PRC 1

Research Cognitive Neuroscience and Information Technologies

Practicum Report

Reducing maladaptive mind wandering and ADHD symptomatology in high school students using the Meditative Mindfulness technique

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1. Title, acronym and scientific summary of the proposal

Project title: Reducing maladaptive mind wandering and ADHD symptoms in high school students using the Meditative Mindfulness technique.

Acronym: MINDFUL-ADHD

Scientific summary of the proposal

Attention Deficit Hyperactivity Disorder (ADHD) is a pervasive neurodevelopmental disorder in childhood and adolescence (Nicolau et al., 2017; Pascual- Castroviejo, 2008; Cruz, 2021). The most effective psychological treatment in the adolescent and adult population is cognitive-behavioural therapy (CBT) combined with psychostimulants (Miller B, 2021). However, the application of the meditative mindfulness technique has been seen to reduce ADHD symptoms. These results have paved the way for multimodal non-pharmacological treatments (Baena-Extremera et al., 2021; Guillaume et al., 2021). As psychologists, our proposal aims to explore the benefits of Mindfulness in reducing ADHD symptoms, improving attentional capacities in different domains and increasing metacognition (Hasenkamp et al., 2012) and better emotional regulation (Miller B, 2021). To do this, we have designed a program that will help us identify and quantify the therapeutic potential by applying neurological and functional tests before and after the 31-month rehabilitation program. These consist of a one-month long MM pre-workout, followed by a daily workout for the remaining 30 months. Assessment tests will measure attentional control (SART, TMT, and TAP), the emotional state (PANASN), metacognition (MAAS) and brain plasticity; measured with EEG cap. The program sample consists of *N*=80, who will receive training in MM three experimental groups and Jacobson's Relaxation (RJ) the control group. We hypothesize that attentional control, emotional regulation, and metacognition will improve in subjects who receive MM training. If this is confirmed, psychologists and professionals in education could train this technique and apply it in their professional activities.

Acronyms: MM: Mindfulness Meditation; RJ: Jacobson's progressive relaxation; FA: Attentional focus; AM: Acceptance monitoring; MW: Mind Wandering; DMN: Default Mode Network.

2. Summary of the proposal for a non-specialized public

The current project will explore the therapeutic benefits of the Meditative Mindfulness (MM) technique for inattention problems in adolescents diagnosed with ADHD. This disorder is common in childhood and adolescence and has been shown to persist into adulthood (Andreu et al., 2015). The main characteristics of this pathology are inattention, impulsiveness, difficulty in performing complex tasks and difficulty in concentrating. Attention problems in childhood and adolescence are a risk factor that hinders learning and cognitive-social and academic development. Assigns of attention problems we select "mind wandering", which refers to the unconscious, automatic and involuntary thoughts people have in different situations. This phenomenon is common in humans and is linked to different adaptive functions and dysfunctions in their control (see *Appendixe 1*). Several studies have demonstrated the protective and therapeutic capacity of MM since they facilitate the control of mental wandering and improve emotional regulation, attention and metacognition. Our program consists of a 31-month MM training associated with behavioural and neuroimaging (EEG) tests and evaluations. These will allow us to compare the evolution of the participants throughout the process in order to define the effectiveness of this meditative practice in improving the symptoms of ADHD in adolescents.

3. Context, conceptual framework and state of knowledge

Attention deficit disorder and hyperactivity

People with ADHD show constant attention and behavioural or thought control problems (Nicolai et al., 2017). According to the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 2013), inattention is defined by the presence of six (or more) symptoms for at least six months; the main ones are used to careless mistakes, difficulty in maintaining attention, mind wandering, difficulty in completing tasks, difficulty with organization and avoidance of activities that require sustained mental effort. Impulsivity is expressed with hasty actions, impatience, and difficulty achieving medium-long-term goals (Nicolai et al., 2017). In adolescence, this disorder, in 40-80% of cases, can be associated with disruptive, anxiety, affective and learning disorders and the use/abuse of narcotic substances (Nicolai et al., 2017). As we can see, these conditions can cause problems in behavioural, psychological, academic, work and social expression, leading to poor cognitive-behavioural development. This disorder has an approximate worldwide prevalence of 5% - 10%, according to some epidemiological studies (Nicolau et al., 2017; Pascual-Castroviejo, 2008; Cruz, 2021), while in Spain, its prevalence is more varied, standing between 1,13% and 17.9% (Jover and Valdes, 2020). Multidisciplinary studies (López-Martín, 2014) have shown different anomalies in the frontal-striatum circuit that characterize ADHD (see *Appendixe 2*).

Currently, most psychological treatment is Cognitive Behavioral Therapy (CBT), but it has been seen that the improvement of symptoms occurs more when combined with psychopharmacological treatment (Miller, 2021). However, in recent years, third-generation CBTs have included alternative treatments such as psychoeducation or family training (Nicolau et al., 2017), but the Mindfulness technique is giving better results to reduce the symptoms of ADHD (Baena-Extremera et al., 2021; Guillaume et al., 2021).

Attention

Attention is the ability to direct, select and focus on relevant stimuli and stay focused on them. Posner's integrative attentional theory relates three attentional networks with functions associated with different brain areas (Funes and Lupiañez, 2003): 1) The posterior attentional network; is related to processes that allow directing attention towards a potentially relevant stimulus; this capacity is also called orientation reflex. Its neuroanatomical correlates are the posterior parietal cortex, the pulvinar and reticular apparatus of the thalamus, and the superior colliculi. 2) The attentional surveillance and/or alert network; is related to the level of cortical or arousal activation; its function is to maintain an initial state of alert related to the speed of stimulus detection. Its neuroanatomical correlates are the parietal and frontal areas of the right hemisphere, which receive projections of the activity of LC-NE (locus coeruleus using norepinephrine as a neurotransmitter). 3) The previous attentional network; is related to voluntary control over information processing and is associated with the controlled selection of stimuli, the controlled distribution of resources in the face of concurrent tasks, and processes related to working memory to respond to new situations. Its neuroanatomical correlates are mainly associated with different areas of the frontal cortex. On the other hand, the human being is endowed with different attentional capacities -selective, divided and sustained- connected that fulfil different functions. Selective attention is the process that allows us to select certain stimuli and ignore others. Thanks to this, we can produce an organized behaviour; it is usually related to the posterior attentional network (Estévez-González et al., 1997). Sustained attention is the process that allows us to focus on a specific task persistently despite boredom and frustration; it is usually related to the attention network of vigilance and/or alertness. Divided attention is usually associated with the previous

attentional network and is the cognitive process that allows us to attend to two or more tasks simultaneously for a specific time. However, this capacity is not simultaneous; Although it is perceived that way; What happens is that thanks to the orientation reflex, we are making attentional jumps from one task to another, so it is not possible to attend with the same effectiveness as if we only attend to one task.

