Correlation Between Stress, Lifestyle, and EEG-alpha Activity

Stress, Lifestyle, and EEG

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HUG- OG FÉLAGSVÍSINDASVIÐ

Lokaverkefni til

BA gráðu í sálfræði

Deild

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12 eininga lokaverkefni
sem er hluti af
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Dr. Yvonne Höller

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Útdráttur

Bakgrunnur

Því hefur verið haldið fram að heilsusamlegur lífstíll geti hjálpað fólki í að ráða við ýmis geðvandamál s.s. þunglyndi, streitu, og kvíða. Sálfræðingar og aðrir sérfræðingar á sviði geðheilsu hafa verið þekktir fyrir að ráðleggja skjólstæðingum sínum að breyta lífstílsmynstri sínu til hins betra. Breyting á þáttum eins og hreyfingu, alkóhól inntöku, reykingum, og mataræði, er hagnýtt meðferðarúrræði þegar óviðráðanlegir streituvaldar stofna geðheilsunni í hættu. Markmið okkar var að skoða víxlverkun milli streitu, lífstíls, og heilastarfsemi. Markmið okkar var að gera út um hvort heilastarfsemi sýndi fylgni við streitu sem greint var frá á huglægan hátt, og/eða EEG-alfa virkni.

Aðferð

N=119 þátttakendum var boðið þátttaka í rannsókn sem notaðist við heilalínurit (e. EEG, electroencephalogram) og ýmsa spurningalista, meðal þeirra var svefnleysiskvarði (e. BIS, Bergen Insomnia Scale), streitukvarði (e. PSS, Perceived Stress Scale) og þunglyndis, kvíða og streitu kvarði (e. DASS, Depression Anxiety Stress Scale). Þátttakendur svöruðu spurningum og spurningalistum sem höfðu það að markmiði að meta lífstílsmynstur og streitu. Heilastarfsemi var mæld með heilalínuriti á meðan þátttakendur þreyttu Stroop prófið (e. The Stroop test). Við settum saman lífstíls breytu úr svörum við spurningum um hreyfingu, mataræði, alkóhól inntöku, og reykingar, ásamt því að setja saman stigakerfi fyrir þá breytu. Spearman fylgnistuðullinn var notaður við að meta fylgni milli streitu og EEG-alfa virkni, lífstíls og streitu sem greint var frá á huglægan hátt, og lífstíls og EEG-alfa virkni.

Niðurstöður

Niðurstöður úr Spearman fylgnistuðli á streitu breytunum og EEG-alfa vikni í heilablöðunum fimm á meðan Stroop prófinu stóð, sýndu enga marktæka fylgni. Marktæk fylgni var á milli DASS og PSS breytna (p=<0,001), á milli tóbaks og alkóhóls (p=0,005), og á milli BIS og beggja streitu breytnanna, PSS (p=0,000), og DASS (p=0,002). Hærra hlutfall af þýðinu lifði óhollum lífstíl, með meðaltal upp á -0,424. Lífstíls breyturnar sýndu marktæka fylgni við EEG-alfa bylgjur á meðan á Stroop prófinu stóð. Eftir að hafa að hafa leiðrétt fyrir fjölda samanburða (p/5=0,10) var marktæk fylgni að finna milli lífstíls og alfa bylgna í framheilablaði (p=0,007). Engin marktæk fylgni var á mili lífstíls og streitu sem greint var frá á huglægan hátt.

Túlkun

Niðurstöðurnar benda til þess að heilsusamlegur lífstíll sem felur í sér hluti svo sem hreyfingu, hollt mataræði, takmörkun á alkóhól inntöku og reykingum, geti sýnt sig í frekari EEG-alfa virkni á meðan Stroop prófinu stendur.

Efnisorð: streita, lífstíll, EEG, heilalínurit, stroop.

Abstract

Background

It is sometimes suggested that living a healthy lifestyle can help people to cope with various mental problems such as depression, anxiety and stress. Psychologists and other mental health professionals have been known to recommend to their clients that they change their lifestyle patterns. Modification of exercise, alcohol consumption, use of tobacco, and diet are viable therapeutic approaches when uncontrollable stressors put mental health at risk. We aimed to examine the interaction between stress, lifestyle, and brain activity. We aimed to determine whether brain activity correlates with subjectively reported increased stress levels and whether a healthy lifestyle based on exercise, refraining from alcohol and tobacco as well as a well-balanced diet interact with subjectively reported stress and/or EEG-alpha activity.

Method

N=119 participants were invited to a study using the electroencephalogram (EEG) and several questionnaires, amongst them the Bergen Insomnia Scale (BIS), Perceived Stress Scale (PSS), and the Depression Anxiety Stress Scales (DASS). Participants answered questions and questionnaires that aimed at gauging lifestyle patterns and stress. The EEG was recorded whilst conducting the Stroop test. We computed a lifestyle variable from answers about exercise, diet, consumption of alcohol and tobacco. Spearman correlation was used to examine correlations between stress and EEG-alpha activity, lifestyle and subjectively reported stress levels, and lifestyle and EEG-alpha activity.

Results

Results from a Spearman correlation of the stress variables and EEG-alpha activity in the five brain lobes during the Stroop test, showed no significant correlations. A significant correlation was found between DASS and PSS variables (p=<.001), between tobacco and alcohol (p=.005), and between the BIS and both stress variables, PSS (p=.000), DASS (p=.002). A higher proportion if our sample lived an unhealthy lifestyle, with a mean of -0.424. The lifestyle variables correlated significantly with EEG alpha power during the Stroop test. After correcting for multiple comparisons (p/5=.01), a significant correlation was found between lifestyle and frontal alpha power (p=.007). No significant correlations were found between lifestyle and subjectively reported stress levels.

Conclusions

The results suggest that living a lifestyle more directed towards health by ways such as exercising, consuming healthy foods, limiting alcohol and tobacco use, can showcase itself in greater EEG alpha-band power during the Stroop task.

Keywords: stress, lifestyle, EEG, electroencephalography, stroop.

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I would like to express my deepest gratitude to Dr. Yvonne Höller. Thank you for your lasting support and guidance, not merely during this process of research, but through the course of my study, a better mentor is hard to come by. Thank you for answering my many questions with such depth and detail, and for sparking an interest in research I suspect will take me down a long and adventurous rabbit hole. It has been an honour and a privilege being your student, you are an inspiration to me and a true asset to the university.

- Máni Snær Hafdísarson

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Introduction

Stress is a major cause for common mental and physical diseases such as coronary heart disease (CHD), cardiovascular disease (Steptoe & Kivimäki, 2012), depression and anxiety (Heim, Newport, Tanja, Miller, & Nemeroff, 2008). Furthermore, long-term stress can increase the risk of recurrent coronary heart disease and mortality (Albert et al., 2017). The prevalence of cardiovascular disease in the UK is between 3-4% (Bhatnagar, Wickramasinghe, Wilkins, & Townsend, 2016), causing the UK economy costs of 29.1 billion pounds in 2004 (Luengo-Fernández, Leal, Gray, Petersen, & Rayner, 2006). A common recommendation to reduce stress is to live a healthier lifestyle, as therapeutic lifestyle change can be as effective as either psychotherapy or pharmacotherapy (Walsh, 2011). Important lifestyle changes are exercise, diet, and refraining from tobacco and alcohol (Walsh, 2011). However, data collected from 20 European countries showed that 53% of the population are overweight and obese (Marques, Peralta, Naia, Loureiro, & Matos, 2014). The prevalence of smoking in adult population in most European countries is over 25% (Precioso et al., 2009) and alcohol is a wide-spread risk factor causing even more diseases than tobacco (Rehm, Zatonksi, Taylor, & Anderson, 2011). Our aim is to see if a healthy lifestyle interacts with subjectively reported stress and/or EEG-alpha activity.

