviation from the mean. An eyeblink is really clear because it is much larger than most of the EEG signal. ICA works best if the data is not one continuous sample but split up in small epochs. There is one ICA function used on all the files, meaning the setting where for all files the same. Choosing for retaining 95% of variance helps capture most neural signals while minimizing noise. The choices of random state = 97 and maximal iterations = 500 in the ICA configuration serve specific purposes related to reproducibility and computational efficiency: 1. The random state parameter controls the random number generator used in the ICA algorithm. By setting random state = 97, it is ensured that ICA decomposition is deterministic and reproducible across different runs. Without this parameter, each run of ICA might produce slightly different results, which can make it challenging to consistently identify and exclude the same components. The number 97 here is arbitrary—it could be any integer. The main point is to set a fixed value so that results are consistent. maximal iterations is the maximal number of iterations of the ICA algorithm that will run to achieve convergence. ICA algorithms can take longer to converge, especially if the data contains noise or if the number of components is high. Setting a maximal iterations = 500 limit allows a reasonable maximum time for the ICA to solve without getting stuck in an endless loop or taking excessive time. This value is chosen because it is generally high enough for convergence in typical EEG datasets, but not so high that it leads to unnecessary computation time if the algorithm fails to converge. If convergence is not reached within 500 iterations, there is a warning received, which can then be addressed by adjusting the data or parameters.

Annotations and Interpolation
The process of creating annotations for artefacts in the signal was an iterative process. Before applying the automatic functions such as ICA and Autoreject several artefacts were marked as bad by hand. However, also after applying these functions, which restoring the signal, the EEG signal was again checked for artefacts that were not restored. Combining these different strategies in an iterative way there is tried to detect as much noise as possible which can be excluded within the analysis.

The last part was interpolating the channels that were marked as bad. The spherical spline method for EEG channel interpolation, as described in Perrin et al. (1989), involves projecting the EEG channel locations onto a unit sphere and then using these projections to interpolate the signal at "bad" channels based on the data from surrounding "good" channels. This method ensures that the topographic layout remains intact, allowing for consistent data dimension across all files. By using this interpolation, it becomes possible to subtract data from different recordings and visualize complete topomaps without losing information from missing channels.

5 Results

5.1 Questionnaires

When looking at the results of the personality questionnaire, especially the result of Neuroticism, which is the tendency to experience negative feelings. It illustrates that the third participant has the most tendency to experience negative feelings as can be seen in Figure 5.1. However, all participants are in the 'normal' range which is between 40 and 80. As explained in the literature of Section 2.6.8 *Mindset*, it is therefore likely that participant three shows the least progress at the end of the six weeks imagery training program compared to the other participants. Although, this is also related to the initial ability to imagery movement in sports which can be seen in Figure 5.2. The blue shows the subjective impression of the participants about their imagery ability before starting the training program and the red after the training program. As can be seen in the figure it indeed shows that participant three has the least progression after the session. It shows even a decrease in Global Sports Imagery Ability after the imagery training program which is their general sports imagery ability. However, also a small decrease could also be seen for participant four, who has a low-normal (just above 40) score on Neuroticism. However, knowing that this participant already has a high level (6 out of 7) of Global Sports Imagery Ability, as seen in Figure 5.2, can also make it harder to improve this score. Participants one, two and five show an improvement within the Global Sports Imagery Ability category after six weeks of practising imagery movement, this is according to expectation.

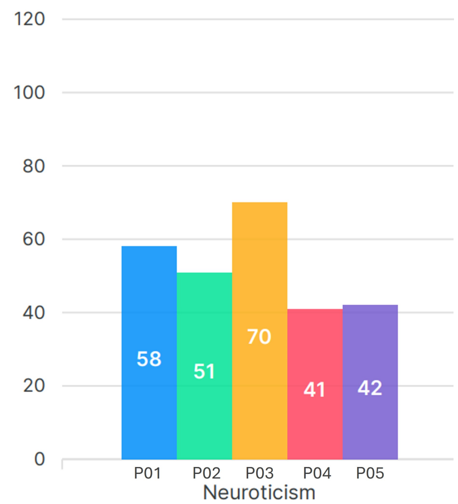

Figure 5.1: Neuroticism results from the IPIP Questionnaire

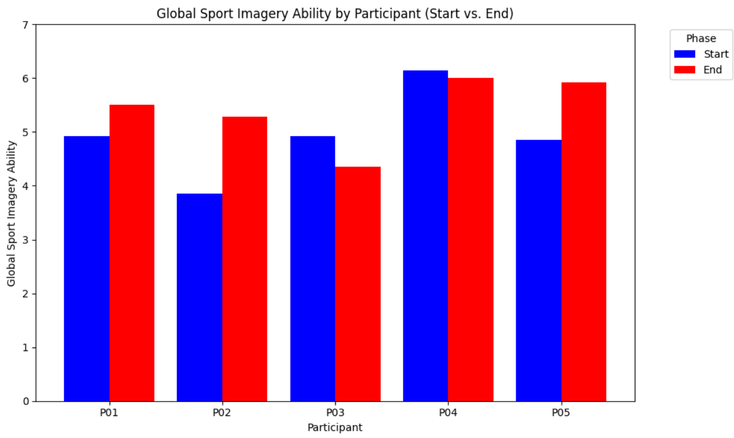

Figure 5.2: Global Sport Imagery Ability Results

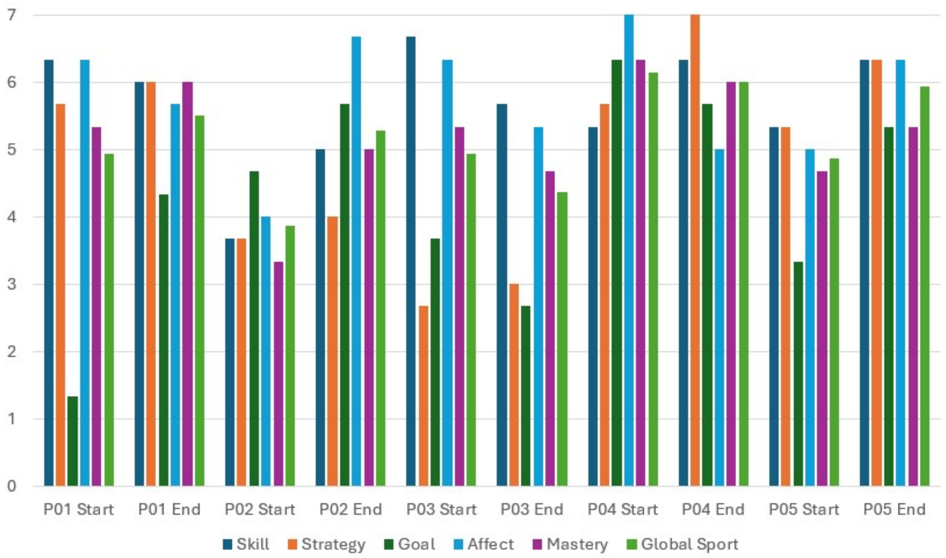

Figure 5.3: Sports Imagery Ability Questionnaire Individual Results.

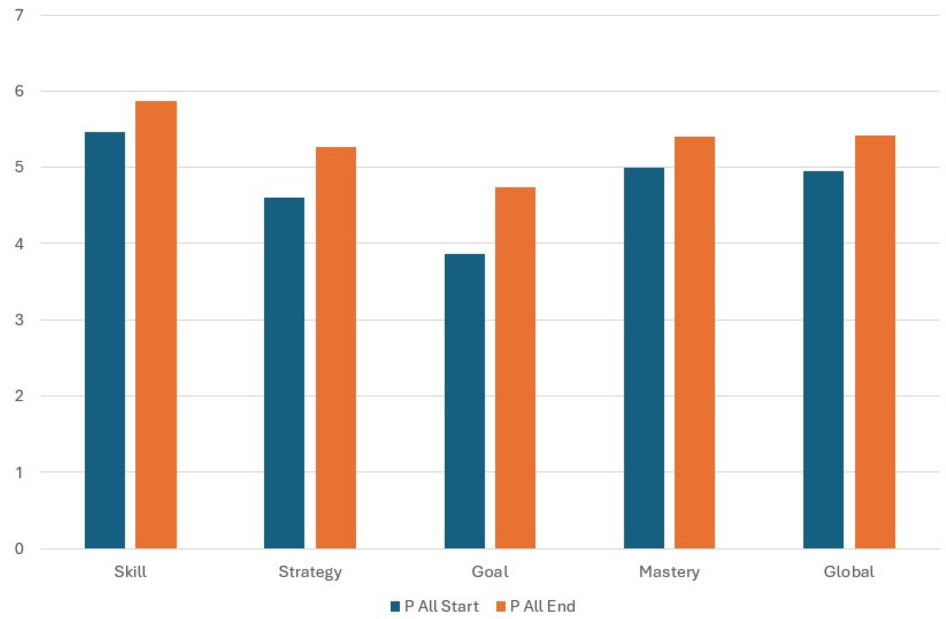

Figure 5.4: Average results Sports Imagery Ability Questionnaire
P all = Merged data of all participants.

When splitting out the results of the SIAQ in its original categories as can be seen in Figure 5.3 below. An increase for all participants can be seen in the 'Strategy' related' category. This can be due to the strategy-oriented scenarios that were created for the experiment. Taking the average over all participants as can be seen in Figure 5.4 there is an improvement on average in all categories and that on average the biggest improvement is within the 'Goal' related category.
Although, within the SIAQ a decrease is observed in Global Sports Imagery Ability for participant three and four individually, within the debriefing all participants were convinced that imagery training proved to them to be useful. Furthermore, when averaging the results, as in Figure 5.4, there still is an increase in Global Sports Imagery Ability measured. This implies that the Mental Imagery capabilities of the participants on average did improve after six weeks of mental imagery training. The debriefing results

are mapped within Table 5.1 and a complete overview of the results of the debriefing questionnaire per week can be found in Appendix N.

Table 5.1: Participant opinion about the mental imagery training program

Participant	Opinion
P01	"I found it quite relaxing. Your schedule was clear, with fixed times and a routine. I tried to follow that in my practice. It's getting better as the weeks go by; I'm improving each time. I'm not quite sure where I started or where I'll end up, but it's definitely getting better. Initially, I was pretty sceptical, but I think there's really something to it. I was doubtful about what it could do for me, but now I see it's helping me set aside mental setbacks more easily. The more often I experience something, the easier it becomes to deal with it. I noticed a clear progression in the scenarios, very much so. It could apply to skating, maybe even with technical aspects."
P02	"I thought it was nice/fun to try. I didn't find it super easy to play it all out as one continuous scene, but I think I did manage to get a feeling for it. I think that with skating, I would benefit more from it by focusing on the technical aspects. I believe I could gain a lot from it. The scenarios became more detailed each time, which actually made it easier. I could definitely sense a progression."
P03	"It was pretty intense, and I can see how it could be beneficial. If you're in similar situations often, it could help more than I initially expected. Visualizing the situation was challenging for me, but I managed to do it. Whether it truly helped is another question. But the act of visualizing does make you more engaged with the sport. Even more so compared to rowing or water polo, where you're only focused on training. It made me more aware of how something should feel. There was a progression toward more detail, but I'm not entirely sure if that's good or bad. I don't see myself using this far into the future because it's not something I'd normally do, but I could see it being helpful with mountain biking. I can appreciate its value."
P04	"I thought it was fun. At first, I thought I'd have to sit on a bike to do it. I ended up doing it quite often, so I'll keep going with it. I pictured myself winning, which was motivating. I noticed differences between the weeks. Each time, more things were added, making it progressively more complex. Overall, it was quite good. There was one time when the transition from week 4 to 5 felt bigger, but that also went well."
P05	"I thought it was enjoyable; I noticed that I got better at it over time. I found it to be a fun experience. I'm not sure if I'll continue using it, but maybe in the spring when competitions come around, it could be helpful. I noticed differences between the weeks. Each week was different in terms of how you thought about it because the scenario changed."

5.2 EEG

When inspecting the results per individual participant, no conclusive patterns were observed. Within each subject, there was no clear pattern in the topomaps, either on average or across frequency bands. While some weeks showed similarities within participants, other weeks displayed opposing results, these individual results are in Appendix Q. To highlight the common regions among participants, the decision was made to merge their data which is labelled as *Pall.* This was done by normalizing each participant's data before merging, to prevent participants with stronger brain activity from disproportionately influencing the topomaps.

$$X_{\text{normalized}} = \frac{X - \mu}{\sigma} \tag{5.1}$$

where:

- μ is the mean of the data,
- σ is the standard deviation of the data.

The individual results of the participants are available in Appendix Q. The resulting topomaps of EC, GS and US using the absolute values can be seen below in Figure 5.5. With the term 'absolute' is meant that it displays the unreferenced data values, as opposed o the relative values if the differences are calculated by subtracting the baseline. For example, to neglect the 'mood of the day' below the topomaps of GS and US can be seen with the EC data subtracted, this can be seen in Figure 5.6. If a topomap is plotted using raw voltage values without subtracting the baseline (EC) it is an absolute topomap. On the contrary, if the baseline (EC) is subtracted then it highlights a difference which is a relative topomap. These topomaps can be found on the next page, on top of each topomap a title can be found which states what is included in that topomap. Pall means the merged data of all participants, EC = Eyes Closed (baseline), GS = Guided Scenario, US = Unguided Scenario.

5.2.1 Topomaps

When inspecting the absolute values for EC in Figure 5.5, it can be seen that there is overlap between the weeks, especially for week 0, 2, 3 and 5. It shows heightened activity in the occipital region of the brain. A likely reason that week 1 and week 4 are not showing overlap for EC is due to the fact that the data of week 1 for participant 4 and 5 and, week 4 for participant 5 were marked as unusable, as mentioned in Section 4.9.2 *Bad Channels* and Appendix L, and is therefore, not in the Pall merged dataset. For GS it is more difficult to see visually a pattern. However, weeks 5 and 6 show similar behaviour on average. While for US the absolute values are all different for weeks. This likely to be due to recessive noise within the data, even after extensively cleaning the data beforehand. It is possible that this is external noise and is present in all the event files of that specific week. Therefore, it is decided to subtract the EC value in order to subtract the external noise. This topomap can be seen in Figure 5.6.
When looking at these topomaps for the GS and US event can be seen that in the occipital region is not much activity left for all weeks except for week 1 and 4. These topomaps give still no clear optical pattern. Therefore, these average topomaps are split up in topomaps per frequency band, which can be seen in Figure 5.7.
When inspecting these topomaps more closely it can be seen that overall occipital activity is more pronounced in the theta band compared to the other regions. For the alpha frequency band, it is harder to see outstanding regions. In the beta frequency band, it can be seen that frontal, central, and parietal region is active. Whereas in the gamma region the frontal region is more pronounced.

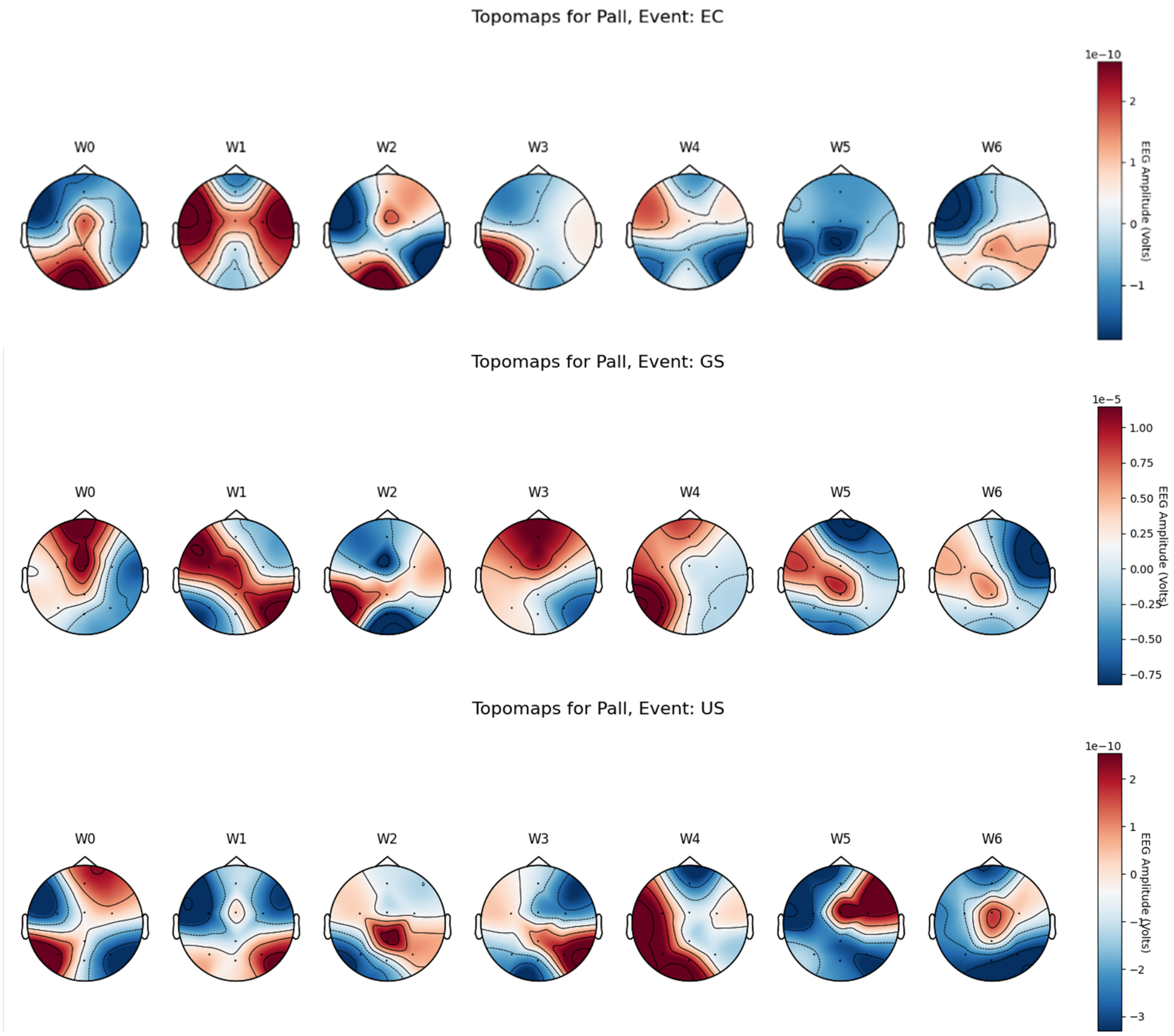

Figure 5.5: Topomaps of EC, GS and US.
Pall = all participants, EC = Eyes Closed, GS = Guided Scenario, US = Unguided Scenario, WX = Week X
Note: for EC: the data of P4 is omitted, data of P5 is omitted W1, W4;
for GS: the data of P4 is omitted for W1, data of P5 is omitted for W1 and W4;
for US: the data of P4 is omitted for W1, data of P5 is omitted for W1, W2 and W4

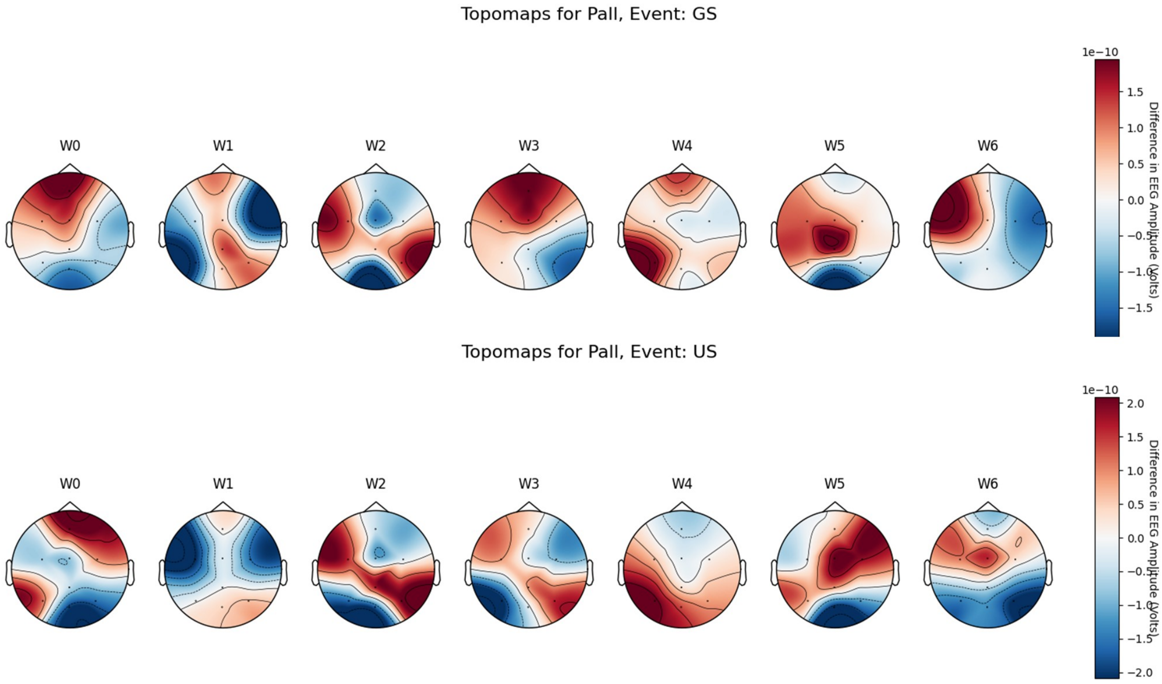

Figure 5.6: Topomaps of GS and US with EC subtracted.
Pall = all participants, EC = Eyes Closed, GS = Guided Scenario, US = Unguided Scenario, WX = Week X
Note: for GS: the data of P4 is omitted for W1, data of P5 is omitted for W1 and W4;
for US: the data of P4 is omitted for W1, data of P5 is omitted for W1, W2 and W4

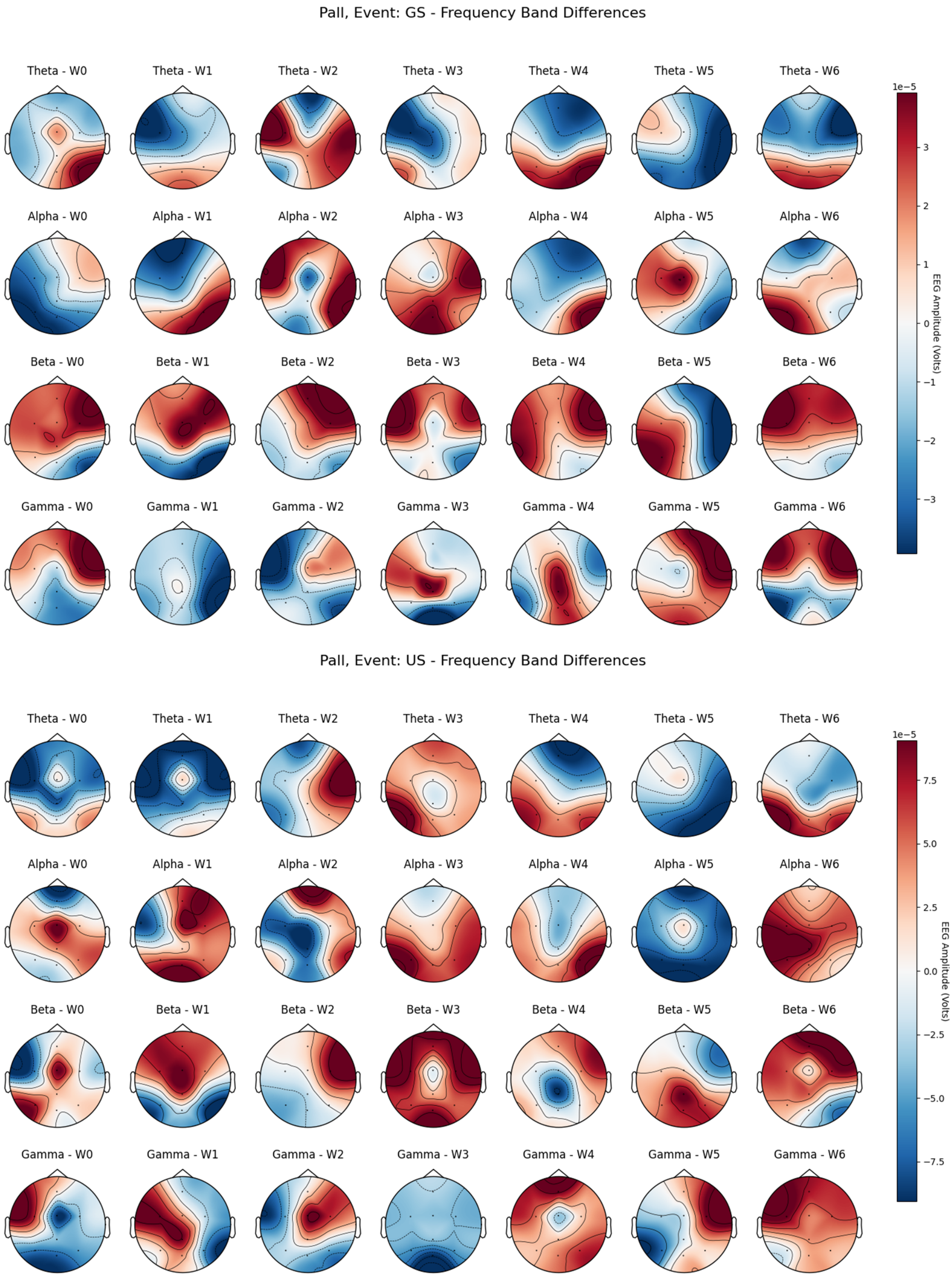

Figure 5.7: Frequency band topomaps of GS and US with EC subtracted.
Pall = all participants, GS = Guided Scenario, US = Unguided Scenario, WX = Week X
Note: for GS: the data of P4 is omitted for W1, data of P5 is omitted for W1 and W4; for US: the data of P4 is omitted for W1, data of P5 is omitted for W1, W2 and W4

5.2.2 Stress Ratio and Concentration Index

When calculating the Stress Ratio and Concentration Index using formulas 3.1 and 3.2 from Chapter 3.3. it can be seen in Figure 5.9 that the Concentration Index gradually increases of the weeks. Whereas the Stress Ratio remains approximately constant. When calculating the slope with the use of linear regression it results in a positive slope for the concentration index (GS: 0.028; US: 0.035) and negative slope for the stress ratio (GS: -0.028; US: -0.069). Which indicates a slightly improvement in concentration and a slightly decrease in stress over the weeks on average over all participants.
The choice to calculate this with linear regression is because it is a straightforward way to interpret the trends that could be observed in the graph, it flattens out the fluctuations and provides therefore a clear overall trend without overfitting to the noise. Furthermore, because the dataset is small it avoids overcomplicating the analysis as more complex models would require more datapoints.
The resulting trend is in line with expectation beforehand. However, as can be seen in the graph W1 shows quite unexpected behaviour compared to the other weeks especially due to the relatively high stress ratio. A reason for this can again be that the merged data of Pall in week 1 only contains participant 1, 2 and 3 because participants 4 and 5 had unusable data as mentioned in Section 4.9.2 *Bad Channel Detection* and Appendix L. When neglecting week 1 as is shown in Figure 5.9 the concentration index increases stronger (GS: 0.058; US: 0.045) whereas the stress ratio remains more constant (GS: 0.008; US: -0.010). Therefore, an increase in concentration is more likely to be the case then the claim that stress reduces according to these results.

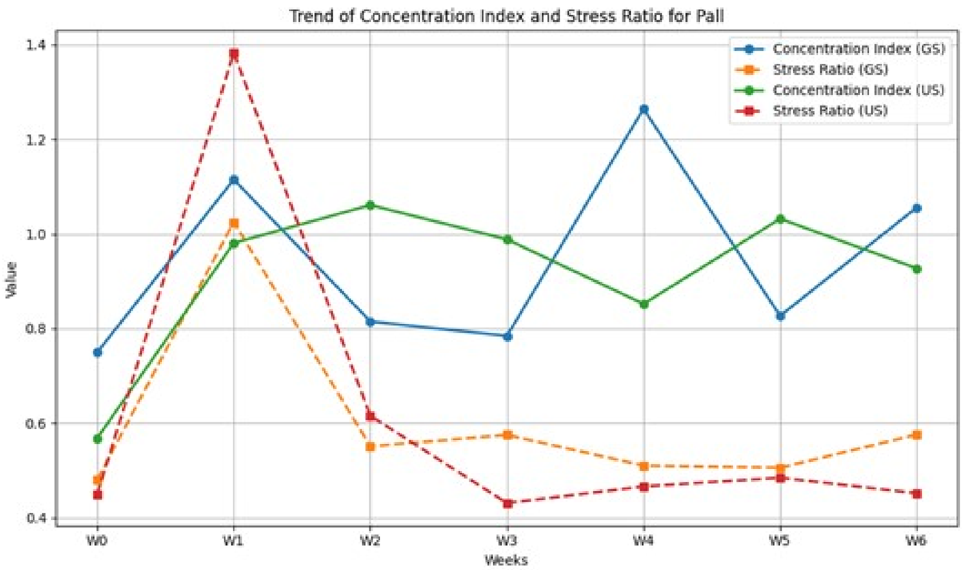

Figure 5.8: Average Concentration Index, and Stress Ratio over all participants over the weeks.
Note: for GS: the data of P4 is omitted for W1, data of P5 is omitted for W1 and W4; for US: the data of P4 is omitted for W1, data of P5 is omitted for W1, W2 and W4

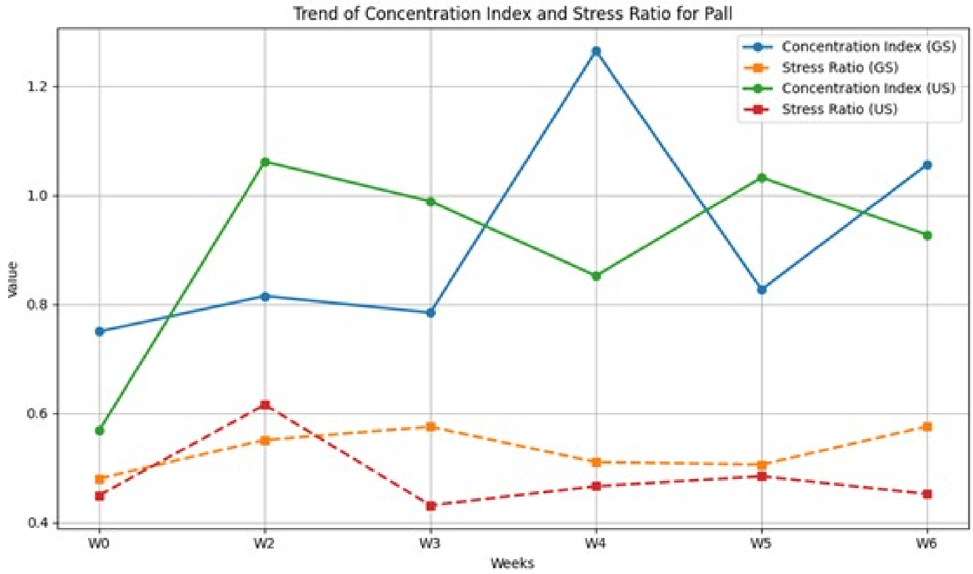

Figure 5.9: Average Concentration Index, and Stress Ratio over all participants over the weeks with week 1 excluded.
Note: for GS: the data of P5 is omitted for W4; for US: the data of P5 is omitted for W2 and W4

5.2.3 Frequency band trends

According to Chapter 3.3 *EEG and Mental Imagery Training*, it is expected that motor skills, attention and concentration improves, and that anxiety decreases after practicing visualisation over several weeks. To be able to check if that occurred during this experiment the average power over the weeks is plotted for each frequency band.