Mind wandering

During wakefulness, people spend approximately 50% of the time on thoughts unrelated to the task at hand, not even to the stimuli around them (Killingsworth et al., 2010). This phenomenon, called *mind wandering*, refers to automatic thoughts outside of the task, mental wandering and spontaneous cognition, the latter being understood as the result of unconscious processes that lead to a conclusion (Boayue et al., 2021). This phenomenon compromises a brain region called the Default Mode Network (DMN), which is associated with off-task or resting thoughts and with different mental processes such as retrieving past experiences in episodic memory or imagining future situations (Klinger, 2013, Christoff et al., 2016). Thanks to neuroimaging techniques, it has been seen that this region is not coexistent with the conscious MW (Klinger, 2013). There is consensus that this region includes nodes such as the medial prefrontal cortex (mPFC), the posterior cingulate cortex (PCC), the pre-wedge, both angular gyrus, the posterior inferior parietal regions, the lateral temporal cortex, the hippocampal formation; including the parahippocampus (Buckner et al., 2008; Hasenkamp et al., 2012; Bradmeyer and Delorme, 2016). Christoff et al. have defined different subareas (DNCORE, DNMTL and DNSUB3) of this region with their respective functions. In *Appendixe 3*, we expand this information and show the location of different areas activated during states of mind wandering.

It is necessary to differentiate conscious thoughts from unconscious thoughts to understand mind wandering. The former were processed into thought processes related to relevant stimuli that are the object of our conscious and intentional attention. Unconscious thoughts are the thought processes that occur while our attention is directed elsewhere, either by an external or internal stimulus. Studies on decision-making (Dijksterhuis & Nordgren, 2006) that associate conscious thinking with solving problems requiring strict criteria or rules on a dimension, while unconscious thinking is associated with solving complex problems that do not require criteria so strict. On the other hand, Seli et al. (2018) have defined mind wandering as a heterogeneous construct endowed with different processes: thoughts not related to the task, unintentional thoughts, thoughts independent of the stimuli, thoughts not related to the task and independent of the stimuli, self-generated thoughts and mind wandering. We will not detail these unconscious processes because they are not relevant for the current project; However, knowing the heterogeneity of the MW can help to understand it. Finally, there is consensus on the correlation between MW, task time and working memory (Risko et al., 2012; Kane et al., 2007; Klinger, 2013); It has been shown that there is a positive relationship between MW frequency and task time and a negative relationship between MW frequency and memory about reading material or activities that require more resources.

Mindfulness Meditation

Mindfulness is a meditative practice that directs attention in the present moment without judging (Gazella, 2005). The target elements of Mindfulness are usually breathing sensory experiences or body scanning. It is about returning attention to the object each time one is aware of mental wandering (Hasenkamp et al., 2012; Santachitaa, 2015). Mindfulness is based on Buddhist meditation, from which it bases its three fundamental pillars -posture, focus of attention and constancy- (Santachitaa et al., 2015): 1) Posture and breathing are efficient

instructions to activate the relaxation mode and send signals to the reticular formation that is associated with arousal, consciousness and emotional regulation. 2) Attentional orientation is usually focused on the breath, the body scan and the current moment. 3) Practice consistency is essential for the effects to last and deepen over time (Santachitaa et al., 2015; Kabat, 2003). We have modifiable neural networks called Hebbian networks (Mayorga, 2015), which consolidate learning and are related to the modulation of habits. They are modulated according to the frequency of the stimuli that activate them, which means that perseverance and practice can produce physiological changes at the neuronal level. There are three essential skills in Mindfulness meditation, focused attention (FA), monitoring of care with acceptance (AM) and open monitoring (OM). The first focuses on training the ability to maintain attention on a specific object (Lutz et al., 2008; Feruglio et al., 2021); the second adds acceptance training that has been observed to be a critical mechanism for the reduction of MW states (Rahl et al., 2017); while the third tries to focus conscious attention on everything that is happening (Lutz et al., 2008; Feruglio et al., 2021). See some of the benefits of this practice in *Appendixe 4*.

EEG

The electroencephalogram is a neuroimaging technique that records the electrical activity of brain cells (Mayor et al., 2013). The sum of postsynaptic action potentials results in electrical activity, represented in a graph of voltage on the vertical axis and time on the horizontal axis (Mayor et al., 2013). We can differentiate waves with different frequency ranges (alpha, beta, delta, theta and gamma). Electrodes are typically placed according to a specific and standard system called System 10-20 (Mayor et al., 2013) since it is a standardized method that relates the location of the electrode to the underlying area of the brain and also guarantees that the results can be compiled, reproduced, compared and analyzed effectively (Mayor et al., 2013). Currently, there is the consensus of the association between some psychoeducational anomalies; like ADHD, with a high Theta / Beta ratio in the prefrontal areas; mainly an increase in theta activity and a decrease in fast rhythms (Martin et al., 2017; Arns, Conners and Kraemer, 2013; Barry, Clarke and Johnstone, 2003; Loo and Makeig, 2012; Lopez, 2014). In this way, it has been seen that the absolute values theta and theta/beta ratio can be differential biomarkers between children with ADHD and children without this disorder (Markovska-Simoska et al., 2017). However, it has been observed that some clinical ADHD syndromes show a normal EEG and only manifest clinical symptoms, with a prevalence of approximately 16-18% (Loo and Makeig, 2012). Other studies with EEG (Braboszcz & Delorme, 2011; van Son et al., 2019) coincide in reporting alpha desynchronization and theta synchronization during states of mind wandering compared to the attention focused on breathing in inexperienced meditators. On the other hand, several investigations (Bradmeyer and Delorme, 2016; Rodriguez-Larios and Alaerts, 2021) have shown improved cortical processing during long-term mindfulness practice, specifically an increase in theta activity in the middle frontal regions and alpha activity in the somatosensory cortex.

4. General long-term and short-term aims

The overall long-term objective of this project is to facilitate the creation of preventive and treatment protocols for inattention that can be included in the academic curriculum in secondary education.