1.1 Healthy Lifestyle and Stress

Certain lifestyle factors can be as effective in the treatment of various mental disorders as psychotherapy and medication, exercise is one of those factors (Khaw et al., 2008). Regular exercise functions as a stress reliever, as well as a preventive measure to ward of symptoms of stress (Walsh, 2011). The acute benefits of exercise are to relieve stress and tension, while the long-term metabolic and biochemical effects help building resilience against day-to-day stressors (Walsh, 2011). Diet is another factor, with the right diet often regarded as one that is high in whole grain, fruits, vegetables, fish and especially omega 3 rich fish such as salmon, and one that strays away from animal fats (Cena & Calder, 2020). This type of diet has been associated with a range of health beneficial factors, such as reduced risk for coronary heart disease, stroke, cardiovascular disease, cancer, as well as providing cognitive benefits, and allowing an individual to be better equipped in dealing with day-to-day stressors (Cena & Calder, 2020). The western diet is typically rich in saturated fats and refined carbohydrates and is linked to all of the aforementioned diseases (Cena & Calder, 2020). It is furthermore increasingly recognized to impair optimal brain development and function, which prevents optimal cognitive functions (Francis & Stevenson, 2013). Also, alcohol consumption and its effect on health is a well-documented topic with low to moderate consumption linked to various health benefits (Huang et al., 2014; Fernández-Solà, 2015). However, excessive consumption is documented to cause a variety of health problems, with one of them being negative effects on the hypothalamic pituitary adrenal (HPA) axis' function, which is a brain circuit that regulates stress response (Allen, Rivier, & Lee, 2011; Becker, 2017).

1.2 Stress and the Brain

Feeling stress is a natural phenomenon. The brain is the key organ organizing the overall stress response, since the brain identifies events and circumstances that are stressors, i.e. that could be threatening (McEwen, 2008). Stress can have effects on brain functions, for example repeated stress can have an effect on the hippocampus where there are high concentrations of cortisol receptors, and cortisol is well known as the stress hormone (Shields, Sazma, & Yonelinas, 2016). Stress that lasts for a long duration of time can cause death of hippocampal neurons (McEwen, 1998). However, the hippocampus is a deep brain region and neuronal death is a long-term effect, while stress can be acute. The EEG has been used to assess acute effects of stress on the brain and it is predominantly measured in the prefrontal cortex (Saeed, Anwar, Majid, Awais, & Alnowami, 2018; McEwen & Morrison, 2013; Shields, Sazma, & Yonelinas, 2016). As neurons communicate with each other the EEG is able to capture that activity, and abnormality can then be distinguished from normality when the EEG-graph is read. Thus, different mental states such as deep sleep, REM sleep, epilepsy seizures, or stress can be distinguished from each other (Al-shargie, Tang, Badruddin, & Dass, 2016; Subhani, Xia, & Malik, n.d.). According to Saeed, Anwar, Majid, Awais, & Alnowami (2018) low beta, high beta, and low gamma are the most significant neural oscillations for classifying stress in humans. Furthermore, it has been documented that under stressful conditions the power of the alpha band decreases, the beta waves increase and under condition that might be considered as panic, the beta waves increase (Sanei & Chambers, 2007; Hamid, Sulaiman, Murat, & Taib, 2015).

1.3 Electroencephalography

Electroencephalography (EEG) is used to measure brain activity by placing electrodes on the scalp, it is as such, a non-invasive method (Libenson, 2010). Contrarily, if electrodes are placed on the cerebral cortex or brain, the method is called electrocorticography or depth EEG recordings, and is considered invasive. The EEG captures the sum of electrical activity of many neurons and the analysis is done by amplifying the voltage differences between electrodes (Libenson, 2010; Kalita and Misra, 2005). A system of electrode placement is necessary to maintain consistency between readings and the 10-20 system of electrode placement is today's standard (Kalita og Misra, 2005). The EEG has become one of the most common sources for information used to study functions of the brain and conditions (Al-shargie, Tang, Badruddin, & Dass, 2016). Furthermore, it has become the most studied non-invasive brain imaging device, for reasons such as its relative ease to use compared to other methods, as well as having a low set up cost (Al-shargie, Tang, Badruddin, & Dass, 2016). EEG signals give excellent temporal resolutions and measure changes in cognitive activity within milliseconds (Subhani, Xia, & Malik, n.d.).

1.4 The Stroop Test

Sometimes referred to as "the colour-word naming test", the Stroop test is an instrument designed by John Ridley Stroop (1897-1973). The test is simple in application but has shown significant correlations with other, more complex psychological instruments (Jensen & Rohwer, 1966). The Stroop test has been used to measure a variety of cognitive processes, one of those being selective attention (Jensen, 1965; Lamers, Roelofs, & Rabeling-Keus, 2010). According to Jensen (1965) there is no standardized version of the test, in general participants are showed words in varying colours such as green, blue, and red. The words shown are the names of colours and participants are then required to answer in correspondence to the colour shown, not the word. The conflicting situation is answering "red" when the word one reads is "blue", or "green".

1.5 Motivation and Hypothesis

Pressures from economical and intuitional forces push therapists today towards briefer forms of psychological intervention, and psychiatrists in particular are pressured to offer brief sessions of 15 minutes, to prescribe more drugs, and less psychotherapy (Mojtabai & Olfson, 2008). The cost of psychotherapy isn't within the economical means of many of the population. One of the motivations for this study is to look at lifestyle factors that the general public can implicate irrespective of socioeconomical status, that are effective in terms of therapeutic change, and which are cost-effective (Walsh, 2011). Exercise, as previously stated, is one of those factors. Brief counselling has shown to be effective in motivating many to exercise (Long et al., 1996), making it a viable option for psychiatrists and other mental health professionals to recommend and motivate the general public to implement to their lifestyle. According to the Harvard Mental Health Letter (2000) exercise is “insufficiently used for a variety of psychiatric disorders”. The therapeutic benefits where exercise can be seen to bring about change includes reducing symptoms of depression and anxiety, the severity of Alzheimer’s disease, body dysmorphic disorders, some schizophrenia symptoms, as well as a range of physical diseases (Daley, 2002; Stathopoulou, Powers, Berry, Smits, & Otto, 2006). We hypothesize that living a healthier lifestyle interacts with subjectively reported stress and/or EEG-alpha activity.

Method

This study was conducted within a larger project, led by Dr. Yvonne Höller and Dr. Ragnar P. Ólafsson, researchers at the University of Akureyri and University of Iceland, respectively, as well as Kristján H. Hjartarson, a PhD student at the University of Iceland. The original study done by Dr. Höller, Dr. Ólafsson and Hjartarson aimed to see if seasonal changes in affect were associated with EEG-biomarkers and cognitive vulnerabilities for depression. This thesis is done as a final assignment and part of a bachelor’s degree in psychology from the University of Akureyri. The authors worked as assistant researchers to Dr. Höller, Dr. Ólafsson and Hjartarson, and were sanctioned to add data such as questionnaires, to be filled out by participants of the original study. This data could then be used in writing a bachelor thesis. The data added were questions and questionnaires on diet, exercise, alcohol and tobacco use, and were aimed to gauge lifestyle patterns, as well as stress levels.

