INHIBITING VISUAL DISTRACTOR DURING VISUAL WORKING MEMORY TASK: EFFECT OF VISUAL DISTRACTOR DIFFICULTY TO OCCIPITAL ALPHA-ACTIVITY AMONG OLDER ADULTS

Saara Westerholm

Master`s Thesis

Department of Psychology

University of Jyväskylä

December 2018

UNIVERSITY OF JYVÄSKYLÄ

Department of Psychology

WESTERHOLM, SAARA: Occipital cortex alpha-activity during visual distraction among older adults

Master`s Thesis, 40 op.

Supervisor: Tiina Parviainen

Psychology

December 2018

ABSTRACT:

Aging declines ability to inhibit different distractions during working memory process. Alpha activity (10 Hz) is generally known to reflect rest or inhibition in human brain. In cognitive processing alpha oscillations reflect for example distractor inhibition. Brains visual areas are known to locate in occipital cortex. In this thesis I want to solve how visual inhibition differs between easy and difficult visual distractor pictures. I want also solve whether occipital alpha activity during distraction and visual working memory task performance correlate. My hypothesis is that easy and difficult distractor pictures lead to different occipital alpha activity states and that higher occipital alpha activity during distraction picture predict better performance in visual working memory task.

In this study we used visual working memory task with visual distractor. There was both easy and difficult distractor pictures. Alpha power in occipital cortex during working memory task was measured from 28 older adults born between years 1935 and 1946 using magnetoencephalography. The results reveal that there is difference between occipital alpha activity during either easy or difficult distractor pictures. Easy distractor picture leads to different modulation of occipital alpha than difficult distractor picture. Instead of that there wasn´t correlation between occipital alpha activity during distraction and visual working memory task performance.

Keywords: working memory, occipital cortex, alpha-activity, aging, MEG, visual distraction

JYVÄSKYLÄN YLIOPISTO

Psykologian laitos

WESTERHOLM, SAARA: Takaraivon häiriönaikainen alfa-aktiivisuus iäkkäillä henkilöillä

Pro gradu, 40 op.

Ohjaaja: Tiina Parviainen

Psykologia

Joulukuu 2018

TIIVISTELMÄ:

Ikääntyminen heikentää ihmisen työmuistin kykyä torjua erilaisia häiriötekijöitä. Alfa-aktiivisuuden (noin 10 Hz) tiedetään heijastavan lepoa tai inhibitiota ihmisen aivoissa. Kognitiivisessa prosessoinnissa alfan tiedetään reflektoivan esimerkiksi häiriötekijöiden ehkäisemistä prosessin aikana. Aivojen visuaalisten alueiden tiedetään sijaitsevan takaraivon aivokuorella. Tässä tutkielmassa halusin selvittää, miten visuaalinen inhibitio eroaa helppojen ja vaikeiden visuaalisten häiriökuvien välillä. Halusin myös selvittää korreloivatko häiriönaikainen visuaalisen aivokuoren alfa-aktiivisuus ja visuaalisessa työmuistitehtävässä pärjääminen toistensa kanssa. Hypoteeseina esitin, että helpot ja vaikeat visuaaliset häiriötekijät aikaansaavat erilaiset alfa-vasteet ja että voimakkaampi häiriönaikainen alfa-aktiivisuus korreloi paremman työmuistisuorituksen kanssa.

Tässä tutkimuksessa käytettiin visuaalista työmuistitehtävää visuaalisen häiriötekijän kanssa. Käytössä oli sekä helppoja että vaikeita visuaalisia häiriökuvia. Alfa-aktiivisuus takaraivon alueella mitattiin kahdeltakymmeneltäkahdeksalta koehenkilöltä käyttäen magnetoenkefalografiaa. Koehenkilöt olivat syntyneet vuosina 1935-1946. Tulokset paljastavat, että helppojen ja vaikeiden visuaalisten häiriöiden aikainen alfa-aktiivisuus poikkeavat toisistaan. Helppo häiriökuva aiheuttaa aivoissa erilaisen alfa-aktiivisuuden modulaation kuin vaikea häiriökuva. Sen sijaan visuaalista työmuistia mittaavassa tehtävässä pärjäämisessä ei havaittu eroja sen mukaan, kuinka voimakas alfa-aktiivisuus takaraivon aivokuorella oli häiriökuvien aikana.

Avainsanat: työmuisti, visuaalinen aivokuori, alfa-aktiivisuus, ikääntyminen, MEG, visuaalinen häiriö

Table of Content

1. INTRODUCTION

Working memory

Working memory is needed to maintain information for a while during absence of sensory input. Information can be any kind of representation; for example visual, auditory, verbal or spatial. Time window of working memory is considered to be from seconds to several minutes. Working memory enables humans to carry out different everyday functions smoothly. In normal daily functions we need to keep many kind of little things on our mind to carry out normal life. Problems with working memory make things complicate and slow. As stressed or busy our working memory can be suffering and that we will quickly notice.

There is variety between individuals working memory capacity. Studies have shown that those differences among people are quite stable even though over time (Kane & Engle, 2002). These differences may be due different functional capacity of individual brains. Despite differences in human brain anatomy, there is differences also in neural networking between individuals. As known for example physical training creates new synaptic connections and therefore it is possible to develop brains neural function through one´s life. It is also possible that synaptic plasticity is one of the most important things in working memory process and that working memory can use non-consciously perceived information (Eriksson, J., Vogel, EK., Lansner, A., Bergström, F & Nyberg, L. 2015).

Working memory is composed of interactions among different long-term memory representations and basic processes. Attention is one of those basic processes and attention is often thought to be like a basis of working memory. Basic processes include also prospection and perceptual representations. Processes dealing with working memory are selective attention, rehearsal, recognition/ pattern completion, retrieve/ readout, update, sustained attention and inhibition (Eriksson, J., Vogel, EK., Lansner, A., Bergström, F & Nyberg, L. 2015). In this thesis I am going to discuss inhibition process.

Inhibition

Working memory is a function that enables normal everyday functions. Working memory process can easily be disturbed by different confusing information from external environment. Also internal distractions disturb working memory process. The ability to inhibit distractors is important part of human information process. Individuals with different brain abnormalities have problems to ignore these internal and external distractions which leads major problems to their attention and working memory performance. During different kind of distractions it is important for brain to have ability to inhibit that kind of stimuli so that attention to ongoing working memory functions wouldn´t suffer.