If there is an improvement in motor activation the beta frequency is expected to increase during the imagery training in the central region. As can be seen in Figure 5.10 and 5.11 below, there is no slope (GS: 0.009 * 10-2; US: -0.017 * 10-2) visible over the weeks for beta power, which means that there is not especially an increase in motor activation during the imagery training over the weeks on average.

Furthermore, for an increase in cognitive alertness/attention there could be increase in the SMR (alpha and beta) frequency waves in the frontal region. This is the case due to the small increase of alpha power in both figures 5.12 and 5.13 (GS: 0.173 * 10-2; US; 0.348 * 10-2). Furthermore, the beta increases also but remains quite constant (GS: 0.014 * 10-2; US: 0.020 * 10-2).

For an increase in visual attention there is an increase in beta waves expected in the parietal – occipital region. This is the case with a small positive slope of over all week (GS: 0.039 * 10-2; US: 0.032 * 10-2). In Figure 5.14 and 5.15 can this be seen.

If concentration is increasing, then it is expected that beta increases and theta decreases in the frontal region. When measuring the change, it occurred that indeed the theta frequency band decreases in both events (GS: -0.041 * 10-2; US: -0.162 * 10-2). Whereas the beta frequency also increases (GS: 0.014 * 10-2; US: 0.020 * 10-2). This is illustrated in Figure 5.12 and 5.13.

As for the anxiety theorem one, as explained in Chapter 3.3 *EEG and Mental Imagery Training* it is not expected to measure a decrease in the frontal – central region for the alpha, beta and theta frequency band. However, as described in the previous Alinea, it is explained that there is a decrease in activity in the theta frequency band in the frontal region. When looking at the frontal-central region combined it can indeed be seen that there is a decrease in theta activity (GS: -0.199 * 10-2; US: -0.289 * 10-2). However, there is an increase in alpha activity (GS: 0.269 * 10-2; US: 0.529 * 10-2) and beta stays approximately constant (GS: 0.010 * 10-2; US; -0.008 * 10-2), see Figure 5.16 and 5.17.

The second theorem only uses the frontal region and says that the beta wave is not expected to increase, which is not true because the beta frequency band has a positive slope (GS: 0.014 * 10-2; US: 0.020 * 10-2). However, this is so small that it more remains constant. Furthermore, this second theorem expect alpha not to decrease which is true because alpha shows an increase in power (GS: 0.173 * 10-2; US; 0.348 * 10-2). The same values are used as for measuring the cognitive alertness/attention. This can therefore also be seen in Figure 5.12 and 5.13.

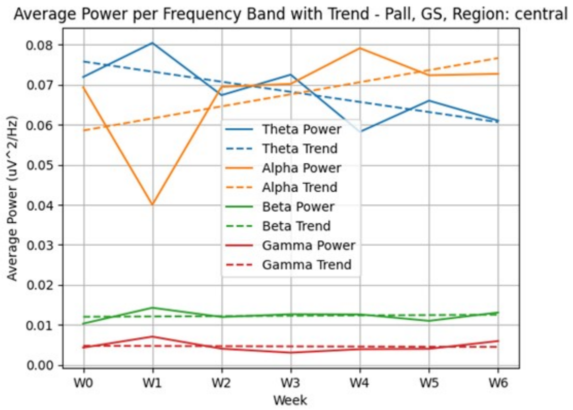

Figure 5.10: Pall = All participants; GS = Guided Scenario
Note: data of P4 is omitted for W1, data of P5 is omitted for W1 and W4

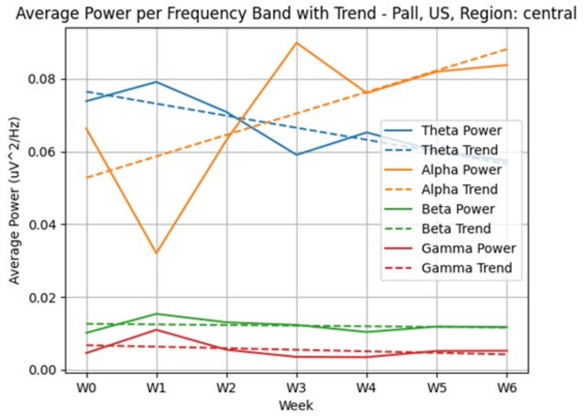

Figure 5.11: Pall = All participants; US = Unguided Scenario
Note: data of P4 is omitted for W1, data of P5 is omitted for W1, W2 and W4

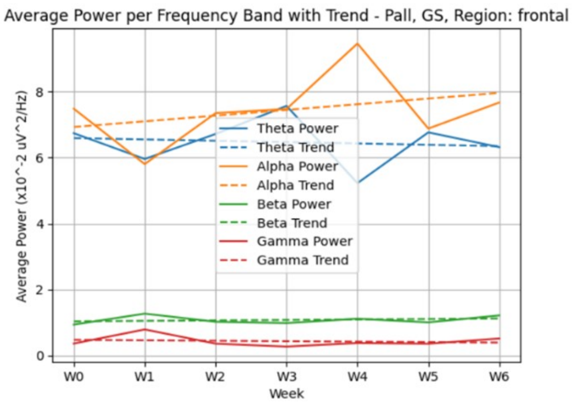

Figure 5.12: Pall = All participants; GS = Guided Scenario
Note: data of P4 is omitted for W1, data of P5 is omitted for W1 and W4

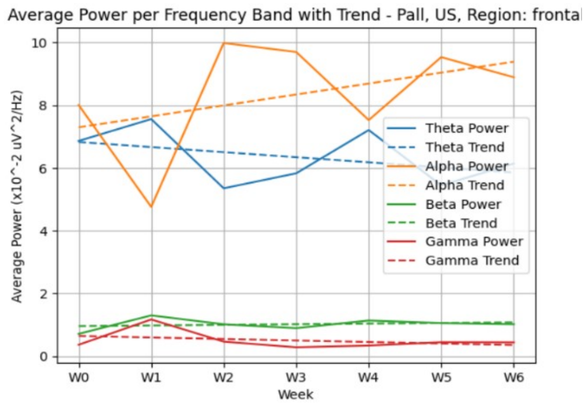

Figure 5.13: Pall = All participants; US = Unguided Scenario
Note: data of P4 is omitted for W1, data of P5 is omitted for W1, W2 and W4

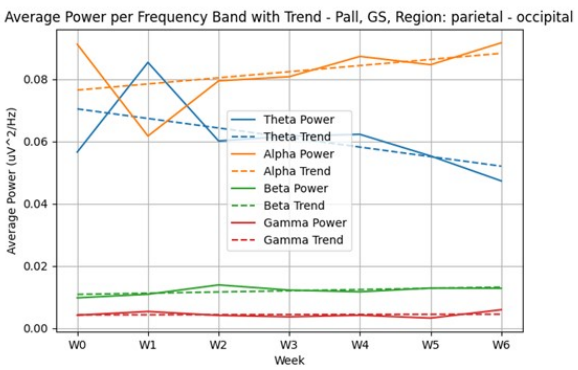

Figure 5.14: Pall = All participants; GS = Guided Scenario
Note: data of P4 is omitted for W1, data of P5 is omitted for W1 and W4

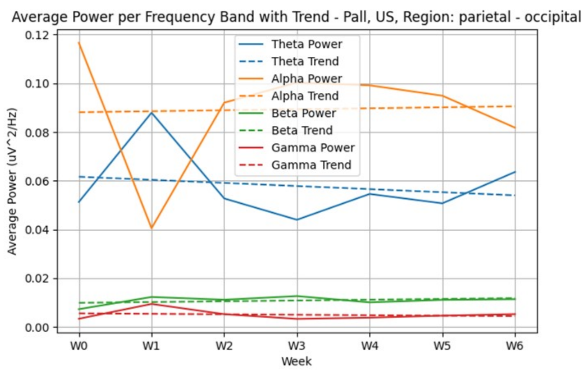

Figure 5.15: Pall = All participants; US = Unguided Scenario
Note: data of P4 is omitted for W1, data of P5 is omitted for W1, W2 and W4

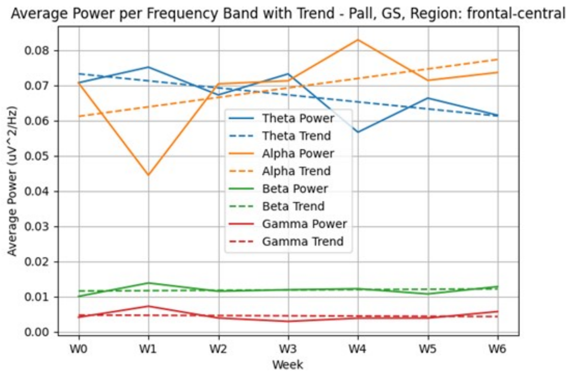

Figure 5.16: Pall = All participants; GS = Guided Scenario
Note: data of P4 is omitted for W1, data of P5 is omitted for W1 and W4

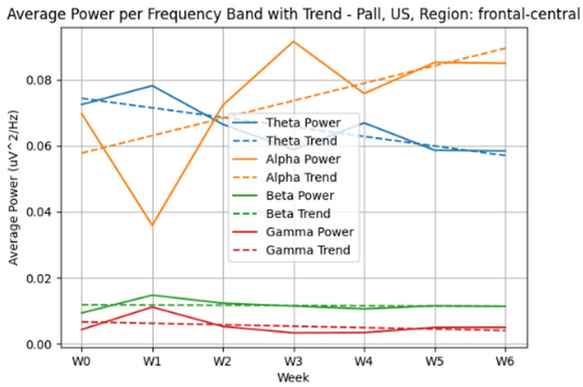

Figure 5.17: Pall = All participants; US = Unguided Scenario
Note: data of P4 is omitted for W1, data of P5 is omitted for W1, W2 and W4

In summary, when looking at all regions and measured frequency bands it seems that there is an increasing trend in alpha activity and a decreasing trend in theta activity whereas beta and gamma activity remain more constant over the weeks on average. An increase in alpha activity in general is often associated with stress reduction and relaxed states. Whereas a decrease in theta activity is linked to more analytical or problem-solving mental state, the reduction might indicate that the participants are more task oriented. The decrease in theta activity could also mean an improvement in emotional regulation (Zhang et al., 2013). A summary of the phenomena can be seen in Table 5.2 below, that is based on the theory from Chapter 3.3 *EEG and Mental Imagery Training* and Table 3.1. Such tables which contain the individual results of the participants can also be found in Appendix Q. The True or False markings in Table 5.2 below indicate whether the described trend aligns with the expected slope of the dataflow. However, these markings reflect only the if the slopes are in line with the slope expectations and are not based on statistical analysis.

- **Trend 1**: If there is an improvement in motor activation, the beta frequency is expected to increase during the imagery training in the central region.
- **Trend 2**: For an increase in cognitive alertness/attention, there could be an increase in the SMR (alpha and beta) frequency waves in the frontal region.
- **Trend 3**: For an increase in visual attention, there is an expected increase in beta waves in the parietal–occipital region.
- **Trend 4**: If concentration increases, it is expected that beta increases and theta decreases in the frontal region.
- **Trend 5**: **Theorem 1 - Wang**: It is not expected to measure a decrease in the frontal–central region for the alpha, beta, and theta frequency bands if anxiety reduces.
- **Trend 6**: **Theorem 2 - TuerxuenWaili**: It is not expected that in the frontal region, the beta wave increases and the alpha wave decreases if anxiety reduces.

Table 5.2: Combined Results of the Trends

Participant	Event	Trend 1	Trend 2	Trend 3	Trend 4	Trend 5	Trend 6
Pall	GS	True	True	True	True	True	Partly
Pall	US	False	True	True	True	True	Partly

6 Discussion

This Chapter discusses the factors that influenced the results presented in the previous chapter. It examines the research methodology, highlighting its strengths and weaknesses, analyses the results, including any unusual or unexpected findings, and compares these outcomes with the existing work reviewed in Chapter 3, Related Work.

6.1 Results

6.1.1 EEG Results

Although, within this report several EEG results are shown. It is still not guaranteed that the results are trustable due to the excessive noise and extensive cleaning process. This because useful data could be deleted, or noise could still be within the files. With combining the files of all participants and so averaging out the noise what could be left within the recording there tried to obtain trustable results.

6.1.2 Cleaning Choices

If the channels were bad for more than 50% of the channel it was dropped for the whole recording to decrease complexity in interpolating for only small segments. The choice to do it like this was in favour of limiting the number of handlings that are applied to the data. How more steps there are used to clean the data the more complex it will become. Also, when the steps increase more data will be adjusted and the results become also less trustable.

6.1.3 Manual Cleaning

Inspecting the PSD and EEG plots is only done manually because it was difficult to achieve a threshold that did not mark to many channels as bad. Therefore, it was done manually. However, this was subjective to the researcher and other researchers might do it differently and achieve therefore different results.

6.1.4 ICA and Autoreject

ICA an Autoreject are both applied when iterating over all files. The same thresholds and settings are used for each file. This is not necessarily the best option if there is looked at the individual files. However, to minimize complexity the choice was made to do it like this.

6.1.5 Files Not Suitable for Analysis

It also occurred that a complete file was not usable for analysis. This because within all channels there was a lot of noise. An example of this can be seen in Figure 6.1 below. If this was an EC file, the average of the other weeks was then used to replace the missing EC file. This because the idea is that in EC the participants close its eyes and does not perform any task. Therefore, the results must approximately be the same. However, if the file was a GS or US event the weeks were neglected for this participant. The list with excluded files can be found in Appendix L. This also influences the merged data of Pall that is shown in Chapter 5.2 *EEG*. Week 1 only consists of participant 1, 2 and 3 and for week 4 is also participant 5 missing.

Table 6.1: Summary of Not Suitable Files

Variable	Category	N	Percentage (%)
All Files	Total	105	100.00
Files per Participant	Total	35	100.00
Excluded Files	Total	12	11.4
	P03	1	2.86
	P04	3	8.67
	P05	8	22.89

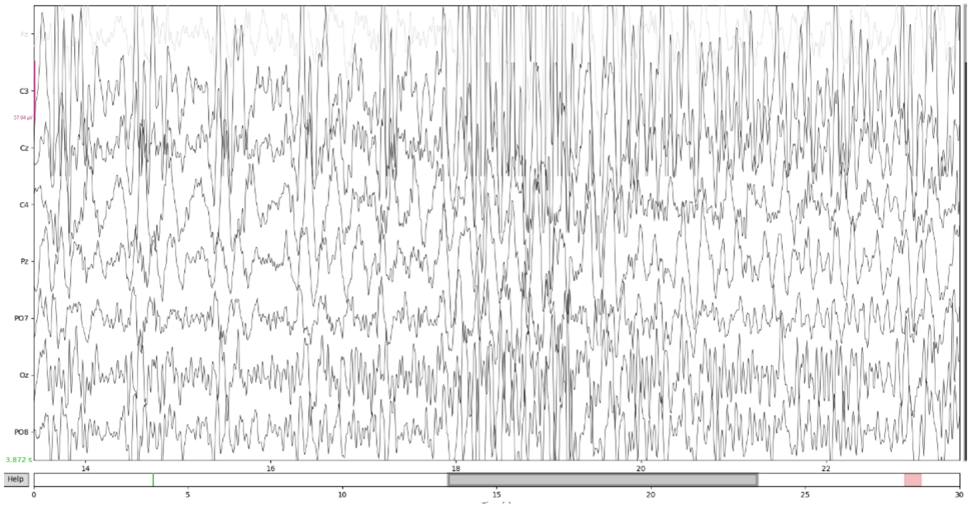

Figure 6.1: Example of an excluded file for analysis

6.2 Methodology

6.2.1 Material

Choice for Dry Headset

The first topic to discuss is the decision to use the Unicorn Hybrid Black EEG headset. This device was chosen because it uses dry electrodes, eliminating the need for gel, which was expected to save time. The headset's setup takes about 20–30 minutes per participant, with a maximum of 45 minutes in some cases. In contrast, gel-based headsets often take 45 minutes to an hour to apply. Initially, this seemed like a good choice for efficiently recording data from five participants. However, after two weeks of recording, it became clear that the data contained more noise than anticipated. Cleaning and processing this noisy data to make it usable for analysis turned out to be highly time-consuming. Using a gel-based headset could have significantly reduced this effort and improved the reliability of the data. In hindsight, the trade-off between faster headset application and data quality was not worth it, as the Unicorn Hybrid Black's dry electrode system compromised data quality too much.

Channels in the Frontal Region

To address the research questions, extensive information was needed from the brain's frontal region. However, the Unicorn Hybrid Black headset includes only one channel, Fz, in this area. If this channel was found to be faulty, there were no other frontal channels available for substitution, and it had to be interpolated using non-frontal channels. Even when the Fz channel functioned correctly, it still provided limited data as a single source of information. Furhtermore, as described in Section 3.3.5 *Anxiety* anxiety is likely to be measured at the right-side frontal part of the brain. With only one channel in the middle, this gives not the most trustable results.
In hindsight, it would have been more effective to choose a headset with multiple frontal channels to ensure more reliable and detailed data collection from this critical region. This change would have improved the robustness and quality of the results.

6.2.2 Scenarios

The most significant improvement was observed in the SIAQ results within the goal imagery ability category (see Figure **??**). This may be partly due to how the scenarios were designed. Each week, the scenarios focused on a different tactic, becoming more tactically oriented rather than technically oriented. This shift likely influenced the results. For instance, the EEG data showed no signs of improvement in motor skills or activation, which might be due to insufficient emphasis on technical aspects. Additionally, as suggested in the literature in Section 2.6.2 *Learnable*, there was variation in the scenarios to keep them engaging and challenging. However, this approach sometimes caused substantial differences in the sprinting scenarios across weeks, which could have also affected the results. A recommendation is to focus on a single scenario (e.g., a 20-second sprint with a set number of opponents) and introduce variations only within this framework. This would allow for more consistent comparisons while balancing tactical and technical aspects evenly. Implementing such changes could lead to more reliable and comparable results over time.

6.2.3 Participant Factors

Quality differences

There were notable differences among the participants, despite all being amateur cyclists of similar age and right-handed. These differences were particularly evident in their sprinting preferences: some favoured short sprints, while others preferred longer ones. This variation likely influenced their confidence in winning sprints, which is crucial for mental imagery training as explained in Section 2.6.3 *Personality* and could have affected how they engaged with the training process. Having participants with more similar sprinting abilities could have been beneficial for the experiment. More homogeneous groups might allow for clearer conclusions, as differences in physical qualities and confidence levels could influence outcomes. However, finding even five participants who were available for the experiment proved to be challenging. In future studies, more careful participant selection could help control for these factors and enhance the reliability of the results.

Practicing consistently

Although a practice schedule was provided for the participants, some chose to follow their own plans and did not practice as much as required. The goal was for all participants to practice twenty-four times independently. However, as shown in Figures 6.2 and 6.3 below, this target was not met. This discrepancy may explain why the progress in mental imagery training was less than expected. To address this in future studies, it may be helpful to emphasize the importance of adhering to the practice schedule more clearly. Regular reminders and stronger communication about the significance of consistent practice could improve participant commitment and ensure better results if the research is repeated.

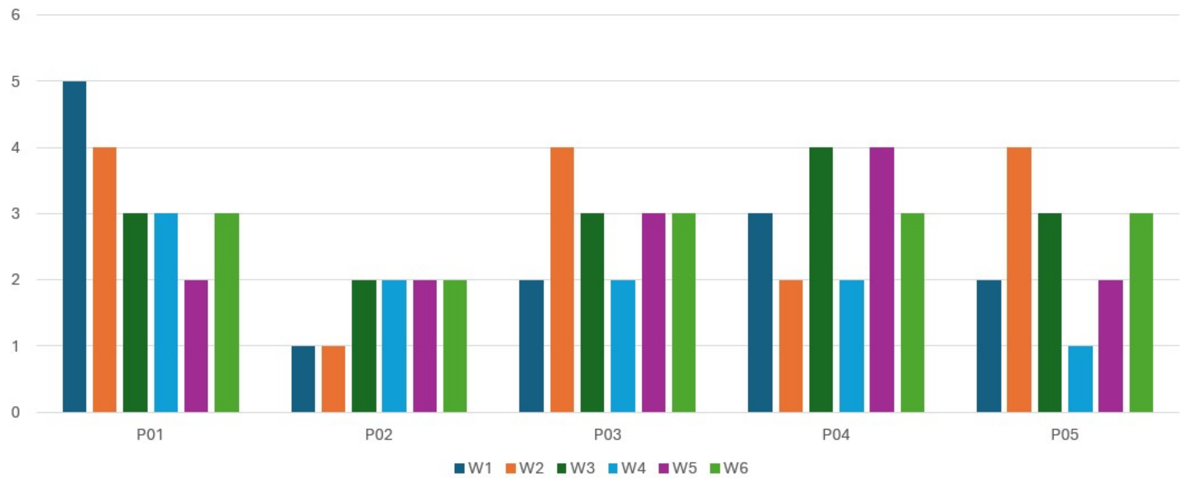

Figure 6.2: Executed practice sessions per week for each participant

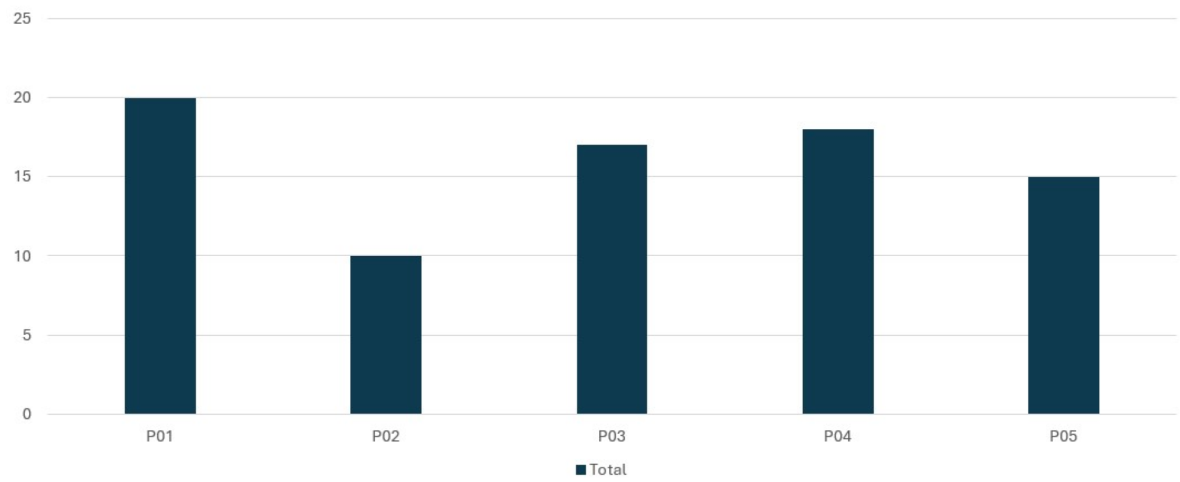

Figure 6.3: Total amount of practice per participant over six weeks

Sample size
In this experiment, data was collected from five participants (n=5). This sample size is too small to produce statistically significant results. To draw reliable conclusions, a larger group of participants would be needed. However, due to time and resource limitations, it was not possible to include more participants in this study. Instead, the focus was on identifying visible trends that might be interesting for future research. If promising trends are observed, the study could be repeated with a larger sample size and other suggested improvements. Additionally, based on the knowledge from Section 2.4.5 *Illiteracy*, 15-30% of individuals exhibit brain behavior that differs from what is commonly expected. This could have a significant impact on the outcomes of this research, especially if at least one participant exhibits such atypical brain behaviour.

6.2.4 Comparison to Existing Work

The implementation of key topics, as discussed by Birrer (Birrer & Morgan, 2010) in Chapter 3 *Related Work*, highlights the importance of a systematic, goal-oriented, planned, controlled, and evaluated script for mental imagery training. To ensure participants become fully familiar with every detail of the scenario, structured planning (see Table A.1) and weekly monitored and unmonitored scenario assignments are incorporated. These assignments are further enriched with the PETTLEP guidelines by Holmes and Collins (Holmes & Collins, 2001) and the recommendations by Ekeocha (2015), offering a comprehensive approach to the training process.

As noted in Chapter 3, the expected outcomes from Predoiu et al. (2020) include improvements in concentration, motor skills, attention, and self-confidence, alongside a reduction in anxiety. These findings serve as the foundation of this research - as the research questions are built upon them - and are further examined in Chapter 3.3 *EEG and Mental Imagery Training*. Here, the neural correlates of these outcomes are explored, including how they manifest in EEG data. Results from the designed experiment indicate improvements in concentration and attention, aligning with the literature. However, no significant increase in motor skills was observed across participants. While some individuals (Appendix Q) demonstrated improvements in motor skills, these trends were not strong enough to reflect in group-level analyses.

Similarly, anxiety levels showed no significant decrease on average, though the stress ratio—a related measure—did not exhibit any worsening trend either. This suggests that while anxiety did not improve significantly, it also did not deteriorate following mental imagery training. Self-confidence was not directly measurable with EEG; however, qualitative feedback collected during participant debriefings (Chapter 5.1 *Questionnaires*) indicates potential benefits. Two participants specifically noted that mental imagery helped them overcome mental setbacks and motivated them by visualizing victory, suggesting an improvement in self-confidence for some, even if this outcome was not quantifiable.

7 Conclusions

Within this Chapter, conclusions will be derived from the results in Chapter 5 and the research questions created in Chapter 1.3. The research questions are answered as follows:

1. **Do amateur cycling athletes experience progress in mental imagery training when practising their bunch sprint?**
   Three of the five participants experienced progress in mental imagery training based on the results of the SIAQ self-assessment. This were participant 1, 2, and 5, as can be seen in Chapter 5.1. On average there is an improvement measured as can be seen in Figure 5.4.

   Furthermore, when looking at the qualitative results from the debriefing questionnaire (also described in 5.1), four out of five participants experienced definite progress. These were the same participants, 1, 2 and 5 supplemented with participant 4. Participant 4 also mentions progress, but within the SIAQ, he stayed approximately on the same level, which was already high (6 out of 7).

   Additionally, when inspecting the individual results in Appendix Q it shows that participants 1, 4 and 5 show individual progress in most trends as described in Table 5.2. Which are inline with their own expectation. For participant 2 this is not the case, who experiences progress but it is not visible in the EEG trend results. Participant 3 does not experience progress and there is also no progress visible in the individual EEG trend results.

   a. **And if so, in which aspects do they experience progress the most?**
      All participants showed progress, in the SIAQ, in the Strategy Imagery Ability category, which can be seen in Figure **??**. However, when looking at the average results in Figure 5.4 the increase is on average the highest in the Goal Imagery Ability category. However, this is subject-dependent, as it differs between participants in which categories they improve. From the debriefing questionnaire (described in Table 5.1), some takeaways were that participants experience mental imagery training as fun, helpful in mental setbacks, fostering self-belief, more aware of how something should feel, and more focused on technical and tactical aspects.

2. **Does EEG reveal changes in brain activity following a seven-week imagery sprint training program among cyclists?**
   Yes, changes in brain activity were observed when inspecting the topomaps over the weeks. As shown in Figure 5.7, the patterns differ between weeks, particularly when comparing Week 0 to Week 6. Notably, Week 6 exhibited higher activity levels during both the Guided Scenario (GS) and Unguided Scenario (US) events. However, some variations could also be attributed to signal quality issues, as discussed in Section 6.1.5 *Files not suitable for Analysis.* While the topomaps provided a general sense of change, they did not reveal clear or consistent patterns. To gain deeper insights, the values of individual frequency bands were measured and plotted over the weeks. This approach seemed more informative. By analysing these plots, trends with discernible slopes were observed, indicating the direction of changes in brain activity for each frequency band. The findings align with the expected phenomena related to concentration, motor skills, attention, and anxiety, as described in 3 *Related Work* and summarized in Table 3.1. Specifically, five out of six expected trends were confirmed for the Guided Scenario, and four out of six for the Unguided Scenario that could be seen in Table 5.2. However, it is important to note that the observed changes were small and, given the limited sample size, are statistically insignificant.

   a. **And if so, in which brain regions can these differences be identified?**
      In all brain regions, differences can be identified as described in Chapter 5.2 *EEG*. However, changes in the frontal and central regions of the brain are more prominent than changes in the parietal–occipital region of the brain, as can be seen in the Figures that are part of Section 5.2.3 *Frequency band trends.*

      i. **What kind of trends are visible in the brain activity of these brain regions?**
         In all brain regions, an increase in alpha activity and a decrease in theta activity can be seen (see Figures that are part of Section 5.2.3 *Frequency band trends*). Although there is a small

increase in beta activity in some regions, it remains, together with gamma activity, mostly constant.

b. **Can one measure an individual's proficiency in mental imagery training?**
Due to the excessive noise in the individual EEG data, no insightful individual results were obtained from the topomaps. However, with the use of the SIAQ, it is evident that most participants showed improvement in their mental imagery ability. Participants 1, 2, and 5 showed improvement, while participant 4, who was already proficient in mental imagery ability, showed no improvement. Participant 3 even showed a decrease in ability (see Figure **??**. Furthermore, using the same trends provided in Chapter 3.3 *EEG and Mental Imagery Training* and Section 5.2.3 *Frequency band trends* that measured the difference in power in the frequency bands over the weeks, it showed in Appendix Q that participants 1, 4, and 5 showed improvement in most trends. Whereas participants 2 and 3 did not show any improvement based on their EEG data. Although there is some overlap in the outcomes (participants 1 and 5), there are also contradicting results (participant 2). Therefore, the conclusion from this experiment, when combining both outcomes, is that one cannot measure an individual's proficiency with a subjective questionnaire, such as the SIAQ, in combination with outcomes from the frequency analysis of the EEG data, but it can give an indication of it.

i. **And if so, what are the observable indicators in the brain that correlate with proficiency?**
An increase in the global imagery ability category of the SIAQ as shown in Figure **??** combined with marking most trends (1 until 5 for GS and 2 until 5 for US) from Section 5.2.3 *Frequency band trends.* as 'True'

3. **How does imagery training for a bunch sprint influence the various brain regions involved in attention, concentration, anxiety, and motor skills?**
Using the combined results from all participants of the trend analysis and plots of concentration index and stress ratio, it can be said that attention, according to trend analysis in Table 5.2 for trend 2 and 3, improved and that concentration according to the concentration index in Figure 5.8 and trend analysis in Table 5.2 for trend 4 improved, while anxiety shows more contradicting results as that it stayed the same or slightly decreased when analysing the stress ratio (see Figure 5.9) and that it decreased in trend analysis for trend 5 but that trend 6 is contradicting in Table 5.2. No noticeable difference was found in motor skills activation as that it did slightly improve for event GS but not for US in the trend analysis for trend 1. Additionally, based on participants' qualitative feedback, mental imagery training helped them feel more prepared for certain events which attributes to self-confidence which was first neglected to be researched due to that it could not be measured with EEG.