2.1 Ethics

We applied for a Research Permit to the local authority, which is the national bioethics committee (NBC) of Iceland. On 09/04/2019 the NBC responded to our application and our research project was given the number VSN-19-090, we were instructed to give further explanations on three factors. (1) information on the EEG part of the research, (2) information on translation of the questionnaires used, (3) information on safety of the data gathered using smartphones. These addendums where confirmed by the NBC on the 28/05/2019. On the 19/10/2019, in both instances’ students of the University of Akureyri and University of Iceland where being added to the team of researchers, on the part of them writing their bachelor thesis. On the 29/10/2019 we received a Research Permit from the NBC for this revised study protocol.

2.2 Recruitment

The recruitment of participants took place through the distribution of flyers, advertisements on social media platforms such as Facebook, through emails sent to both students and University personnel, and through word-of-mouth. When advertising, a document was used that had been sent to the NBC and been approved. The invitation contained a link to the first part of the research, which was a questionnaire aimed at finding out how likely a person was to suffer from Seasonal Affective Disorder (SAD), and used the seasonal pattern assessment questionnaire (SPAQ) as a screening procedure for this purpose. Each question had multiple answers which were listed on a Likert scale from 0-4. Our cut-off mark was 11. If a person scored 11 or above, him/her got grouped in the high seasonality group, if a person scored below 11, he/she got grouped in the low seasonality group. Our recruitment aim was then to select 120 participants in such a way that half would derive from each group, as well as half being female and half male. Each possible participant was contacted via email which was pre-written and had been approved by the NBC, and where the research as well as the participation procedure was explained, and a fee of 4000 ISK in the form of a voucher to a local mall promised for participation. If the recipient of the email responded showing interest, and wanting to participate, another pre-written document was sent, as well as a session scheduled with a researcher.

2.3 Subjects

Subjects were 119 in total, 96 female and 22 males. All were over 18 years of age, ranging from 18 – 66, with a mean age of 33.94. Most subjects lived in and around the Akureyri area.

2.4 Procedure

Participants met with a researcher at the research lab at the University of Akureyri, Department of Psychology. Upon arrival each participant was offered something to drink or eat, as well as to use the bathroom, as it was informed that the procedure could take upwards of two hours to complete. An informed consent form was read and signed by each participant upon arrival. Whilst the mounting of the EEG took place, participants answered various questionnaires, as listed in the following subsection. During EEG recordings the participants finished various tasks, those were:

- Three minutes at rest with eyes open.
- Three minutes at rest with eyes closed.
- A picture learning task where the participant was shown 60 pictures and where he/she attributed each picture to a specific season, either spring, summer, autumn, or winter.
- Picture recall task where the participant was asked how many of the 60 pictures shown he/she remembered.
- A picture recognition task where the participant was shown the same 60 pictures as before intermixed with 60 new pictures, he/she had not seen before. The participant was then asked to indicate if the picture shown was new, or old.
- The Stroop test.
- A rumination task where participants listened to instructions via headphones and then answered questions.

This marked the end of the EEG recordings. An application was then installed on the participant's smartphone which served the purpose of an experience sampler, and participants were asked to answer the follow up questions during the following 4 days, as well as in October, December, February, and April for another four-day sampling period. These follow-up sessions consisted of the measurement of daily fluctuations in mood and cognitions, as well as a short internet survey that aimed to detect occurrence of winter depression. For the purpose of the present thesis, only the Stroop task and part of the psychological questionnaires are relevant.

2.5 Questionnaires

The following questionnaires were used in the baseline assessment of the study: Seasonal Pattern Assessment Questionnaire (SPAQ, Rosenthal et al, 1987; Magnússon & Stefánsson, 1993). Patient Health Questionnaire (PHQ-9, Kroenke et al., 2001). Bergen Insomnia Scale (BIS, Pallesen et al., 2008). Life Orientation Test Revised (LOT-R, Scheier et al., 1994). Ruminative Responses Scale-short form (RRS; Treynor et al., 2003). Habit-Index of Negative Thinking (HINT; Verplanken et al., 2007). Perceived Stress Scale-4 (PSS-4; Cohen & Williamson, 1988). Depression Anxiety Stress Scales-21 (DASS-21; Lovibond & Lovibond, 1995). Creature of Habit Scale (COHS; Ersche et al., 2017). Positive Believes in Rumination Scale (PBRS; Watkins & Moulds, 2005). The following questionnaires were used at the follow up assessment via Internet survey: Patient Health Questionnaire (PHQ-9, Kroenke et al., 2001). Ruminative Responses Scale-short form (RRS; Treynor et al., 2003). Perceived Stress Scale-4 (PSS-4; Cohen & Williamson, 1988). Depression Anxiety Stress Scales-21 (DASS-21; Lovibond & Lovibond, 1995). Four questions were posed on traveling (have you since the last assessment travelled and staid abroad for one week or longer?) and on the use of psychotherapy, medications or other therapy strategies because of symptoms of depression (are you using any medications at the moment because of symptoms of depression? Are you in psychological treatment at the moment because of symptoms of depression? Are you using any other means (light therapy, visiting a counsellor or any other help-provider) to get counselling or help because you are not feeling well?). The questionnaires in particular importance to our research questions are the BIS, PSS-4, DASS-21, as well as questions on diet (41 questions), exercise (seven questions), alcohol consumption (two questions), use of tobacco (one question), gender (one question), and age (one question).The BIS was constructed in order to meet the current formal clinical criteria for diagnosing insomnia. The six items address sleep onset, maintenance of sleep, and early morning awakening, feeling rested, daytime impairment and dissatisfaction with sleep. The BIS has good psychometric properties and was validated against subjective as well as polysomnographic data. The Icelandic translation is currently being validated in a study supervised by Dr. Yvonne Höller. The PSS-4 is a short version of this widely used psychological instrument for measuring the perception of stress. It is a measure of the degree to which situations in one's life are appraised as stressful. Items were designed to tap how unpredictable, uncontrollable, and overloaded respondents find their lives. The questionnaire is available in Icelandic and has been used in studies here. The DASS-21 is a 21-item questionnaire designed to measure symptoms of depression, anxiety, and stress in clinical and non-clinical populations. Each domain contains seven items in which the respondent is asked to indicate the extent to which a statement applies to them using a four-point Likert scale. Studies show that all three scales have good psychometric properties (Antony et al., 1998). The questions on diet are on the consumption of fruit, vegetables, meat, fish, dairy, non-alcoholic drinks, cookies and sweets, and the amount of consumption each day, week, or month, on average. The questions on exercise were on the amount of exercise, lasting 10 minutes or more, the participant had done in the last seven days; the difficulty of the exercise, if it was considered tough such as running and swimming at a fast rate, not so tough such as playing golf or running and swimming at a slower rate, and the amount of time spent exercising on each difficulty-level, as well as how much time in the last seven days was spent walking.