Because working memory is vulnerable to distractions, it is very important that sustained attention is working properly. Sustained attention and rehearsal process helps maintenance after encoding and during time when perceptual input is not present. As well known, attention is complex process with several brain structures interacting. For example such brain areas like posterior parietal cortex, thalamus, anterior cingulate and prefrontal cortex are involved to attention process. When discussing on distractor suppressing, dorsolateral prefrontal cortex is playing important role (Kane & Engle, 2002).

Older people may have more difficulties in distractor suppressing. There is no consensus about that in science but in practice it seems like aging affects to inhibition abilities. Scientifically it would be interesting to solve underlying mechanisms related to that phenomena.

Aging brain

Aging causes many kind of physical and biological changes in human brain. Aging is also economically one of the most interesting scientific areas because of its huge economic effects to society. Healthier aging would benefit both older people themselves and whole society. Brain health influences to everyday functions in many ways. Preventing brain health problems in older adulthood should be one of the most important health care areas that should be in focus also in policy-making. Aging touches all developed societies in short-term future.

When discussing on aging brain we can find some typical patterns: brain changes typically follow “front to back” and “last in, first out” trajectories (Lustig & Lin. 2016). That means that frontal areas, which develop last and are responsible for higher cognitive functions are areas that decline first. On the other hand, first developing brain areas are those that last longest. Like generally known, in memory disorders first declining functions are typically higher cognitive functions like learning and working memory.

Despite the fact that aging declines many brain functions reflected also as decrease in grey matter volume and by causing different structural changes it has been proven that aging brain also has potential to develop and create new neural connections. It is generally known that physical and cognitive activity prevent older people from dementia and mild cognitive impairment. For example aerobic exercises improves cognitive function (Gajewski & Falkenstein 2016). At the level of brain, physical interventions both increase cortical blood flow and volume of grey matter. Hippocampus, that is important anatomical part of memory process, has been shown greater grey matter volume in physical active people.

Aging seems to affect brain in a way that inhibition process suffers. Solesio-Jofre, Lorenzo-López, Gutiérrez, López-Frutos, Ruiz-Vargas & Maestú (2011) noticed that in MEG-results older adults had lower activations in posterior-frontal regions compared to younger adults during interferences in working memory tasks. So, they thought that aging affects to posterior-frontal regions in that way that vulnerability to distractions increases. Finding out what are the underlying mechanisms in distraction sensitivity in older people would give practically useful knowledge for example to preventing elderly care and to rehabilitation.

Janowich, Mishra & Gazzaley (2015) have gone further in detailing interferences to two subcategories: to-be-attended interrupters and to-be-ignored distractors. They suggest that older adults are more easily confused by to-be-attended interrupters than by to-be-ignored distractors. They propose that these different kind of interferences causes different kind of neural responses. In practice older people do react to-be-attended interrupters very easily. One practical and well-known example is senior car driver who starts to focus on bypassing car too much and same time looses ones ability to focus on ones own driving performance.

There are also contradictory points whether older adults would exhibit more negative impact on working memory than younger adults because of interferences. Janowich, Mishra & Gazzaley (2015) bring out that there is conflicting knowledge whether there would be differences in neural activity between younger and older adults while resolving interferences. Brain aging process in its entirety is thereby an area that needs more and more scientific observation.

Brain areas related to working memory

Working memory needs many brain areas interaction to work properly. Especially frontal and posterior cortical areas and subcortical structures are important. More accurately, prefrontal cortex is maybe the most important anatomic structure to working memory function. Also the back of the cortex is known to be anatomically important structure.

There is evidence from brain imaging studies that under circumstances with much distractors human dorsolateral and anterior prefrontal cortical areas are activated while individual is trying to recall stimuli (Kane & Engle, 2002). It has also been proven that this kind of activation is related to unsuccessful recalling (Kane & Engle, 2002). So, little activation in prefrontal areas while recalling is joined both with low-interference circumstances and also with successful recalling. Prefrontal areas are known to be responsive areas of complicated cognitive processes. Kane & Engle (2002) propose that there is correlation between working memory performance and dorsolateral prefrontal cortex functioning.

Parietal cortex regions and dorsolateral prefrontal cortex are known to be important areas when discussing on executive functions like attention, working memory and spatial perception (Melloni, Urbistondo, Sedeno, Gelormini, Kichic & Ibanez 2012). Normal function of prefrontal cortex is known to be especially important for working memory process. That has been proven both by neuroimaging and by examples of living patients suffering prefrontal cortex lesions.

Maybe one of the most important brain structure related to distractor suppressing process is dorsolateral prefrontal cortex (Kane & Engle,, 2002). Dorsolateral prefrontal cortex has executive-attention role in maintaining access to stimulus representations in contexts with much of distractors (Kane & Engle, 2002). Generally speaking it is problematic to locate specific functions to brain structures because processes in the brain are usually interconnected many ways. Damage in one part of neuronal circuit influences to whole process.

Studies have shown that during dual-task situations frontal and parietal areas of the brain are more activated. During distraction brain activation moves from visual, posterior and spatial areas to prefrontal cortex (Schweizer TA., Kan K., Hung Y., Tam F., Naglie G. & Graham SJ. 2013). Because of that it is important to take account correct timing when planning research protocol and analyzing results from collected brain data.

MEG as method

MEG provides possibility to study brains neural activity direct by measuring changes in the magnetic fields (Hansen, Kringelbach & Salmelin, 2010). Changes in magnetic fields are produced by little changes in brains electrical function and so brains neural function is revealed by these changes. MEG is an excellent method to study brains function because it has both precise localization of active brain area and precise temporal accuracy (Hansen, Kringelbach & Salmelin, 2010).

MEG has some extra benefits compared to other brain imaging techniques. It doesn´t predispose participants to magnetic fields or to X-rays. It is also silent and doesn´t require any invasive operations. MEG is suitable for infants and even for pregnant women. It is very safe method to study brain function. MEG is also quite comfortable to participants.