8 Further Research

There are several suggestions for further research. The first to mention is that this study was limited in terms of resources, time, and results. But the trends in the EEG signals could lead to further research. If it becomes possible to implement the recommendations from the discussion, such as using different EEG equipment that focuses more on the frontal region of the brain or creating improved scenarios, it would be worth redoing this research or investigating it furhter. Another suggestion for further research is to conduct an improved experiment with more participants to obtain statistically significant results. These two suggestions remain closely tied to the current study.

In addition, future research could explore how this information might benefit athletes and trainers in sports. For instance, investigating the possibility of developing a smart device to assist athletes by monitoring progress in mental imagery training could be valuable. Such a device might help athletes manage high-stress situations, guiding them to overcome challenges and be better prepared for competition.

Another important direction that should not be overlooked is the ethical aspect of this field. Questions arise about who should have access to this data and how it should be used, especially if EEG signals could measure someone's concentration or attention potential in the future. For example, understanding the topomaps of successful athletes could guide trainers and managers in team selection. This raises the question of how measuring brain signals differs from tracking heart rate or power output with other sensors. Would brain signals be a helpful addition, or do they require stricter privacy regulations due to their personal nature?

9 Use of AI

During the preparation of this work, I used ChatGPT to help writing code and finding errors in the code in Python. Furthermore, I used it as a tool for Grammar and Spelling in English together with Grammarly. After using ChatGPT and Grammarly, I thoroughly reviewed and edited the content as needed, taking full responsibility for the final outcome.[2]

[2] Required sentence obtained from: Guidelines for Using AI During Your Studies At UT https://www.utwente.nl/en/education/student-services/news-events/news/2023/7/1041467/guidelines-for-using-ai-during-your-studies-at-ut

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Appendices

Appendix A. Participant Information Letter

Monitoring Cyclists' Brain Activity During Six Weeks of Visualization Training Evaluating Changes in Brain Behaviour and the Measurability of Visualization Practice

Introduction
Dear possible participant,

With this information letter I want you to ask if you want to participate in my graduation project. You will read in this letter information where the study is about, what participating for you will mean, and what the possible pro and cons for you can be if you want to decide to participate. Participating is completely voluntary, and you can stop your participation at all times.
This letter contains a lot of information. Please, read the information carefully before you decide if you want to participate. If you decide to participate, I need a written consent from you. This consent can be found in Attachment A (at the end of this document). The researcher will bring this form to the start of the experiment for you to complete (or you can send it back to me).
Thank you for considering this opportunity.

Information
If you have any questions or concerns after reading this letter, please ask them to the researcher who gave you this letter. All contact information can you find in Attachment B.

1. Am I suitable to participate?
This study will be executed by the University of Twente (UT). For this study we are looking for 4 healthy participants that meet the following criteria.
o You are between 20 and 35 years old.
o You are an active cyclist (2 or more times a week).
o You are right-handed.
o You did not experience any trauma in life that visualization could trigger.

2. What is the goal of this study?
This study aims to determine whether practicing visualization over several weeks affects brain behaviour. We do this by training you in visualization and measuring your brain activity over several weeks.

3. What is the background of this study?
In the world of competitive sports, the line between winning and losing is incredibly thin. That is why athletes are always looking for ways to improve their performance. One technique that has shown promising results is visualization. Research suggests that visualizing success can enhance concentration, attention, and reduce nerves. However, we are still not sure exactly how it works in the brain, or how much it can really help.

That is where you come in. We are conducting a study to see how visualization affects brain activity over six weeks of training. We want to know if there are specific changes in your brain as you practice visualization. To do this, we will be using a method called electroencephalography (EEG). This involves placing small sensors, called electrodes, on your scalp to measure brain activity.

Do not worry, it is painless and safe. We will be using a special cap with dry electrodes, so there is no need for any messy gels or liquids. By participating in this study, you will be helping us understand more about how visualization can improve performance in sports.

4. What is the timeline of this study?
The complete study will take approximately 7 hours in total. However, this will be spread out over 7 weeks. The timeline starts with 'Week 0' up to 'Week 6'. Week 0 is for getting to know you and gather

information for creating your baseline. Week 1 until 6 are for training you in visualisation.

Week 0
In week 0 you will fill in three questionnaires, one about some general information about you what possible can matter for the results, one personality questionnaire because according to several studies your personality influences how your brain reacts on visualisation. The last questionnaire is to decide what your visualisation basis level already is, some people are from nature already better in thinking in images then others. Filling in these questionnaires can you do by yourself at home.

Furthermore, on a separate day we want to do together a visualization exercise while you are sitting on a static bicycle and measuring your brain activity with EEG.

Week 1 until 6
Every week you will be asked to do four times a week (on different days) a small visualisation exercise at home. This will take you approximately five minutes. It does not matter when you are doing this however it is recommended to do this at:
o Approximately the same time every day.
o To do this at a quiet place.
Suggestions would be for example, just before diner, or just before you go to bed.

At the end over every week, we meet each other at the University of Twente. There we will do a visualisation exercise together while you are wearing an EEG headset. In Table 1 below you can find the proposed schedule. If you forget to do one of the five minutes on a specific day, please do still this exercise and inform the researcher that you did this at another moment. However, it is of importance that you are able to physically meet (preferably every Thursday), if you have one specific case that you are not able to come, please inform the researcher for rescheduling this appointment.

UMT = Unmonitored Training; MT = Monitored Training; S = Session; W = Week; PQ = Pre-Questionnaires
Example: UMT W1S1 = Unmonitored Training Week 1 Session 1

Table A.1: Weekly Schedule

Date	Week	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
31 – 6 Sept.	0			PQ			SM/S0	
7 – 13 Sept.	1	UMT W1S1	UMT W1S2		UMT W1S3	UMT W1S4	MT S1	
14 – 20 Sept.	2	UMT W2S1	UMT W2S2		UMT W2S3	UMT W2S4	MT S2	
21 – 27 Sept.	3	UMT W3S1	UMT W3S2		UMT W3S3	UMT W3S4	MT S3	
28 – 4 Oct.	4	UMT W4S1	UMT W4S2		UMT W4S3	UMT W4S4	MT S4	
5 – 11 Oct.	5	UMT W5S1	UMT W5S2		UMT W5S3	UMT W5S4	MT S5	
12 – 18 Oct.	6	UMT W6S1	UMT W6S2		UMT W6S3	UMT W6S4	MT/S6	

5. What side effects or adverse effects and discomforts might you experience?
While wearing the EEG you can feel the sensors contacting your head, this can be experienced as annoying or uncomfortable. However, the EEG headset will never be experienced as painful at any moment.

6. What are the advantages and disadvantages of participating in the study?
Advantages after participating in this study, you learnt a scientific substantiated way of training visualisation which you can use for your own sport performances. Disadvantages of participating in this research could be participating will costs (maximum) 1 hour every week (1 meeting session with the researcher and four times 5 minutes practicing by yourself) and wearing the EEG headset can be experiences as uncomfortable.

7. When will the experiment of the study stop for you? In the following situations the study will stop:
o If you finish the protocol

o If you want to stop participating in the study. This can be at any moment. Contact the researcher if you want to quit. You do not have to tell the reason why you are quitting.
o The researcher finds it better for you to stop participating. An example reasons can be: if you are not able to do the assignments in the protocol as expected.

If you would like to stop participating in this study the researchers are allowed to use the data obtained up until that moment.

8. What will happen after the study?
What will happen with your data?
With attending this research, you give permission collect and use and storage your data (questionnaire data, EEG data).

Why do we collect and use and storage your data?
We collect, use and storage your data to answer the research questions of this study and to process the results.

How do we protect your privacy?
To protect your privacy, we label your data with a code. This code will be saved on a secure location at the University of Twente. If we use your data, we will only use this code, and no personal data that can be traced back to you, like your name, will be used.

In possible reports of publications will also no personal data be shared that can trace back to the participant. In this case, to you.

How long do we store your data?
We will keep your data until the end of this graduation project. After this period your data will be deleted or transformed to completely anonymous data. If we completely make the data anonymous, we will destroy the code that labels your personal information to the data.

Can you revoke your consent to use your data?
You can revoke your consent to use your data at any moment. If that is the case, please contact your researcher. NB: If you revoke your permission, and we have already obtained data for the study, then this data may still be used.

Do you want to know more about your privacy?
Do you want to know more about your rights when processing personal data? Please take a look at www.autoriteitpersoonsgegevens.nl

Do you have questions or have a complaint about the processing of your personal data? Then you can contact the secretariat of the Ethics Committee Information & Computer Science: ethicscommitee-CIS@utwente.nl

9. Will you receive compensation if you participate in this study?
Participating in this study will costs you no money but you will also receive no compensation. Furthermore, travel expenses will also not be compensated.

10. Do you have any questions?
Please ask them to the researcher if anything is still unclear for you.

11. How do you give permission to participate in this study?
If you want to participate in this study you can sign the form of consent to give permission to participate in this study.

Kind regards, Florien Bolks

Appendix B. Attachment A - Informed Consent

Attachment A – Informed Consent

Statements	**Answer**
I have read and understood the study information dated 11/06/2024, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	o Yes o No
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	o Yes o No
I understand that taking part in the study involves: - six weeks of practising visualisation. - questionnaires about my personality and imagery skills. - several EEG recordings of my brain activity. - Written and audio notes about the experiment	o Yes o No
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	o Yes o No
I give permission for the EEG data that I provide to be (anonymous) archived in the repository of the University of Twente so it can be used for future research and learning.	o Yes o No
I give permission for gathering photo/audio and/or video material during the research. The media used will always be anonymous if it will be used in presentations, or publications.	o Yes o No

Signature

Name of participant:

Signature: Date:

I have accurately read out/send the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Name researcher: Florien Bolks

Signature Date: 11/06/2024

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee Information & Computer Science: ethicscommittee-CIS@utwente.nl

Appendix C. Participant Selection Criteria and Personal Information Questionnaire

These two questionnaires are merged in the digital form for the participant in order to decrease the number of questionnaires for the participant.
The link to the Google form which is used: `https://forms.gle/GMCxXqJvUJKDUL126`

Participant Selection Criteria

Number	Question	Answer	
1	I am in between the age range of 20-35.	o Yes	o No
2	I am right-handed.	o Yes	o No
3	I am an experienced sport cyclist* (*practicing cycling on a racing bike at least 2 times a week)	o Yes	o No
4	I did not experience any trauma in life that visualization could trigger.	o Yes	o No
5	Sex assigned at birth is male.	o Yes	o No

Personal Information Questionnaire

Number	Questions	Answer		
1	Hair thickness	o Thin	o Intermediate	o Thick
2	What is your Functional Threshold Power (FTP)?			
3	What is your weight?			

Appendix D. Attachment B - Study Contact Details

Florien Bolks
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+316 28585560

Main Supervisor
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Second Supervisor
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Lecturer, University of Twente
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Appendix E. IPIP-Neo-120 Personality Questionnaire

Big Five Personality Test

The questionnaire is digitally performed at `bigfive-test.com`. At the end of the questionnaire, the participants are able to see their own results and obtain a unique ID. This ID will be sent to the researcher, which makes it possible for the researcher to also access the participants' results. The questions of the questionnaire are listed below.

	Statement	**1**	**2**	**3**	**4**	**5**
1.	Worry about things.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
2.	Make friends easily.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
3.	Have a vivid imagination.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
4.	Trust others.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
5.	Complete tasks successfully.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
6.	Get angry easily.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
7.	Love large parties.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
8.	Believe in the importance of art.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
9.	Use others for my own ends.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
10.	Like to tidy up.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
11.	Often feel blue.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
12.	Take charge.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
13.	Experience my emotions intensely.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
14.	Love to help others.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
15.	Keep my promises.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
16.	Find it difficult to approach others.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
17.	Am always busy.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
18.	Prefer variety to routine.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
19.	Love a good fight.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
20.	Work hard.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
21.	Go on binges.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
22.	Love excitement.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
23.	Love to read challenging material.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
24.	Believe that I am better than others.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
25.	Am always prepared.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
26.	Panic easily.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
27.	Radiate joy.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
28.	Tend to vote for liberal political candidates.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
29.	Sympathize with the homeless.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
30.	Jump into things without thinking.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
31.	Fear for the worst.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
32.	Feel comfortable around people.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
33.	Enjoy wild flights of fantasy.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
34.	Believe that others have good intentions.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
35.	Excel in what I do.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
36.	Get irritated easily.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
37.	Talk to a lot of different people at parties.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
38.	See beauty in things that others might not notice.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate

39.	Cheat to get ahead.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
40.	Often forget to put things back in their proper place.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
41.	Dislike myself.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
42.	Try to lead others.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
43.	Feel others' emotions.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
44.	Am concerned about others.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
45.	Tell the truth.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
46.	Am afraid to draw attention to myself.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
47.	Am always on the go.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
48.	Prefer to stick with things that I know.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
49.	Yell at people.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
50.	Do more than what's expected of me.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
51.	Rarely overindulge.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
52.	Seek adventure.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
53.	Avoid philosophical discussions.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
54.	Think highly of myself.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
55.	Carry out my plans.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
56.	Become overwhelmed by events.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
57.	Have a lot of fun.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
58.	Believe that there is no absolute right or wrong.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
59.	Feel sympathy for those who are worse off than myself.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
60.	Make rash decisions.	Very Inaccurate	Moderately Inaccurate	Neither Accurate Nor Inaccurate	Moderately Accurate	Very Accurate
61.	Am afraid of many things.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
62.	Avoid contacts with others.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
63.	Love to daydream.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
64.	Trust what people say.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
65.	Handle tasks smoothly.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
66.	Lose my temper.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
67.	Prefer to be alone.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
68.	Do not like poetry.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
69.	Take advantage of others.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
70.	Leave a mess in my room.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
71.	Am often down in the dumps.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
72.	Take control of things.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
73.	Rarely notice my emotional reactions.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
74.	Am indifferent to the feelings of others.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
75.	Break rules.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
76.	Only feel comfortable with friends.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
77.	Do a lot in my spare time.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate

78.	Dislike changes.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
79.	Insult people.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
80.	Do just enough work to get by.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
81.	Easily resist temptations.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
82.	Enjoy being reckless.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
83.	Have difficulty understanding abstract ideas.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
84.	Have a high opinion of myself.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
85.	Waste my time.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
86.	Feel that I'm unable to deal with things.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
87.	Love life.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
88.	Tend to vote for conservative political candidates.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
89.	Am not interested in other people's problems.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
90.	Rush into things.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
91.	Get stressed out easily.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
92.	Keep others at a distance.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
93.	Like to get lost in thought.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
94.	Distrust people.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
95.	Know how to get things done.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
96.	Am not easily annoyed.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
97.	Avoid crowds.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
98.	Do not enjoy going to art museums.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
99.	Obstruct others' plans.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
100.	Leave my belongings around.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
101.	Feel comfortable with myself.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
102.	Wait for others to lead the way.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
103.	Don't understand people who get emotional.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
104.	Take no time for others.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
105.	Break my promises.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
106.	Am not bothered by difficult social situations.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
107.	Like to take it easy.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
108.	Am attached to conventional ways.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
109.	Get back at others.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
110.	Put little time and effort into my work.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
111.	Am able to control my cravings.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
112.	Act wild and crazy.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
113.	Am not interested in theoretical discussions.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
114.	Boast about my virtues.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
115.	Have difficulty starting tasks.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
116.	Remain calm under pressure.	Very	Moderately	Neither Accurate	Moderately	Very

		Inaccurate	Inaccurate	nor Inaccurate	Accurate	Accurate
117.	Look at the bright side of life.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
118.	Believe that we should be tough on crime.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
119.	Try not to think about the needy.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate
120.	Act without thinking.	Very Inaccurate	Moderately Inaccurate	Neither Accurate nor Inaccurate	Moderately Accurate	Very Accurate

Appendix F. Sport Imagery Questionnaire (SIAQ)

Here is the link to the Google form used for participants to fill in the questionnaire digitally: https://forms.gle/3NuA4i33usQ6vMqq9

No.	**Statement**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	Making up new plans/strategies in my head	1	2	3	4	5	6	7
2	Giving 100% effort even when things are not going well	1	2	3	4	5	6	7
3	Refining a particular skill	1	2	3	4	5	6	7
4	The positive emotions I feel while doing my sport	1	2	3	4	5	6	7
5	Myself winning a medal	1	2	3	4	5	6	7
6	Alternative plans/strategies	1	2	3	4	5	6	7
7	The anticipation and excitement associated with my sport	1	2	3	4	5	6	7
8	Improving a particular skill	1	2	3	4	5	6	7
9	Being interviewed as a champion	1	2	3	4	5	6	7
10	Staying positive after a setback	1	2	3	4	5	6	7
11	The excitement associated with performing	1	2	3	4	5	6	7
12	Making corrections to physical skills	1	2	3	4	5	6	7
13	Creating a new event/game plan	1	2	3	4	5	6	7
14	Myself winning	1	2	3	4	5	6	7
15	Remaining confident in a difficult situation	1	2	3	4	5	6	7

Appendix G. Weekly Debriefing Questionnaire

No.	Question
1	Did you imagine your sprint in an existing location?
2	How long was your end sprint in meters?
3	How long was your end sprint in seconds?
4	How long did you think you took for your end sprint just now?
5	On what technical part did you focus (the most)?
6	On what tactical part did you focus (the most)?
7	In this scenario, do you think it is likely for you to win? Why or why not?
8	What would you like to change in this scenario to increase your chances of winning?

Appendix H. Procedure Monitored Training Sessions

Step 1: Introduction to Visualisation

The first experiment that includes EEG is the visualisation practice itself. But before putting on the EEG, the participant will be introduced to visualisation. The introduction includes telling the participant where to focus on and with an example.
Point of Attention - Visualisation

- It is important that you visualise at the same speed as you think actual movement is.
- Example: If you want to focus on your pedalling stroke, do that at the same speed you would push. Do not speed up the process or imagine the movement in slow motion.
- It is important to visualise the movement from an internal perspective (first-person perspective). That is, through your own eyes.
- Example: If you want to visualise a final sprint, you see your opponents through your own eyes. Do not imagine in a way that you see yourself and your opponents from, for example, a flying perspective.

Step 2: Placement of the EEG Cap

Following this, the EEG cap will be placed on the participant. The procedure for placing the EEG cap can be found in Appendix J. Furthermore, during the placement of the cap, there is small talk about what kind of sprinter the participant is and what, in their experience, a successful strategic choice is to win a sprint. This way, the participant starts unconsciously getting familiar with the visualisation of a sprint.

Step 3: Start EEG Imagery Script Pilot Testing

Phase 1: Determine Baseline Condition

Please find a comfortable seated position. Close your eyes and take a moment to settle into your body. We will begin with two minutes of keeping your eyes open, followed by two minutes with your eyes closed.

Phase 2: Relaxation

Now, let's transition into relaxation using a technique called the breathing box. Imagine a box in front of you, with four sides. As you breathe, we will trace each side of the box, syncing your breath with the movement.

- **Inhale:** As you trace the first side of the box, slowly breathe in through your nose for a count of four.
- **Hold:** Pause for a moment as you trace the second side of the box, holding your breath for a count of four.
- **Exhale:** Trace the third side of the box as you exhale slowly through your mouth for a count of four.
- **Pause:** Finally, pause again as you trace the fourth side of the box, holding your breath for a count of four.

Let's repeat this cycle three times, focusing on the sensation of your breath and the movement of your imaginary box.
[Lead participants through three cycles of the breathing box technique, ensuring they maintain a steady and relaxed pace.]
Take a moment to notice how your body feels now compared to before. Embrace this sense of calm and relaxation as we move into the visualisation phase.

Phase 3: Visualisation Task

Before we begin the visualisation protocol, we will establish a baseline measurement of your brain activity. This will help us understand how your brain responds during different phases of the test. The participant will be asked to take a seat on a chair.

[label=–]Close your eyes gently. Relax your body and find a comfortable position.

Next, the scenarios corresponding to that week will be read to the participant. The scenarios of all weeks can be found in Appendix L.
[Ask the participant to do the visualisation of the sprint again by themselves. And take the time you think is necessary. If they are finished, ask the following questions:]

1. How long was your end sprint? (meters and seconds)
2. How much time do you think you took for your end sprint?
   Can be compared to the time they took to visualise; according to the mentioned research, if you are better at visualisation, the actual time and the time to visualise will get closer to each other.
3. On what technical part did you focus (the most)?
4. On what tactical part did you focus (the most)?
   Can be compared to whether cognitive brain regions are more stimulated or motor skills-related regions are more stimulated.
5. In this scenario, do you think it is likely for you to win? Why or why not?
6. What would you like to change in this scenario to increase your chances of winning?
   With these questions, the self-belief, which is important for visualising according to the mentioned research, can be checked. Furthermore, with the last question, tactical thinking and getting familiar with own qualities will be stimulated.

Appendix I. Scenarios

Training Scenarios

The scenarios that are proposed and trained during the imagery sessions will increase in difficulty over the weeks. Three different sprinting situations are considered:

- **Two-Rider Sprint (Beginner level)**: A two-rider sprint often results from a breakaway during the cycling race. This specific situation is not necessarily easier to win than any other type of sprint, but it is considered a beginner level scenario due to the presence of only one other cyclist to consider.
- **Group Sprint Four Riders (Intermediate Level)**: This can also be the result of a breakaway during the cycling race. However, this situation is more complex than the two-rider sprint, as there are more cyclists to take into account.
- **Peloton Sprint (Advanced Level)**: In the absence of a leading group in the race, the winner will be decided by a peloton sprint. All riders compete to win, making this a difficult situation where positioning is crucial.

There can be differences among participants in the type of sprinter they are. Some sprinters have a strong long sprint (approximately 30-60 seconds), while others excel in short sprints (maximum 15 seconds). During the imagery training, participants can decide for themselves which kind of sprint they will use to win.
From Week 0 to Week 2, a Two-Rider sprinting scenario will be used. Weeks 3 and 4 will focus on a Group sprinting scenario, and Weeks 5 and 6 will use a Peloton sprinting scenario. The scenarios are written in Dutch, with the English translation available at the end of each scenario.

Twee-Renners Sprints

Week 0 - Scenario 0: Sprint vanuit de Eerste Positie

Stel je voor dat je in het laatste stuk van een race bent, met de finish in zicht. Je ligt aan de leiding; de tweede renner zit vlak achter je, het is niet de meest optimale positie. Terwijl je de laatste bocht nadert, weet je dat de eindsprint cruciaal is. Voel de grip van je stuur terwijl je soepel door de bocht gaat. Je bent als eerste uit de bocht, en de weg voor je is vrij, nog maar 200 meter tot de finish. Je hoort het gejuich van het publiek, hun opwinding voedt je vastberadenheid. Zonder aarzeling kom je uit het zadel en begint aan je sprint. De tweede renner probeert je in te halen, maar jij houdt je krachtige cadans vast, en duwt je maximale wattage. Focus op de finishlijn, houd je vorm strak en aerodynamisch. Elke pedaalslag telt. Voel de brandende pijn in je benen, maar duw door de pijn heen, wetende dat de overwinning binnen bereik is. De tweede renner komt dichterbij, maar jij gaat dieper, en vindt die extra energieboost. Steek de finishlijn over met een snelheidsexplosie, triomfantelijk en zegevierend.

- **Fysiek**: Voel de kracht en energie van elke pedaalslag terwijl je accelereert.
- **Omgeving**: Visualiseer de weg die versmalt naar de finishlijn.
- **Taak**: Focus op het behouden van een soepele en efficiënte sprint.
- **Timing**: Tim je eindsprint perfect.
- **Emotie**: Voel de adrenaline en vastberadenheid.

Week 1 - Scenario 1: Sprint vanuit de Tweede Positie
Stel je voor dat je in het laatste stuk van een race bent, met de finish in zicht. Je zit in de tweede positie, dicht achter de leidende renner. Terwijl je de laatste bocht nadert, weet je dat dit jouw moment is. Voel de grip van je stuur terwijl je soepel door de bocht gaat. De leidende renner neemt de bocht strak, en jij volgt dicht, behoudt je positie. De weg voor je versmalt, nog maar 200 meter tot de finish. Je hart bonst van opwinding terwijl je laag blijft, handen in de beugels, klaar om te reageren. Zodra de leidende

renner uit het zadel komt om te sprinten, volg je onmiddellijk, komt uit het zadel en geeft je maximale inspanning, je bent alert. De leidende renner probeert je tegen te houden, maar jouw vastberadenheid is sterker. Je voelt je snelheid toenemen, je benen pompen krachtig. Focus op je vorm, houd je sprint soepel en efficiënt. De finishlijn nadert snel. Je hoort het gejuich van het publiek, hun aanmoedigingen duwen je tot het uiterste. Met een laatste uitbarsting van energie, passeer je de leidende renner, je voorwiel komt voor. Steek de finishlijn over als winnaar, je harde werk en vastberadenheid betalen zich uit.

- **Fysiek**: Voel de kracht en energie van elke pedaalslag.
- **Omgeving**: Visualiseer de weg die versmalt naar de finishlijn.
- **Taak**: Focus op het behouden van een soepele en efficiënte sprint.
- **Emotie**: Voel de adrenaline en vastberadenheid.

Week 2 - Scenario 2: Vroege Sprint
Stel je voor dat je in het laatste stuk van een race bent, met de bijna finish in zicht. Jij en een andere renner liggen nek-aan-nek, beide vastberaden om te winnen. Terwijl je de laatste kilometer nadert, neem je de gedurfde beslissing om een vroege aanval te plaatsen en vroeg te sprinten. Je houdt je benen even stil zodat je achter de tegenstander komt. Om vervolgens je sprint keihard aan te kunnen trekken zodat hij niet direct in je wiel kan komen. Je verrast je concurrent. Je voelt de grip van je stuur terwijl je naar een zwaardere versnelling schakelt en uit het zadel komt. De weg voor je versmalt, je gaat weer zitten op het zadel maar blijft maximale kracht geven. De laatste bocht nadert en je weet dat na de bocht de finishlijn in zicht komt. Je neemt de bocht. Na de bocht kom je weer uit het zadel. Je benen branden van de inspanning, maar je duwt door, voelend de kracht van elke pedaalslag. De andere renner heeft gereageerd op jouw aanval, maar jij hebt een kleine voorsprong opgebouwd. Focus op het behouden van je sprint, houd je vorm aerodynamisch en soepel. Elke seconde telt. Het gejuich van het publiek wordt luider, en moedigt je aan. Het zicht van de finish boog geeft je extra kracht. Je concurrent komt dichterbij, maar jij behoudt je voorsprong, duwend met elke gram kracht die je nog hebt. De finishlijn is nog maar een paar meter weg. Met een laatste uitbarsting van energie, geef je alles wat je hebt. Steek de finishlijn over als winnaar, je vroege sprintstrategie betaalt zich briljant uit.

- **Fysiek**: Voel de kracht en energie van elke pedaalslag.
- **Omgeving**: Visualiseer de weg die versmalt naar de finishlijn.
- **Taak**: Focus op het behouden van een soepele en efficiënte sprint.
- **Timing**: Time je vroege sprint perfect.
- **Emotie**: Voel de adrenaline en vastberadenheid.

Groep Sprints vier renners

Week 3 - Scenario 3: Sprint vanuit Derde Positie met een Tactisch Wachten
Stel je voor dat je in het laatste stuk van een wedstrijd bent, met de finish in zicht, je bevindt je in de kopgroep. De groep bestaat uit vier renners. Je zit momenteel in de derde positie binnen deze kopgroep van vier renners. Terwijl je de laatste bocht nadert, beslis je dat je de sprint niet gaat aantrekken maar zodra iemand gaat, dat je dan direct mee probeert te gaan. Je neemt de bocht. Je doet je handen alvast naar de beugels en bent alert. Je behoudt je positie, je komt uit de bocht met nog 200 meter te gaan. De weg voor je versmalt, de finishlijn komt in zicht. Je hart bonst van opwinding en vastberadenheid. Je blijft wachten. blijf alert. Je blijft laag zitten op je zadel, je behoudt een efficiënte en krachtige cadans. De renner aan kop komt uit het zadel en begint te sprinten. Je reageert onmiddellijk, blijft zitten en gefocust, houdt je cadans hoog. De tweede renner reageert ook onmiddellijk en begint ook te sprinten, en je kan in zijn wiel blijven, energie besparend door in hun slipstream te blijven. Focus op het behouden van je positie, houd je vorm strak en aerodynamisch. Het gejuich van het publiek wordt luider, hun energie duwt je vooruit. Je voelt de adrenaline door je aderen stromen, je aansporend om harder te duwen. De vierde renner probeert je in te halen. Maar dit sta jij niet toe. Op dat moment beslis je dat

jij echt je laatste kracht gaat inzetten en er nog eens een klap op geeft. Met nog 100 meter te gaan, voel je dat het moment juist is, de afstand is niet groot tot de finish. Je komt uit het zadel en begint je sprint nu met maximale kracht. Voel de brandende pijn in je benen, maar duw door de pijn heen, wetende dat de overwinning binnen bereik is. Je benen pompen krachtig, stuwen je vooruit bij elke slag. Met de finishlijn snel naderend, geef je alles wat je hebt. Je zoekt naar ruimte waar je de renners kunt passeren, je gaat aan de linkerkant van de weg. Je passeert de renner in tweede positie, en nadert de koploper. De laatste paar meters doen het meeste pijn, maar je graaft diep, vindt die extra energieboost. Met een laatste uitbarsting passeer je de koploper net voor de finishlijn. Steek de finishlijn over als winnaar, je tactische wachtstrategie betaalt zich briljant uit. Stel je voor dat je je armen in triomf omhoog steekt terwijl je de lijn oversteekt.

- **Fysiek**: Voel de kracht en energie van elke pedaalslag. Pijn
- **Omgeving**: Visualiseer de weg die versmalt naar de finishlijn, zoekend naar ruimte, wetend waar de andere renners zich bevinden. De vierde renner die van achter komt.
- **Taak**: Focus op het behouden van een soepele en efficiënte sprint. Houding en wachten totdat je begint met sprinten.
- **Timing**: Time je sprint perfect.
- **Emotie**: Voel de adrenaline en vastberadenheid.