2.6 EEG Recordings and Analysis

EEG was recorded using a BrainVision EasyCap and a BrainVision amplifier. The cap consisted of 32 electrodes and employed the international 10/20 system. The electrodes were positioned corresponding to the 10/20 system, and the following electrodes were used for the purpose of this study: F7, F3, FZ, F4, F8, T7, C3, CZ, C4, T8, P7, P3, PZ, P4, P8, O1, O2. Vertical eye movement and blinks were recorded with an electrode placed beneath the right eye. An abrasive electrolyte gel was used to get low impedances and good signal quality, subjects were asked to arrive preferably with washed hair to improve signal quality. Recordings took place when impedances were below 15 kOhm and impedances most often ranged <10 kOhm. The recording software used was the BrainVision Recorder (Brain Products), and recordings were done at a sampling rate of 256 Hz.

2.6.1 EEG analysis.

EEG data was analysed with Brain Vision Analyzer. We analysed EEG-data from the Stroop condition in the following steps: For pre-processing, data was filtered from 0.5-30 Hz with zero-phase shift Butterworth filters. Then, re-referencing was performed by averaging the activity of all electrodes and subtracting this mean from all other channels. Next, an independent component analysis (ICA) was performed in order to automatically remove eye-blink artefacts. The vertical lower oculogram was used as vertical activity channel. The ICA algorithm used was the infomax restricted. As a last pre-processing step, a raw data inspection was done in order to automatically identify and exclude artefacts by applying the standard thresholds as implemented in Brain Vision Analyzer:

- Check gradient: maximal allowed voltage step 50 microvolt/ms.
- Check difference: maximal allowed difference of values in intervals of 200ms: 200 microvolt.
- Lowest activity allowed in 100ms intervals: 0.5 microvolt.

Bad events were marked +- 200ms around the identified artefacts. For the purpose of EEG analysis, the data was segmented into segments of 500ms for the instances when coloured words were shown, each starting at time 0 (when the word appeared on the screen). This was done separately for matching words, where the font colour matched the word, and the nonmatching words, where the font colour was different from the word. Each segment was transformed with fast Fourier transform (FFT). All FFTs within one category (rest, rumination) were averaged across segments. From the average FFT per subject and per condition, we averaged activity in the frequency range 8-13 Hz, which corresponds to alpha. The values were exported from each participant to a table for further statistical processing.

2.7 Questionnaire Evaluation

The BIS score was calculated as the sum of the six questions, as indicated in the original publication (Pallesen et al., 2008). The PSS-stress score was calculated as the sum of the four items. The DASS-stress score was calculated as the sum of the stress items dass_1, dass_6, dass_8, dass_11, dass_12, dass_14, and dass_18.

2.8 Lifestyle Variables

To find out if a healthy lifestyle correlates with stress levels, we first needed to construct a definition of a healthy lifestyle. We did so by using questions in the data set that gauged lifestyle, such as amount of exercise, tobacco use, alcohol consumption, and diet. Using SPSS, we recoded the aforementioned variables and created a point system in which a participant could obtain points on the range of -3 to 3. To illustrate, smoking gave minus points, exercising plus points, vegetables in the diet plus points, excessive alcohol use minus points, et cetera. The point system was constructed as follows: there were 27 questions on diet relevant to us, three questions on exercise, two questions on alcohol, and one question on tobacco.

2.8.1 Diet.

Diet answer possibilities for various types of food concerned the frequency of consumption: 1 =<1x month; 2=1-3x month; 3=1x week; 4=2-4x week; 5=5-6x week; 6=1x day; 7=2-3x day; 8=4-5x day; 9=<6x day. Two variables were computed for diet; healthy_food and unhealthy_food. The former variable consisted of consumption of skimmed milk (250ml), whole milk (250ml), cottage cheese (125g), fruits raw, fruits cooked or dried, vegetables raw, vegetables cooked or dried, egg (1 egg), chicken or turkey (100-200g), fish (100-150g), whole wheat bread (1 slice), potatoes baked or boiled (1 piece) or potato mousse (1 cup), rice or pasta (1 cup), nuts (small bag or 50g), fish oil (1 tbsp), and D vitamin supplements. If a participant answered 1 = > 1x a month he/she got 0 points, 2= 0 points, 3= 1 point, 4=2 points, 5-9= 3 points. To compute the variable unhealthy_food the consumption of ice cream (125g, medium size), butter (1 tsp), bacon (2 slices), processed meat e.g. hotdog or pepperoni (1 piece or 5 slices), hamburger (1 piece), chocolate (50g), sweets without chocolate (50g), cake (slice), cookies (100g), white bread (slice), French fries (1 fistful), potato chips (small bag or 100g), and drinks that contain sugar such as cola or fruit juice (250ml), were considered. If a participant answered 1 = > 1x a month he/she got 0 points, 2= 0 points, 3= -1 point, 4= -2 points, 5-9= -3 points.

2.8.2 Exercise.

Exercise answer possibilities were amount of days spent exercising at an intermediate level, exercising at a difficult level, and walking activity each day a week. When recoding and scoring the variable we used the following: tough or medium exercise at least three days per week = 3 points, tough or medium exercise at least two days per week = 2 points, tough or medium exercise at least one day per week or walking at least three days per week = 1 point.

2.8.3 Alcohol.

Alcohol consumption was first measured as units consumed per day: 0=never drinking alcohol; 1=1 unit per day; 2=2 units; 3=3 units; 4=4 units et cetera. Second, the habit to drink more than six drinks at occasions when alcohol is consumed was measured as "0= never; 1= >1 a month; 2= monthly; 3= weekly; 4= daily or nearly daily". When recoding the variable and assigning scores we did the following: one unit per day = -1 points, two units per day = -2 points, three units per day and greater= -3 points. When drinking more than six drinks at all = -1 point, when drinking more than 6 drinks a day at least once a month = -3 points. The maximum of the daily drinking habit and the excessive drinking habit was taken as the final alcohol score.

2.8.4 Tobacco.

The tobacco variable was computed from number of cigarettes or e-cigarettes used per day. Tobacco answer possibilities were; 0 = 0 units, 1 = 1 unit, 2 = 2 units, etc. When recoding and scoring the tobacco variable we used the following: "0= 0; 1-3= -2; 4<= -3".

2.8.5 Lifestyle.

Our lifestyle variable was then computed as the sum of the scores for unhealthy foods, healthy foods, exercise, tobacco, and alcohol variables. In order to have a similar influence on the lifestyle variable of all of these components, food variables were standardized via z-transformation to follow a distribution centred at +1.5 and -1.5 for the healthy and unhealthy foods, respectively, with a standard deviation of 0.5.

2.9 Statistics

We did descriptive statistics, including means, standard deviations, minimum, maximum, and range, of the following variables: BIS sum score, DASS stress, PSS stress, and lifestyle. In order to answer our first research question the EEG data was averaged over electrodes within each region of interest before correlation was done. This resulted in five variables, for each region of interest, the frontal lobe, central lobe, temporal lobe, parietal lobe and occipital lobe. For the two stress scales that were used for this research the sum was calculated for each participant. Thus, one variable represented subjectively reported stress according to the DASS scale that had answers from eight questions, and the other represented subjectively reported stress from the PSS scale that had answers from four questions. Four participants' information's were excluded from the correlations, two were excluded because EEG data was missing and two were excluded because behavioural data was missing from the stress scales. Relation between each EEG-variable and each stress variable was assessed with Spearman's correlation. In order to answer our second research question "does a healthy lifestyle based on exercise and a well-balanced diet interact with subjectively reported stress and/or EEG-alpha activity?", we did bivariate Spearman correlations between the created lifestyle variable, the two stress variables, and EEG-alpha activity during the Stroop test, averaged in the five brain regions. Because of multiple comparisons for the five brain regions, the critical p-value is divided by 5, i.e. it is $p<.01$.