MEG is able to resolve millisecond events and fast oscillations. Other neuroimaging techniques are not able to do this. MEG is accurate in spatial tracking. With MEG researchers are able to localize sources even accuracy of millimeters. MEG is used except normal brain functioning research also to pre-surgical mapping of functional cortical areas. One of the most important clinical application of MEG method is pinpointing seizure origin with epilepsy patients.

As method MEG is quite expensive. MEG needs to be located in special shielded room and requires some extra carefulness from researchers because of extremely cold helium. So compared to for example to EEG there is some extra points when using MEG in studies. MEG is also little challenging when studying some special groups, for example children who typically may have some problems when asked not to move head under measurements. MEG helmet is one size helmet and that can sometimes cause problems. Participant should also be small enough to sit in MEG chair and so sometimes overweight might be a problem.

MEG also has other limitations. One practically complex phenomena is MEG devices sensitivity to external distractions from outside of the brain. That’s why there is an important role for both careful preparing of subject and careful raw data preprocessing before statistical analysis. For example different metallic tooth work can cause harm to collected data. So does also subject moving his/ hers head in MEG helmet during measurement. MEG is sensitive also to noise from outside of shielded room. For example noise of bypassing van near shielded room is irritating enough to cause harm to collected raw data.

Brain oscillations

One possibility to observe human brain function is by recording brain oscillations. Oscillations are relevant source of information when focusing on brain activation and its modulation during ongoing cognitive operations. There are several known, systematically shown rhythms in the brain, of which 10 Hz oscillation is probably most well known, and it has been termed alpha oscillation. Studying brain oscillations has been under increasing interest during last decades. Brain oscillations reflect brains neural functioning during different tasks and during different activity states. Brain oscillations exist when group of neurons located close each other fire and go quiet in phase. One burst of activity and one period of silence is one oscillation. 1 Hertz means that there is one oscillation a second. So 10 Hz means that there is 10 oscillations a second etc. When a system is oscillating at 1 Hz, it means that one cycle of oscillation runs in one second, and a system is said to show 1 Hz oscillatory activity.

Alpha oscillations are found in human brain while resting and during inhibiting processes. Alpha is often also linked to attentional demands. Alpha oscillations and increase of them reflect functional inhibition in the brain (Jokisch & Jensen, 2007). Alpha oscillations can be easily done by simply just closing eyes. Alpha oscillations appear as a peak in the power spectrum at a frequency 10 Hz (Gross, 2014). Alpha suppression in occipital, parietal and posterior regions is associated with attentional demands and cognitive progress (Wang, Jung & Lin, 2018). Alpha oscillations are also found to be important for reactivation of long-term memory codes in short-term memory (Klimesch, Schack & Sauseng, 2005).

Beta oscillations (14-30 Hz) are linked to sensimotor system. Theta oscillations reflect for example working memory functions (Klimesch, Schack & Sauseng, 2005). Theta rhythm we can found from 4-7,5 Hz. Theta has been found to increase for example during memory process, specially during encoding and retrieval. Delta rhythm is found from 0,1-3,5 Hz. Gamma band oscillations (30-100 Hz) has been proposed to reflect neuronal maintenance in working memory process (Jokisch & Jensen, 2007). It is still unclear whether it is sure that gamma band oscillations reflect maintenance or simply changes in attention load.

Because of interconnected brain, in this study we are looking at occipital cortex during working memory task assuming that visual inhibition would somehow exist in occipital cortex alpha activity. As known, science has no consensus about what different brain oscillations fundamentally mean in brain. Brain oscillations are known to have an important role in information processing, but there is still need to view different perspectives. In this study we expect to see some differences in occipital alpha activity depending on how difficult distractor picture is. Alpha oscillations during visual working memory task are linked to attentional and executive processing (Palva, Kulashekhar, Hämäläinen & Palva. 2011).

Alpha oscillations and inhibition

Alpha oscillations are linked to inhibiting processes. Ahveninen, Seidman, Chang, Hämäläinen & Huang (2017) studied how distractors affect to brain functioning while auditory working memory tasks. They suggest that alpha oscillations in auditory cortex play inhibitory role during auditory working memory process. I propose that during visual working memory tasks alpha oscillations in occipital cortex reflect similar inhibitory role. Visual areas in brain are located in occipital cortex. Specifically the area of recognizing faces is temporal-occipital area at right side of the brain. At the left side of temporal-occipital area there is area of recognizing letters.

Bonnefond & Jensen (2013) noticed that higher alpha activity did reflect better distracter suppression. They pointed out that pre-distracter alpha activity and phase adjustment also have their role in distracter suppression. Alpha activity increased already before expected distracter. It is quite extensively noticed that alpha activity is a sign of brains inhibiting process. Still there is not perfect consensus about this in scientific area and also contradictory information exist.

The core idea of this work is to solve whether sensitivity to interferences can be seen in MEG signatures in elderly. The susceptibility to interference is an interesting viewpoint when thinking older people´s working memory. In practice is quite clear that older people are more sensitive to interferences than younger people. Instead of comparing younger and older people I am going to study whether there can be seen differences in age group. In this thesis I am going to clarify what are the underlying brain processes for inference suppression during working memory task in older adults? Because alpha oscillations are known to reflect inhibition, I suspect that participants with stronger alpha are more effectively inhibiting distractors.

Aim of this study and research questions

Aim of this study is to solve how alpha oscillations contribute to visual working memory task, specifically to inhibit irrelevant information. In this study we are interested what differences we are able to see in occipital cortex alpha activity during different distractor pictures (easy distractor pictures and difficult distractor pictures) and whether we are able to see correlations between visual working memory task performance and occipital alpha activity.

First exact research question is: "Is there differences in occipital alpha oscillations during easy distraction pictures compared to difficult distraction pictures?" Primary hypothesis is that there is differences in occipital alpha activity depending on quality of distractor picture.

Another aim of this study is to solve whether low alpha activity during distractions could reveal problems in working memory function in older people. Exact research question is: "Does low alpha-activity in occipital cortex while facing a distractor predict worse results in ongoing working memory task?" My primary hypothesis is that those participants who have low alpha-activity in occipital cortex while facing a visual distractor give more wrong answers in visual working memory tasks than those who have higher alpha-activity in occipital cortex while facing a distractor.