Week 4 - Scenario 4: Sprint vanuit de Laatste Positie met een Verrassingsaanval
Stel je voor dat je in het laatste stuk van een race/wedstrijd bent, met de finish in niet ver meer. Je zit in de vierde en laatste positie binnen een kopgroep van vier renners. Terwijl je de laatste 400 meter nadert, besluit je een verrassingsaanval te doen. De welgenoemde alles of niets poging. Het was een taaie wedstrijd, je bent moe en je zit hoog in je ademhaling. Het is warm buiten. Je weet en ziet dat de andere renners ook niet meer zo fris zijn maar met de finish in zicht kunnen veel mensen toch nog veel dus je moet alert blijven. Je voelt de grip van je stuur terwijl je naar een hogere versnelling schakelt, je klaar maken voor de eindsprint. Je hebt een voordeel dat je achteraan zit. De andere renners zijn gefocust op elkaar, niet verwachtend dat jij zal aanvallen. De weg voor je word breder, de finishlijn en finish boog komen in zicht. Je hart bonst van opwinding en vastberadenheid. Je begint je sprint, de andere renners verrassend. Je benen pompen krachtig, stuwen je vooruit bij elke slag. Focus op het behouden van je sprint, houd je vorm strak en aerodynamisch. Je hoort de andere renners reageren. Maar jij laat je niet afleiden. Het gejuich van het publiek wordt luider, hun energie duwt je vooruit. Je voelt de adrenaline door je aderen stromen, je aansporend om harder te duwen. Met een laatste uitbarsting van energie, geef je alles wat je hebt. Steek de finishlijn over als winnaar, je verrassingsaanval strategie betaalt zich briljant uit. Stel je voor dat je je armen in triomf omhoog steekt terwijl je de lijn oversteekt.
Bedenk zelf hoe je de finish oversteekt: Je kan staand blijven sprinten tot de streep. Je moet gaan zitten maar je stort niet zittend in. Dit doet wel erg veel pijn, maar kan wel.

- **Fysiek**: Voel de kracht en energie van elke pedaalslag.
- **Omgeving**: Visualiseer de weg die versmalt naar de finishlijn.
- **Taak**: Focus op het behouden van een soepele en efficiënte sprint.
- **Timing**: Time je verrassingsaanval perfect.
- **Leren**: Put kracht uit eerdere race-ervaringen.
- **Emotie**: Voel de adrenaline en vastberadenheid.

Peloton Sprints

Week 5 - Scenario 5: Sprint vanuit Derde Positie met het Kiezen van de Juiste Lead-out
Stel je voor dat je in het laatste stuk van een wedstrijd bent, met de finish bijna in zicht. Je zit vrij voorin het peloton die de hele breedte van de weg in beslag neemt, de weg is niet heel erg breed. Voor je zit nog 1 teamgenoot (mocht je nooit met een team of duo samenstelling rijden, mag je dit weglaten).

Zowel aan de linker kant van de weg als aan de rechter kant van de weg vormt er een sprint trein. *Kies of je links of rechts zit* Je zit in de deze sprint trein in de derde positie. Focus op het houden van het wiel en let op dat je niet ingesloten raakt/of kan raken. *Denk na over hoe je bijvoorbeeld ingesloten zou kunnen raken en hoe je dit eventueel kan voorkomen* Voel de grip van je stuur terwijl je een strakke formatie aanhoudt, je handen bij de shifters zodat je ieder moment kan reageren. Visualiseer de weg naar de finishlijn, ongeveer 400 meter verderop na een bocht naar links. Het peloton komt snel dichterbij, en je moet je sprint perfect timen. (Mocht je bekend zijn met de Hanhofweg vanaf de kant van de Beuningerstraat, zou je dit als locatie kunnen gebruiken. Dit loopt natuurlijk wel op. Mocht je dat niet fijn vinden, mag je ook natuurlijk een andere vlakke voorstelling maken.) Je blijft wachten totdat iemand anders de sprint aangaat. Je moet het juiste moment kiezen om je sprint te lanceren en er voorbij te gaan. Voel de adrenaline en de eventuele zenuwen door je aderen stromen terwijl je versnelt en richting de finish gaat. Mocht je last van adrenaline en zenuwen hebben haal dan diep adem en focus je op je taak om op te letten dat je niet ingesloten raakt en de sprint direct zou kunnen volgen. De renner op de kop van de linker trein initieert de sprint. De sprint trein aan de rechter kant begint nu ook met sprinten. Je behoudt voor even je positie, om energie te besparen. Zodra je ziet dat de twee treinen naar elkaar toekomen probeer je middendoor te sprinten. De tweede renner in de linker trein neemt de kop over en verhoogt het tempo. Jij rijd daarnaast. Met nog 100 meter te gaan, loopt de bocht naar links waardoor jij van iets verder moet komen door de buiten bocht. Nu voel je het moment, hier moet je er voorbij als je wil winnen. Je probeert alles eruit te halen en nog een versnelling in te zetten. Je benen pompen met explosieve kracht, stuwen je vooruit. De renners achter je geven alles wat ze hebben, maar ze komen jou niet voorbij. Focus op het behouden van een krachtige sprint waar je niet verslapt, houd je cadans hoog en je vorm aerodynamisch. Voel de brandende pijn in je benen, maar duw door de pijn heen in de laatste versnelling, wetende dat de overwinning binnen bereik is. Er staan langs de kant publiek om je aan te moedigen maar je hoort het niet omdat je al je energie nodig hebt in die sprint. Focus op de finishlijn. Met de finishlijn snel naderend, geef je alles wat je hebt. Je steekt de finishlijn nipt eerder over en je bent de winnaar. Het niet opgeven en de laatste versnelling betalen zich uit.

- **Fysiek**: Voel je adrenaline, je zenuwen, je pijn.
- **Omgeving**: Visualiseer de weg.
- **Taak**: Focus op het behouden van een krachtige sprint.
- **Timing**: Voel het verstrijken van de tijd terwijl je de finishlijn nadert, misschien de momenten voordat de sprint echt begint en je nog zenuwachtig bent.
- **Leren**: Put kracht uit eerdere race-ervaringen.
- **Emotie**: Voel de adrenaline.
- **Perspectief**: Beeld je in dat jij de finishlijn als eerste oversteekt.

Week 6 - Scenario 6: Sprint vanuit 20e Positie
Stel je voor dat je in het laatste stuk van een race bent, met de finish op ongeveer 1km. Je zit redelijk voorin het peloton ongeveer rond de 20e positie, maar verre van 'ideaal' gepositioneerd. Je bevindt je aan de rechterkant van de weg achter een renner van een ander team aan de voorkant van de 'buik' van het peloton. Aan de kop van het peloton rijd aan de linkerzijde een trein van zes renners gevolgd door het peloton.

Voel de grip van je stuur terwijl je je positie behoudt. Je weet dat schuiven lastig word op de rechte stukken nu de snelheid hoog ligt. Voor het einde van de wedstrijd ligt er nog één rotonde rechtdoor in de route. Dit kan een laatste mogelijkheid zijn om als de snelheid hoog ligt nog veel plaatsen te kunnen winnen.

(Het peloton kan namelijk splitsen op een rotonde dat de ene helft het peloton links de rotonde neemt en andere deel rechts. Als dus een kant sneller rijd kan je hier plaatsen mee winnen.)

Visualiseer de weg voor je waar je een rotonde nadert, ongeveer 100 meter verderop. Het peloton aan de linkerkant van de weg is dicht opeengepakt, waardoor het moeilijk is om door het midden naar voren te komen.

Je besluit de rotonde aan de rechterkant te nemen. Voel de adrenaline door je aderen stromen terwijl je versnelt, elke pedaalslag die je vooruit stuwt met kracht en vastberadenheid. Enkele andere renners besluiten de gok ook te nemen en gaan ook via rechts de rotonde. Doordat het peloton links rijd is het wel een bewuste keuze en rijd je met een aantal renners dus hard via de rechterkant. Na de rotonde bevind je je op ongeveer de 8e positie. De situatie is veranderd naar twee rijen renners achterelkaar als peloton. Door de snelheid en de rotonde is het peloton lang gerekt. Let op je positie, houd rekening mee dat sommige rijders mogelijk uit kunnen sturen. Blijf alert. Je klaarmaken voor de eindsprint die straks komt. Voor je stuurt een renner uit. Je hebt geen tijd om te balen want je anticipeert direct en versnelt direct om deze opening te vullen. Een andere renner ziet de opening ook, maar jij bent sneller en neemt het initiatief. Hierdoor versnel je zittend. Op het moment dat je met een hogere snelheid aansluit beginnen de renners voor je te sprinten. Maar omdat jij al bezig was met je zittende versnelling kan je zittend nog langer bijblijven. Hiermee kan je je krachten voor de staande sprint nog even sparen. Je houd het overzicht zoek naar mogelijke ruimte als je straks ook je staande sprint kan inzetten en dat je renners kan passeren. Je vind een vrije lijn voor je. *Bedenk hoe dat eruit kan zien* Je komt uit het zadel en ontketent je maximale kracht. Focus op het behouden van een krachtige sprint, houd je cadans hoog en je vorm aerodynamisch. Omdat je je sprint later inzet ligt je snelheid hoger. Voel de brandende pijn in je benen, maar duw door de pijn heen, wetende dat de overwinning binnen bereik is als je niet opgeeft. Het gejuich van het publiek wordt luider, hun energie duwt je vooruit. Je voelt de adrenaline door je aderen stromen, je aansporend om harder te duwen. Met de finishlijn snel naderend, geef je alles wat je hebt. Je passeert de renners aan de linkerkant van de weg, je snelheid geeft je het voordeel. De laatste meters zijn een waas van inspanning en vastberadenheid. Steek de finishlijn over als winnaar.

- **Fysiek**: Voel de kracht en energie van elke pedaalslag.
- **Omgeving**: Visualiseer de weg waar je een rotonde nadert.
- **Taak**: Focus op het behouden van een soepele en efficiënte sprint.
- **Timing**: Voel het verstrijken van de tijd terwijl je de finishlijn nadert.
- **Leren**: Put kracht uit eerdere race-ervaringen.
- **Emotie**: Voel de adrenaline en vastberadenheid.
- **Perspectief**: Beeld je in dat je voor ruimte zoekt.

English Translation:

Two-Rider Sprints

Week 0 - Scenario 0: Sprint from the First Position

Imagine you're in the final stretch of a race, with the finish line in sight. You're in the lead; the second rider is right behind you, not in the most optimal position. As you approach the last corner, you know the final sprint is crucial. Feel the grip of your handlebars as you smoothly take the corner. You're the first out of the bend, with a clear road ahead and only 200 meters to the finish. You hear the crowd's cheers, their excitement fueling your determination. Without hesitation, you get out of the saddle and start your sprint. The second rider tries to catch up, but you keep a powerful cadence, pushing your maximum wattage. Focus on the finish line, keeping your form tight and aerodynamic. Every pedal stroke counts. Feel the burning pain in your legs, but push through, knowing victory is within reach. The second rider closes in, but you dig deeper, finding that extra energy boost. Cross the finish line with an explosive burst of speed, triumphant and victorious.

- **[P] Physical:** Feel the strength and energy in each pedal stroke as you accelerate.
- **[E] Environment:** Visualize the road narrowing towards the finish line.
- **[T] Task:** Focus on maintaining a smooth and efficient sprint.
- **[T] Timing:** Time your final sprint perfectly.
- **[E] Emotion:** Feel the adrenaline and determination.

Week 1 - Scenario 1: Sprint from the Second Position
Imagine you're in the final stretch of a race, with the finish line in sight. You're in the second position, close behind the leading rider. As you approach the last corner, you know this is your moment. Feel the grip of your handlebars as you smoothly take the bend. The leader takes the corner tightly, and you follow closely, holding your position. The road narrows, with only 200 meters left to the finish. Your heart pounds with excitement as you stay low, hands in the drops, ready to react. As soon as the leader gets out of the saddle to sprint, you respond immediately, getting out of the saddle and giving your maximum effort, alert. The leader tries to fend you off, but your determination is stronger. You feel your speed increase, your legs pumping powerfully. Focus on your form, keeping your sprint smooth and efficient. The finish line approaches quickly. You hear the crowd's cheers, their encouragement pushing you to the limit. With one last burst of energy, you overtake the leader, your front wheel pulling ahead. Cross the finish line as the winner; your hard work and determination pay off.

- [P] **Physical:** Feel the strength and energy in each pedal stroke.
- [E] **Environment:** Visualize the road narrowing towards the finish line.
- [T] **Task:** Focus on maintaining a smooth and efficient sprint.
- [E] **Emotion:** Feel the adrenaline and determination.

Week 2 - Scenario 2: Early Sprint
Imagine you're in the final stretch of a race, with the finish line almost in sight. You and another rider are neck and neck, both determined to win. As you approach the final kilometer, you make the bold decision to go for an early attack and start sprinting. You briefly coast to get behind your opponent, then power up your sprint so they can't immediately follow in your wheel. You catch your competitor by surprise. Feel the grip of your handlebars as you shift to a higher gear and get out of the saddle. The road narrows as you sit back down but keep pushing with maximum force. The last corner approaches, and you know that the finish line will be in sight after the bend. You take the corner, then get out of the saddle again. Your legs burn from the effort, but you push through, feeling the power in each pedal stroke. The other rider has reacted to your attack, but you've built a small lead. Focus on maintaining your sprint, keeping your form aerodynamic and smooth. Every second counts. The cheers of the crowd grow louder, urging you on. The sight of the finish arch gives you extra strength. Your competitor closes in, but you maintain your lead, pushing with every ounce of strength. With just a few meters left, you give it everything you've got. Cross the finish line as the winner; your early sprint strategy pays off brilliantly.

- [P] **Physical:** Feel the strength and energy in each pedal stroke.
- [E] **Environment:** Visualize the road narrowing towards the finish line.
- [T] **Task:** Focus on maintaining a smooth and efficient sprint.
- [E] **Emotion:** Feel the adrenaline and determination.

Group Sprints Four Riders

Week 3 - Scenario 3: Sprint from Third Position with Tactical Patience
Imagine you're in the final stretch of a race, the finish line is in sight, and you're in the leading group. There are four riders, and you're currently in the third position. As you approach the final corner, you decide not to initiate the sprint yourself but to go immediately when someone else does. You take the corner, hands ready on the drops, fully alert. You hold your position, exiting the corner with 200 meters to go. The road narrows, and the finish line approaches. Your heart pounds with excitement and determination. You stay patient, stay alert. You remain low in the saddle, maintaining an efficient and powerful cadence. The lead rider comes out of the saddle and starts sprinting. You respond instantly, staying seated and focused, keeping your cadence high. The second rider reacts immediately as well and begins to sprint. You stay in his wheel, saving energy by staying in his slipstream. Focus on maintaining your position, keeping your form tight and aerodynamic. The crowd's cheers grow louder, fueling you forward. You feel adrenaline coursing through you, pushing you to go harder. The fourth rider tries

to overtake you. But you don't allow it. At that moment, you decide to give it everything you've got. With 100 meters to go, you sense the timing is right; the distance to the finish is short. You get out of the saddle and begin your sprint at full power. Feel the burning pain in your legs, but push through it, knowing the win is within reach. Your legs pump powerfully, driving you forward with every stroke. With the finish line rapidly approaching, you give it all you've got. You look for space to pass, moving to the left side of the road. You pass the rider in second place and approach the leader. The final meters hurt the most, but you dig deep, finding that last burst of energy. With a final surge, you pass the leader just before the finish line. Cross the finish line as the winner—your tactical patience pays off brilliantly. Imagine raising your arms in triumph as you cross the line.

- [P] **Physical:** Feel the strength and energy of each pedal stroke. Pain.
- [E] **Environment:** Visualize the road narrowing toward the finish line, seeking space, and being aware of where the other riders are. The fourth rider coming from behind.
- [T] **Task:** Focus on maintaining a smooth and efficient sprint. Posture and waiting until you start sprinting.
- [T] **Timing:** Time your sprint perfectly.
- [E] **Emotion:** Feel the adrenaline and determination.

Week 4 - Scenario 4: Sprint from Last Position with a Surprise Attack Imagine you're in the final stretch of a race, the finish not far off. You're in the fourth and last position within a lead group of four riders. As you approach the last 400 meters, you decide to make a surprise attack—the all-or-nothing move. It's been a tough race; you're tired, breathing heavily. It's warm outside. You know and see that the other riders are also fatigued, but with the finish in sight, many can still give a lot, so you stay alert. You feel the grip of your handlebars as you shift to a higher gear, preparing for the final sprint. Your position at the back is an advantage. The others are focused on each other, not expecting you to attack. The road widens, and the finish line and arch come into view. Your heart pounds with excitement and determination. You start your sprint, taking the others by surprise. Your legs pump powerfully, driving you forward with every stroke. Focus on sustaining your sprint, keeping your form tight and aerodynamic. You hear the other riders react, but you stay focused. The crowd's cheers grow louder, their energy pushing you forward. You feel the adrenaline flowing through your veins, spurring you to push harder. With one last burst of energy, you give it all you've got. Cross the finish line as the winner—your surprise attack strategy pays off brilliantly. Imagine raising your arms in triumph as you cross the line.
Decide how you'll cross the finish line:
You can stay standing and sprint all the way to the line. You may need to sit but not collapse in the saddle. It's painful, but manageable.

- [P] **Physical:** Feel the strength and energy of each pedal stroke.
- [E] **Environment:** Visualize the road narrowing toward the finish line.
- [T] **Task:** Focus on maintaining a smooth and efficient sprint.
- [T] **Timing:** Time your surprise attack perfectly.
- [L] **Learning:** Draw strength from past race experiences.
- [E] **Emotion:** Feel the adrenaline and determination.

Peloton Sprints

Week 5 - Scenario 5: Sprint from Third Position, Choosing the Right Lead-Out
Imagine you're in the final stretch of a race, with the finish line almost in sight. You're near the front of the peloton, which takes up the full width of a narrow road. Ahead of you is one teammate (if you typically race alone, you may imagine without them). Both on the left and right sides of the road, sprint trains are forming.

Choose whether you're on the left or right train. You're in the third position in this train. Focus on staying on the wheel in front, ensuring you don't get boxed in. Think about how you might get boxed in and ways to avoid it. Feel the grip of your handlebars as you maintain a tight formation, with your hands by the shifters, ready to react instantly. Visualize the road leading to the finish, about 400 meters away after a left turn. The peloton is closing in fast, and you'll need to time your sprint perfectly.
(If you're familiar with the Hanhofweg from the Beuningerstraat side, imagine it as the location; it has a slight incline. If that's challenging, you can also visualize a flat course.) You wait until someone else starts the sprint. You'll have to choose the right moment to launch yours and overtake. Feel the adrenaline and any nerves coursing through you as you accelerate toward the finish. If you feel the nerves and adrenaline building, take a deep breath and stay focused on staying out of a box-in and reacting quickly to the sprint.
The rider at the front of the left train initiates the sprint, and the train on the right begins sprinting as well. You hold your position briefly to save energy. When you see both trains start converging, you aim to sprint through the middle. The second rider in the left train takes the lead, increasing the speed. You move up alongside.
With only 100 meters to go, the road veers left, forcing you to take the outer curve. Now's the moment to pass if you want to win. You push with everything you have and shift into the highest gear. Your legs pump explosively, propelling you forward. The riders behind give their all, but none pass you. Focus on maintaining a powerful sprint, keeping your cadence high and your form aerodynamic.
Feel the burn in your legs, but push through it, knowing victory is within reach. Crowds cheer along the road, though you can't hear them—every ounce of your focus is on the finish. As the finish line nears, you give it everything you've got. You cross just ahead and claim victory. Your persistence and final burst of speed pay off.

- **[P] Physical:** Feel the adrenaline, nerves, and pain.
- **[E] Environment:** Visualize the road.
- **[T] Task:** Focus on maintaining a powerful sprint.
- **[T] Timing:** Sense the passage of time as you near the finish, including any pre-sprint nerves.
- **[L] Learning:** Draw strength from past race experiences.
- **[E] Emotion:** Feel the adrenaline.
- **[P] Perspective:** Picture yourself crossing the finish line first.

Week 6 - Scenario 6: Sprint from 20th Position
Imagine you're in the last part of a race, with the finish line about 1 km ahead. You're positioned near the front of the peloton, around 20th, though not ideally placed. You're on the right side of the road behind a rider from another team, at the head of the peloton's "belly." The peloton's front left is led by a train of six riders, followed closely by the pack.
Feel your grip on the handlebars as you hold your position. The high speed makes shifting forward on straight sections difficult. Near the end, there's one roundabout that could be a final chance to gain places if the speed holds high.
(The peloton may split at the roundabout, with one group going left and the other right. If one side is faster, you could gain positions.) Visualize the road ahead as the roundabout nears, about 100 meters away. The left side of the peloton is densely packed, making it hard to push through the middle.
You decide to take the roundabout on the right. Adrenaline surges as you accelerate, each pedal stroke driving you forward with strength and determination. A few other riders make the same move, taking the right side. With the peloton on the left, you drive hard on the right, emerging around 8th position after the roundabout. The peloton stretches into two single-file lines due to the speed and roundabout. Stay alert, aware that some riders might swerve off. Prepare for the final sprint coming soon.
The rider ahead swerves, opening a gap. Without hesitation, you react immediately and speed up to fill it. Another rider sees it too, but you act first, taking the initiative. You increase speed while seated. As you approach the riders ahead, they start sprinting, but you hold your seated acceleration longer, conserving energy for a standing sprint. Stay focused on the gaps, searching for space to begin your standing sprint and pass other riders. You find a clear path ahead. Imagine what this looks like.

You rise out of the saddle and unleash your full power. Focus on keeping a strong sprint, high cadence, and aerodynamic form. Because of your delayed sprint, your speed is higher. Feel the searing pain in your legs, pushing through it, knowing victory is within reach if you don't give up.
The cheering crowd's energy pushes you onward as adrenaline surges through you, urging you to dig deeper. With the finish line fast approaching, give everything you've got. You pass riders on the left side, using your speed advantage. The final meters blur with effort and resolve. Cross the finish line as the winner.

- **[P] Physical:** Feel the power and energy of each pedal stroke.
- **[E] Environment:** Visualize the road and roundabout ahead.
- **[T] Task:** Focus on a smooth and efficient sprint.
- **[T] Timing:** Sense time passing as you approach the finish.
- **[L] Learning:** Draw strength from past race experiences.
- **[E] Emotion:** Feel the adrenaline and determination.
- **[P] Perspective:** Imagine searching for space.

Appendix J. EEG Cap Procedure Protocol

The EEG cap procedure is taken from the tutorial video from G.tec, the manufacturer of the Unicorn Hybrid EEG set.
YouTube link: `https://www.youtube.com/watch?v=UVVUJTwvGnw&t=129s&ab_channel=gtecmedicalengineering`

1. **Measuring the Head:**
   - Measure the circumference of the participant's head to determine the appropriate cap size.
   - Note the location of specific landmarks on the scalp, such as the nasion (bridge of the nose), inion (bump on the back of the head), and preauricular points (just above the ears).
2. **Cap Placement:**
   - Position the EEG cap on the participant's head, ensuring that the cap is centred and aligned with the landmarks measured earlier.
   - Adjust the straps or elastic bands on the cap to achieve a snug but comfortable fit.
   - Ensure that the cap covers the entire scalp, with the electrodes evenly distributed across the head.
3. **Electrode Placement:**
   - Identify if the eight electrodes are in the correct position placed on the cap.
   - Gently press each electrode against the scalp to ensure good contact without causing discomfort.
   - Verify that all electrodes are securely attached and that there are no loose connections.
4. **Final Checks:**
   - Double-check the cap placement and electrode connections to ensure accuracy.
   - Verify that the participant is comfortable and ready to proceed with the EEG recording.
   - If necessary, adjust the cap or electrodes to address any issues or discomfort reported by the participant.
5. **Recording:**
   - Once the EEG cap is properly positioned and electrodes are secured, begin the recording session according to the specified protocol.
   - Monitor the EEG signal quality throughout the recording session and make any necessary adjustments to optimize data collection.

Appendix K. Validation Indicator Results

File Name	Total Samples	Bad Quality Count	Bad Quality Percentage
EEG_W0_P01.csv	202488	792	0.39%
EEG_W0_P02.csv	174536	804	0.46%
EEG_W0_P03.csv	144272	1263	0.88%
EEG_W0_P04.csv	154680	0	0.00%
EEG_W0_P05.csv	168616	0	0.00%
EEG_W1_P01.csv	131344	0	0.00%
EEG_W1_P02.csv	121288	0	0.00%
EEG_W1_P03.csv	114984	0	0.00%
EEG_W1_P04.csv	120064	0	0.00%
EEG_W1_P05.csv	147896	16178	10.94%
EEG_W2_P01.csv	134056	0	0.00%
EEG_W2_P02.csv	140288	0	0.00%
EEG_W2_P03.csv	114856	39	0.03%
EEG_W2_P04.csv	188320	2341	1.24%
EEG_W2_P05.csv	132704	6	0.00%
EEG_W3_P01.csv	149512	0	0.00%
EEG_W3_P02.csv	182664	0	0.00%
EEG_W3_P03.csv	130368	0	0.00%
EEG_W3_P04.csv	167448	0	0.00%
EEG_W3_P05.csv	149704	0	0.00%
EEG_W4_P01.csv	136416	0	0.00%
EEG_W4_P02.csv	138416	0	0.00%
EEG_W4_P03.csv	122504	0	0.00%
EEG_W4_P04.csv	152816	0	0.00%
EEG_W4_P05.csv	113704	0	0.00%
EEG_W5_P01.csv	158568	0	0.00%
EEG_W5_P02.csv	159320	0	0.00%
EEG_W5_P03.csv	129464	0	0.00%
EEG_W5_P04.csv	176864	0	0.00%
EEG_W5_P05.csv	152280	0	0.00%
EEG_W6_P01.csv	159296	0	0.00%
EEG_W6_P02.csv	173200	0	0.00%
EEG_W6_P03.csv	152408	0	0.00%
EEG_W6_P04.csv	168032	0	0.00%
EEG_W6_P05.csv	149504	0	0.00%

Appendix L. Excluded Files List

Table L.1: List of EEG files that are not used in the study.

File Name	Description
W1_P03_EC_eeg.fif	
W1_P04_EC_eeg.fif	Whole week 1 for Participant 4
W1_P04_GS_eeg.fif	
W1_P04_US_eeg.fif	
W1_P05_EC_eeg.fif	All below is Participant 5
W1_P05_GS_eeg.fif	Whole week 1 for Participant 5
W1_P05_US_eeg.fif	
W2_P05_EC_eeg.fif	
W2_P05_US_eeg.fif	
W4_P05_EC_eeg.fif	Whole week 4 for Participant 5
W4_P05_GS_eeg.fif	
W4_P05_US_eeg.fif	
W5_P05_EC_eeg.fif	

Table L.2: Summary of file counts and exclusions.

Variable	Category	N	Percentage (%)
All Files	Total	105	100
Files per Participant	Total	35	100
Excluded Files	Total	13	11.4
P03		1	2.86
P04		3	8.67
P05		9	25.71

Appendix M. Bad Channels List

Table M.1: Bad channel data summary for all files and minus excluded files.

Variable	Bad Channel	Total Files	N Bad Channel Files	Percentage (%)
All Files	None	105	38	36.19
	Fz	105	17	16.19
	C3	105	38	36.19
	Cz	105	34	32.38
	C4	105	19	18.10
	Pz	105	39	37.14
	PO7	105	23	21.90
	Oz	105	39	37.14
	PO8	105	29	27.62
Minus Excluded Files	None	92	38	41.30
	Fz	92	4	4.35
	C3	92	25	27.17
	Cz	92	21	22.83
	C4	92	6	6.52
	Pz	92	26	28.26
	PO7	92	10	10.87
	Oz	92	26	28.26
	PO8	92	16	17.36

Table M.2: Bad channel data summary for weeks, participants, and events.