Results

3.1 Sample Characteristics and Descriptive Statistics

In the beginning, participants were n=119 in total, 96 female and 22 males. When doing our statistics, we excluded several participants due to missing data. Therefore, the actual number of participants varies between the tests that were conducted and the actual N will be reported alongside with the results. In the whole sample (n=119) participants were between the ages of

18 – 66, with a mean age of 33.94 (*SD*=13.09). Descriptive statistics on the BIS score, DASS stress variable and PASS stress variable can be seen in Table 1.

Table 1

Descriptive Statistics – BIS, DASS and PSS Stress Variables

	N	Range	Minimum	Maximum	Mean	SD
BIS	114	42.00	0.00	42.00	16.02	8.99
Dass_Stress	112	20.00	0.00	20.00	6.62	4.56
PSS_Stress	115	11.00	2.00	13.00	7.81	2.16

Note. BIS: Bergen Insomnia Scale, Dass: Depression, Anxiety and Stress Scales, PSS: Perceived Stress Scale, SD: Standard deviation.

Of those who answered (*n*=106) on tobacco usage 34.7% were smokers. A histogram can be seen in Figure 1 showing statistics on the question "how often do you consume an alcoholic drink". On a typical day of drinking alcohol, the most common number of units were two units at 17.8%, one unit at 13.6%, three units at 11% and six units at 11%. Figure 1 shows the original Icelandic version of the questions and answers. The question translates to "how often do you drink alcohol". The answers, from left to right, translate to "never", "once a month or less", "2-4 times a month", "2-3 times a week", and "4 times a week or more".

Figure 1

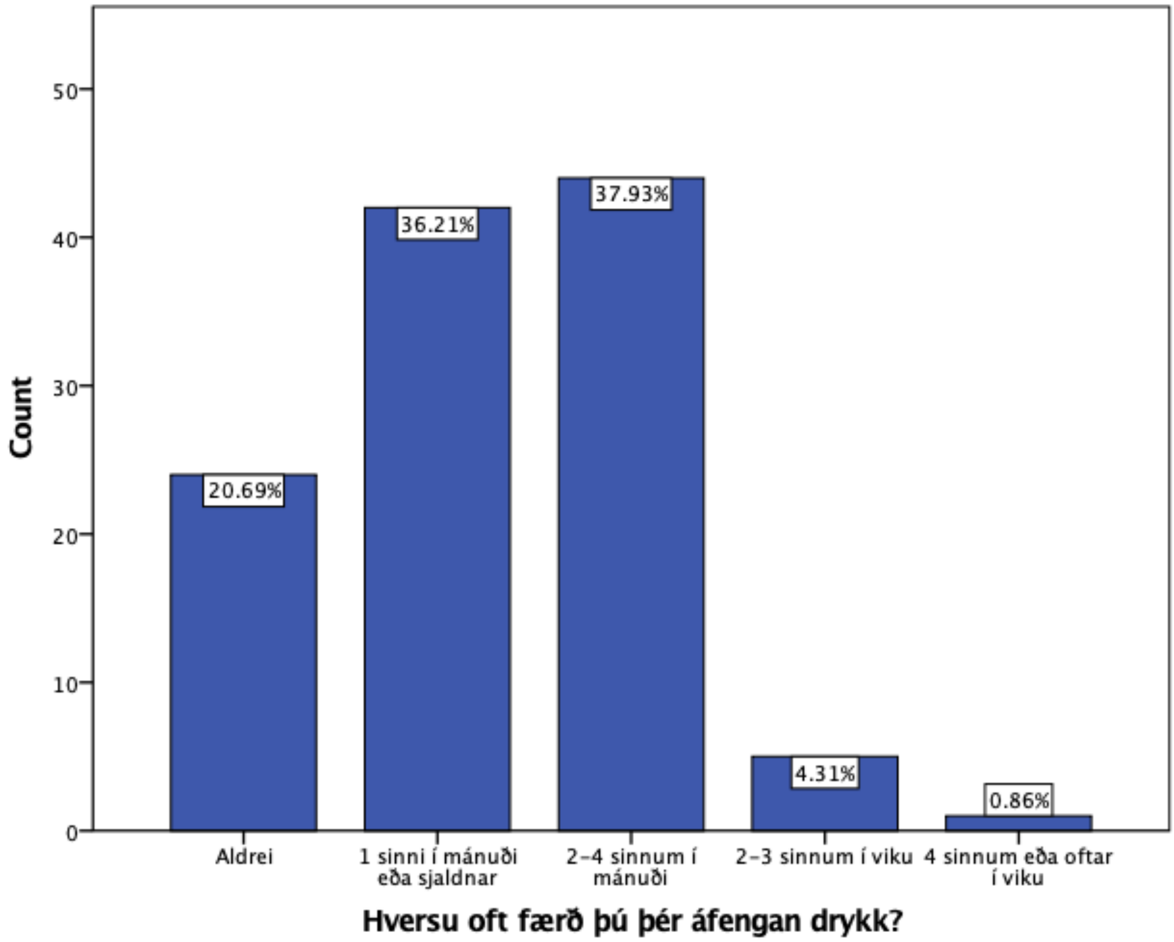

Figure 1: Histogram showing answers to the question "how often do you consume alcohol?"

The histogram in Figure 2 shows the amount of days, during the past seven days, spent doing tough exercise. The question translates to "think exclusively of exercise that lasted for at least 10 minutes at a time: How many days of the last seven days did you partake in tough exercise such as aerobics, running, swimming and/or cycling fast?"