Childhood and adolescence are stages of development in which the individual continues to create their identity and face a future in which individuals capable of being creative, endowed with critical thinking and the ability to solve problems will be needed (Meller, 2019). The uncontrolled exposure of this population to digital technologies, as well as to social networks, hinders healthy cognitive development. (Lizondo-Valencia et al., 2021). This proposal goes along the lines of facing research towards a new vision of health, in which prevention is equal to or more important than cure. We hypothesise that it is not necessary to wait for an individual to be incapable of solving their psychological and attentional problems to respond. However, it is necessary to transmit affordable and accessible tools and strategies for the majority that prevent maladaptive situations in the academic field. For this, we consider that this project can contribute to this long-term objective, insofar as the practice of Mindfulness can be taught in schools, thus becoming an accessible tool for students that could improve their academic performance and their psychological and emotional development.

The general objective in the short term is to verify the effectiveness of the Mindfulness Meditation (MM) technique for the treatment of inattention in adolescents with ADHD.

Currently, ADHD is a pervasive neurodevelopmental disorder in childhood and adolescence, and it has a worldwide prevalence of 5% -10%, according to the most careful epidemiological studies (Nicolau R. et al., 2017; Pascual-Castroviejo, 2008; Cruz Ripoll, 2021). So far, most attention problems have only been answered when expressed in a maladaptive way in the form of a diagnosis of ADHD or other related psychopathology. When these cases are detected, they are mostly treated from a multimodal perspective with psychotropic drugs and cognitive-behavioural therapy in most cases. However, there has been a growing interest in Mindfulness Meditation (MM) as a strategy to reduce symptoms related to inattention, which has given rise to third-generation cognitive-behavioural therapies (CBT). Where MM is included with good results (Baena-Extremera et al., 2021; Guillaume et al., 2021), that is why our proposal is aimed at identifying what cognitive and neurophysiological benefits the continued practice of MM can have to modulate the control of the Default Mode Network (DMN) in a sample of students diagnosed with ADHD. It has been observed that the DMN is closely related to the states of mind wandering and, in turn, with the symptoms of inattention related to ADHD (Sood and Jones, 2013, p.137).

5. Specific aims of the proposal

Specific aim 1: We will train participants in Mindfulness Meditation and record and evaluate their metacognition and emotional state over 36 months.

Participants will be trained during the third month (March 2022) in different MM applications: focused attention (FA), open monitoring (OM); monitoring of attention + acceptance (AM) (Rahl H et al., 2017) for the experimental conditions and Jacobson's relaxation training for the control condition. Depending on the results during this month's training, we will consider using Neuroenginering of Mindfulness, a technological application to facilitate said learning in case of severe symptoms assessed (Diego C, 2016). Subsequently, a contract will be executed with the participants where they will commit to carrying out training of 20 minutes from 4^{th} month to 9^{th} month and 40 minutes from 11^{th} month to 34_{th} month. The experimenters will facilitate these sessions through online meditations, and they will be recorded by audiovisual recording online. They will be provided with a specific schedule for this. We will use the Mindful Attention and Awareness Scale (MAAS; Brown & Ryan, 2003) to evaluate their meditative abilities; the will be applied before starting the first training, after the first month of training and every six months after that. We will also administer the PANASN scale (the Positive and Negative Affect Schedule, Watson et al., 1988) the two weeks prior to pre-training, just after it, and every six months throughout the study to assess their emotional state. With this training, we hypothesise that metacognition will improve in the participants, the willingness to attend to the present moment, and overcome internal stimuli or disturbing states (Mehnwolo et al., 2018) and increase positive affect.

Specific objective 2: We will identify the differences in the frequency and duration of the mind wandering states during different attention tasks in adolescents with ADHD before, during and after a Mindfulness Meditation training regimen and evaluate its effectiveness.

We will collect the results of the sample in three attentional tests accompanied by the cap EEG technique together with the simultaneous application of self-caught mind wandering (for example, pressing a button every time the participant is aware of a state of mental wandering) (Rodriguez- Larios and Alaerts, 2021). The EEG cap will serve to observe the activations of the DMN as expressions of mind wandering (Klinger E., 2013), and we will consider the contributions of Christoff, Irving, Fox et al. (2016) that establish different locations that are associated with the DMN and that facilitate the differentiation of the functions of mind wandering at each specific moment (for example, DNCORE, DNMTL and DNSUB3). We hypothesise that there will be a positive correlation between MM treatment time and MW control ability and a significant correlation between the results of attentional tests (SART, TAP and TMT), MW awareness, and EEG recording. For subsequent correlation of the results of the different variables.

6. Materials and methods: General aspects of the proposal

6.1. Study design and sample of subjects

This project is a 36-month longitudinal treatment experimental study that will use an intentional non-probabilistic sampling to obtain a sample of 80 adolescents attending ESO, all diagnosed with ADHD. We will use a pre-post quasi-experimental design with a control group, and the subjects will be divided according to sex and then randomly assigned to four identical treatment conditions. The research aims to focus observation from a multidisciplinary approach to evaluate the effect of Mindfulness training on cognitive, emotional, behavioural and neurological variables. All participants will be recruited through the Association ADHD Catalonia and the Catalan Federation of Associations of Relatives and People Affected by ADHD (FCAFA ADHD). All recruited candidates will receive a study information sheet to obtain informed consent and a participation contract (see section 13).

Subjects: 80 adolescents diagnosed with ADHD between 12 and 16 years of age who are attending ESO (FAg = 20; AMg = 20; FAAMg = 20 and gRJ = 20).

6.2. Criteria for selecting the participants

The participants will be males and females between 12 and 16 years old and attend Compulsory Secondary Education (ESO). In addition, they will understand and speak native Spanish. Candidates in psychopharmacological treatment who have previous experience in meditation techniques and the Jacobson Relaxation technique who present comorbidity with another psychopathology and have a history of consumption and abuse of alcohol and narcotic substances will be discarded. In addition, due to the characteristics of the treatment, we will also rule out subjects with a long-term respiratory disorder.

6.3. Methods and tasks

Once the total sample is obtained, the participants will be randomly assigned to four treatment groups: experimental group 1 (FAg) that will receive training in focused attention (FA) from MM; experimental group 2 (AMg) that will receive training in follow-up acceptance; the experimental group 3 (FAAMg) that will receive training in the two previous modalities and the control group (RJg) that will receive training in RJ. Two weeks before the training, we will carry out different psychometric tests for the multidisciplinary pre-assessment. Then, during the first month of the project, each participant will be trained in each of the techniques corresponding to their treatment group. The tests will also be administered during the treatment and, once the quantification is finished, the variables will be studied and compared at different times, and thus their effectiveness will be measured as a function of the practice time.