Variable	**Category**	**Total Files**	**Bad Channel Files**	**Percentage (%)**
Week	Week 0	15	11	73.33
	Week 1	15	15	100
	Week 2	15	10	66.67
	Week 3	15	8	53.33
	Week 4	15	12	80.00
	Week 5	15	9	60.00
	Week 6	15	2	13.33
Participant	P01	21	13	61.90
	P02	21	17	80.95
	P03	21	14	66.67
	P04	21	5	23.81
	P05	21	18	85.71
Event	EC	35	22	62.86
	GS	35	23	65.71
	US	35	21	60.00
Week (minus excluded files)	Week 0	15	11	73.33
	Week 1	8	8	100
	Week 2	13	8	61.54
	Week 3	15	8	53.33
	Week 4	12	9	75.00
	Week 5	14	8	57.14
	Week 6	15	2	13.33
Participant (minus excluded files)	P01	21	13	61.90
	P02	21	17	80.95
	P03	20	13	65.00
	P04	18	2	11.11
	P05	12	9	75.00
Event (minus excluded files)	EC	29	16	55.17
	GS	32	21	65.63
	US	31	17	54.84

Index	**File Name**	**Bad Channels**
0	W0_P01_EC_eeg.fif	Cz
1	W0_P01_GS_eeg.fif	None
2	W0_P01_US_eeg.fif	None
3	W0_P02_EC_eeg.fif	Oz
4	W0_P02_GS_eeg.fif	C3, PO8
5	W0_P02_US_eeg.fif	C3, PO8
6	W0_P03_EC_eeg.fif	Oz, PO8
7	W0_P03_GS_eeg.fif	Oz
8	W0_P03_US_eeg.fif	Oz
9	W0_P04_EC_eeg.fif	None
10	W0_P04_GS_eeg.fif	PO7
11	W0_P04_US_eeg.fif	None
12	W0_P05_EC_eeg.fif	Cz, Oz, C3, Pz
13	W0_P05_GS_eeg.fif	Cz, C3, Fz, Pz
14	W0_P05_US_eeg.fif	C3, Cz, Pz
15	W1_P01_EC_eeg.fif	Oz
16	W1_P01_GS_eeg.fif	Oz
17	W1_P01_US_eeg.fif	Oz
18	W1_P02_EC_eeg.fif	C3, Pz

Index	File Name	Bad Channels
19	W1_P02_GS_eeg.fif	C3, Pz
20	W1_P02_US_eeg.fif	Pz, C3
21	W1_P03_EC_eeg.fif	C3, Pz, PO8, PO7, Oz, C4, Cz, Fz
22	W1_P03_GS_eeg.fif	C3, Pz, PO7, Oz, PO8
23	W1_P03_US_eeg.fif	C3, Cz, Pz, Oz, PO7, PO8
24	W1_P04_EC_eeg.fif	PO8, PO7, Oz, Pz, C4, Cz, C3, Fz
25	W1_P04_GS_eeg.fif	PO8, Pz, PO7, Oz, C4, Cz, C3, Fz
26	W1_P04_US_eeg.fif	PO7, PO8, Oz, Pz, C4, Cz, C3, Fz
27	W1_P05_EC_eeg.fif	PO8, PO7, Oz, Pz, Cz, C3, Fz, C4
104	W1_P05_GS_eeg.fif	PO8, PO7, Oz, Pz, Cz, C3, Fz, C4
28	W1_P05_US_eeg.fif	PO8, PO7, Oz, Pz, Cz, C3, Fz, C4
29	W2_P01_EC_eeg.fif	Pz
30	W2_P01_GS_eeg.fif	PO8
31	W2_P01_US_eeg.fif	Pz, PO8, Oz
32	W2_P02_EC_eeg.fif	None
33	W2_P02_GS_eeg.fif	None
34	W2_P02_US_eeg.fif	None
35	W2_P03_EC_eeg.fif	Pz
36	W2_P03_GS_eeg.fif	Pz
37	W2_P03_US_eeg.fif	Pz
38	W2_P04_EC_eeg.fif	None
39	W2_P04_GS_eeg.fif	Pz
40	W2_P04_US_eeg.fif	None
41	W2_P05_EC_eeg.fif	C4, PO8, Oz, PO7, Pz, Cz, C3, Fz
42	W2_P05_GS_eeg.fif	C4, Oz, PO7, Pz, Cz
43	W2_P05_US_eeg.fif	C4, Cz, Pz, PO7, Oz, PO8, Fz, C3
44	W3_P01_EC_eeg.fif	None
45	W3_P01_GS_eeg.fif	Oz
46	W3_P01_US_eeg.fif	Oz
47	W3_P02_EC_eeg.fif	C4, PO8, Cz, Pz, PO7, Oz
48	W3_P02_GS_eeg.fif	Cz, C4, PO8, Oz, PO7, Pz
49	W3_P02_US_eeg.fif	C4, Cz, PO8, Pz
50	W3_P03_EC_eeg.fif	None
51	W3_P03_GS_eeg.fif	None
52	W3_P03_US_eeg.fif	None
53	W3_P04_EC_eeg.fif	None
54	W3_P04_GS_eeg.fif	None
55	W3_P04_US_eeg.fif	None
56	W3_P05_EC_eeg.fif	C3, Pz, C4, Oz, PO8
57	W3_P05_GS_eeg.fif	C3, Cz, Pz, C4, Fz, Oz, PO8
58	W3_P05_US_eeg.fif	Oz, Pz, C3, Cz
59	W4_P01_EC_eeg.fif	C3, PO7
60	W4_P01_GS_eeg.fif	Cz, PO7, C3, Fz
61	W4_P01_US_eeg.fif	Cz, PO7, C3, Fz
62	W4_P02_EC_eeg.fif	Cz, Pz, Oz
63	W4_P02_GS_eeg.fif	Cz, Pz, Oz
64	W4_P02_US_eeg.fif	Cz
65	W4_P03_EC_eeg.fif	C3
66	W4_P03_GS_eeg.fif	PO8, C3
67	W4_P03_US_eeg.fif	C3, PO8
68	W4_P04_EC_eeg.fif	None
69	W4_P04_GS_eeg.fif	None
70	W4_P04_US_eeg.fif	None
71	W4_P05_EC_eeg.fif	PO8, Oz, PO7, Pz, Cz, C3, Fz, C4
72	W4_P05_GS_eeg.fif	Cz, Fz, C3, C4, PO7, Pz, Oz, PO8

Index	File Name	Bad Channels
73	W4_P05_US_eeg.fif	Fz, PO8, PO7, Oz, Pz, C4, Cz, C3
74	W5_P01_EC_eeg.fif	C3, Pz, PO8
75	W5_P01_GS_eeg.fif	None
76	W5_P01_US_eeg.fif	None
77	W5_P02_EC_eeg.fif	Cz, Oz, C3
78	W5_P02_GS_eeg.fif	Cz, Oz, Pz
79	W5_P02_US_eeg.fif	Cz, Oz, Pz
80	W5_P03_EC_eeg.fif	C3
81	W5_P03_GS_eeg.fif	C3, PO7
82	W5_P03_US_eeg.fif	None
83	W5_P04_EC_eeg.fif	None
84	W5_P04_GS_eeg.fif	None
85	W5_P04_US_eeg.fif	None
86	W5_P05_EC_eeg.fif	C3, Oz, PO8, Pz, PO7, C4, Fz, Cz
87	W5_P05_GS_eeg.fif	C3, Oz
88	W5_P05_US_eeg.fif	C3, Oz, PO8
89	W6_P01_EC_eeg.fif	None
90	W6_P01_GS_eeg.fif	None
91	W6_P01_US_eeg.fif	None
92	W6_P02_EC_eeg.fif	None
93	W6_P02_GS_eeg.fif	Cz
94	W6_P02_US_eeg.fif	Cz
95	W6_P03_EC_eeg.fif	None
96	W6_P03_GS_eeg.fif	None
97	W6_P03_US_eeg.fif	None
98	W6_P04_EC_eeg.fif	None
99	W6_P04_GS_eeg.fif	None
100	W6_P04_US_eeg.fif	None
101	W6_P05_EC_eeg.fif	None
102	W6_P05_GS_eeg.fif	None
103	W6_P05_US_eeg.fif	None

Appendix N. Debriefing Result

ID	Week	Practice Sessions (per week)	Location	Able to Win	Focus Technical	Focus Tactical	Remarks
P01	0	0	Existing	Yes	Hands in drops Tighten core Stay low	Wait until opponent passes then grab the wheel, wait and sprint later from the wheel	
	1	5	Existing	Yes	Tighten core Posture Legs	Staying behind the opponent and waiting until the very last moment	
	2	4	Existing	No	Pedalling hard	Exactly doing it like the scenario	Has been sick
	3	3	Imagery	Yes	Tighten core	Watching the opponents, staying alert, waiting until the last moment	Mentally bit heavy, sick
	4	3	Existing	Yes	Keep head low Pedalling hard Tighten core	Watching the opponents, choose the right moment	
	5	2	Existing	No	Tighten core	Looking for space, not getting locked in	
	6	3	Existing	No	Tighten core	Staying in the saddle	
P02	0	0	Existing	No	Standing	Giving everything	
	1	1	Imagery	Yes	Standing Angle in the corner Staying in the wheel	Not giving up	
	2	1	Existing	Yes	Aerodynamic posture Hands in the drops	Surprise effect, start the sprint really hard	
	3	2	Existing	Yes	Hands in the drops Posture Power output	Watching the opponents	
	4	2	Imagery	Yes	Staying low Power output Aerodynamic posture	Not thinking, just go	
	5	2	Existing	No	Power output	Not getting	

						locked in	
	6	2	Imagery	No	Power output	Being alert	
P03	0	0	Existing	No	Cadence Hold speed	Paying attention where the opponent is	
	1	2	Existing	Yes	Stay close after the corner	Paying attention when the opponent starts their sprint	
	2	4	Imagery	No	Good corner	Getting back on pace after the corner Power output	Personal issues
	3	3	Imagery	Yes	Staying in the wheel op opponent Staying alert Listening to the opponents when they shift	Waiting	
	4	2	Imagery	Yes	Finding the right gear in the sprint Standing until the finish line	Choosing the right moment	
	5	3	Existing	Yes	Power output	Not getting locked in	
	6	3	Imagery	Doubt	Power output Focussing on the other cyclists	Staying alert	Personal issues
P04	0	0	Existing	No	Power output Pull on handlebars	Holding still and before the corner giving everything	
	1	3	Existing	Yes	Cadance Power output	Thinking how long I can prolong a standing sprint	
	2	2	Imagery	Yes	Power output Aerodynamic posture	Holding still to surprise the opponent in the attack Good apex in the corner	
	3	4	Existing	No	Waiting Shifting Pull on handlebars Listening	Staying in the wheel of opponent	
	4	2	Imagery	Yes	Finding the right gear in the sprint Pull on handlebars Posture	Holding still in the group to surprise the opponent in the attack	
	5	4	Existing	Yes	Keep hands close to shifters Pull on handlebars	Staying in the wheel of the opponent	

	6	3	Imagery	Yes	Staying in the wheel Cadance Holding my handlebars	Paying attention to the other riders Riding the best apex at the roundabout
P05	0	0	Existing	Yes	Right apex in the corner	Search for space in the corner
	1	2	Existing	Yes	Posture Tighten core Staying alert	Waiting and giving everything
	2	4	Imagery	No	Power output Aerodynamic posture	Timing
	3	3	Existing	Yes	Waiting Look behind Power output	Aerodynamic posture Staying in the wheel of opponent
	4	1	Imagery	Yes	Cadance	Timing
	5	2	Existing	No	Timing	Staying in the wheel of the opponent, not getting locked in
	6	3	Imagery	No	Positioning	Riding the best apex at the roundabout

Appendix O. ICA Results

File Name	Samples Omitted	Percentage Omitted	Total Samples Retained	Percentage Retained
W0_P01_EC_eeg.fif	129	0.57%	22372	99.43%
W0_P01_GS_eeg.fif	280	1.49%	18471	98.51%
W0_P01_US_eeg.fif	1255	3.59%	33746	96.41%
W1_P01_EC_eeg.fif	708	2.57%	26793	97.43%
W1_P01_GS_eeg.fif	738	3.04%	23513	96.96%
W1_P01_US_eeg.fif	803	5.95%	12698	94.05%
W2_P01_EC_eeg.fif	72	0.27%	26179	99.73%
W2_P01_GS_eeg.fif	172	0.69%	24829	99.31%
W2_P01_US_eeg.fif	594	3.66%	15657	96.34%
W3_P01_EC_eeg.fif	1606	6.42%	23395	93.58%
W3_P01_GS_eeg.fif	1298	3.71%	33703	96.29%
W3_P01_US_eeg.fif	247	1.41%	17254	98.59%
W4_P01_EC_eeg.fif	1287	5.15%	23714	94.85%
W4_P01_GS_eeg.fif	0	0.00%	27500	100%
W4_P01_US_eeg.fif	0	0.00%	14750	100%
W5_P01_EC_eeg.fif	2479	9.92%	22522	90.08%
W5_P01_GS_eeg.fif	344	0.96%	35407	99.04%
W5_P01_US_eeg.fif	4706	15.30%	26045	84.70%
W6_P01_EC_eeg.fif	1028	4.33%	22723	95.67%
W6_P01_GS_eeg.fif	334	0.80%	41667	99.20%
W6_P01_US_eeg.fif	659	2.87%	22342	97.13%
W0_P02_EC_eeg.fif	2610	9.49%	24891	90.51%
W0_P02_EC_eeg.fif	1989	7.96%	23012	92.04%
W0_P02_GS_eeg.fif	1989	7.96%	23012	92.04%
W0_P02_US_eeg.fif	3593	35.05%	6658	64.95%
W1_P02_EC_eeg.fif	1963	6.83%	26788	93.17%
W1_P02_GS_eeg.fif	0	0%	17250	100%
W1_P02_US_eeg.fif	405	3.31%	11846	96.69%
W2_P02_EC_eeg.fif	1015	3.53%	27736	96.47%
W2_P02_GS_eeg.fif	492	1.86%	26009	98.14%
W2_P02_US_eeg.fif	328	1.90%	16923	98.10%
W3_P02_EC_eeg.fif	0	0%	27500	100%
W3_P02_GS_eeg.fif	0	0%	37250	100%
W3_P02_US_eeg.fif	0	0%	17250	100%
W4_P02_EC_eeg.fif	1405	5.11%	26096	94.89%
W4_P02_GS_eeg.fif	0	0%	21750	100%
W4_P02_US_eeg.fif	63	0.57%	10938	99.43%
W5_P02_EC_eeg.fif	541	2.16%	24460	97.84%
W5_P02_GS_eeg.fif	174	0.47%	37077	99.53%
W5_P02_US_eeg.fif	33	0.18%	18718	99.82%
W6_P02_EC_eeg.fif	478	1.82%	25773	98.18%
W6_P02_GS_eeg.fif	1011	2.13%	46490	97.87%
W6_P02_US_eeg.fif	575	2.56%	21926	97.44%
W0_P03_EC_eeg.fif	208	0.76%	27293	99.24%
W0_P03_GS_eeg.fif	1711	8.05%	19540	91.95%
W0_P03_US_eeg.fif	6898	68.97%	3103	31.03%
W1_P03_EC_eeg.fif	1414	5.01%	26837	94.99%
W1_P03_GS_eeg.fif	0	0.00%	22250	100.00%

W1_P03_US_eeg.fif	0	0.00%	7500	100.00%
W2_P03_EC_eeg.fif	483	1.93%	24518	98.07%
W2_P03_GS_eeg.fif	387	1.63%	23364	98.37%
W2_P03_US_eeg.fif	1015	9.67%	9486	90.33%
W3_P03_EC_eeg.fif	0	0.00%	25000	100.00%
W3_P03_GS_eeg.fif	192	0.61%	31059	99.39%
W3_P03_US_eeg.fif	0	0.00%	11250	100.00%
W4_P03_EC_eeg.fif	221	0.84%	26030	99.16%
W4_P03_GS_eeg.fif	820	3.28%	24181	96.72%
W4_P03_US_eeg.fif	0	0.00%	12500	100.00%
W5_P03_EC_eeg.fif	240	0.96%	24761	99.04%
W5_P03_GS_eeg.fif	345	0.92%	37156	99.08%
W5_P03_US_eeg.fif	0	0.00%	13250	100.00%
W6_P03_EC_eeg.fif	277	1.11%	24724	98.89%
W6_P03_GS_eeg.fif	273	0.56%	48478	99.44%
W6_P03_US_eeg.fif	728	3.69%	19023	96.31%
W6_P03_US_eeg.fif	344	1.20%	28407	98.80%
W0_P04_EC_eeg.fif	0	0.00%	28751	100%
W0_P04_GS_eeg.fif	0	0.00%	19500	100%
W0_P04_US_eeg.fif	480	3.00%	15521	97.00%
W1_P04_EC_eeg.fif	5647	19.99%	22604	80.01%
W1_P04_GS_eeg.fif	2523	11.60%	19228	88.40%
W1_P04_US_eeg.fif	1945	12.97%	13056	87.03%
W2_P04_EC_eeg.fif	0	0.00%	2500	100%
W2_P04_GS_eeg.fif	272	1.09%	24729	98.91%
W2_P04_US_eeg.fif	168	0.62%	27083	99.38%
W3_P04_EC_eeg.fif	78	0.30%	26173	99.70%
W3_P04_GS_eeg.fif	103	0.29%	34898	99.71%
W3_P04_US_eeg.fif	289	0.96%	29712	99.04%
W4_P04_EC_eeg.fif	0	0.00%	26250	100%
W4_P04_GS_eeg.fif	463	3.09%	14538	96.91%
W4_P04_US_eeg.fif	0	0.00%	27500	100%
W5_P04_EC_eeg.fif	2120	7.71%	25381	92.29%
W5_P04_GS_eeg.fif	0	0.00%	37500	100%
W5_P04_US_eeg.fif	1214	4.22%	27537	95.78%
W6_P04_EC_eeg.fif	0	0.00%	26250	100%
W6_P04_GS_eeg.fif	543	1.28%	41958	98.72%
W6_P04_US_eeg.fif	1880	4.85%	36871	95.15%
W0_P05_US_eeg.fif	858	4.29%	19143	95.71%
W1_P05_EC_eeg.fif	0	0.00%	28750	100.00%
W1_P05_GS_eeg.fif	-	-	-	-
W1_P05_US_eeg.fif	517	4.05%	12234	95.95%
W2_P05_EC_eeg.fif	1745	6.65%	24506	93.35%
W2_P05_GS_eeg.fif	382	1.48%	25369	98.52%
W2_P05_US_eeg.fif	344	3.06%	10907	96.94%
W3_P05_EC_eeg.fif	0	0.00%	25000	100.00%
W3_P05_GS_eeg.fif	0	0.00%	34250	100.00%
W3_P05_US_eeg.fif	461	5.12%	8540	94.88%
W4_P05_EC_eeg.fif	0	0.00%	25000	100.00%
W4_P05_GS_eeg.fif	-	-	-	-

W4_P05_US_eeg.fif	138	1.84%	7363	98.16%
W5_P05_EC_eeg.fif	437	1.59%	27064	98.41%
W5_P05_GS_eeg.fif	6466	17.24%	31035	82.76%
W5_P05_US_eeg.fif	4170	27.80%	10831	72.20%
W6_P05_EC_eeg.fif	1568	5.23%	28433	94.77%
W6_P05_GS_eeg.fif	3061	6.80%	41940	93.20%
W6_P05_US_eeg.fif	1551	8.27%	17200	91.73%

Appendix P. Event Timeframes

With the use of this table the csv files are split into five different .fif files using the start and end time in seconds.

Participant	Week	EO start	EO end	EC start	EC end	BA start	BA end	GS start	GS end	US start	US end
P01	W0	20	100	140	230	310	420	535	610	645	785
P02	W0	60	100	120	230	305	440	520	620	645	686
P03	W0	10	115	130	240	310	375	418	503	520	560
P04	W0	5	115	125	240	320	390	425	503	550	614
P05	W0	19	125	132	245	294	382	450	536	568	648
P01	W1	30	140	155	265	280	350	367	464	466	520
P02	W1	16	130	135	250	270	322	356	425	433	482
P03	W1	10	120	137	250	255	300	319	408	415	445
P04	W1	10	120	130	243	254	316	324	411	420	480
P05	W1	10	120	130	245	256	321	345	440	536	587
P01	W2	22	130	145	250	265	345	360	460	465	530
P02	W2	18	123	130	245	265	360	371	477	491	560
P03	W2	12	120	140	240	258	291	319	414	417	459
P04	W2	20	140	250	260	285	375	410	510	641	750
P05	W2	10	127	135	240	255	350	365	468	480	525
P01	W3	19	130	150	250	270	320	340	480	485	555
P02	W3	10	110	180	290	303	437	457	606	625	700
P03	W3	10	110	135	235	263	300	325	450	470	515
P04	W3	25	135	145	250	300	350	380	520	540	660
P05	W3	15	120	140	240	255	330	370	507	540	576
P01	W4	25	135	150	250	285	351	370	480	485	544
P02	W4	10	110	130	240	270	350	383	470	496	540
P03	W4	10	120	135	240	260	300	325	425	435	485
P04	W4	30	140	160	265	285	340	360	420	495	605
P05	W4	5	50	60	160	200	260	270	370	375	405
P01	W5	10	120	140	240	250	310	352	495	505	628
P02	W5	15	120	140	240	360	380	400	549	555	630
P03	W5	15	120	140	240	265	285	300	450	455	508
P04	W5	15	120	140	250	260	360	425	575	585	700
P05	W5	20	130	145	255	300	360	380	530	540	600
P01	W6	20	130	145	240	255	300	352	520	530	622
P02	W6	20	130	145	250	270	360	390	580	600	690
P03	W6	25	125	140	240	255	285	310	505	515	594
P04	W6	15	120	140	245	260	300	315	485	515	670

Continued on next page

(Continued)

P05	W6	20	120	140	260	270	305	325	505	515	590

Appendix Q. Individual Participant EEG Results

Trends in EEG Data

1. **Trend 1:** If there is an improvement in motor activation, the beta frequency is expected to increase during the imagery training in the central region.
2. **Trend 2:** For an increase in cognitive alertness/attention, there could be an increase in the SMR (alpha and beta) frequency waves in the frontal region.
3. **Trend 3:** For an increase in visual attention, there is an increase in beta waves expected in the parietal–occipital region.
4. **Trend 4:** If the concentration is increasing, then it is expected that beta increases and theta decreases in the frontal region.
5. **Trend 5:** It is not expected to measure a decrease in the frontal–central region for the alpha, beta, and theta frequency bands.
6. **Trend 6:** The second theorem only uses the frontal region and says that the beta wave is not expected to increase and expects alpha not to decrease.

Table Q.1: Summarizing Table: Individual Trend Results

Participant	**Event**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
P01	**GS**	True	True	False	Partly	True	Partly
P01	**US**	True	True	True	Partly	True	Partly
P02	**GS**	False	False	False	Partly	False	Partly
P02	**US**	False	False	False	Partly	False	Partly
P03	**GS**	False	False	False	Partly	False	Partly
P03	**US**	False	False	False	Partly	False	Partly
P04	**GS**	True	True	True	Partly	True	Partly
P04	**US**	True	True	True	Partly	True	Partly
P05	**GS**	True	False	True	Partly	False	Partly
P05	**US**	True	Partly	True	True	Partly	False

Participant 1

When inspecting the absolute values for EC, in Figure X1, it can be seen that there is some overlap between the weeks, especially for week 1, 5 and 6 in the frontal region. Furthermore, over all weeks, except week 2, a light activity in the occipital region. The overall activity is much lower in GS compared to EC. The first two weeks show light activity in the occipital region. But overall, there is much blue present in the topomaps which indicates low activity. For US are the absolute values different for each week.

When subtracting the EC Event from the events GS and US the topomaps of Figure X2 are created. Within these topomaps for GS there is most low activity in the frontal and central region of the brain. And for week 1 and 6 high activity in the occipital region of the brain. Where for GS week 1 and week 6 show high similarities this is completely different for US where weeks 1 and 5 show more overlap.

When inspecting the frequency band topomaps for GS, Figure X3, the following things could be observed:
Theta: Overall low activity. Weeks 1, 3 and 6 show high activity in the occipital region for the theta band. And week 2 and 4 show light activity in the central region of the brain.
Alpha: Light activity in the frontal region of the brain for week 0 and 2. High activity in the central region of the brain for week 1 and 5.
Beta: Frontal activity in the frontal region of the brain for week 0, 1, 3 and 6. Week 5 shows higher activity in the left side of the brain compared to the right side of the brain. Week 6 shows also a little bit more right side of the brain-oriented activity but not so clear as in week 5.
Gamma: Weeks 1, 2 and 6 show overall high activity.

When inspecting the frequency band topomaps for US, Figure X3, the following things could be observed:
Theta: overall more parietal, occipital focused.
Alpha: High activity could be observed for week 0, 4 and 5 on the right side in the parietal region.
Beta: Not many similarities could be observed over the weeks.
Gamma: Weeks 0, 1 and 4 show high activity in the central left side of the brain. Week 3 shows also more left side-oriented activity but more towards the parietal region. Whereas week 2 and 5 are more right-side oriented and week six more frontal central oriented.

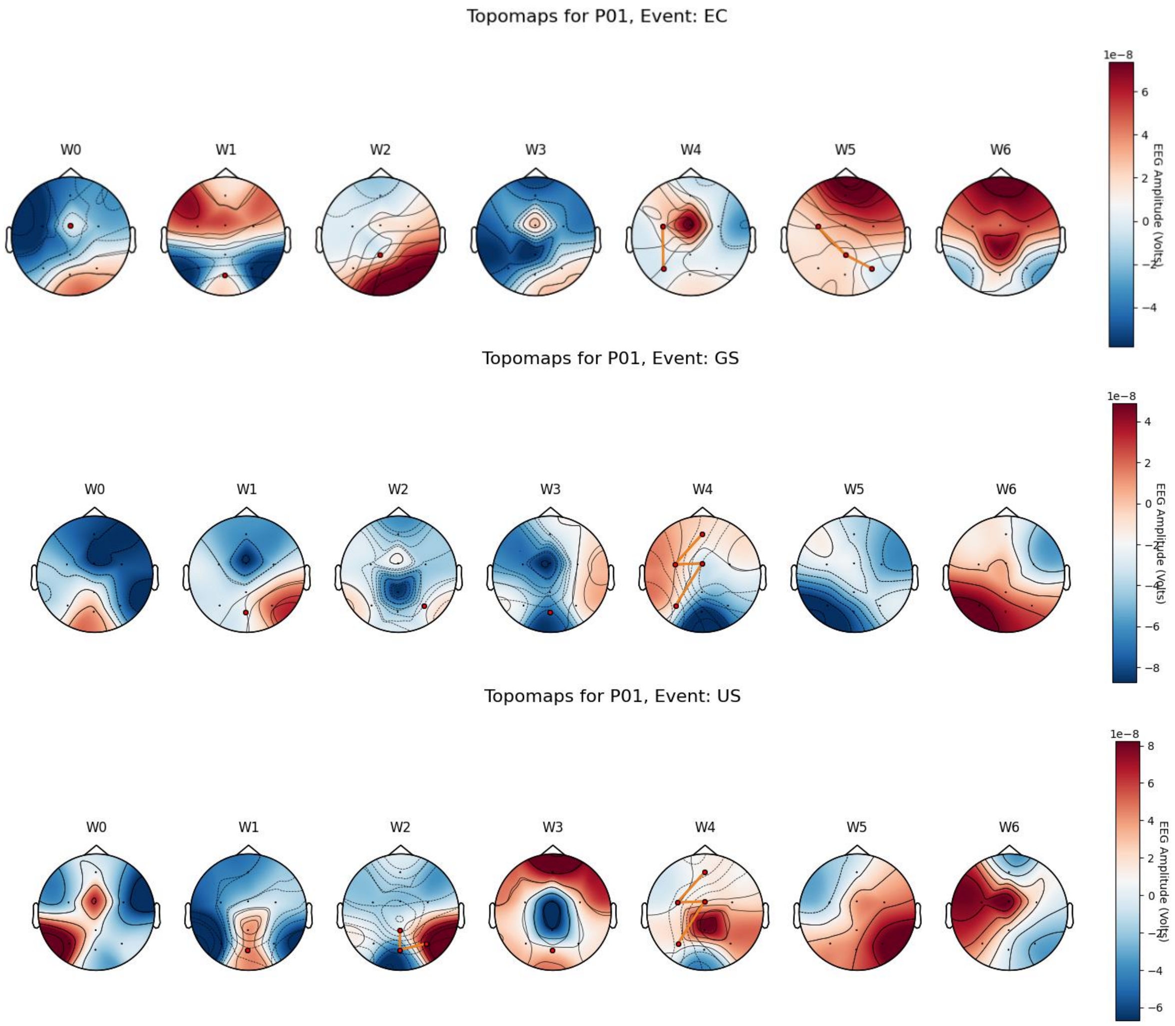

Figure X1: Absolute Topomaps of P01.

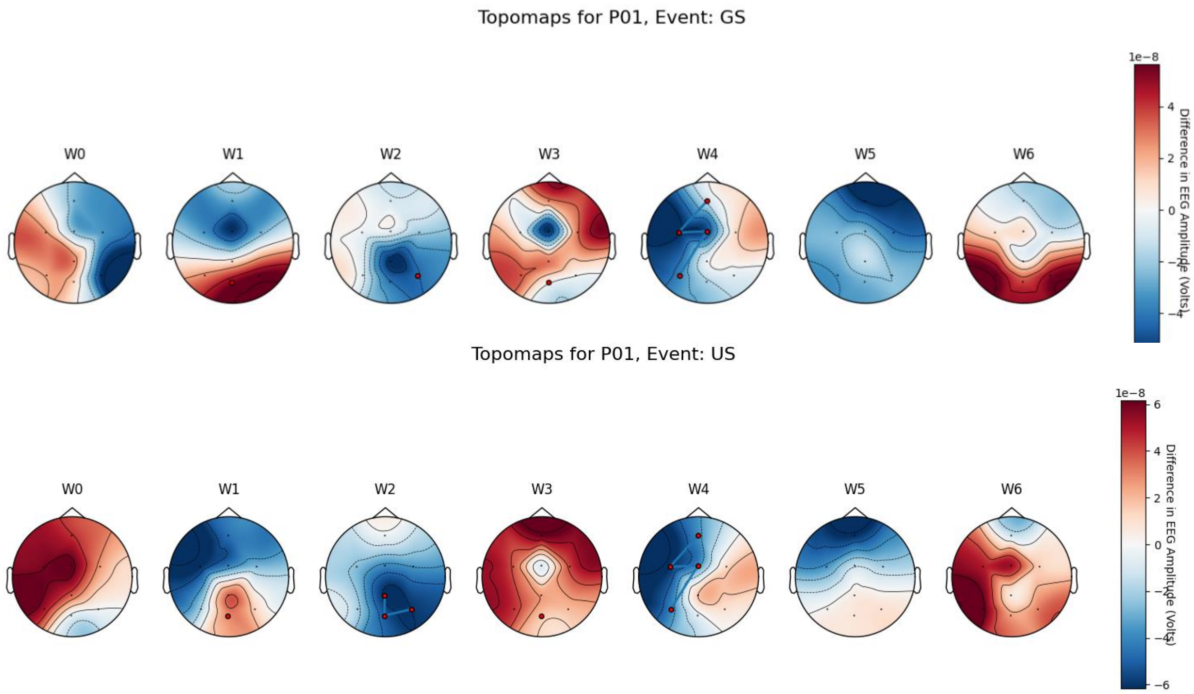

Figure X2: Topomaps of GS and US with EC subtracted of P01.

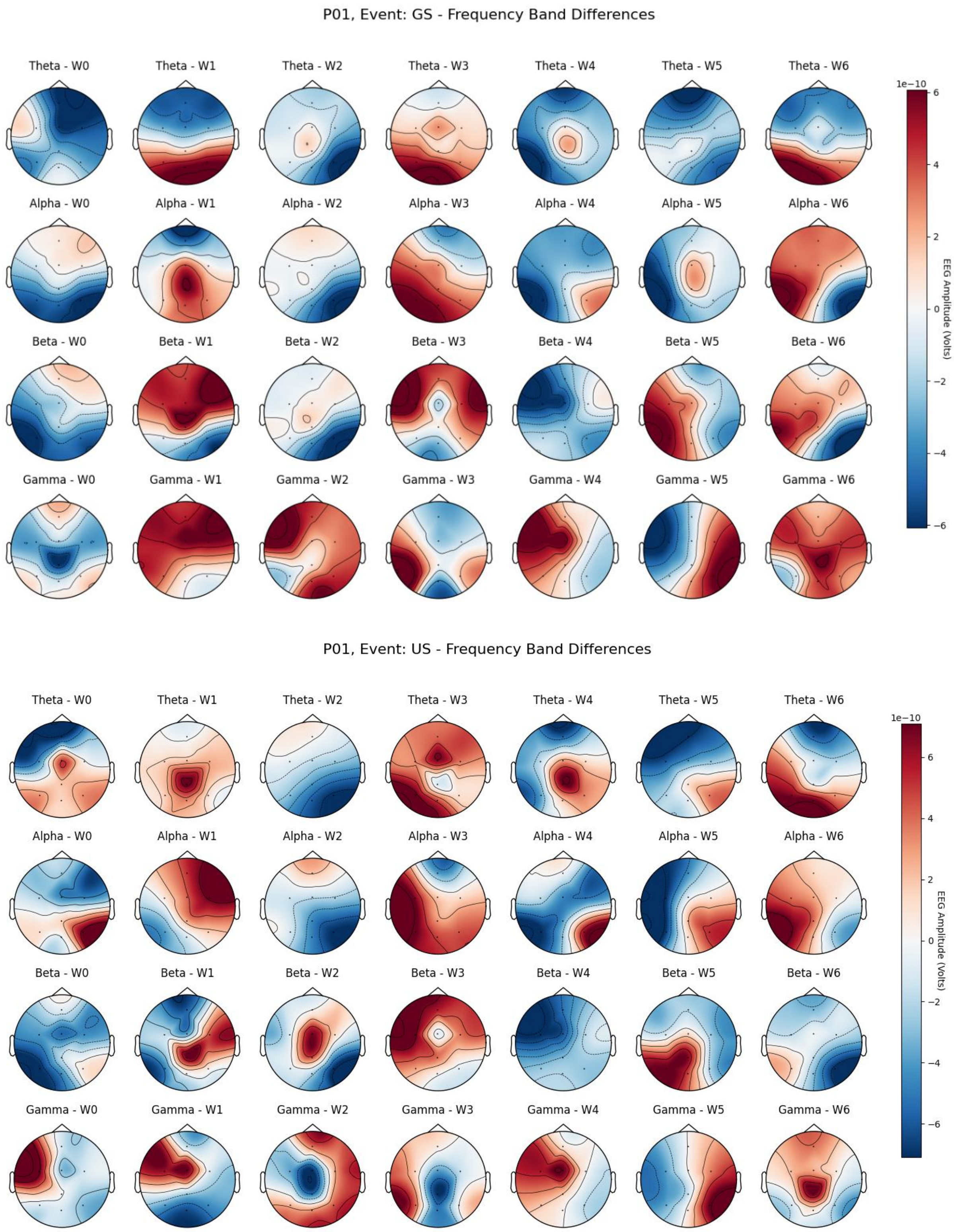

Figure X3: Frequency band topomaps of GS and US with EC subtracted.