Figure 2

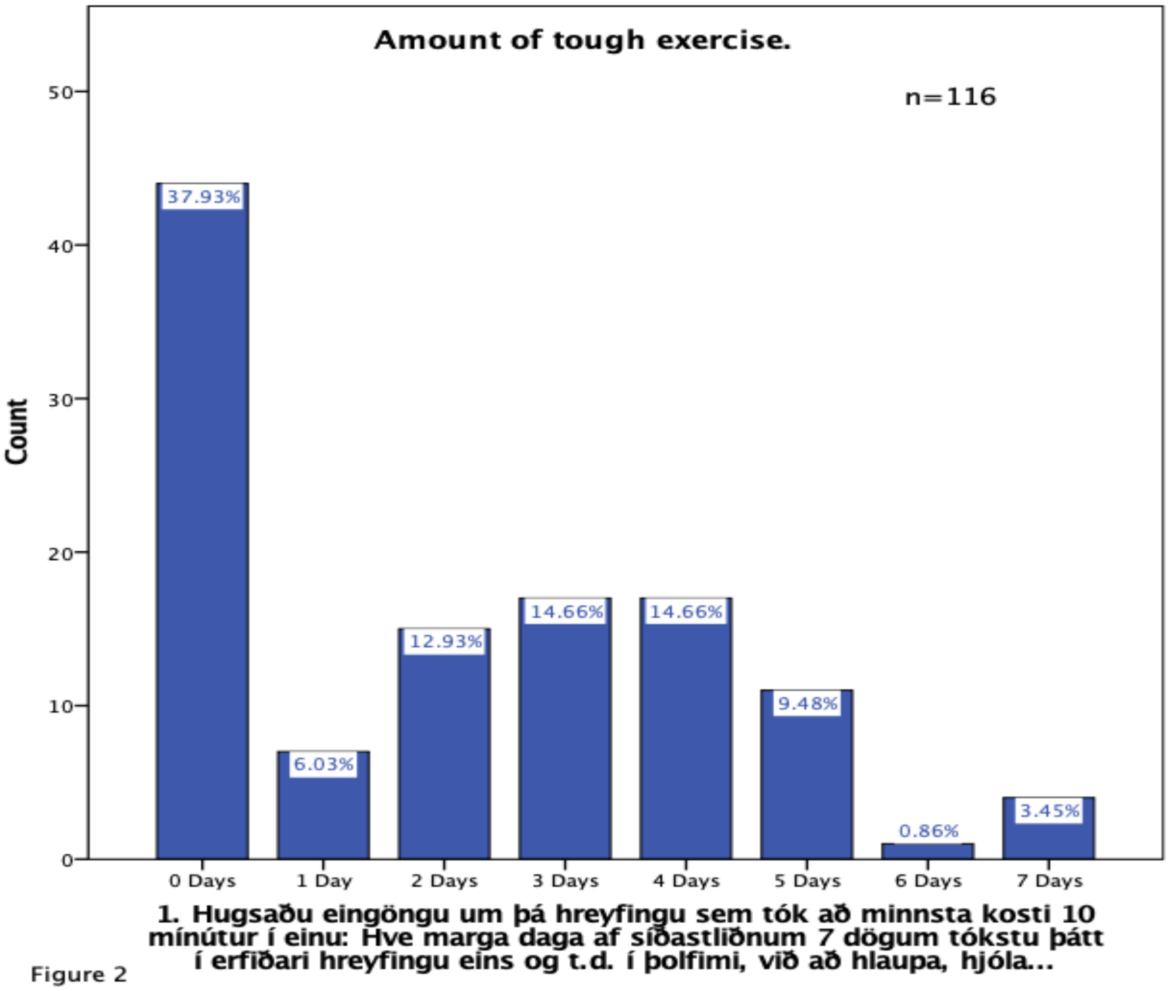

Figure 2: Histogram showing answers to the question "Think strictly about exercise that lasted for at least 10 minutes at a time. How many days during the last seven days did you participant in tough exercise such as aerobics, running, cycling at a fast rate and swimming at a fast rate, during leisure time?"

The histogram in Figure 3 shows the amount of days, during the past seven days, spent doing intermediate exercise. The question translates to "think exclusively of exercise that lasted for at least 10 minutes at a time: How many days of the last seven days did you partake in intermediate exercise such as cycling or swimming at an average rate, or playing golf?"

Figure 3

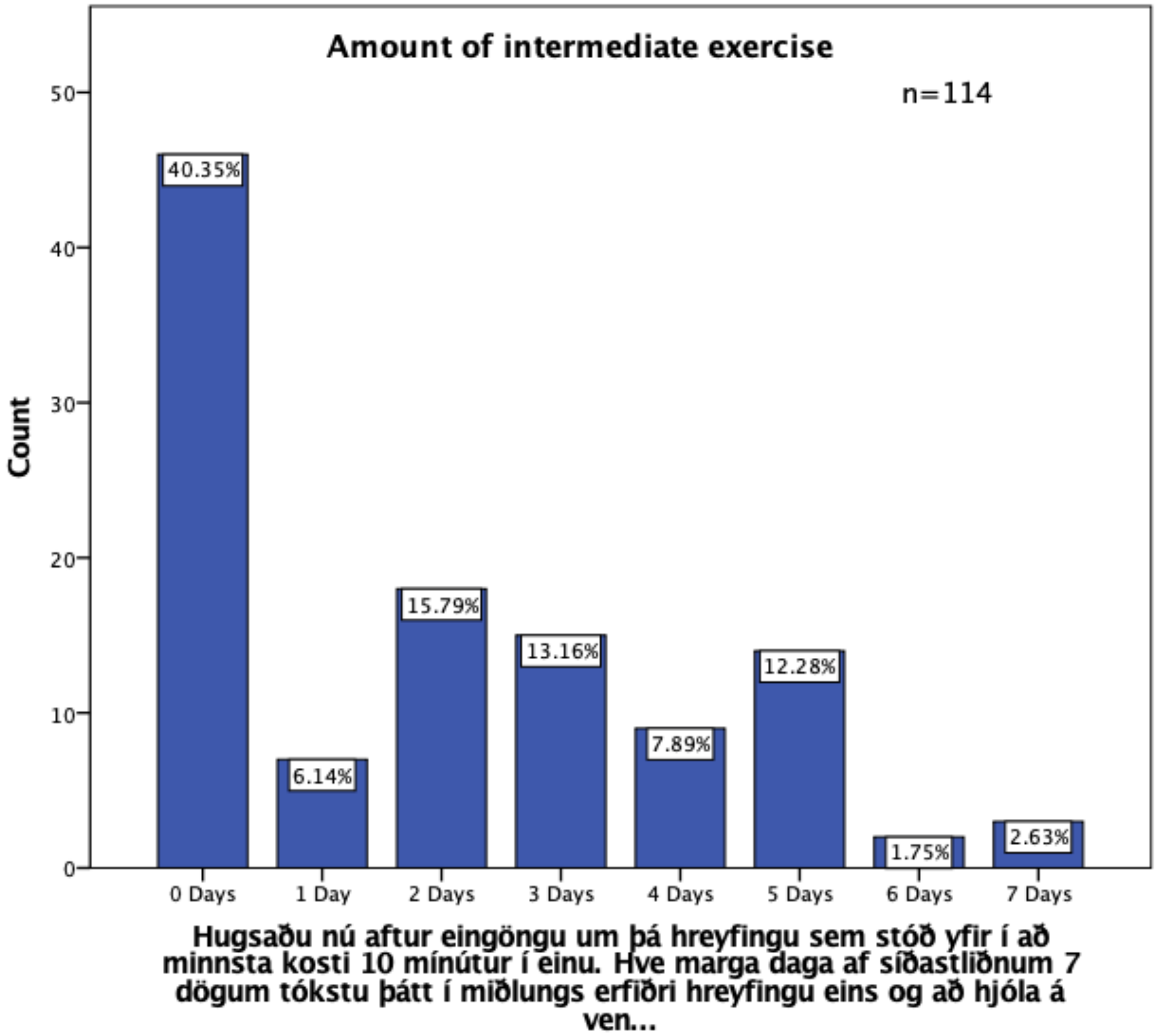

Figure 3

Figure 3: Histogram showing answers to the question “Again think strictly about exercise that lasted for at least 10 minutes at a time. How many days during the last seven days did you partake in exercise of moderate intensity, such as cycling at an average rate, running at an average rate, and playing golf during leisure time? Do not count any walking”.