2. METHODS

PASSWORD project

This study is part of the research project called PASSWORD (Physical and cognitive training intervention among older community-dwelling sedentary men and women). In this research project the main focus is to solve whether cognitive and physical training could prevent older adults from falls. Participants were divided in two groups: one group get only physical training (PT group) and another group get both physical and cognitive training (PTCT group). Hypothesis is that PTCT group would have greater benefits than PT group. Previous studies suggest that good cognitive and physical abilities reduce fall risk. It will be scientifically very interesting to compare these two groups and how different training interventions have influenced to their working memory performance and do we see better inhibition abilities after these interventions.

This thesis is a part of BRAIN-sub study in PASSWORD project. In my thesis I am using only first measurement results. In this thesis I am going to observe inhibition process in occipital cortex during visual working memory task.

Participants

In this study participants were older adults, born between years 1935-1946. Inclusion required that participants lived independently in City of Jyväskylä and they were able to walk 500 meters independently. There was also requirement that participants should get at least 24 score from Mini Mental State Examination, what is indicator of possible cognitive decline. All participants gave their informed consent to participate in the study. There was also demand that participants should be only moderately physically active, so that they walked less than 150 minutes per week and they didn´t participate gym activities.

Exclusion criteria was that participants shouldn´t have severe chronic illness or medication affecting physical or cognitive function. Also high consumption of alcohol was in the exclusion criteria. That mean more than 14 portion per week in women and more than 21 portion per week in men. It was also required that participant hadn´t contraindication for physical training or walking test.

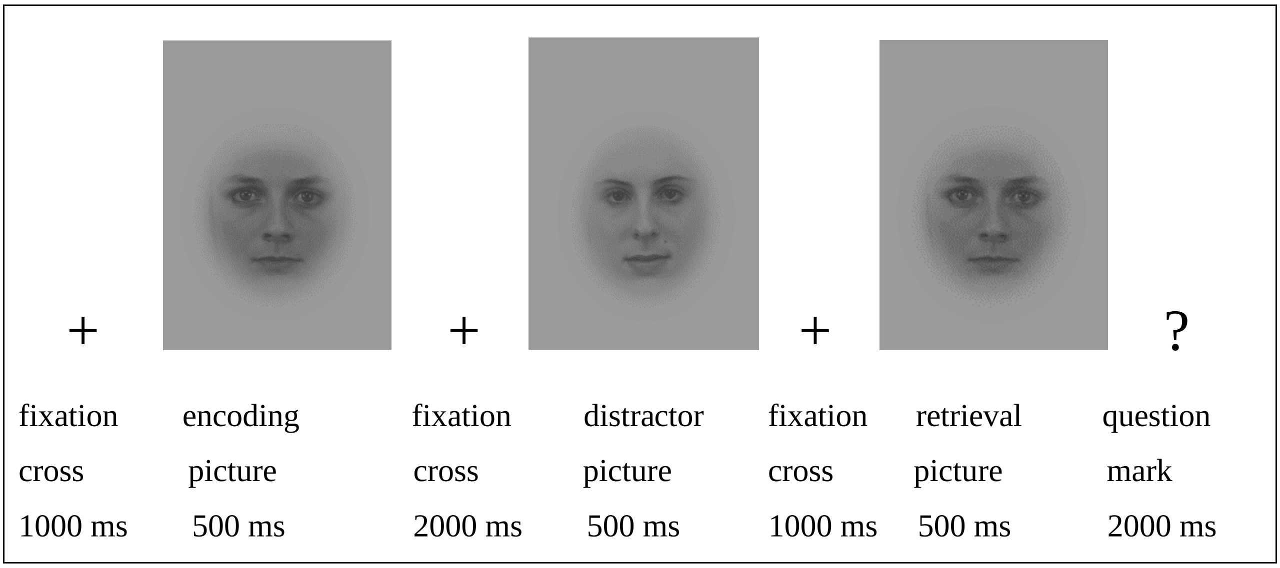
Our sample included 28 participants, born between years 1935-1946. 9 of them were men and 19 of them were women. Participants were checked in for metallic items before measurements and they were informed how to behave during working memory test.

Stimuli and research protocol

In this sub-study we asked participants to answer to visual working memory task in which we showed pictures from Karolinska Emotional Faces. In order to make the task difficult enough, faces were modified to be as neutral as possible in all the other measures but facial characteristics, i.e. hair border and any specific markers were removed. In working memory test, we showed participants three facial picture and participants had to answer whether the third picture was the same or not compared to the first picture we had shown them. Between the first and the third picture there was either an easy or a difficult distractor. An easy distractor was simply a grey area that was in similar oval shape that did facial images. A difficult distractor was another facial image. Because all the faces were unfamiliar to participants, this task build lot of pressure to encoding process. So, participants couldn´t rely on long-term memory representations when trying to remember faces. In this study we used to-be-ignored distractors so that participants weren´t separately told to avoid focusing to distraction picture.

Participants were told not to move during measurement and they were informed how to get help from us during measurement if needed (for example if participant would have sickness or claustrophobia symptoms in shielded room).

All participants saw 240 trials including both male and female faces. First they saw fixation cross (1000 milliseconds), then they saw encoding picture (500 milliseconds), after that they saw again fixation cross (2000 milliseconds), then distractor picture (500 milliseconds), again fixation cross (1000 milliseconds), then retrieval picture (500 milliseconds) and at last question mark (max. 2000 milliseconds). During question mark participants had to answer whether the third picture was same or not compared to the first seen picture. Fixation cross was needed to keep participants eyes from walking during tasks. 240 trials were divided into 4 periods. Each period included 60 trials. Picture 1 below demonstrates one trial with difficult distractor picture. Between periods participants had an opportunity to have a break. Some participants didn´t want to keep pauses at all.