6.4. Materials

The material used in the project, in general terms, will be composed of: 1) Specific material for sanitary tests (SART, TAP, TMT); 2) psychometric tests to assess metacognition (MAAS); changes in emotional state (NPANAS); 3) specific material for the EEG cap; 4) specific material for Mindfulness and Jacobson's Progressive Relaxation sessions; 5) specific material for Mindfulness Neuroengineering (if necessary); 6) Computers with SPSS and JASP for the analysis of the study data.

6.5. Analysis

We hypothesize that there will be an improvement in the attentional, metacognitive and affective dimensions and a cortical improvement in the experimental groups compared to the control group.

The EEG dataset will be cleaned up with the PREP pipeline in EEGLAB v2019.0 and MATLAB R2018a.

For the statistical analysis, we will use the JASP 0.9.2 software.

7. Materials and methods detailed for specific aims

7.1. Specific objective 1

Methodology and procedures:

We will carry out a one-month face-to-face instruction to each treatment group. Once completed, a participation commitment contract will be provided. In addition, each condition will initiate a daily online training for the next 31 months. An evaluation will be done before, during and after the treatment.

1) Face-to-face instruction (3rd month): Students will be instructed in FA and AM in the treatment groups. The control groups will be instructed in RJ (see *Appendixe 7*). At the end of the instruction, a commitment contract (*Appendixe 6*) will be provided to the candidates, where they will commit to carrying out the daily sessions according to their specific group. Their participation will be rewarded with academic credits.

3) Treatment (4th-34th month): In the experimental groups (FAg, AMg and FAAMg), it will consist of 20 min/day for the first six months and 40 min/day for the rest of the treatment. The established practice time is based on different studies (Tanaka et al., 2015; Morrison et al., 2014; Dimidjian and Linehan, 2008) that determine an increase in the positive effect of the 40-minute sessions in different dimensions. We will apply a strategic balance of the two types of sessions in FAAMg. The practice will consist of 20 min/day of RJ in the control groups throughout the treatment.

4) Online assessment: We will administer Mindful Attention and Awareness Scale (MAAS; Brown & Ryan, 2003) and PANASN (the Positive and Negative Affect Schedule for children and adolescents, Watson et al., 1988) before and after instruction, also during treatment every six months and at the end of it to assess changes in metacognition (Brown and Ryan, 2003) and affect; respectively. On the one hand, we chose the MAAS scale given its solid psychometric properties and easy administration and correction; also, it is online and is completed in approximately 10 minutes (Brown and Ryan, 2003). On the other hand, we chose PANASN for its solid empirical basis favouring its two-dimensional structure of affectiveness and its validity and reliability (Sandin, 2002).

Materials

MM and RJ face-to-face task: We have three instructors in Mindfulness and three instructors in Jacobson's progressive relaxation with years of experience who will travel to give face-to-face training. The UAB, UB, UdG and UdL will give us room for this activity.

Online training: The MM and RJ sessions will be online and facilitated by the Mindful Science platform following a pre-established program. We choose this platform for its clinical application experience and solid scientific base (Mindful Science, 2020). E-prime 3.0 and E-Run will be used for the administration and registration of the sessions. We will equip the 80 candidates of SriHome Webcam PC Full HD 1080P with Stereo Microphone for audiovisual recording. Regarding the Neuroenginering Mindfulness System (Diego C, 2016) (see section 8), it will serve as an alternative for candidates with severe ADHD who do not pass the face-to-face instruction phase (see *Appendixe* 7).

Psychometric tests: MAAS (Mindful Attention Awareness Scale, Kirk et al., 2003) and PANASN (the Positive and Negative Affect Schedule for children and adolescents, Watson et al., 1988)

Analysis

We will use simple regression statistics to analyze the relationship between the practice time with MAAS and PANASN. ANOVA will also be used to compare the results between the groups.

We hypothesize that there will be a significant positive relationship between the training time in MM and the metacognitive capacity evaluated with MAAS and the positive affect measured with PANASN compared to the control group.

7.2. Specific objective 2

Technologies, methodology and procedures

We will apply three attentional tests at different times accompanied by the EEG cap technique and the simultaneous application of self-caught mind wandering to check if there is a positive relationship between performance in attentional tests, MW awareness and brain plasticity.

Attentional tests

To evaluate *sustained attention*, we will apply the SART (*Sustained Attention to Response Task*) test since some studies have observed a significant correlation in the results of this with the neurophysiological registry and self-reports (Cheyne et al., Carriere, & amp; Smilek, 2006; Christoff, Gordon, Smallwood, Smith, & amp; Schooleret al., 2009; Marcusson D, Terhune D and Cardeña E., et al. 2009). This test consists of completing a Go / No-Go task that requires participants to press or not press a button based on a specific signal. It is evaluated by the response time, error rate, and the interval between errors (Robertson et al., 1997).

We will apply the TAP test (*Test for Attentional Performance*, by Zimmerman and Finn, 1995) to evaluate *divided attention and executive function*. It consists of a battery of computerised tests that are highly indicated to evaluate attention deficits (Zimmermann and Fimm, 2007).

We will use the TMT test (*Trail Making Test,* de Reitan and Wolfson, 1985) to evaluate *Selective Attention*. It consists of an evaluation tool that has two parts, it is timed, and with the maximum possible precision, it is not computerised, so the researcher will be the one who records the precision and time (Takeda et al., 2019).

Self-caught mind wandering

This test will be applied while one of the attentional tasks is being carried out. It will consist of an extension in each test software where the subjects must press a button with the label M each time they are aware that their mind wanders.

Cap EEG

The two tasks described above will be completed simultaneously with an EEG cap study in a quiet room designed for EEG experiments. An ElectroCap International registration cap will be used with an electrode location using the International 10-20 system (see *Appendixe 8*). The alpha/theta and TBR synchronise during attentional tasks, and their correlation with self-caught mind wandering will be analysed. Activations in the areas associated with DMMTL, DMCORE, DMSUB3 and DAN (Christoff et al. 2016) will be considered for a more detailed correlation with scores in the attentional and self-caught MW tests.

Analysis

We will use the Pearson / Spearman statistics to correlate the DVs (EEG, attentional tests, and self-caught MW scores). To analyze a causal relationship between the training time and the changes in the different tests, we will use Linear Regression. Finally, we will analyze the differences between groups using the ANOVA statistic.

We hypothesize a significant positive relationship between MM training time and an improvement in the results of attentional tests, mind wandering awareness tested with the self-caught probe, and neurophysiological control measured with EEG. Specifically, we hypothesize that the FAAM group will show a better evolution than the rest of the groups and that the AM group will show better results than FA.