Figure 4

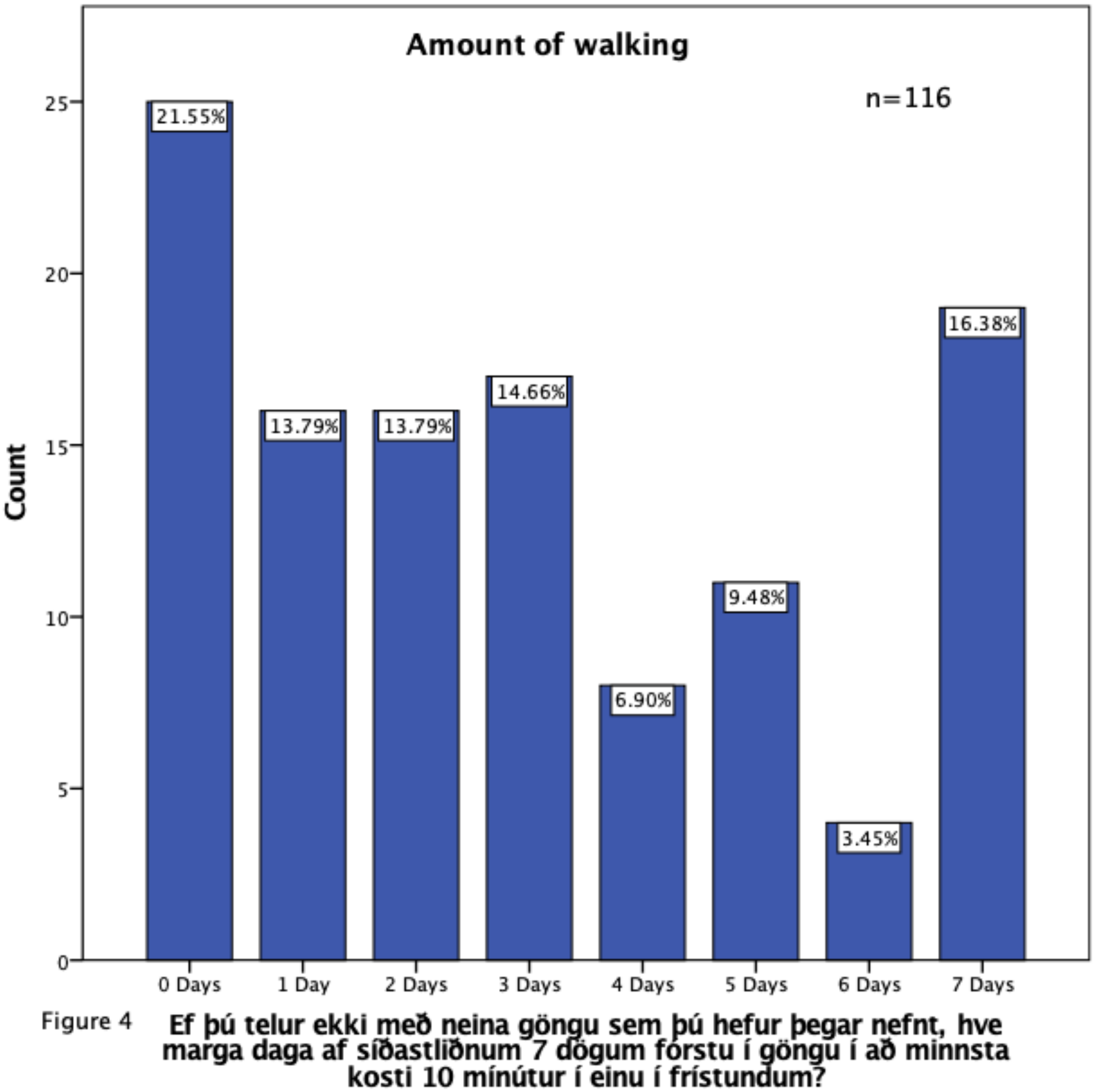

Figure 4: Histogram showing answers to the question "If you do not include any walking that you have already mentioned, how many days during the last seven days did you go for a walk for at least 10 minutes at a time during leisure time?".

3.2 EEG-alpha Activity and Stress

Table 2

Stress Scales and Brain Region Correlations

		Frontal	Central	Temporal	Parietal	Occipital
DASS	Correlation Coefficient	.029	.017	.010	.074	.080
	Sig. (2-tailed)	.760	.860	.919	.433	.398
	N	115	115	115	115	115
PSS	Correlation Coefficient	-.033	.108	.026	.117	.102
	Sig. (2-tailed)	.729	.252	.784	.215	.279
	N	115	115	115	115	115

Note. DASS: Depression, Anxiety and Stress Scales, PSS: Perceived Stress Scale

In table 2 the results from the Spearman correlation between stress variables and EEG-alpha activity in the five brain lobes during Stroop test can be seen. The result of the Spearman correlation shows that there is no significant correlation between the stress scales and alpha activity in the five brain regions. The PASS stress scale shows slightly higher coefficients than the DASS scales. The highest correlation for the PASS scale was found in the parietal lobe during the match trials in the Stroop task.

3.3 Lifestyle, Stress, and EEG-alpha Activity

No significant correlation was found between the lifestyle variable and the DASS (n=82, r=-.142; p=.202) and PSS stress variables (n=84, r=-.139; p= .208). A significant correlation was found between the DASS and PSS variables (n=111, r=.525; p=.000), as well as between consumption of tobacco and alcohol (*n*=106, *r*=-.271; *p*=.005). A significant correlation (*n*=111 *r*=.560; *p*=.000) was found between the BIS test and the DASS stress variable, as well as between BIS and PSS stress variable (*n*=113, *r*=.285; *p*=.002).