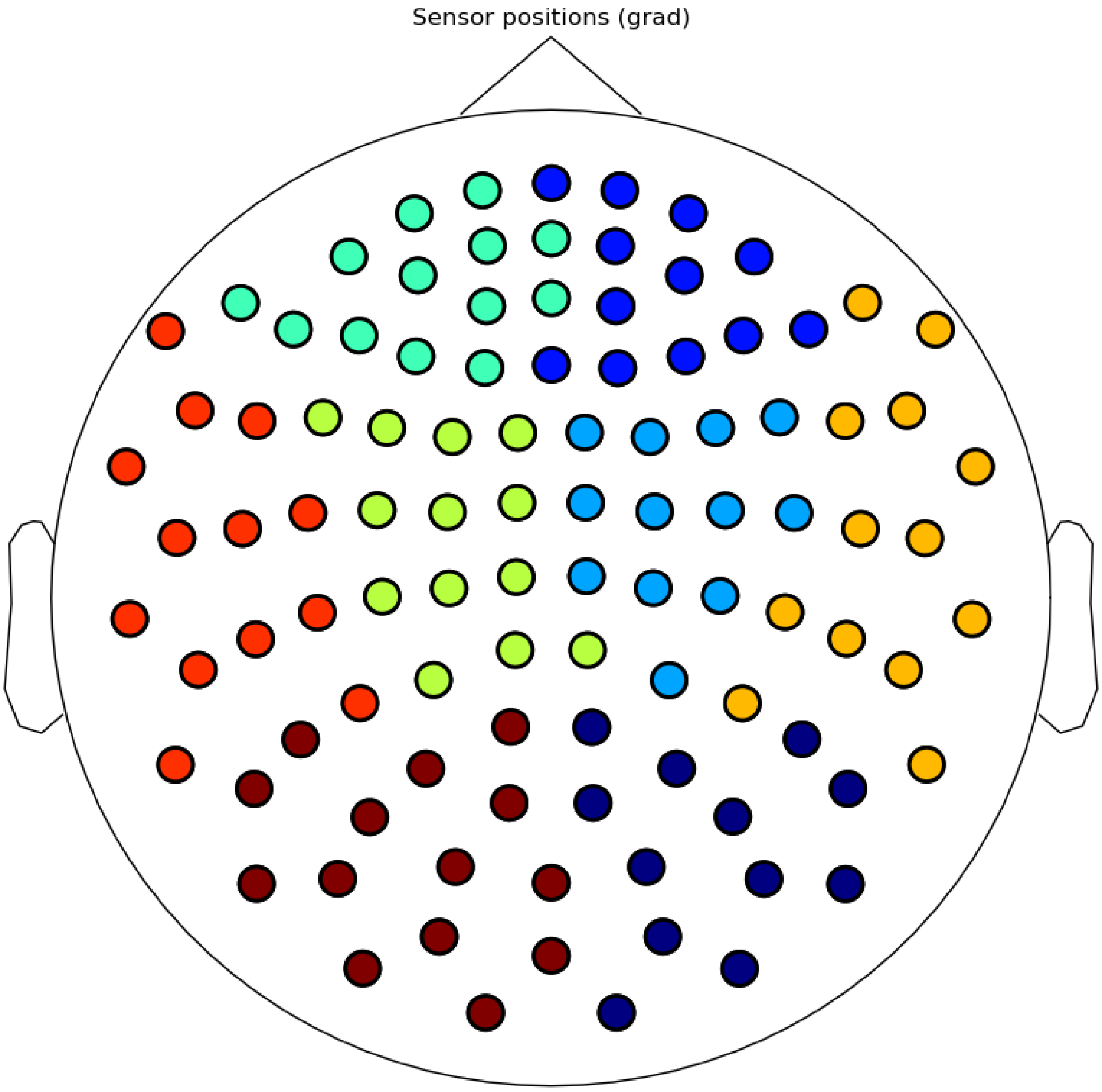


picture 1. Working memory task with difficult distractor picture

Meg data acquisition

MEG data was measured with a 306-channel whole head Elekta Neuromag® system (Elekta Oy, Helsinki, Finland) in a magnetically shielded room (VacuumSchmelze GmbH, Hanau, Germany). The system consists of 102 sensor units, each with two gradiometers and one magnetometer. Four or five head localization coils continuously recorded the position of the head in the MEG helmet. The data were recorded with a 1250 Hz sampling frequency, a low-pass anti-aliasing filter of 410 Hz and a high-pass filter of 0.1 Hz. The position of the head localization coils and the shape of the scalp were digitized using a 3D digitizer (Fastrak, Polhemus, Colchester, VT, USA). Alpha activity was measured from MEG channels all around the head. For this data analysis we took into account channels located in right occipital and in right temporal areas. These cortical areas are known as facial recognizing areas of the brain.

Right-occipital and right-temporal areas are dark blue and yellow points in picture below. Every point in picture refers to one gradiometer pair.



picture 2. Gradiometer pairs.
Right-occipital (dark blue) and right-temporal (yellow). Created by Erkka Heinilä

Meg data analysis

MEG data is typically contamined by artefacts that spoil results by affecting spectral analysis without preprocessing (Gross, 2014). With empty room recordings data was ensured to be free of non-physiological artefacts like air-conditioning equipment noise. The research material was first preprocessed with MaxFilter 3.0 and after that with Meggie. Meggie is a python software built in-house for analyzing MEG/EEG data (Heinilä et al., 2018). MaxFilter clears brain data from outside-brain distractions. MaxFilter also fixed so called “bad channels”. Bad channels are those MEG channels that unaccountably are exceptionally confused.

Meggie cleans data from artefacts produced by eyeblinks and heartbeats. Cardiac artefacts and eyeblinks are removed with ICA (independent component analysis). ICA relies on assumption that data space can be divided into signal space and artefact space and that this allocation is stabile and reliable during whole data (Gross, 2014). MEG is typically known to be sensitive to cardiac artefacts. From maxfilter-processed data we picked up and removed those components that were polluted by either cardiac or eyeblink artefacts. From Meggie we saw both topographies and time courses and by piecing together information given by these, we could do decisions which components should be removed. Looking at sources there was typically clearly visible those components that were polluted by eyeblinks or cardiac artefacts.