Stress Ratio and Concentration Index

When calculating the Stress Ratio and Concentration Index with the formulated formulas in X. it can be seen that in Figure X4 that the Concentration Index and the Stress Ratio gradually increases over the weeks up until week 4. When calculating the slope with the use of regression it results in a positive slope for the concentration index (GS: 0.020; US: 0.065) and stress ratio (GS: 0.014; US: 0.009). Which indicates a slightly improvement in concentration and a slightly increase in stress over the weeks for participant 1. The expectation for Concentration Index is in line with literature whereas the Stress Ratio shows an increase where a decrease was expected. However, when inspecting the graph week 4 shows different results than expected, which have a strong influence on the slope behaviour when calculating the slope with regression. The causes of this high peak for participant 1 are unknown but could be due to personal circumstances.

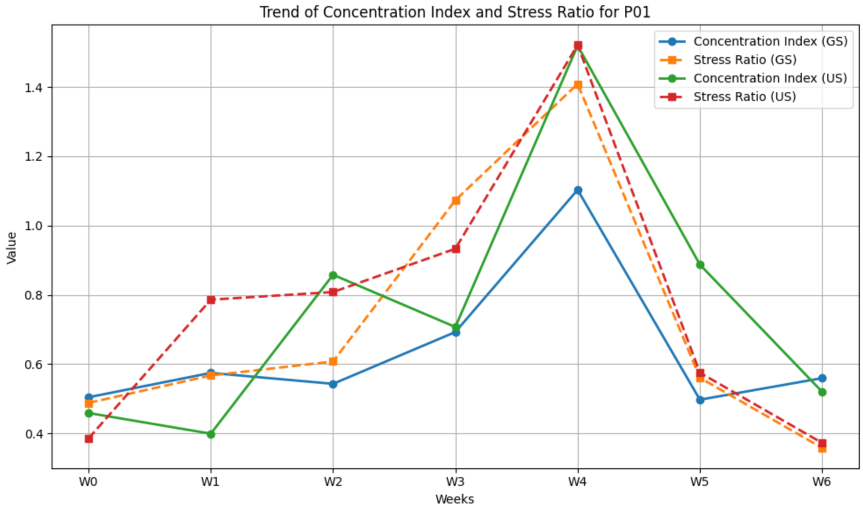

Figure X4: Average Concentration Index, and Stress Ratio for P01 over the weeks.

Frequency band trends[5]

If there is an improvement in motor activation the beta frequency is expected to increase during the imagery training in the central region. As can be seen in Figure X5 and X6 below, is there no high slope (GS: 0.021; US: 0.022) visible over the weeks for beta power, which means that there is not especially high increase in motor activation during the imagery training over the weeks on average.

Furthermore, for an increase in cognitive alertness/attention there could be increase in the SMR (alpha and beta) frequency waves in the frontal region. This is the case due to the increase small increase of power in both Figures X7 and X8 in the alpha frequency (GS: 0.735; US: 0.520) whereas for the beta frequency it approximately remains the same (GS: 0.121; US: 0.077).

For an increase in visual attention there is an increase in beta waves expected in the parietal – occipital region. This is not the case with a minimal negative slope for GS and a minimal positive slope for US (GS: -0.014; US: 0.023). In Figure X9 and X10 can this be seen.

If concentration is increasing, then it is expected that beta increases and theta decreases in the frontal region. When measuring the change, it occurred that the theta frequency band increases (GS: 0.336; US: 0.415) and that the beta frequency increases quite minimal (GS: 0.121; US: 0.077). This is illustrated in Figure X7 and X8.

As for the anxiety theorem one, as explained in Table 1 within the report, it is not expected to measure a decrease in the frontal – central region for the alpha, beta and theta frequency band.
When looking at the frontal-central region combined it can indeed be seen that there is no decrease in all these frequency bands (Alpha - GS: 0.325; US: 0.291) (Beta – GS: 0.046; US: 0.036) (Theta – GS: 0.105; US: 0.210). However, some of these positive slopes are quite minimal, see Figure X11 and X12.

The second theorem only uses the frontal region and says that the beta wave is not expected to increase, which is approximately the case because the beta frequency band remains almost constant (GS: 0.121; US: 0.077). However, the values are positive and therefore still increasing. Furthermore, this second theorem expect alpha not to decrease which is also true because alpha shows an increase in power (GS: 0.735; US: 0.520). For this theorem are the same values and figures (X7 and X8) used as for the cognitive alertness/attention.

In summary, when looking at all regions and measured frequency bands it seen that there is an increase in all frequency bands although some are quite minimal. An increase in alpha activity in general is often associated with stress reduction and relaxed states.

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[5] All values are $1e^{-12}$ uV^2/Hz

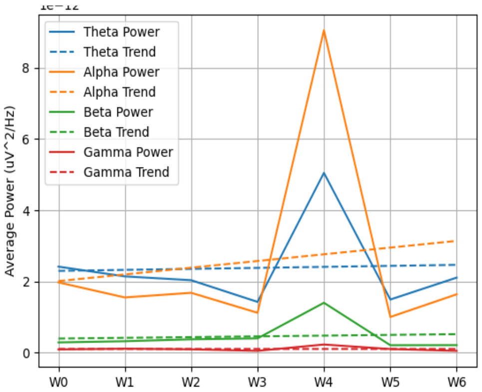


Figure X5

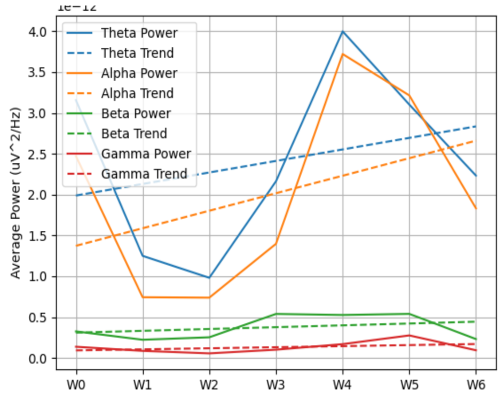


Figure X6

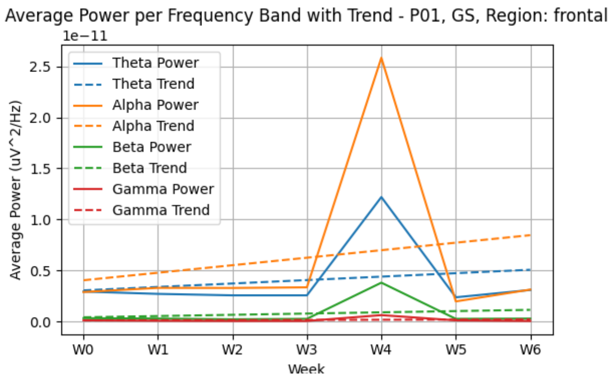


Figure X7

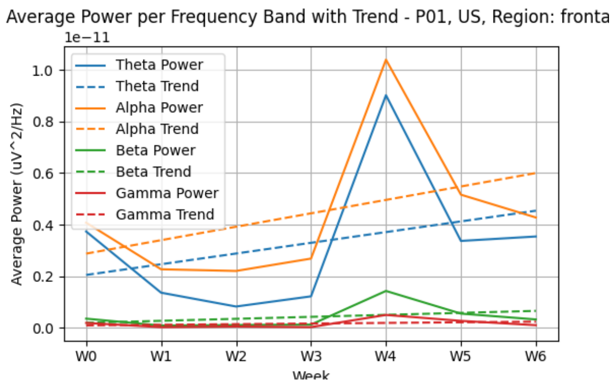


Figure X8

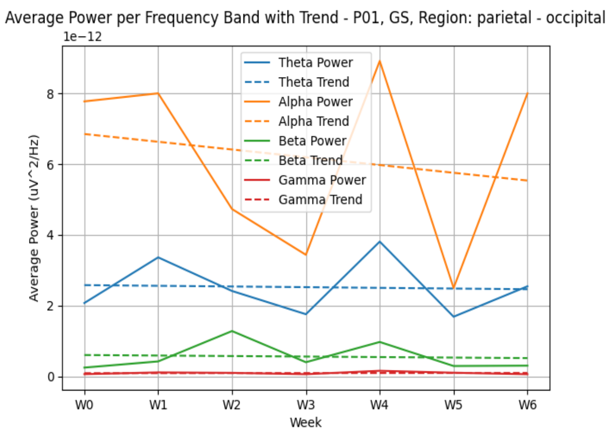


Figure X9

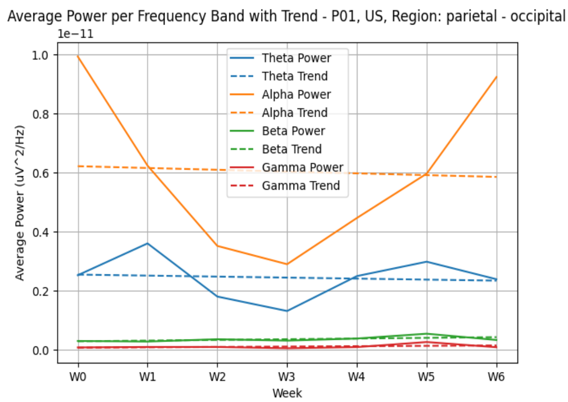


Figure X10

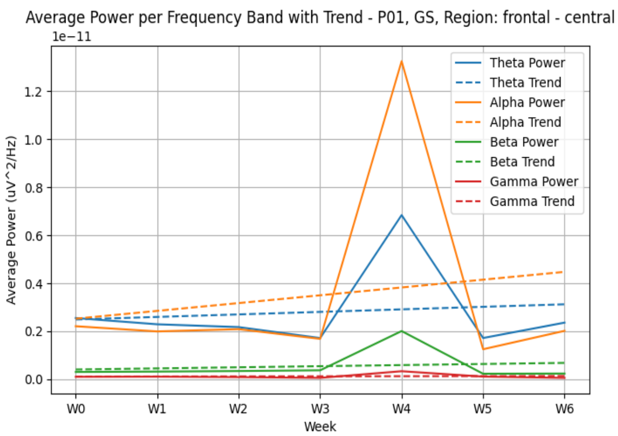


Figure X11

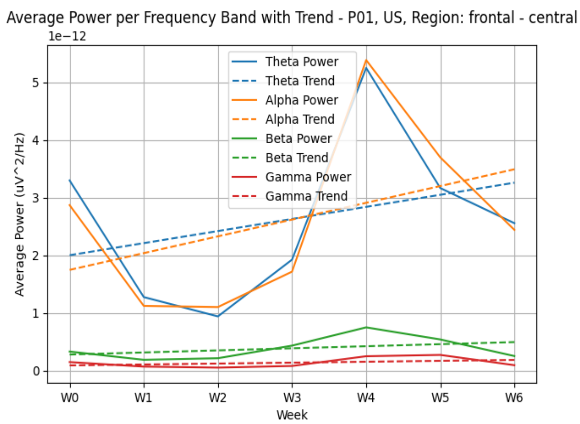


Figure X12

Participant 2

When inspecting the absolute values for EC, in Figure X13, it can be seen that there is some overlap between the weeks, especially for week 1, 2 and 4 and 6 in the frontal region. However, comparing other regions they seem quite different.

The overall activity is much lower in GS compared to EC. Absolute values for GS and US are much different from week to week.

When subtracting the EC Event from the events GS and US the topomaps of Figure X14 are created. Within these topomaps for GS there is high activity in the central region of the brain especially in week 1, 2, 5 and 6. This is also still the case for US but then also frontal regions are more pronounced in week 3 and 4.

When inspecting the frequency band topomaps for GS, Figure X15, the following things could be observed:
Theta: Weeks 0, 5 and 6 show overall high activity except for the frontal region. Week 1, 2, 3 and 4 show overall lower activity. But the highest activity is still in the occipital region of the brain.
Alpha: Shows a shifting from low occipital activity in week 0 towards frontal high activity in week 6.
Beta: No clear pattern could be observed.
Gamma: Weeks 0, 2 and 3 show more pronounced activity in the parietal – occipital region of the brain whereas week 5 and 6 show high activity in the frontal region of the brain.

When inspecting the frequency band topomaps for US, Figure X15, the following things could be observed:
Theta: more right-side frontal oriented especially for week 3, 4 and 6.
Alpha: not a clear pattern could be observed.
Beta: not a clear pattern could be observed.
Gamma: not a clear pattern could be observed.

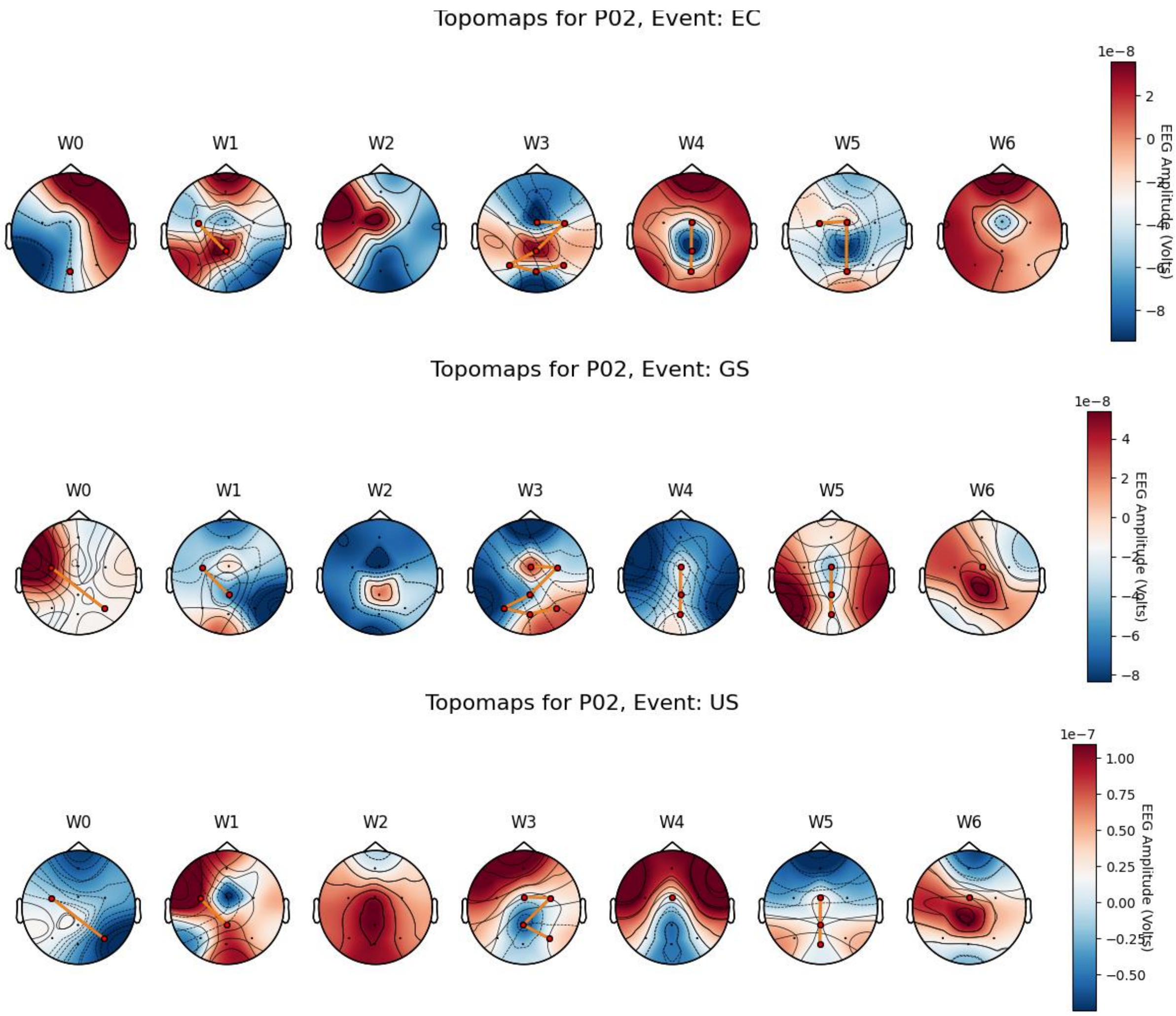


Figure X13: Absolute Topomaps of P02.

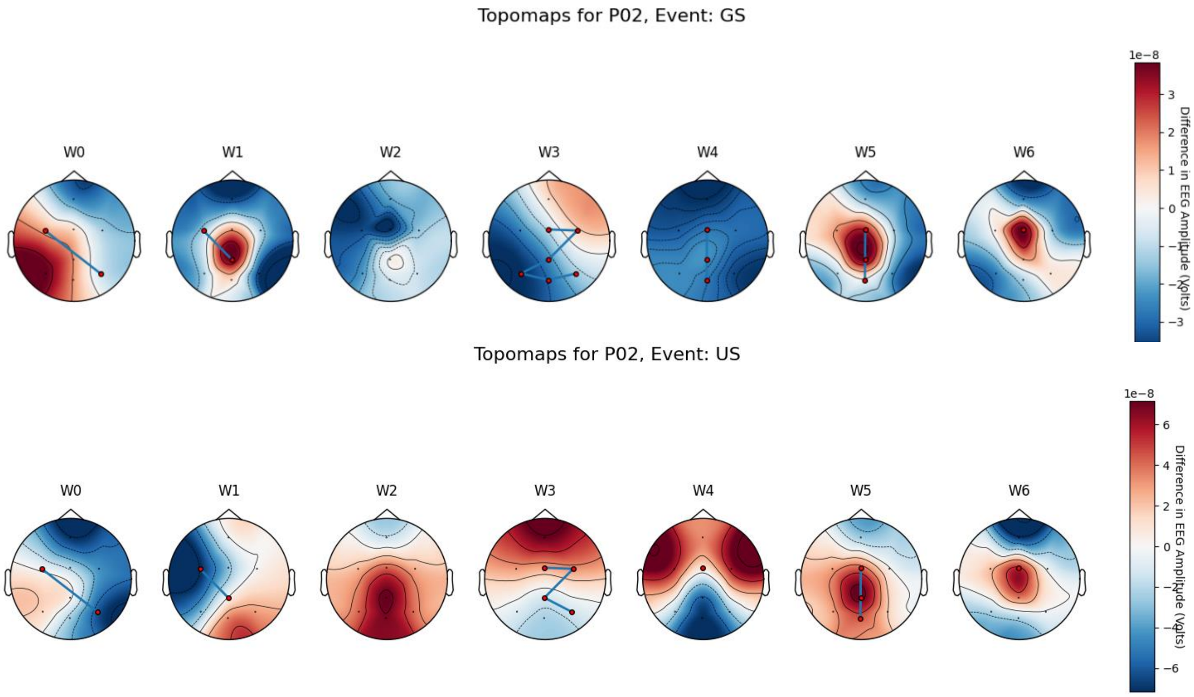


Figure X14: Topomaps of GS and US with EC subtracted of P02.

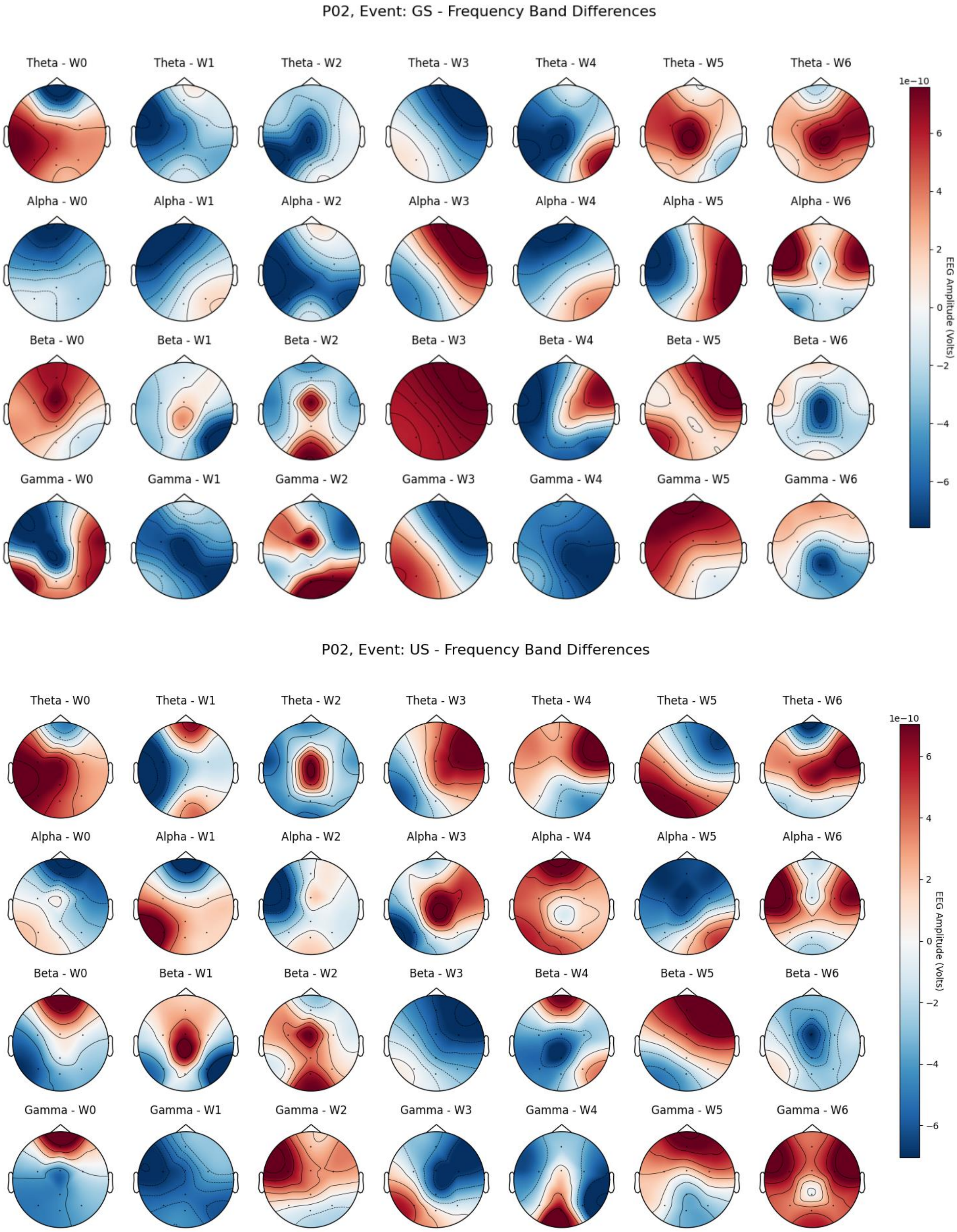


Figure X15: Frequency band topomaps of GS and US with EC subtracted.

Stress Ratio and Concentration Index

When calculating the Stress Ratio and Concentration Index with the formulated formulas in the report in 3.3.4. it can be seen that in Figure X16 that the Concentration Index and Stress Ratio fluctuates over the weeks. When calculating the slope with the use of regression it results in a positive slope for the concentration index (GS: 0.013; US: 0.041) and flat slope for the stress ratio (GS: -0.007; US: 0.002). Botch could indicate a slightly improvement in concentration and no difference in stress over the weeks on average for participant 2.

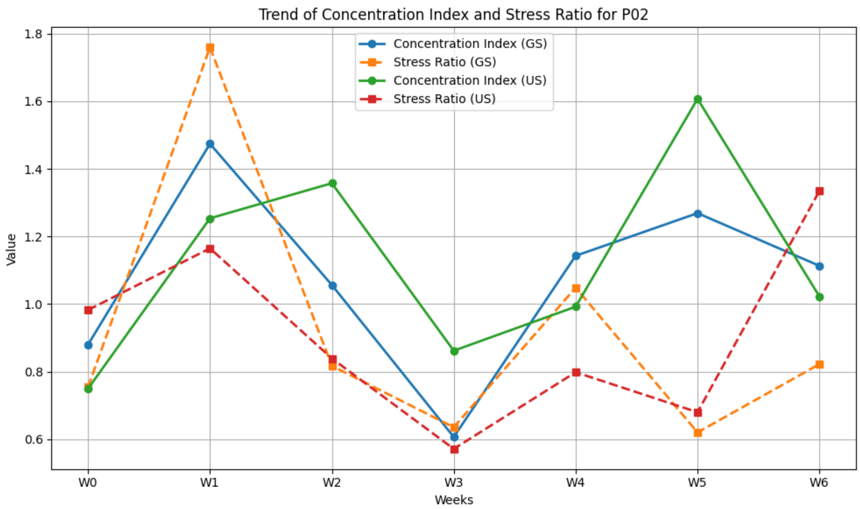


Figure X16: Average Concentration Index, and Stress Ratio for P02 over the weeks.

Frequency band trends[6]

If there is an improvement in motor activation the beta frequency is expected to increase during the imagery training in the central region. As can be seen in Figure X17 and X18 below, is there a negative slope (GS: - 0.068; US: -0.051) visible over the weeks for beta power, which means that there is not especially an increase in motor activation during the imagery training over the weeks on average.

Furthermore, for an increase in cognitive alertness/attention there could be increase in the SMR (alpha and beta) frequency waves in the frontal region. This is not the case due to a small decrease of power in both figures X19 and X20 in the alpha frequency (GS: -0.111; US: -0.008) and the beta frequency (GS: -0.065; US: -0.036).

For an increase in visual attention there is an increase in beta waves expected in the parietal – occipital region. This is not the case with a minimal negative slope (GS: -0.067; US: -0.029). In Figure X21 and X22 can this be seen.

If concentration is increasing, then it is expected that beta increases and theta decreases in the frontal region. When measuring the change, it occurred that the theta frequency band decreases (GS: -0.298; US: -0.231) and that the beta frequency also decreases (GS: -0.065; US: -0.036). This is illustrated in Figure X19 and X20.

As for the anxiety theorem one, as explained in Table 1 within the report, it is not expected to measure a decrease in the frontal – central region for the alpha, beta and theta frequency band.
When looking at the frontal-central region combined it can be seen that there is a decrease is measured in most of these frequency bands (Alpha - GS: 0.045; US: -0.001) (Beta – GS: -0.067; US: -0.047) (Theta – GS: -0.261; US: -0.326). This was not expected. However, some of these negative slopes are quite minimal, see Figure X23 and X24.

The second theorem only uses the frontal region and says that the beta wave is not expected to increase, which is the case because the beta frequency band decreases (GS: -0.065; US: -0.036). Furthermore, this second theorem expect alpha not to decrease which is not true because alpha shows a minimal decrease in power (GS: -0.111; US: -0.008). For this theorem are the same values and figures (X19 and X20) used as for the cognitive alertness/attention.

In summary, when looking at all regions and measured frequency bands it seen that there is an decrease in all frequency bands although some are quite minimal.