Figure 5

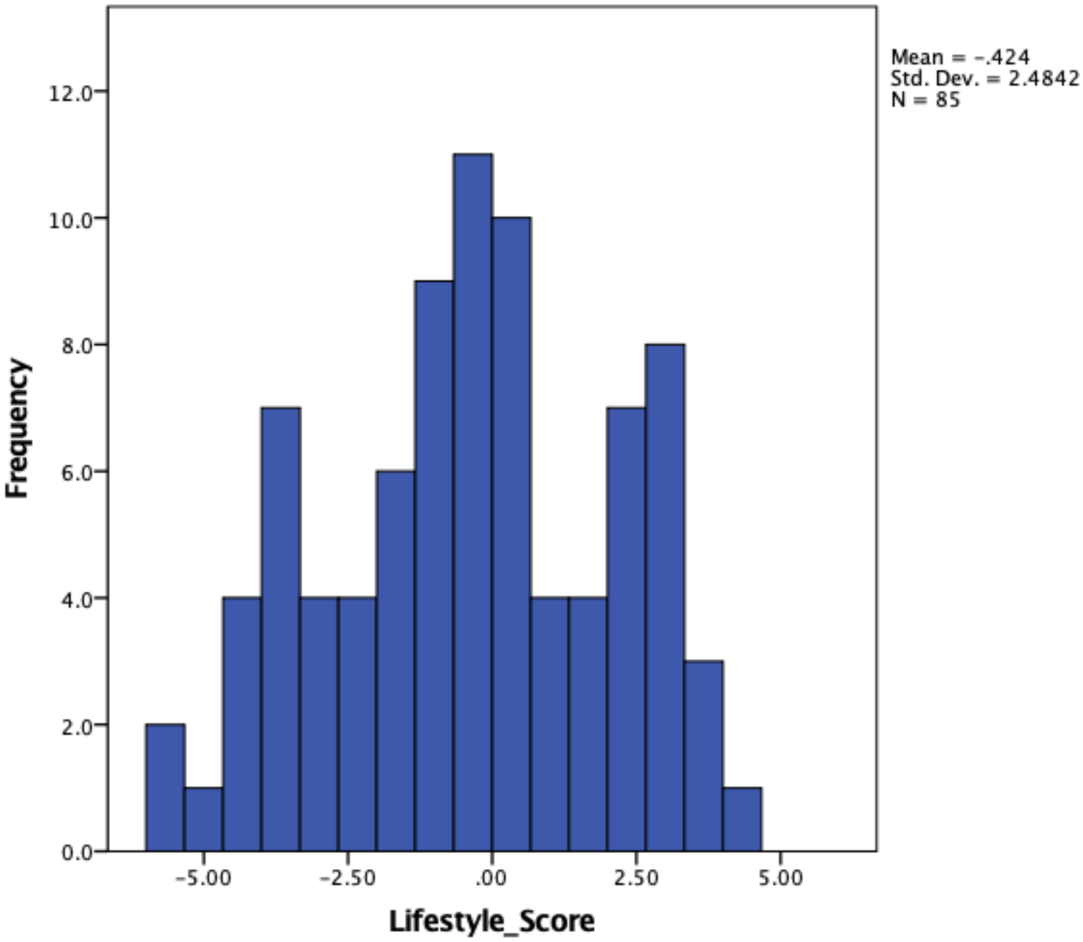

Figure 5: Histogram showing the distribution of the lifestyle variable.

Figure 5 shows a higher proportion of our sample living an unhealthy lifestyle, with a mean of -0.424. We found a significant correlation between our first and second exercise variables, those of participating in tough exercise, and in intermediate exercise (n=115; r= .487; *p*<.001). The lifestyle variables correlated significantly with EEG alpha power during the Stroop test (see Table 3). After correcting for multiple comparisons (*p*/5=.01), a significant correlation was found between lifestyle and frontal alpha power, but correlations between lifestyle and temporal alpha power, and between lifestyle and occipital alpha power were significant only at the uncorrected level. According to this result, those living a healthier lifestyle showed greater EEG activity in in the alpha frequency band in the frontal lobe while conducting the Stroop test.

Table 3

EEG Alpha Power and Lifestyle Correlations

		Lifestyle
Frontal	Correlation Coefficient	.294
	Sig. (2 tailed)	.007
	N	83
Central	Correlation Coefficient	.199
	Sig. (2 tailed)	.071
	N	83
Temporal	Correlation Coefficient	.257
	Sig. (2 tailed)	.019
	N	83
Parietal	Correlation Coefficient	.179
	Sig. (2 tailed)	.105
	N	83
Occipital	Correlation Coefficient	.219
	Sig. (2 tailed)	.047
	N	83

Note. Sig: Statistical significance.

Discussion

This study aimed to find out if living a healthy lifestyle would interact with subjectively reported stress and/or EEG-alpha activity. We did not find a significant correlation between subjectively reported stress and living a healthy lifestyle but did find a correlation between a healthier lifestyle and EEG activity in the alpha frequency band in the frontal lobe, and by tendency also in the temporal and occipital lobes, while conducting the Stroop test. The Stroop test was selected as a test that requires attention (Lamers, Roelofs & Rabeling-Keus, 2010). Therefore, these results could indicate that those living a healthier lifestyle have larger alpha activity in the frontal lobe when conducting attention requiring tasks. There were also small correlations between all five lobes and the EEG-alpha frequency activity, which shows a trend of those living a healthier lifestyle showing greater EEG activity in the alpha frequency band during an attention-requiring task to some extent in all brain regions. The temporal lobe, where the correlation found was $r=.257$ is associated, among other things, with language and memory (Sindou & Guenot, 2003). The frontal lobe, where the correlation was $r=.294$, is associated with executive functions, working memory and attention, among other things (Stretton & Thompson, 2012). Since the Stroop test is a tool commonly used to administer measures of frontal lobe functioning (Demakis, 2010), this matches very well the effect that the correlation was strongest in the frontal lobe.

4.1 Prior Research

EEG is a practical tool to do research on stress as it is a non-invasive method that can be used by psychologists. Subhani, Zia and Malik (2016) explained how a researcher could use EEG signals to measure mental stress. Adel, Sajjad, Lamya, Sumayyia, and Murtada (2020) examined potential differences in EEG activity in workload stress that individuals in medical professions could suffer from during their workdays and during their days off. The authors of the study reported that there were no positive relationships found between the EEG parameters in the medical professionals that are on high stress workdays compared to low stress off days (Adel, Sajjad, Lamya, Sumayyia, & Murtada, 2020). Another research by Alonso, Romero, Ballester, Antonijoan and Mañanas (2015) aimed at assessing stress using EEG based variables that was obtained from univariate analysis and functional connectivity evaluation. The research had two kinds of stress-related situations: the Stroop test and sleep deprivation that was applied to 30 people that volunteered. The results showed a decrease of high alpha power, an increase in high beta power and a decrease of approximate entropy. The decrease in high alpha power was not assessed in a similar way in our study, since we performed correlations between stress and brain activity while the work of Alonso et al. examined task-related changes. Seo and Lee (2010) reported that there was a significant positive correlation between cortisol level and relative high beta power at anterior sites and that there was a tendency towards a similar relationship for occipital sites. A research by

Wahbeh and Oken (2013) assessed respiration, EEG and heart rate variability as potential biofeedback parameters for future clinical trials to treat Post Traumatic Stress Disorder (PTSD). They reported that the PTSD groups and no-PTSD groups had similar delta, theta, alpha and beta frequency amplitudes but that the PTSD group had higher peak alpha frequency (Wahbeh & Oken, 2013).

4.2 Limitations

One possible limitation to the study would be the construction of the lifestyle variable, and how a healthy or unhealthy lifestyle was measured in our sample. We were able to use data on amount of days spent exercising, types of food consumed and amount, alcohol consumption as well as tobacco usage. Optimally we would like to know the volume of exercise each day spent exercising. We do not believe this to be a limitation of great magnitude, however. Routine exercise is a valuable proponent to physical and mental health (Daley, 2002), and the data on amount of days spent exercising we find to be a sufficient information in computing a measuring tool of lifestyle. To overcome this limitation in future research we propose that volume of exercise is documented and that perhaps a measurement tool of lifestyle be used that the literature has shown to be affective. Another limitation worth mentioning is our sample size of 119 which ranged considerably between the sub-analyses we did due to missing data.

4.3 Conclusions

The results suggest that living a lifestyle more directed towards health by ways such as exercising, consuming healthy foods, and limiting alcohol and tobacco use, can showcase itself in greater alpha frequency during tasks such as the Stroop test. The Stroop test has been used as a tool to induce acute stress of moderate levels (Willmann, Langlet, Hainaut & Bolmont, 2012) as well as to monitor selective attention (Lamers, Roelofs, & Rabeling-Keus, 2010). Thus, future research could examine whether living a healthier lifestyle correlates with greater alpha activity in other tasks that measure selective attention, as well as under other stressful conditions. EEG recordings could be done whilst administrating stress stimuli, such as mental arithmetic tasks, public speaking, cold pressor, computer work, or videos, as these factors have been used in previous studies to generate a stress response (Al-shargie, Tang, Badruddin, & Dass, 2016).

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