Next step after ICA analysis was epoching. The idea of epoching is cutting out just those pieces of data that is needed. In this case we took 4800 millisecond pieces from data. Epochs were calculated in proportion to 1) encoding and 2) distraction pictures. Epochs were also calculated separately to easy and difficult distractor pictures. An epoch started 2400 millisecond before subject saw either encoding picture, easy distractor picture or difficult distractor picture and last 2400 millisecond after subject saw picture. After epoching there was three categories from each participant: encoding picture epochs, easy distractor picture epochs and difficult distractor picture epochs. Calculating averages from these categories we could see what kind of brain activation each one of these causes and compare the changes in alpha power between easy and difficult distractors. In order to remove any remaining artefact we used rejection values 3000 fT/cm to gradiometers and 4000 fT to magnetometers.

Data processing continued with temporal spectral evolution (TSE) analysis. TSE was done separately to each participant and separately to each epoch category: encoding picture, easy and difficult distractor. In this thesis I focus on the differences in alpha power changes in easy vs difficult distractors. Difficult distractor is shown in picture 1. Easy distractor was just a grey area, without face.

From TSE pictures we picked 3 time window where the alpha power modulated. First one was 1504 milliseconds to 496 milliseconds before distractor picture. Second time window was from 256 milliseconds to 944 milliseconds after distractor picture. The last time window was from 992 milliseconds to 1504 milliseconds after distractor picture. For statistical analysis we needed to calculate averaged power of occipital alpha in these time-windows, separately for each individual and for easy vs. difficult distractor. This was done with Excel.

Statistical analysis

Statistical analysis was done with SPSS. We used repeated measures ANOVA with difficulty level (difficult, easy) and time window (1, 2, 3) as within subject factors. We also used paired samples t-test to investigate differences between alpha activity during easy and difficult distractor pictures and during different time windows. We also calculated correlation coefficient to examine if there was correlation between alpha activity during distraction and task performance in visual working memory task.

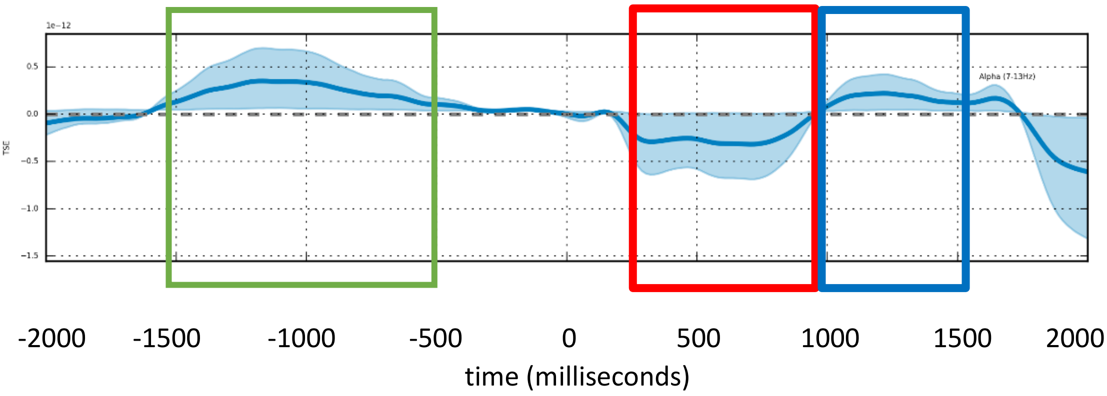
3. RESULTS

Overview of the results

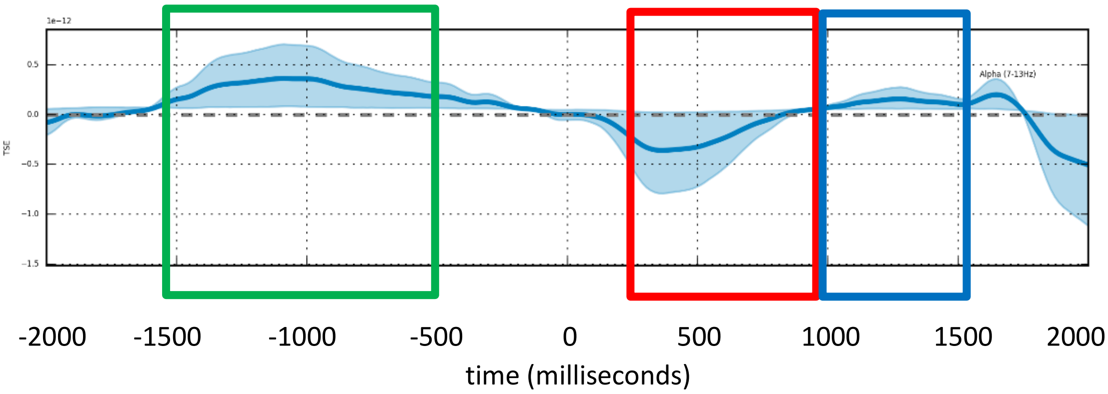
As expected, time-windows showed a significant main effect ($F(2,56) = 47.0$, $p<0.001$) due to alphas modulation to different directions in different time windows. There was no main effect of difficulty level, but there was a significant interaction between time-window and difficulty level ($F(2,56) = 8.1$, $p=0.001$), indicating that the difficulty level influenced alpha level differently in the three time windows. Post hoc t-tests in each time-window separately showed that there was no difference in alpha between difficult and easy trials in 1st or 3rd time-window. In the second time window alpha was significantly lower in difficult distractor picture trials compared to easy distractor picture trials (table 1). Picture 3 and picture 4 below demonstrate that difference. Specifically interesting was the modification between time window 2 and time window 3 because there we can see larger modification in occipital alpha activity during difficult distractor picture trials than during easy distractor picture trials. Picture 5 demonstrates this modification.

TABLE 1: Occipital alpha power in easy and difficult distractor picture trials. Paired samples t-test.

	difficult (SD)	easy (SD)	df	t	sig
time window 1	2,48E-13	2,74E-13	28	1,174	,250
time window 2	-2,57E-13	-1,90E-13	28	2,562	,016
time window 3	1,71E-13	1,22E-13	28	-1,550	,132



picture 3. TSE analysis to difficult distractor pictures. Averaged alpha from all 28 participants. Time window 1 in green box, time window 2 in red box and time window 3 in blue box.



picture 4. TSE analysis to easy distractor pictures. Averaged alpha from all 28 participants. Time window 1 in green box, time window 2 in red box and time window 3 in blue box.