[6] All values are $1e^{-12}$ uV^2/Hz

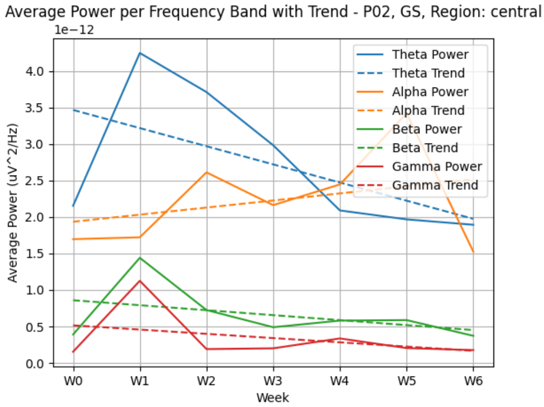


Figure X17

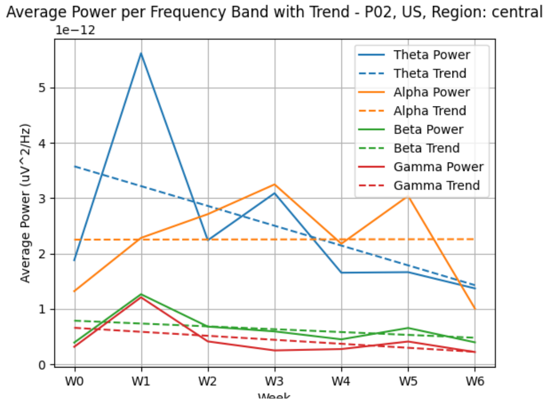


Figure X18

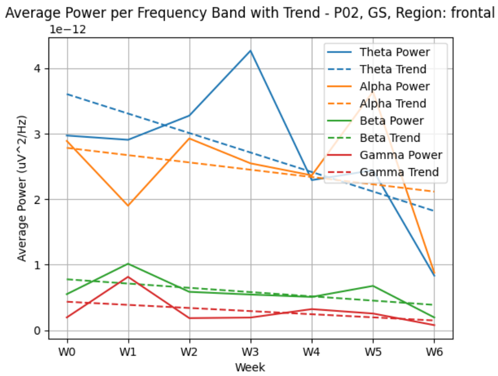


Figure X19

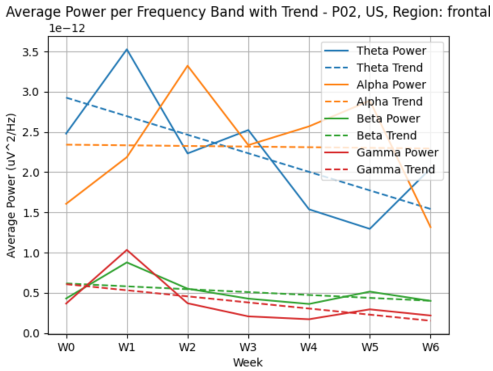


Figure X20

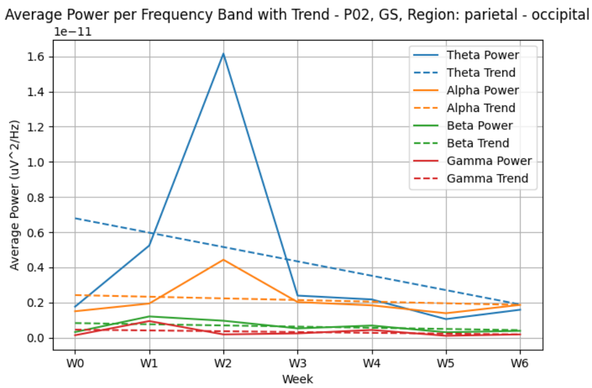


Figure X21

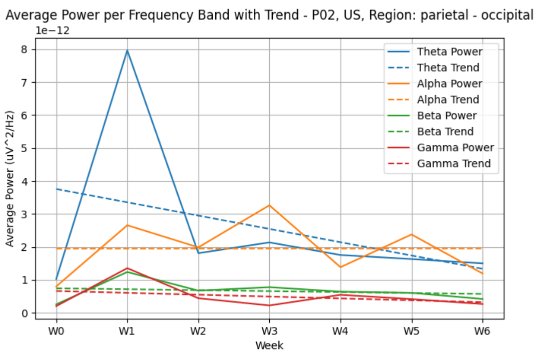


Figure X22

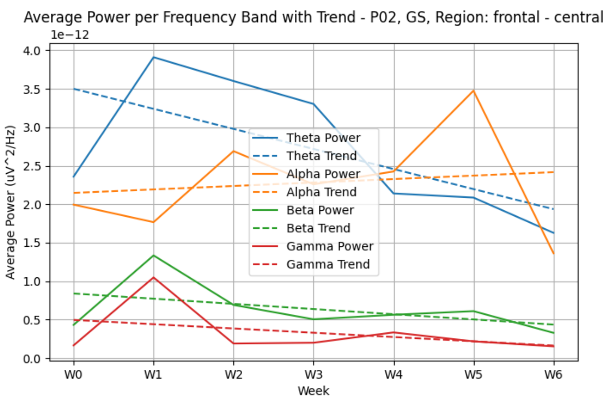


Figure X23

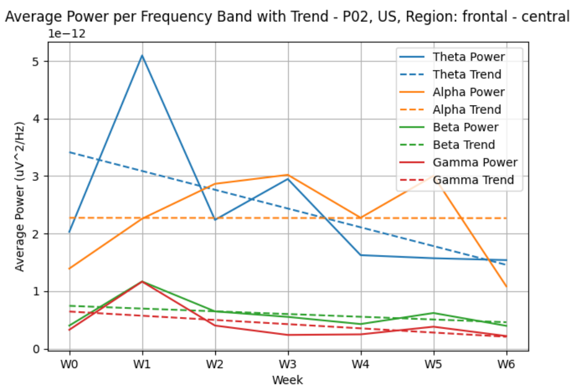


Figure X24

Participant 3

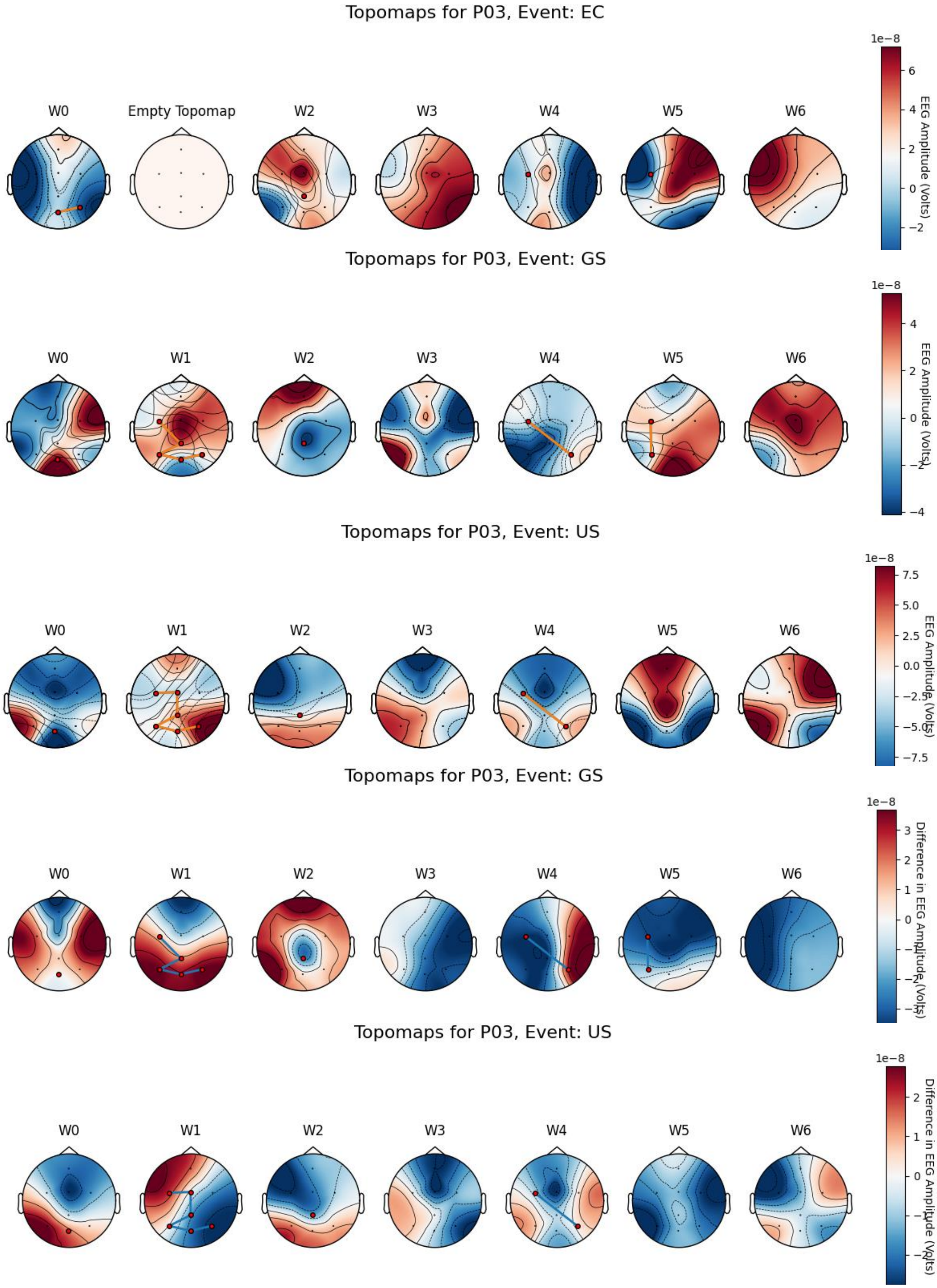


Figure X26: Topomaps of GS and US with EC subtracted of P03.

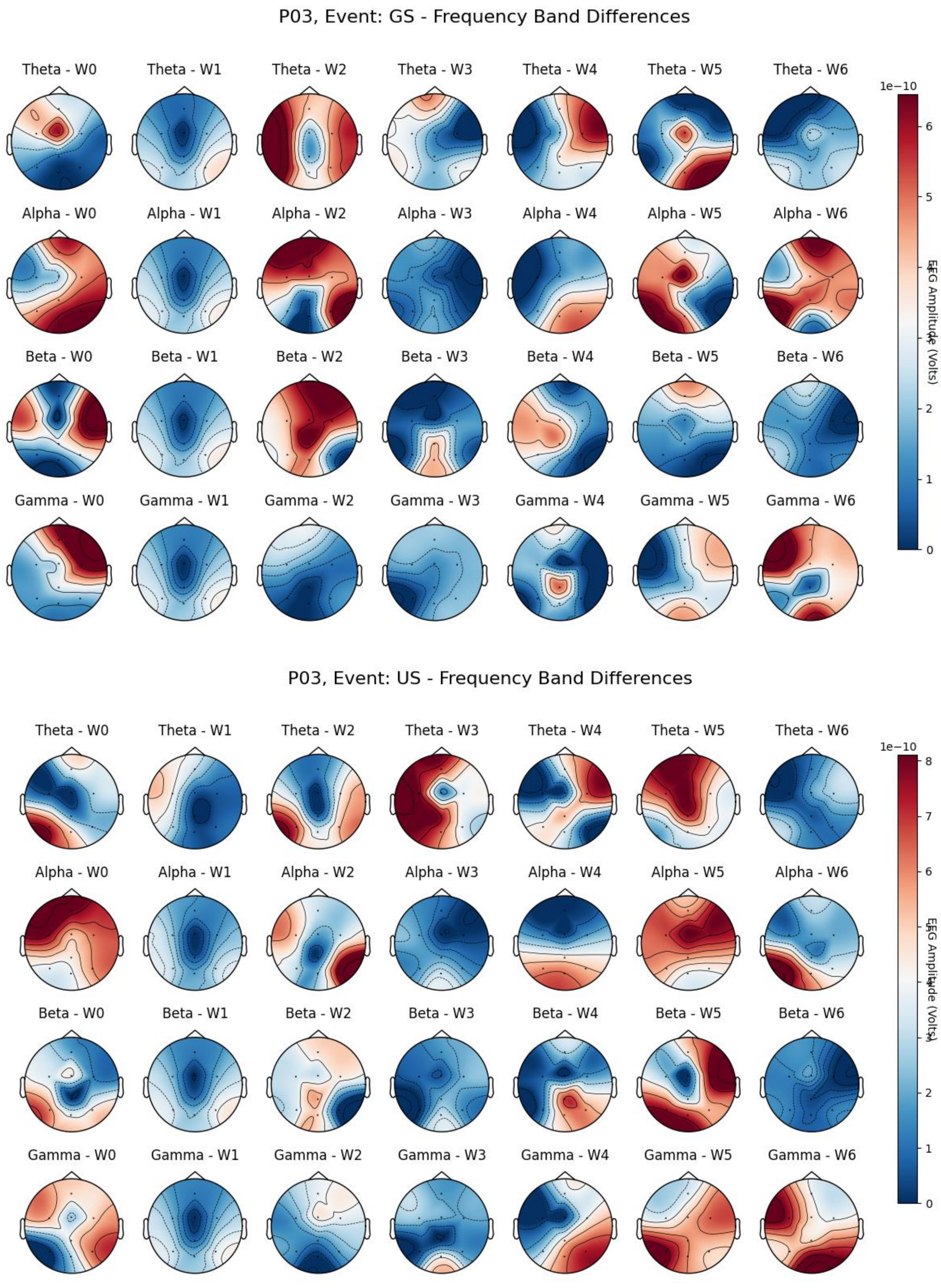


Figure X27: Frequency band topomaps of GS and US with EC subtracted.

Stress Ratio and Concentration Index

When calculating the Stress Ratio and Concentration Index with the formulated formulas in the report in 3.3.4. it can be seen that in Figure X28 that the Concentration Index and Stress Ratio gradually increases over the weeks for GS. Whereas the Concentration Index and Stress Ratio for US decreases. When calculating the slope with the use of regression it results in a positive slope for the concentration index for GS and a negative slope for US (GS: 0.108; US: -0.030) and positive slope for the stress ratio of GS and a negative slope for US (GS: 0.136; US: -0.012).

Which indicates a larger concentration when the scenario is read out loud (GS) but that this also causes higher stress compared to when the scenario is not read out loud (US). Both, Concentration Index and Stress Ratio are approximately constant over the weeks for US.

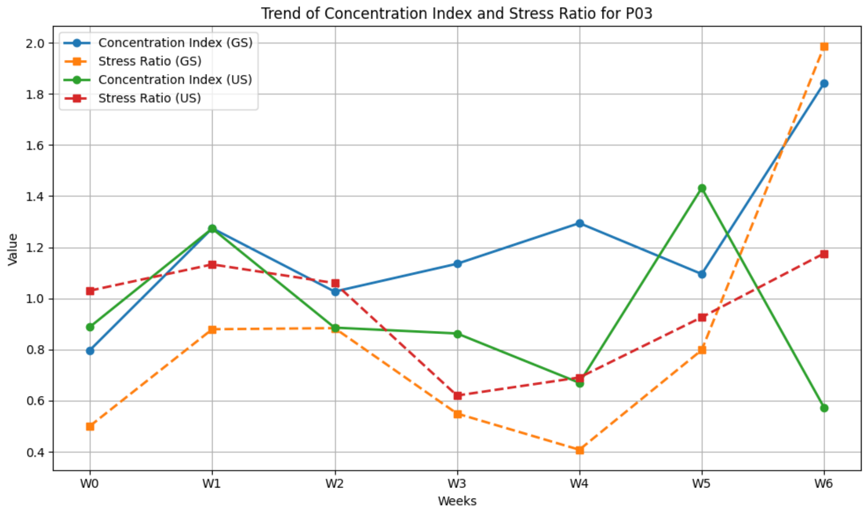


Figure X28: Average Concentration Index, and Stress Ratio for P01 over the weeks.

Frequency band trends[7]

If there is an improvement in motor activation the beta frequency is expected to increase during the imagery training in the central region. As can be seen in Figure X29 and X30 below, is there a negative slope (GS: - 0.062; US: -0.078) visible over the weeks for beta power, which means that there is not especially an increase in motor activation during the imagery training over the weeks on average.

Furthermore, for an increase in cognitive alertness/attention there could be increase in the SMR (alpha and beta) frequency waves in the frontal region. This is not the case due to a decrease of power in both figures X31 and X32 in the alpha frequency (GS: -0.502; US: -0.540) and the beta frequency (GS: -0.131; US: -0.251).

For an increase in visual attention there is an increase in beta waves expected in the parietal – occipital region. This is not the case with a minimal negative slope (GS: -0.012; US: -0.058). In Figure X33 and X34 can this be seen.

If concentration is increasing, then it is expected that beta increases and theta decreases in the frontal region. When measuring the change, it occurred that the theta frequency band decreases (GS: -1.293; US: -1.219) and that the beta frequency also decreases (GS: -0.131; US: -0.251). This is illustrated in Figure X31 and X32.

As for the anxiety theorem one, as explained in Table 1 within the report, it is not expected to measure a decrease in the frontal – central region for the alpha, beta and theta frequency band.
When looking at the frontal-central region combined it can be seen that there is a decrease is measured in all of these frequency bands (Alpha - GS: -0.678; US: -0.280) (Beta – GS: -0.079; US: -0.121) (Theta – GS: -1.721; US: -0.545). This was not expected. However, some of these negative slopes are quite minimal, see Figure X35 and X36.

The second theorem only uses the frontal region and says that the beta wave is not expected to increase, which is the case because the beta frequency band decreases (GS: -0.131; US: -0.251). Furthermore, this second theorem expect alpha not to decrease which is not true because alpha shows a decrease in power (GS: -0.502; US: -0.540). For this theorem are the same values and figures (X31 and X32) used as for the cognitive alertness/attention.

In summary, when looking at all regions and measured frequency bands it seen that there is a decrease in all frequency, especially in the theta band.

[7] All values are $1e^{-12}$ uV^2/Hz

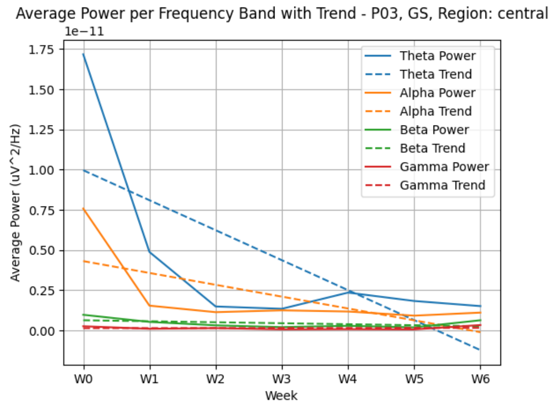


Figure X29

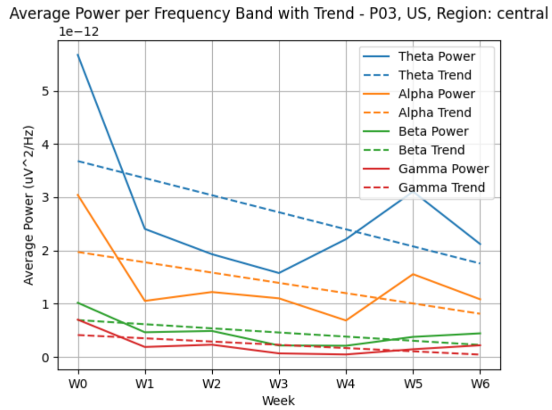


Figure X30

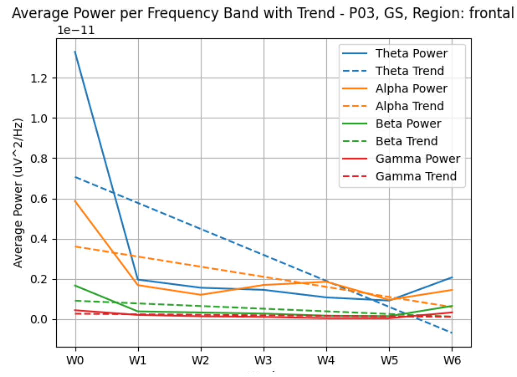


Figure X31

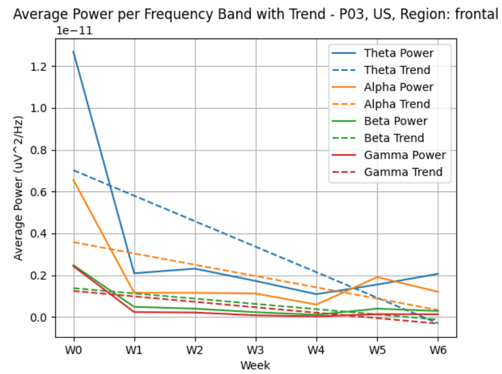


Figure X32

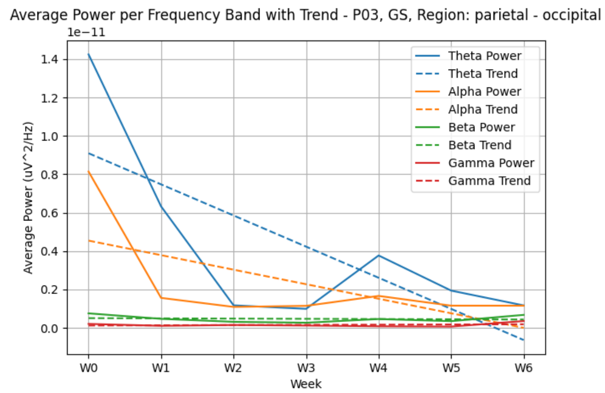


Figure X33

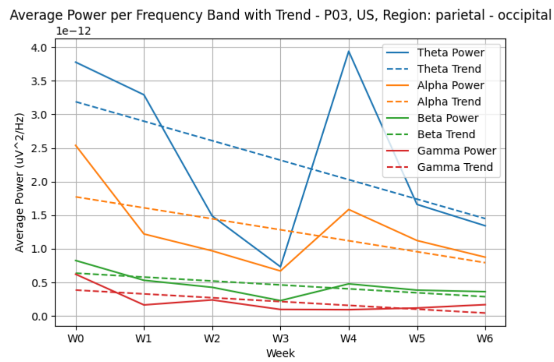
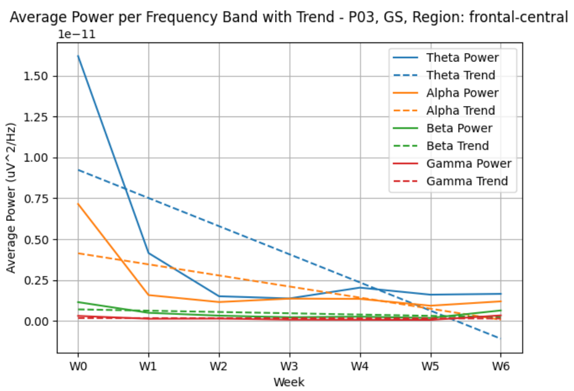
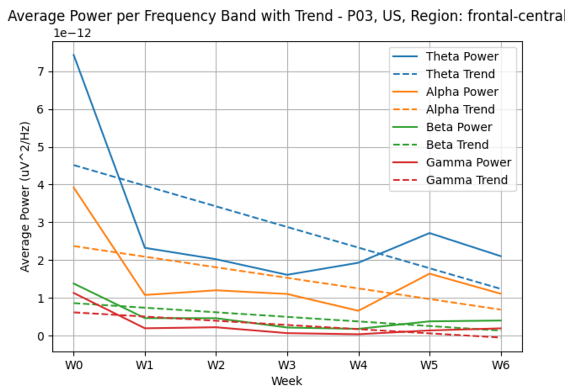


Figure X34





Participant 4

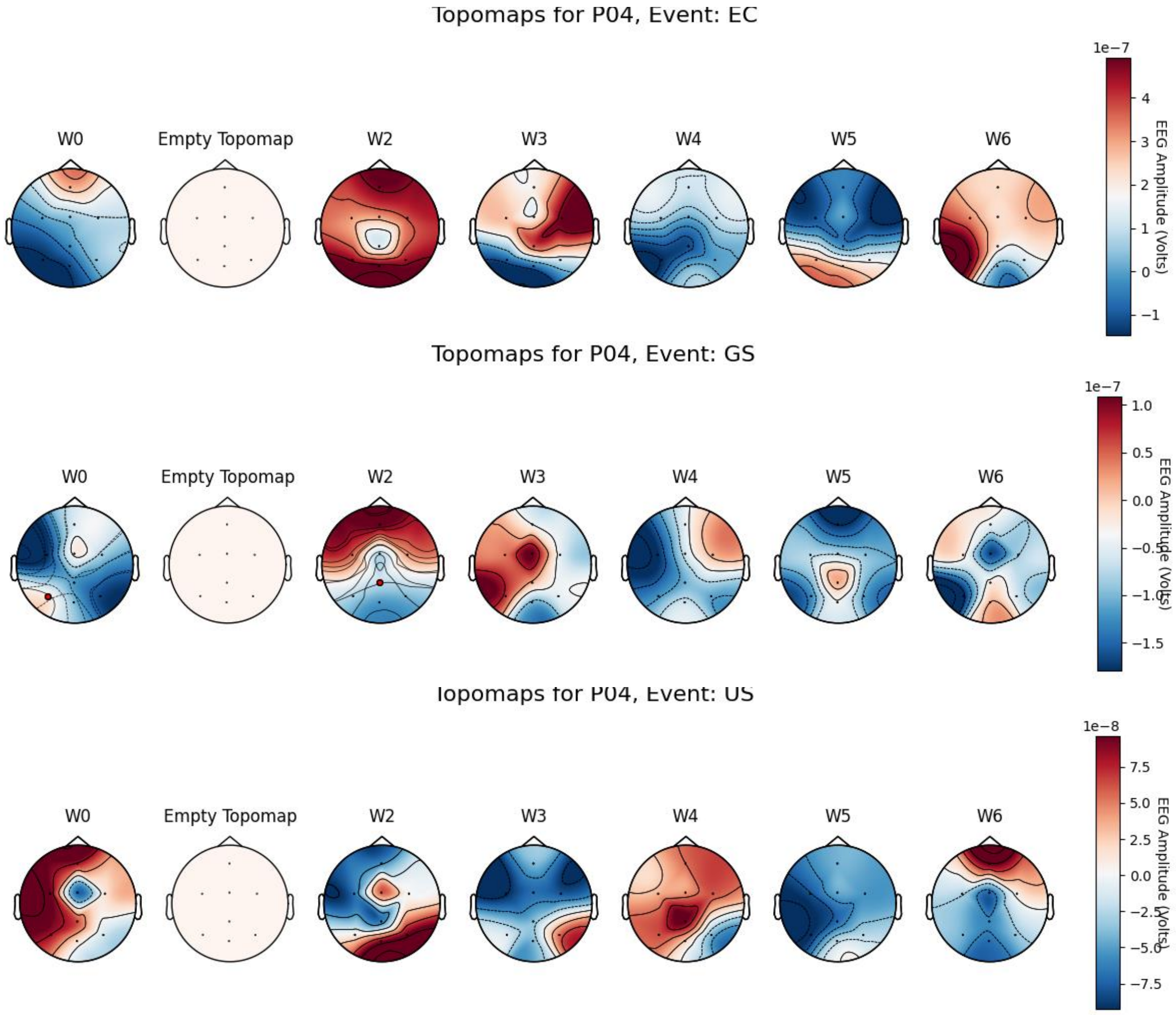


Figure X37: Absolute Topomaps of P04.

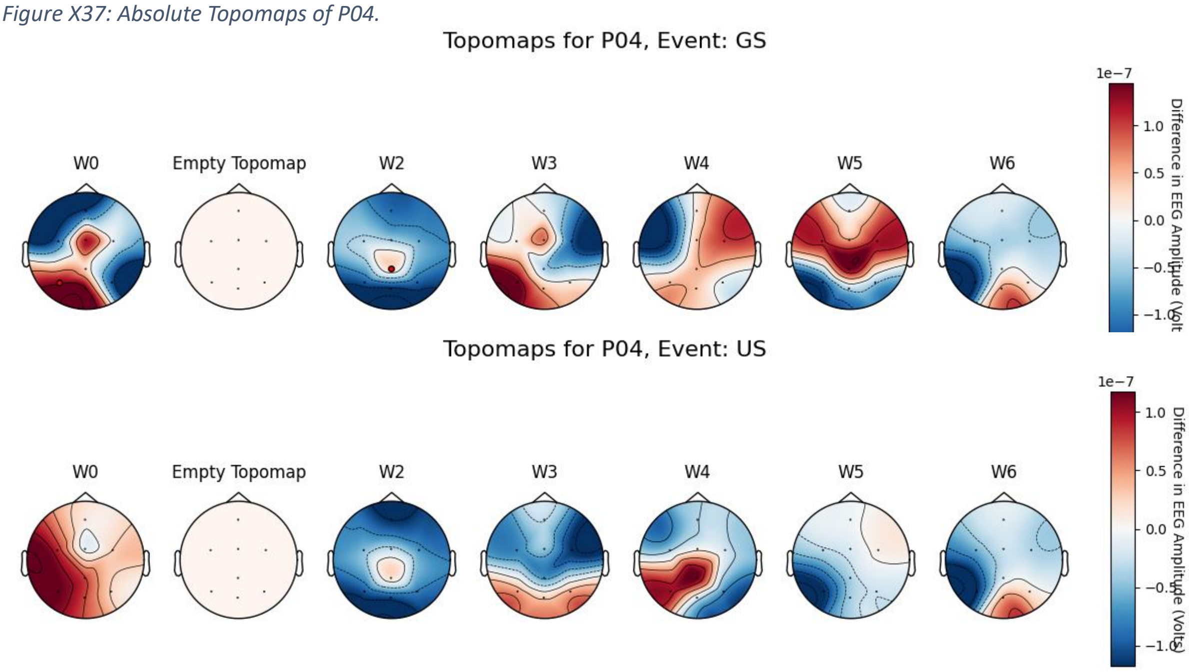


Figure X38: Topomaps of GS and US with EC subtracted of P04.

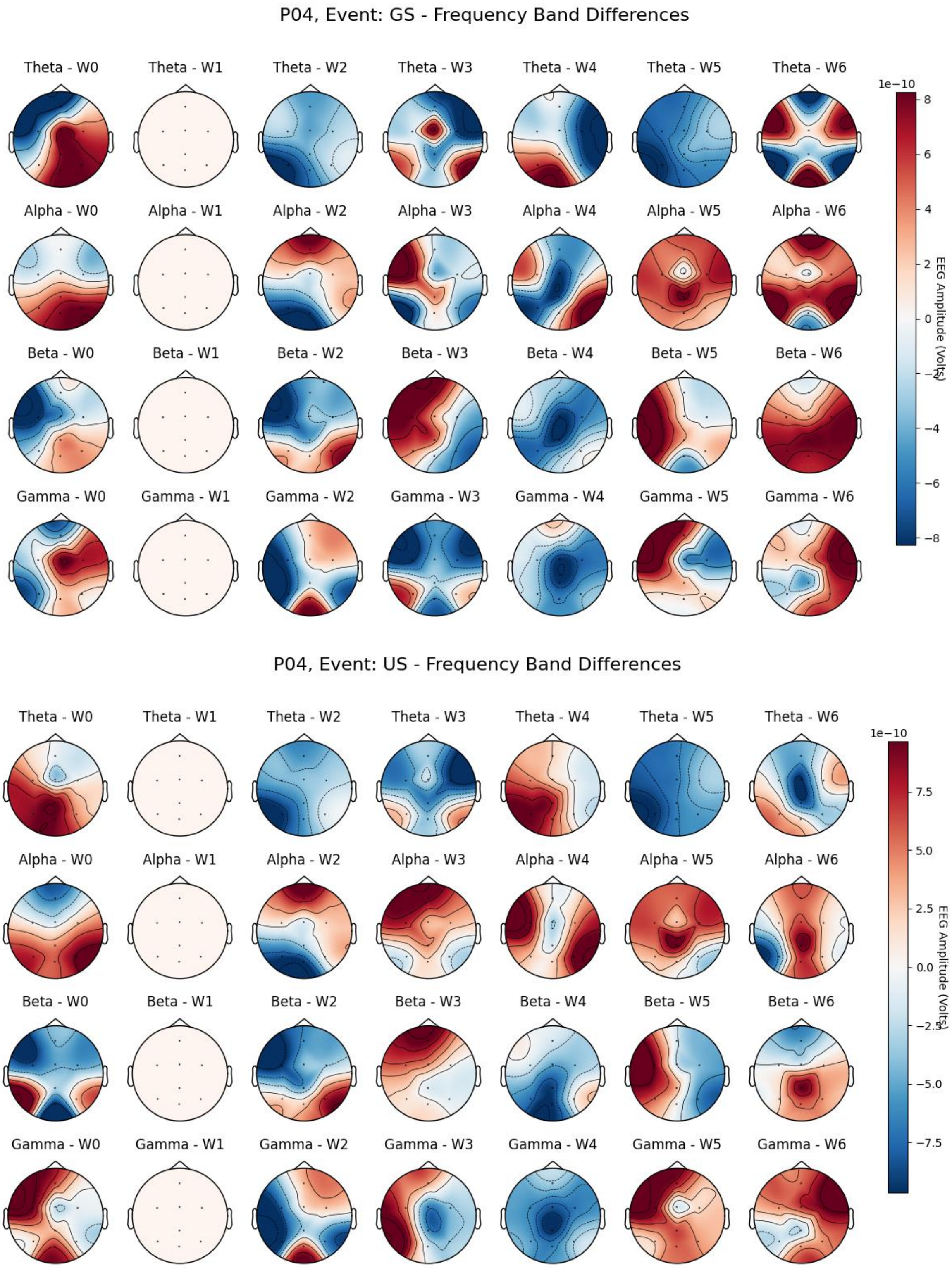


Figure X39: Frequency band topomaps of GS and US with EC subtracted.