8. Possible difficulties/complications (*breakthroughs*) of the project

Difficulty concentrating on the treatment session: Due to the severity of ADHD, some subjects may not focus their attention on the sessions, which could lead to dropout or seriously slow down the learning process. For this, we have an adapted Neuroengineering in Mindfulness system (Diego et al., 2016) that consists of a technology that links an EEG with helmet headphones with an application that will be associated with E-Print Go that will regulate sound reproduction of the subject's respiration as a function of the DMN correlates detected with the helmet. After pre-training, we will decide the requirement to use this system.

Lack of adherence to the experiment: The treatment sessions after the first month are all online; this implies the risk that the participants do not carry out the sessions, and there is deception on their part. However, through the E-Print Go platform, an automatic audiovisual recording of the experimental subject will start once the session has begun. On the other hand, since it is long-term research, there is a risk that the participants will abandon the study due to lack of interest or for different reasons. However, the commitment contract details the incentives/rewards for participation related to academic credits previously scheduled with their respective schools, an incentive that we hope will improve treatment adherence. Finally, we have considered it necessary to create a space where we can know the impressions of the participants related to the motivation in the project, their perceptions about the effects of the project and possible doubts that may appear, for this, they will have face-to-face interviews once a month the first year, every two months the second year and every three the third year. On the other hand, treatment in MM has shown a negative relationship with procrastination (Cheung and NG, 2019), so we hope that adherence will increase while reducing the risk of procrastination as treatment progresses. At least in the groups that receive this treatment.

9. Calendar distribution of phases and targets for specific aims.

YEAR		FIRST YEAR												SECOND YEAR												THIRD YEAR											
MONTH		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
The entire project																																					
Participant selection, group assignment, informed consent																																					
Face-to-face interview																																					
TASKS	**Aim**																																				
Phase 1 Evaluation																																					
Affective evaluation (PANASN)	1																																				
Metacognitive evaluation (MAAS)	1																																				
Attentional and MW evaluation (SART, TAP, TMT) + EEG + self-caught MW	2																																				
Phase 2 Face-to-face instruction																																					
Mindfulness Meditation	1																																				
Jacobson's Relaxation	1																																				
Engagement contract	1																																				
Phase 3 Treatment																																					
Mindfulness Meditation 20 min/day (experimental groups)	1																																				
Mindfulness Meditation 40 min/day (experimental groups)	1																																				
Jacobson's Relaxation 20 min/day (control group)	1																																				
Phase 4 Analysis																																					
Analysis and statistics of the data	1 and 2																																				
Drafting of study results and conclusions	1 and 2																																				

10. The scientific, clinical, social and technological potential impact of the proposal

The purpose of this project is to create and apply for a Mindfulness program so that adolescents affected by ADHD can reduce their symptoms and improve different capacities without the need for psychopharmacological treatment.

This study will have a scientific impact because it can provide new scientific evidence about the modulation of attentional capacities (sustained, selective and divided attention), metacognition, mind wandering, and the general emotional state through the daily practice of Mindfulness comparing the treatment in two skills and combined. Furthermore, it aims to correlate these cognitive and emotional changes with brain plasticity throughout training.

At the clinical level, it can contribute to a change in the psychopharmacological option as the majority of treatment of ADHD, reduced or replaced by other techniques without adverse effects such as Mindfulness, for example, improving adherence to treatments in virtual reality. In addition, it can open the doors for future research to study the specific effects of training on each of their skills (FA, AC, OM) and in their combination.

Technologically, it can provide scientific support for creating future start-ups aimed at psychopathological treatment through Mindfulness with wireless EEG.

Finally, we believe that it will have a social impact because it can empower the population by providing evidence of the benefits of a tool carried out by anyone, anywhere. In addition, it can open the doors to the training development of this technique at an academic level, given its multiple benefits in different areas and all types of populations.

11. Justification of the team of researchers and institutions involved

The team of researchers will be made up of:

Two postdoctoral psychologists specialized in cognitive neuroscience and had research experience in EEG and data analysis.

Two Master in Cognitive Neuroscience students to perform assistant tasks.

R&D team made up of two postdoctoral computer engineers specialized in bioinformatics to develop the Mindfulness Engineering application.

Institutions involved:

The Association of ADHD Catalonia and the Catalan Federation of Associations of Relatives affected by ADHD (FCAFA ADHD) recruit the candidates.

EsMindfulness Institute will provide the three instructors for the one-month face-to-face training in Jacobson's Mindfulness Meditation and Jacobson’s Progressive Relaxation.

Mindfulscience will provide online sessions in MM and RJ.

The Neuroscience Area of the Vall d'Hebron Research Institute (VHIR) will provide us with the EEG laboratories and the material and participate in its application.

12. Approximate budget and justification of budget lines

Service	Price per sesion, service or unit	N sessions	N participants o groups	Total
Face-to-face instruction 1 month	2000	1	3	6000
Mindfulscience sessions	34,9	3	80	8376
EEG+SART sessions	40	9	80	28800
EEG+TAP sessions	40	9	80	28800
EEG+TMT sessions	40	9	80	28800
MAAS license	0	6	80	0
PANASN license	0	6	80	0
Participants phychological evaluation	80	19	80	121600
SriHome Webcam PC Full HD 1080P	20	1	80	1600
Postdoctoral psychologist	2000	36	2	144000
Master's student in Neuroscience	500	36	2	36000
Postdoctoral computer engineer	2000	1	2	4000
				407976

13. Ethical questions or implications of the project

We will carry out the research in compliance with the Research Ethics Regulations not to violate any code of good practices of the Higher Council for Scientific Research (CSIC), as well as the regulations of the Department of Health of Generalitat of Catalonia. We will inform all participants and their tutors of the study's objectives and the techniques we will apply to achieve it before signing the informed consent, where said information is described (see *Appendixe 5*).

The participants will know that they will be divided into four groups and the treatment that will be applied in each one, they will also know that one of the treatments will have the placebo function, but they will not know which of these will be. Once the informed consent has been signed, and after the face-to-face instruction phase, they will be given a commitment contract where the incentives for their participation will be reflected (see *Appendixe 6*).

On the other hand, the Personal Data Protection Law 15/1999 is respected, which guarantees the anonymity of the participants and the principle of confidentiality.

Finally, the research ethics committee will review the conditions and sign informed consent before approving the study.