First time window

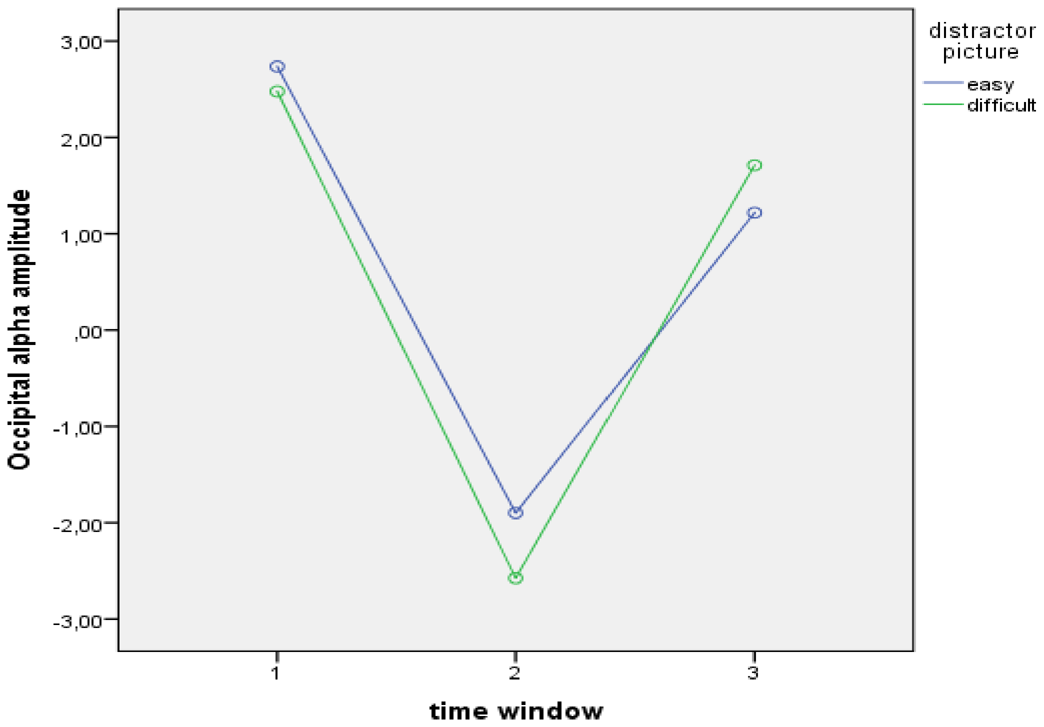
First time window was timed to show brain activation after first (encoding) face presentation and before distractor image. In first time window (1504 milliseconds to 496 milliseconds before distractor picture) there was no difference in alpha activity in occipital cortex when comparing difficult distractor picture trials and easy distractor picture trials.

Second time window

Second time window was timed to capture the first alpha decrease after distractor picture. In second time window (from 256 milliseconds to 944 milliseconds after distractor picture) occipital alpha activity was significantly lower during difficult distractor pictures compared to easy distractor pictures. This difference was statistically significant ($t(28) = 2.6$, $p<0.05$). Compared to first time window there is more difference between alpha amplitude so that difficult distractor picture causes more alpha decrease than easy distractor picture.

Third time window

Third time window was timed to show the first alpha increase after distractor picture. In third time window (from 992 milliseconds to 1504 milliseconds after distractor picture) there was no difference in occipital alpha activity when comparing difficult distractor picture trials and easy distractor picture trials. Compared to previous time windows this time window is exceptional. Alpha amplitude increases in difficult distractor picture trials between second and third time window.



picture 5. alpha amplitude modification during different distractor pictures in three time window

Correlations between different distractor pictures in three time window and correct answers

There was no correlation between alpha amplitude during different distractor pictures and amount of correct answers in visual working memory task despite alphas inhibiting role in brain. Participants answered roughly 70-90% correct in visual working memory task regardless alpha amplitude during distractor picture

4. DISCUSSION

Principal results

We studied alpha power changes in occipital cortex during visual working memory task. The first main hypothesis was that there is difference in occipital alpha oscillations depending on quality of distractor picture. There was no main effect of difficulty level. Instead, we found significant interaction between time-window and difficulty level. Results show that alpha modulates differently depending on distractor pictures quality. The second main hypothesis was that those participants who have low alpha-activity in occipital cortex while facing a visual distractor give more wrong answers in visual working memory tasks than those who have higher alpha-activity in occipital cortex while facing a distractor. There was no correlation between occipital alpha power and task performance in visual working memory task. So, results did not support hypothesis.

Participants conducted visual working memory task in which they had to try to remember first seen faces despite distractor picture between first (encoding picture) and third picture (retrieval picture). Differences between easy and difficult distractor pictures were not statistically significant in time windows 1 and 3. Because participants did not know whether upcoming picture was either easy or difficult distractor picture before seeing that, pre-distractor alpha in first time window does not explain differences in inhibition process between easy and difficult visual distractions. Difference was statistically significant in time window 2. In time window 2 decrease in alpha power was less clear for easy distractors than for difficult distractors.

Most interesting result in this study was difference in alpha amplitude modification between easy and difficult distractor picture trials. Difficult distractor picture trials lead to stronger alpha amplitude modification compared to easy distractor pictures. Difficult distractor pictures lead first, in second time window (from 256 milliseconds to 944 milliseconds after distractor picture), to stronger alpha amplitude decrease and then, in third time window, stronger alpha amplitude increase. Because alpha oscillations are known to reflect rest or inhibition it is logical that occipital alpha during more complex picture is lower than during less complex visual stimuli. Easier visual stimuli does not require as much occipital resources for inhibition than more complex visual stimuli.

Piispala, Starck, Jansson-Verkasalo & Kallio (2018) studied alpha oscillations during visual task in children who stutter compared to typically developed children. They found that those children who stutter, had reduced alpha power in occipital cortex during times when visual stimuli was away. Occipital alpha modulation was different between groups so that stuttering children showed lack of alpha modulation. This study also supports the idea of occipital alpha oscillations role in visual inhibition.