Stress Ratio and Concentration Index

When calculating the Stress Ratio and Concentration Index with the formulated formulas in X. it can be seen that in Figure X40 that the Concentration Index gradually increases of the first weeks and decreases from week 4. Whereas the Stress Ratio decreases and remains approximately constant afterwards. When calculating the slope with the use of regression it results in a slightly negative slope for the concentration index for GS and a quite constant slope for US (GS: -0.023; US: 0.003) and negative slope for the stress ratio (GS: -0.013; US: -0.065). Which indicates a not an improvement in concentration but a slightly decrease in stress over the weeks on average for participant 4. Week 1 is missing due to that the data of this week was marked as unsuitable for analysis.

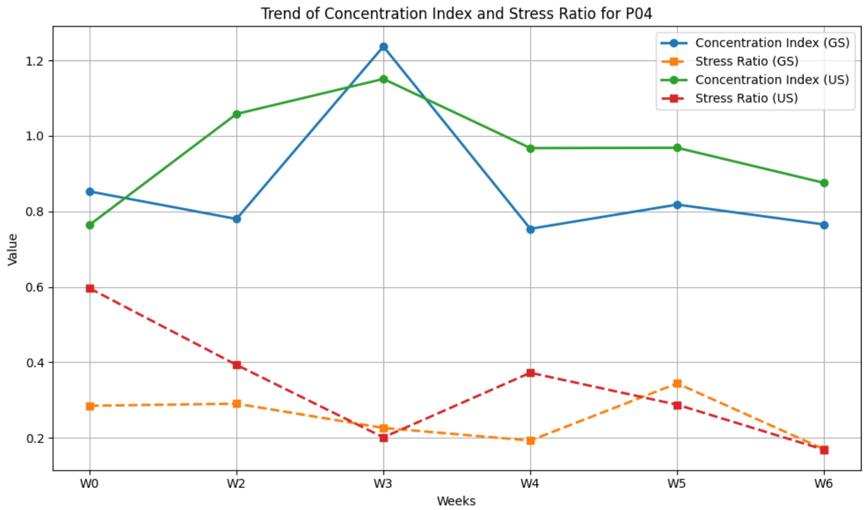


Figure X40: Average Concentration Index, and Stress Ratio for P04 over the weeks.

Frequency band trends[8]

If there is an improvement in motor activation the beta frequency is expected to increase during the imagery training in the central region. As can be seen in Figure X41 and X42 below, there is a positive slope (GS: 0.104; US: 0.181) visible over the weeks for beta power, which means that there is a slight increase in motor activation during the imagery training over the weeks on average.

Furthermore, for an increase in cognitive alertness/attention there could be increase in the SMR (alpha and beta) frequency waves in the frontal region. This is the case due to an increase of power in both figures X43 and X44 in the alpha frequency (GS: 1.859; US: 3.969) and the beta frequency (GS: 0.070; US: 0.222).

For an increase in visual attention there is an increase in beta waves expected in the parietal – occipital region. This is the case with a minimal positive slope (GS: 0.143; US: 0.119). In Figure X45 and X46 can this be seen.

If concentration is increasing, then it is expected that beta increases and theta decreases in the frontal region. When measuring the change, it occurred that the theta frequency band increases (GS: 0.629; US: 1.641) and that the beta frequency increases (GS: 0.070; US: 0.222). This is illustrated in Figure X43 and X44.

As for the anxiety theorem one, as explained in Table 1 within the report, it is not expected to measure a decrease in the frontal – central region for the alpha, beta and theta frequency band.
When looking at the frontal-central region combined it can be seen that there is an increase measured in all of these frequency bands (Alpha - GS: 2.519; US: 4.027) (Beta – GS: 0.095; US: 0.191) (Theta – GS: 0.770; US: 1.524). This was expected. However, some of these positive slopes are quite minimal, see Figure X47 and X48.

The second theorem only uses the frontal region and says that the beta wave is not expected to increase, which is not the case because the beta frequency band does increase (GS: 0.070; US: 0.222). Furthermore, this second theorem expect alpha not to decrease which is true because alpha shows a increase in power (GS: 1.859; US: 3.969). For this theorem are the same values and figures (X43 and X44) used as for the cognitive alertness/attention.

In summary, when looking at all regions and measured frequency bands it seen that there is a increase in all frequency bands, especially in the alpha and theta band.

[8] All values are $1e^{-12}$ uV^2/Hz

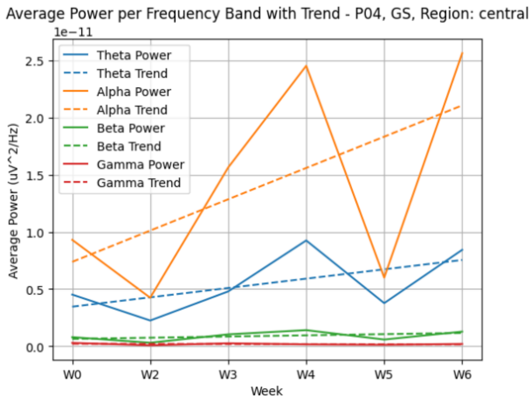


Figure X41

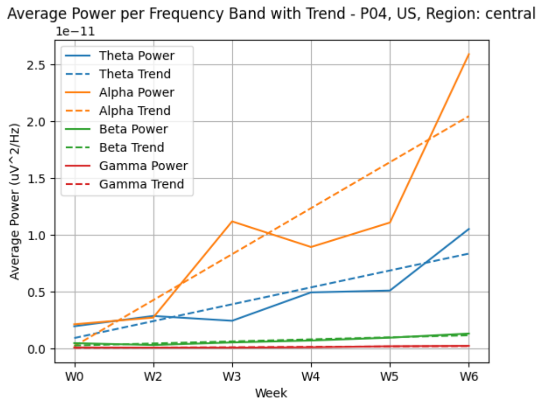


Figure X42

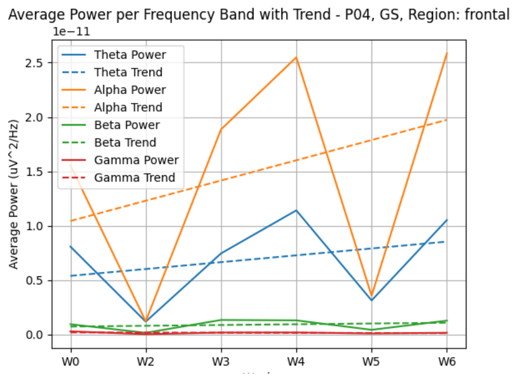


Figure X43

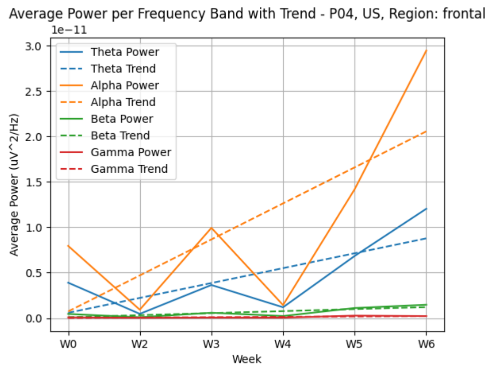


Figure X44

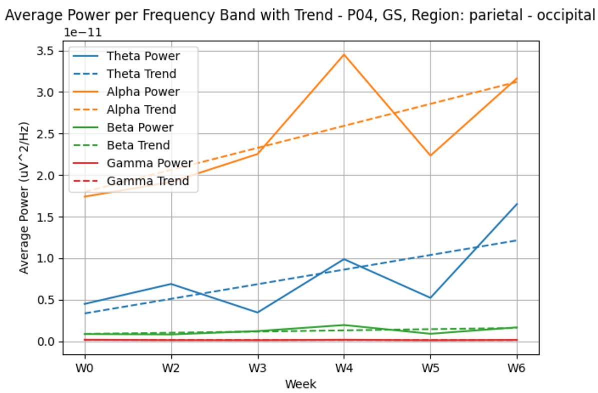


Figure X45

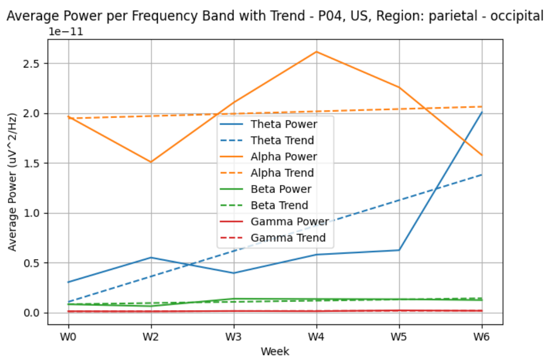


Figure X46

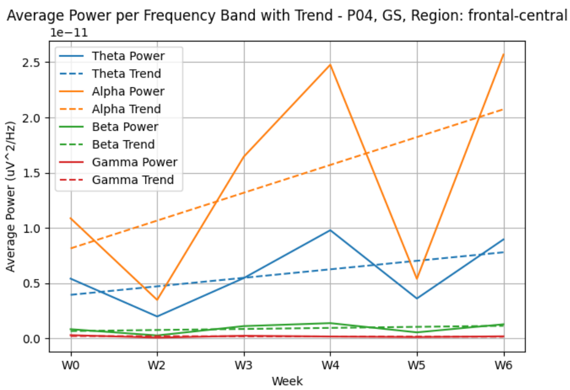


Figure X47

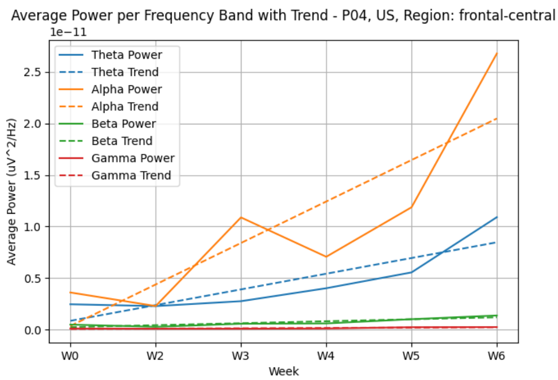


Figure X48

Participant 5

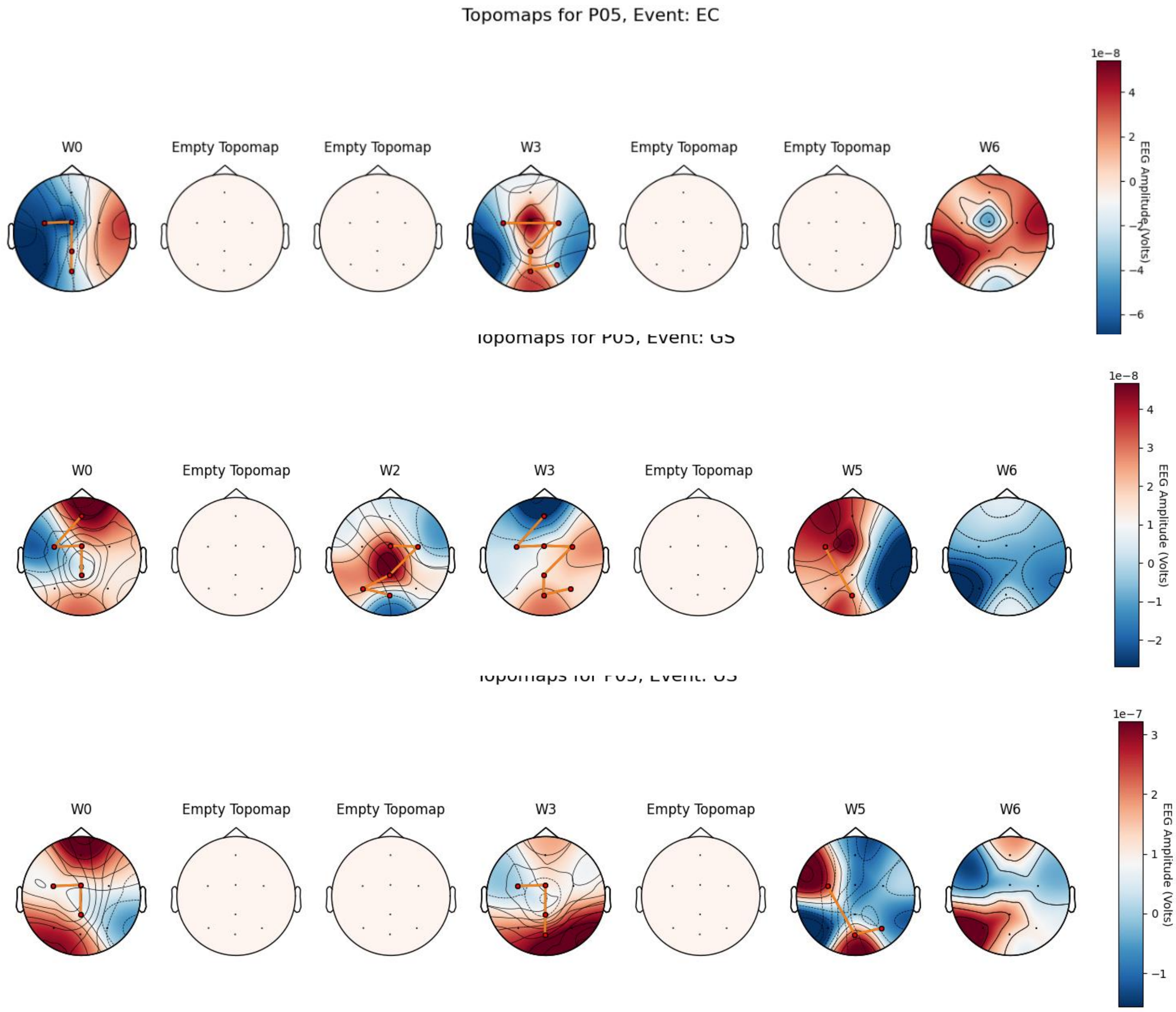


Figure X49: Absolute Topomaps of P05.

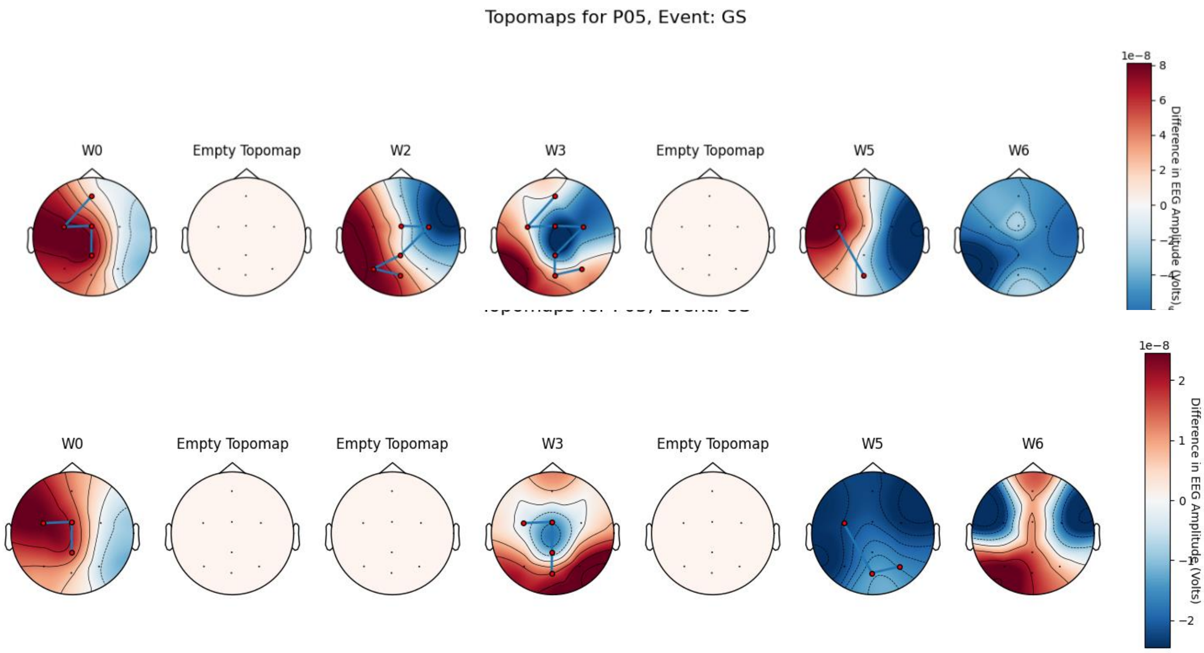


Figure X50: Topomaps of GS and US with EC subtracted of P05.

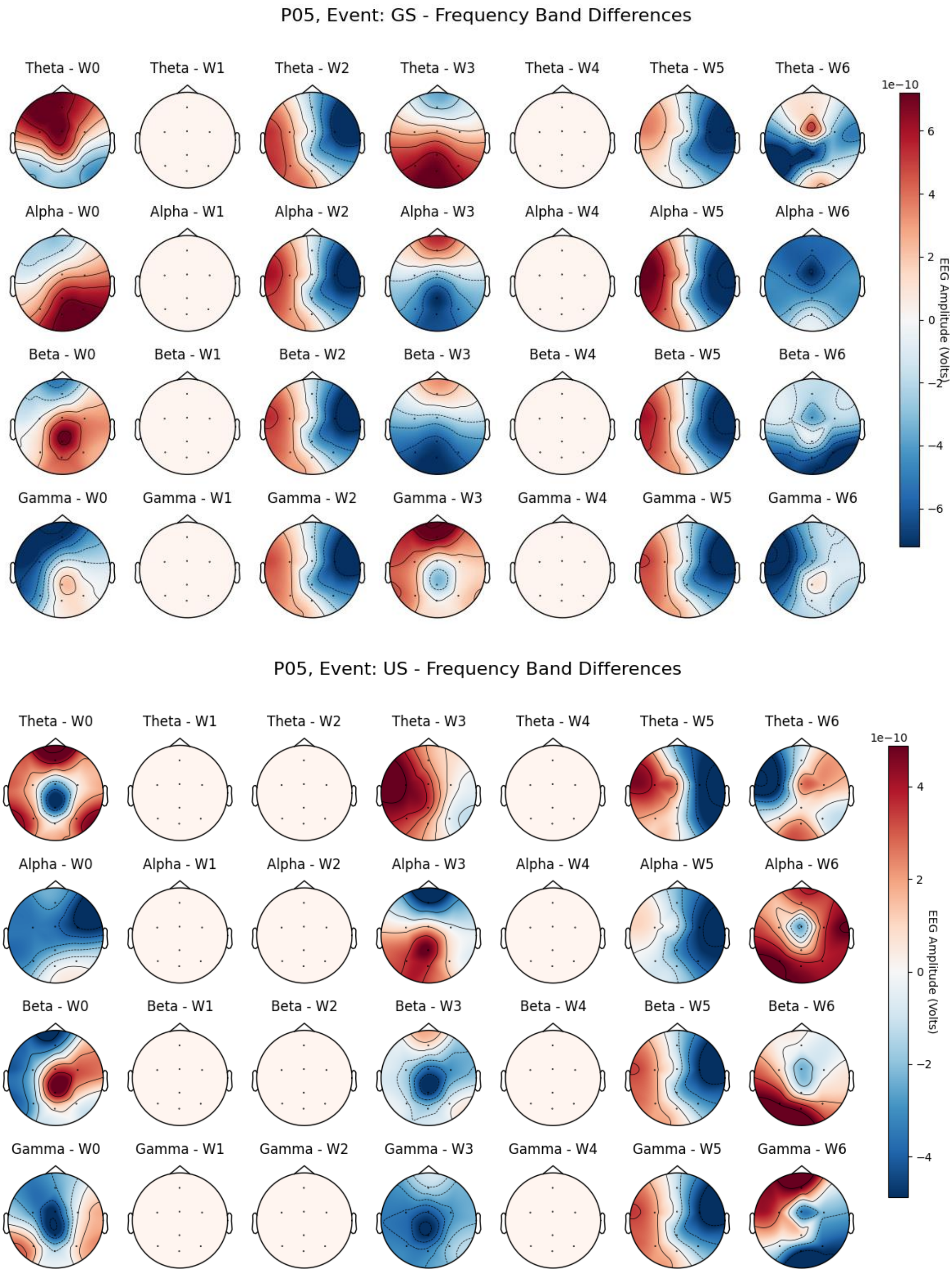


Figure X51: Frequency band topomaps of GS and US with EC subtracted.

Stress Ratio and Concentration Index

When calculating the Stress Ratio and Concentration Index with the formulated formulas in the report in 3.3.4. it can be seen that in Figure X52 that the Concentration Index gradually increases of the weeks. Whereas the Stress Ratio remains approximately constant but also a little increases. When calculating the slope with the use of regression it results in a negative slope for the concentration index for GS and a positive slope for US (GS: -0.216; US: 0.172). This is due to the high drop from week 3 to week 5, and of course the missing weeks. Furthermore, there can a positive slope for the stress ratio (GS: 0.079; US: 0.153) be measured. This indicates a slightly improvement in concentration for US but not for GS and a slightly increase in stress over the weeks on average over participant 5. This is not in line with the expectations beforehand. However, for participant 5 is also a lot of data missing makes the results not that trustable.

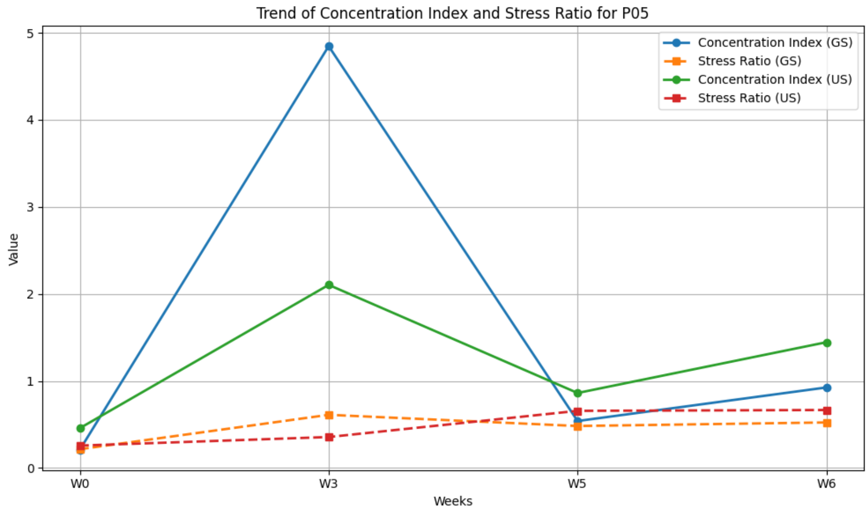


Figure X52: Average Concentration Index, and Stress Ratio for P05 over the weeks.

Frequency band trends[9]

If there is an improvement in motor activation the beta frequency is expected to increase during the imagery training in the central region. As can be seen in Figure X53 and X54 below, there is a positive slope (GS: 0.049; US: 0.069) visible over the weeks for beta power, which means that there is a slight increase in motor activation during the imagery training over the weeks on average.

Furthermore, for an increase in cognitive alertness/attention there could be increase in the SMR (alpha and beta) frequency waves in the frontal region. This is not the case due to a decrease of power in both figures X55 and X56 in the alpha frequency (GS: -1.760; US: -0.690) and the beta frequency for GS (GS: -0.072; US: 0.096). However, for the beta frequency of US there is a small increase measured.

For an increase in visual attention there is an increase in beta waves expected in the parietal – occipital region. This is the case with a minimal positive slope (GS: 0.187; US: 0.156). In Figure X57 and X58 can this be seen.

If concentration is increasing, then it is expected that beta increases and theta decreases in the frontal region. When measuring the change, it occurred that the theta frequency band indeed decreases (GS: -2.895; US: -1.668) and that the beta frequency increases for only US (GS: -0.072; US: 0.096). This is illustrated in Figure X55 and X56.

As for the anxiety theorem one, as explained in Table 1 within the report, it is not expected to measure a decrease in the frontal – central region for the alpha, beta and theta frequency band.
When looking at the frontal-central region combined it can be seen that there is a decrease measured in the alpha and theta frequency bands but not in the beta frequency band (Alpha - GS: -0.660; US: -0.354) (Beta – GS: 0.019; US: 0.075) (Theta – GS: -1.600; US: -0.942). This was not expected. However, some of these positive slopes are quite minimal, see Figure X59 and X60.

The second theorem only uses the frontal region and says that the beta wave is not expected to increase, which is not the case because the beta frequency band does increase for US (GS: -0.072; US: 0.096). Furthermore, this second theorem expect alpha not to decrease which is not true because alpha shows a decrease in power (GS: -1.760; US: -0.690). For this theorem are the same values and figures (X55 and X56) used as for the cognitive alertness/attention.

In summary, when looking at all regions and measured frequency bands it seen that there is a decrease in especially the alpha and theta frequency band.

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[9] All values are $1e^{-12}$ uV^2/Hz

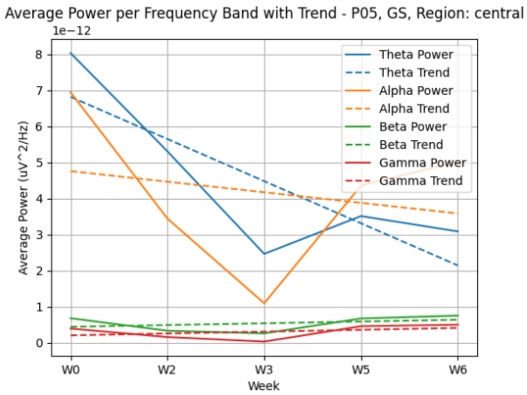

Figure X53

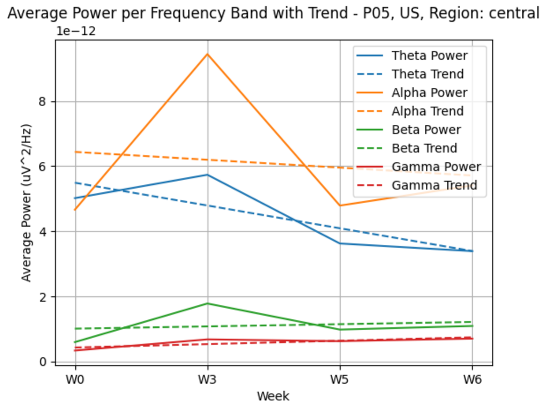

Figure X54

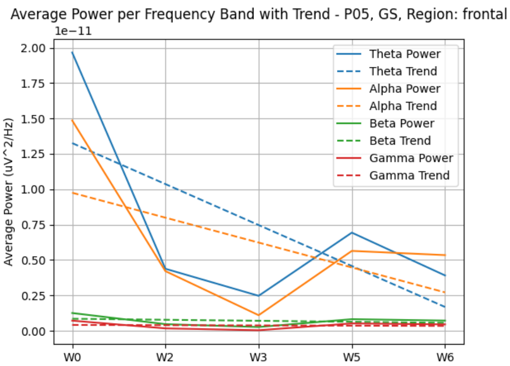

Figure X55

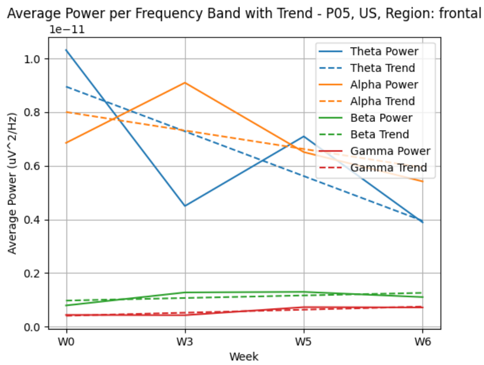

Figure X56

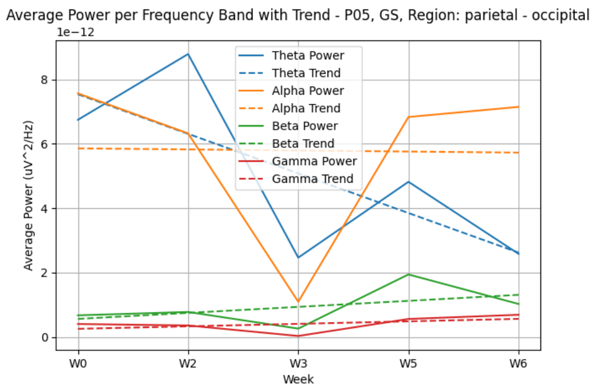

Figure X57

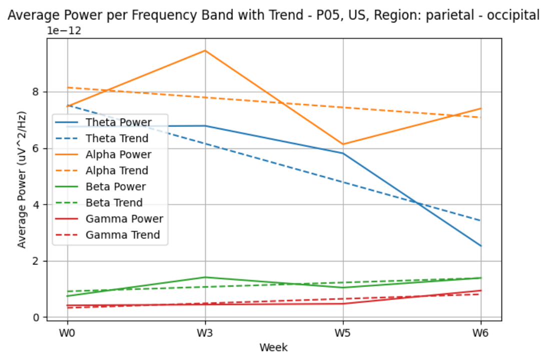

Figure X58

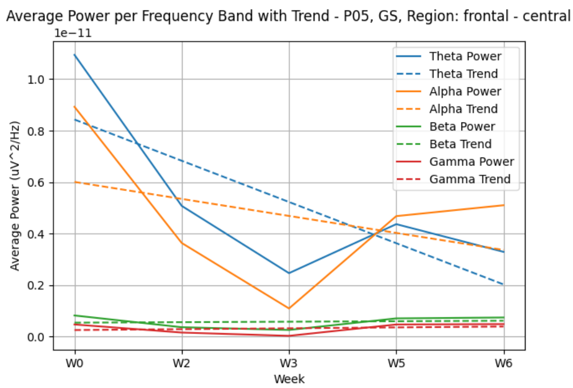

Figure X59

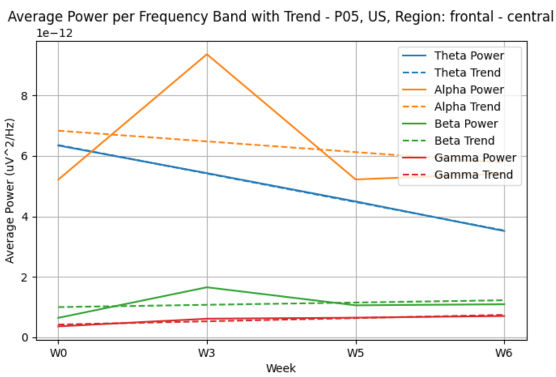

Figure X60