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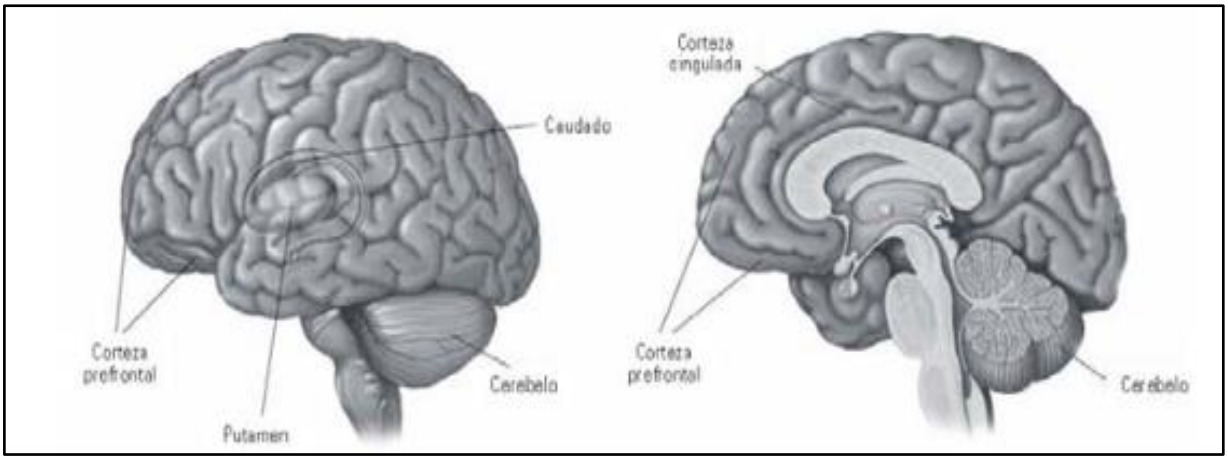
15. APPENDIXES

Appendixe 1: Functional and maladaptative effects of mind wandering.

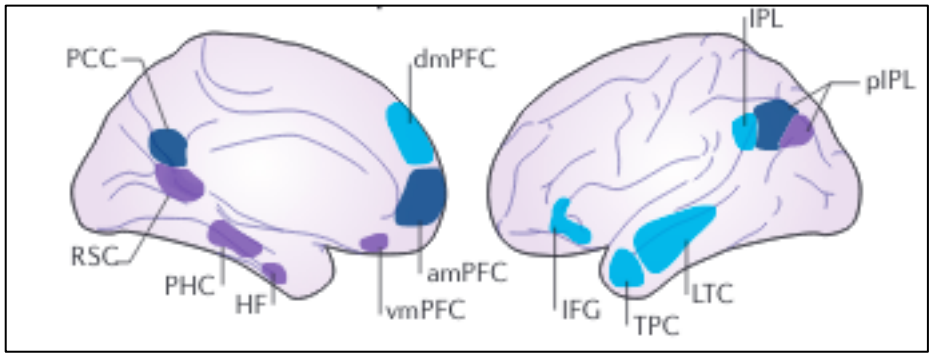
Functions	Disfunctions
- Future planing, goal-directed thinking (Axelrod et al., 2015, Seli et al., 2018 - Mental simulation (Axelrod et al., 2015, Feruglio et al., 2021) - Solving complex problems (Axelrod et al., 2015, Feruglio et al., 2021) - Social problem solving (cited by Chaieb et al., 2019) - Decision making (Axelrod et al., 2015 - Creative thinking (Axelrod et al., 2015, Feruglio et al., 2021) - Learning and memory consolidation (Axelrod et al., 2015, Bradmeyer et al., 2016) - Provides mental breaks from monotonous activities (Chaieb et al., 2019)	- Repetitive, dominant and anxious thoughts (Chaieb et al., 2019). - Learning disabilities (Bradmeyer et al., 2016, Seli et al., 2018) - Affective dysfunction, anxiety and depression (Bradmeyer et al., 2016, Seli et al. 2018) - Pathological concern (Feruglio et al., 2021) - Traffic accidents (Seli et al., 2018) - Reduction of cognitive and autonomic flexibility (Feruglio et al., 2021)

Appendixe 2: Brain regions that appear to be affected in ADHD



Brain regions affected in ADHD: In the fronto-striatum dorsolateral prefrontal cortex (CPDfl) circuit, dorsal region of the anterior cingulate cortex and the dorsal striatum (Bush, Valera & Seidman, 2005; Durston, 2003; Seidman, Valera & Makris, 2005; Willcutt, Doyle, Nigg, Faraone and Pennington, 2005; Zimmer, 2009); in addition to the fronto-parietal circuit, ventral temporal regions and the cerebellum (Castellanos and Proal, 2012; Cortese et al., 2012). Note. Adapted from Regions of the fronto-striatum-cerebellar circuit that seem to be affected in ADHD, from Lopez Martin S., 2014

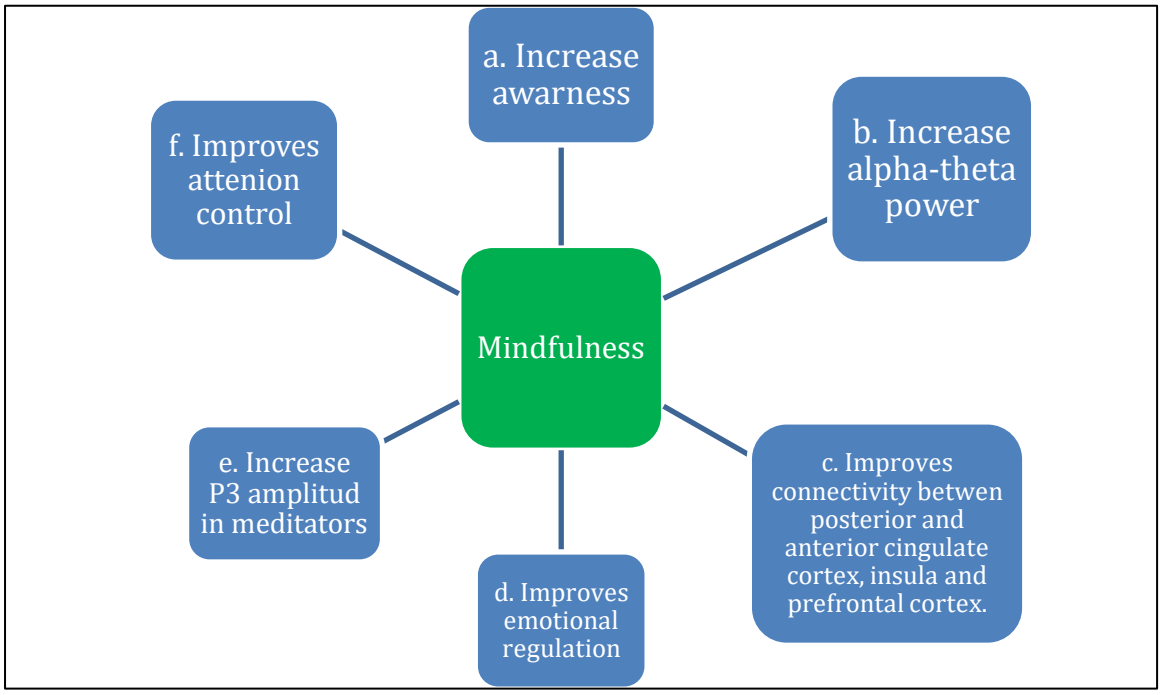
Appendixe 3: Subcomponents of the Default Mode Network (Christoff et al., 2016)



*Note.*Adapted from *Main large-scale brain networks with relevance to spontaneous thought*, by Christoff et al., 2016.

Default Mode Network	Correlación anatómica	Funciones
DN_{CORE}	Medial prefrontal cortex (mPFC) Posterior cingulate cortex (PCC) Posterior inferior parietal lobe (pIPL)	Contributes to internally oriented cognition
DN_{MTL}	Hippocampal formation (HF) Parahippocampal Cortex (PHC) Retrospinal Cortex (RSC) Ventral medial prefrontal cortex (vmPFC) Posterior inferior parietal lobe (pIPL)	Role in memory and in the construction of mental simulations
DN_{SUB3}	Dorsomedial prefrontal cortex (dmPFC) Lateral temporal cortex (LTC) Temporopolar Cortex (TPC) Inferior Frontal Gyrus (IFG)	Mentalization Conceptual processing Emotional processing

Appendixe 4: Some of the benefits of Mindfulness Meditation



Benefits MM. **a:** Hasenkamp et al., 2012; Bradmeyer y Delorme, 2016; **b:** Cahn y Polich, 2006; **c:** Sood y Jones, 2013; **d:** Miller B, 2021; Xu et al., 2017); **e:** Cahn y Polich, 2006 y **f:** Bradmeyer y Delorme, 2016; Sood y Jones, 2013)

Appendixe 5: Informed consent

INFORMED CONSENT SHEET FOR THE MINDFUL-ADHD STUDY

INTRODUCTION

We are writing to inform you about a research study in which you are invited to participate.

Please read the following information to be sure that you fully understand the objectives of this study and sign it if you agree to participate in it.

In summary, this study aims to find an effective non-invasive treatment for cognitive, attentional and emotional symptoms in people with ADHD.

PROCESS

This study requires periodic availability is needed for 36 months and meet the following requirements:

Inclusive requirements:

- Be between 12 and 16 years old.
- Being diagnosed with ADHD.
- Be studying Compulsory Secondary Education at the beginning of the study.
- Understand and speak native Spanish.

Exclusives requirements:

- Receive psychopharmacological treatment.
- Have experience in meditative techniques.
- Have experience in Jacobson's Progressive Relaxation.
- Show comorbidity with another psychopathology.
- Have a history of consumption and abuse of alcohol and/or narcotic substances.
- Have a long-term respiratory disorder

This study will include 80 participants divided into four groups (FAg, AMg, FAAMg and RJg) where each will receive different training. Each group will receive one of the following four treatments: Focused Attention, Acceptance Monitoring, Focused Attention + Acceptance Monitoring, or Jacobson's Progressive Relaxation. All will be executed with periodic frequency. Mindfulness groups will have a daily duration of 20 minutes for the first six months and 40 minutes for the remaining twenty-four months, while RJgroup will do 20 minutes per day during the entire treatment. One of the four treatments is a placebo, but no participant will know which treatment they will receive.

Specific non-invasive tests explained above by certified professionals will be carried out. These will evaluate the emotional state, attention, metacognition and brain plasticity. Do not continue and ask for the corresponding information if you have not received such information

GENERAL RISKS

There aren't evidence that the evaluation with EEG without previous psychotropic drugs produces any adverse effect. Psychotropic drugs will not be administered in any case.

The different evaluation tests do not by themselves produce any adverse effects.

The different treatments do not themselves produce any adverse side effects.

Suppose an unexpected situation or complication arises during the study that requires a procedure other than those provided. In that case, I request and authorize the scientific team to carry out whatever it deems necessary or convenient, including my transfer to a hospital centre.

VOLUNTARY PARTICIPATION

Your participation in the study is entirely voluntary, so there is no penalty for your non-participation.

BENEFITS

The treatment is expected to produce some cognitive and emotional improvement in you. If so, it could also have benefits for other people with ADHD. However, you cannot be sure until you get the results at the end of it.

On the other hand, if you meet the commitment contract criteria described in *Appendixe 6*, you may receive bonuses in the form of academic credits.

EXPENSES

All expenses will be fully assumed by the parties involved in the study.

RIGHT TO WITHDRAW

You have the right to withdraw from the study at any time, and you only have to notify the person responsible for it.

CONFIDENTIALITY

All data will be treated confidentially and processed by current regulations on the protection of personal data (Organic Law 3/2018, Protection of Personal Data and Guarantee of Digital Rights, and Regulation [EU] 2016/679 of the European Parliament and the Council, regarding the protection of natural persons concerning the processing of personal data and the free circulation of these data).

The data collected for the study will be identified by a code so that it does not include information that can identify you, and only your study doctor/collaborators will be able to relate said data to you and your medical history. Therefore, your identity will not be revealed to anyone except for exceptions in case of a medical emergency or legal requirement. The treatment, communication and transfer of personal data of all participants will comply with the provisions of the law.

Access to your identified personal information will be restricted to the study doctor/collaborators, health authorities, the Research Ethics Committee and personnel authorized by the sponsor (study monitors, auditors) when required to verify the data and procedures of the study, but always maintaining their confidentiality by current legislation.

The data will be collected in a research file under the institution's responsibility and will be processed within the framework of its participation in this study.

In accordance with the provisions of the data protection legislation, you can exercise the rights of access, modification, opposition and cancellation of data, for which you should contact your study doctor.

If you decide to withdraw your consent to participate in this study, no new data will be added to the database, but those that have already been collected will be used.

The coded data can be transmitted to third parties, but in no case will they contain information that can directly identify you, such as name and surname, initials, medical record number, etc.

If this assignment occurs, it will be for the same purposes of the study described or used in scientific publications but always maintaining their confidentiality by current legislation.

IN CASE OF DOUBT

If you have any questions, consult with Dr…., from the Service… with a telephone number… he is responsible for this research and will answer any questions you may have related to this study.

Whatever your decision, both the promoter and the research team want to thank you for your time and attention.

INFORMED CONSENT

STUDY TITLE: MINDFUL-ADHD

STUDY CODE:

Me, ……. ……. …… (name and surname of the patient), I declare that

• I have read the information sheet provided to me;

• was able to ask questions about the study;

• received enough information about the study;

• I have spoken with …… .. …… .. …… (name of the researcher);

• I understand that my participation is voluntary;

• I understand that I can withdraw from the study

or when you want,

or without having to give explanations,

or without this affecting my medical care.

By signing this document, I freely consent to participate in the study, and I give my consent for the access and use of my data as stipulated in the information sheet given to me.

I will receive a signed and dated copy of this informed consent document.

Participant sign	Resercher sign
Date: ……/……/……	Date: ……/……/……

(Name, sign and date in the handwritting of the participant)

Appendixe 6: Engagement contract

ENGAGEMENT CONTRACT

I hereby _____ student of the _____ course enrolled in the school institution in the year _____, I have agreed to enter into this commitment contract to account for participation in the MINDFUL-ADHD study for a period of 36 months.

I promise to carry out all treatment sessions during the established period and attend the semester evaluations, not abstaining without cause.

I understand that my participation in the study will be rewarded in the form of academic credits following the following criteria:

- 3 credits for continued participation the first six months.
- 6 credits for continued participation the following 12 months.
- 9 credits for continued participation for the next 18 months.

I understand that withdrawal at any time from the study will result in the withdrawal of these bonuses.

Signature of participant

Date: …… / …… / ……

(Name, signature and date in the handwriting of the patient)

Signature of the researcher

Date: …… / …… / ……

Appendixe 7: Description of face-to-face training and overcoming criteria.

a. Instruction in Mindfulness Meditation

Candidates from the experimental groups in MM (*FAg, AMg and FAAMg*) will receive the same instruction from facilitators from many with years of experience teaching in MM. In the first two sessions, we will instruct you to relax with your eyes closed and focus on the flow of breathing in the nose and mouth. During the guided meditation, we will give indications to be aware of mind wandering and refocus attention to the target object. In the subsequent two sessions, the factors that contribute to the main supports of this practice will be explained (no judgment; patience; beginner's mind; confidence; don't strain; acceptance and give in / let go); the three main targets you use (breathing, body scan, and now) and their common goal; be aware in the present moment. The objective of the theoretical training is that the participants understand the central axis of the practice. In these sessions, there will be meditative sessions of 3 to 10 minutes, depending on the evolution of the participants. The sessions the following week will be designed to focus on different target objects (body sensations, feelings, breathing) (Wallace, 2006) and will increase the time of the meditations up to 20 minutes. At the end of all sessions, they will be given a questionnaire with three questions:

	1	2	3	4	5
Have you been able to keep your attention on your breath for more than 5 seconds?					
Have you been able to return your attention to the object when you have been aware of some intrusive thought?					
Did you feel that you were meditating?					

We will administrate this questionnaire at the end of the sessions of the following two weeks, where it will also be instructed in Attention Monitoring (AM); the sessions of these will be 15min the third week and 20min the fourth week.

On the last day of training, individual interviews will be held with the candidates to discover doubts and their ability to carry out the sessions and progress. The interview and questionnaire's results will assess the use of Neuroengineering for Mindfulness.

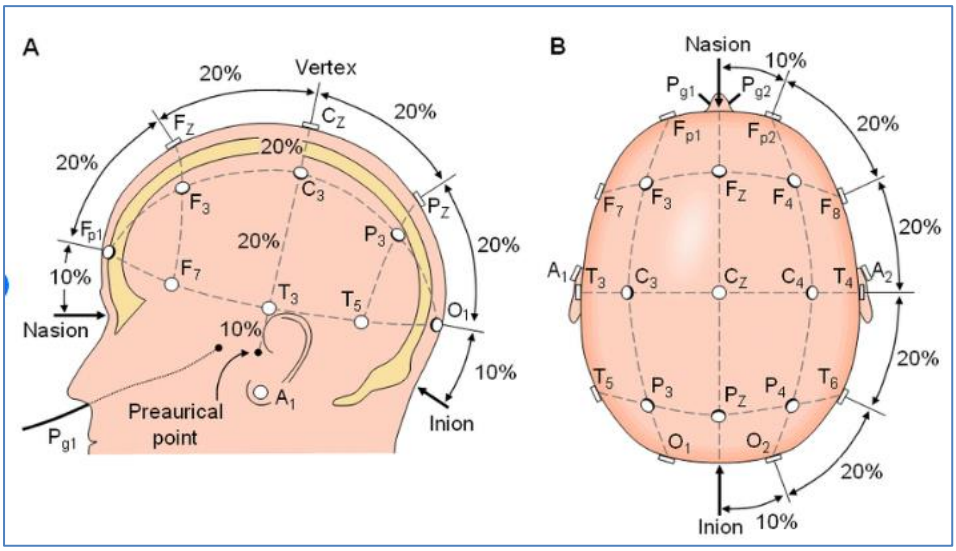
b. Jacobson's Progressive Relaxation Instruction

Candidates in the control group (RJg) will receive training from instructors specialized in the technique. There will be theoretical and practical training.

We will not explain the potential beneficial effects of these practices in any training sessions.

Appendixe 8: Electrode location and nomenclature

We will use a 10-20 system for the placement of the electrodes two weeks before the face-to-face instruction, and we will make measurements to prepare the EEG caps for each of the subjects. And we will record the alpha, beta, delta, gamma and theta frequencies in the areas that we want to evaluate and indicated in appendices 2 and 3.



Electrode location. The letters indicate the area (Fp, prefrontal; F, frontal; C, central; P, parietal; T, temporal and O, occipital), the numbers designate the hemisphere (pairs of the right, nons of the left) and the electrodes the middle line is marked with a "z"; so Fz is frontally on the midline. *Note*: Adapted from EEG diagnostic and therapeutic tool. In Approaches to the study of behavioural neuroscience by Novo et al., 2010.

Nomenglature

Fp1: left frontopolar
Fp2: right frontopolar
Fp3: left medial frontal
Fp4: right medial frontal
C3: left central
C4: right central
Fz: medial frontal
Cz: vertex
Pz: medial parietal
P3: left parietal
P4: right parietal
01: left occipital
02: right occipital
F7: temporary anterior left
F8: temporary anterior right
T3: left medial temporal
T4: right medial temporal
T5: left posterior temporal
T6: temporal posterior right
A1: left earphone
A2: right earphone