In third time window (from 992 milliseconds to 1504 milliseconds after distractor picture) alpha amplitude was stronger in difficult distractor picture trials than in easy distractor pictures. This difference was not statistically significant. That is still interesting because it seems not to be logical that inhibiting alpha oscillations increase in visual areas just after complex visual stimuli. On the other hand, it is possible that assignment to try to remember whether the upcoming third picture was the same or not compared to the first picture causes that kind of reaction in occipital areas.

Neuronal activity may also move in brain during working memory processing. Palva et al. (2011) studied brain oscillations during visual working memory task. They noticed that early stimulus processing and memory encoding were linked to spread of neuronal activity from occipital areas to frontal areas of the cortex. In our study alpha power measured from occipital-temporal areas first decreased and then increased after visual stimuli. That may confirm ideas of alpha oscillations inhibiting feature and neuronal activity moving from back to front round cortex after visual stimuli.

In this thesis we did not found correlation between occipital alpha activity during distraction and visual working memory performance. That is somehow surprising because it would have been logical that stronger visual areas inhibition during visual distraction lead to better working memory performance. It may be that inhibiting alpha oscillations exist elsewhere in the brain during that kind of visual distraction. In this study we observed only occipital and temporal areas in right side of the brain during visual distractions. Evidence of occipital alphas inhibitory role to visual stimuli is anyway so strong that this may not challenge it. Instead more likely may be that visual working memory task performance depends more on higher cognitive functions that are seen in frontal areas. Measuring oscillations from frontal areas during similar visual working memory task may be more fruitful approach.

Some research groups have found correlations between distractor-related alpha power and working memory task performance. For example Weise et al. (2016) found effect in task performance and distractor-related alpha power modulation but their research protocol was different, and they looked that behavioral distraction effect phenomena from different viewpoint. They used auditory distractor (irrelevant sound during task) and their measurements were done with MEG focusing on occipital, parietal and supratemporal cortices. They found correlation between response speed and distractor-related alpha power.

Occipital alpha-band power and its modulation is earlier noticed to reflect distractor suppressing. Murphy et al. (2014) studied children with autism spectrum disorder. Murphy and his colleagues had also control group consisted of healthy children. They used intersensory attention task and measured with EEG. They observed parieto-occipital areas. Their results support the idea that alphas modulation reflect distractor suppressing in human brain. Children with autism spectrum disorders had worse task performance and also lack of alpha-band modulation during distractor.

Implications, future directions and limitations of the study

Linked to previous knowledge our results support the idea of alpha oscillations inhibiting role in cognitive processing. Different occipital alpha modulations depending on visual distractor difficulty reflect alphas inhibitory role in brain. To future research this study gives a new insight to occipital alpha amplitude modification during different visual distractors. Brain oscillations are under growing scientific interest and this study gives new information about how occipital alpha amplitude behave during visual distractions.

This thesis also shows that occipital alpha amplitude during distraction does not straightforward predict visual working memory task performance. Brains ability to inhibit visual distractions during visual working memory task may exist in brain oscillations elsewhere in the brain. That seems still quite unlikely despite our results. To future research it may still be interesting viewpoint to examine other brain regions alpha amplitude during similar visual working memory task and look whether there would exist correlations to working memory task performance. It may be that despite distractions visuality inhibition process in visual working memory tasks does not in first place exist in occipital cortex but rather in frontal areas that are known to be areas of higher cognitive functions. It would be interesting to investigate whether alpha activity would be higher in frontal areas during visual distractions in those people that survive better in visual working memory task.

This study handles only alpha oscillations in occipital cortex. It would be interesting to observe how other oscillations, especially beta and gamma oscillations, behave in this same visual working memory task in occipital area. For example, Palva et al. (2011) have noticed that in occipital-temporal area visual working memory load was noticeable in beta and gamma amplitudes.

In recent study Proskovec, Heinrichs-Graham & Wilson (2016) noticed that older adults had earlier and more widespread alpha activity in parieto-occipital area during working memory tasks. They think that would reflect compensatory mechanism that helps older adults to survive in working memory tasks. So, there is evidence that older people`s brains do work differently compared to younger brains. In this project we do not have younger participants to look this kind of differences but this data gives precious information from aging brains neural functioning during working memory challenges.

Conclusions

Results reveal that occipital alpha amplitude during visual distraction does not straightforward predict visual working memory performance. Instead occipital alpha modulation seems to depend on distractor difficulty. All that seems to support the idea that alpha oscillations in occipital area are linked to visual inhibition but visual working memory depends more on higher cognitive functions.

Trying to inhibit visual distractions during visual working memory task is not as simple phenomena. There is a lot of open questions of how visual inhibition works during visual distractions. Thinking of older people and ability to inhibit visual distractions this area is interesting both scientifically and practically. Finding out what are mechanisms behind inhibiting processes would be interesting. Also the relationship between visual inhibition and how human brain handles distractors in different age periods is interesting. Is the problem in inhibitory mechanisms or elsewhere like in frontal areas? We need more different approaches and larger samples to study what are the neural mechanisms lying behind aging brains sensitivity to distractors.

Differences between alpha amplitude modification during different visual working memory task trials gives information of how occipital alpha behaves depending of quality of distractor. Easier distractor picture caused less steep alpha amplitude modification in occipital cortex than difficult distractor picture. This difference in alpha power modification may reflect difference in pictures visual complexity in time window 2 and different need of visual suppression in time window 3. It may be that in visual working memory task easy distraction pictures does not cause so much need to suppress visual information than difficult distractor picture does and that suppression happens roughly in time window 3.

This study has some limitations, which are quite small sample size (28 participants) and absence of younger control group that would have given an opportunity to observe differences between age groups. Observing between-age groups in occipital alpha amplitude during visual distractions would give information of how aging brain changes and why older people seems to be more vulnerable to different distractions.

ACKNOWLEDGEMENTS

Special thanks to Tiina Parviainen, Erkka Heinilä and Hanna-Maija Lapinkero for all guidance and support during this project.

REFERENCES

Ahveninen, J., Seidman, LJ., Chang, WT., Hämäläinen, M. & Huang, S. Suppression of irrelevant sounds during auditory working memory. Neuroimage. 2017 Aug 14; 161:1-8.

Bonnefond, M & Jensen, O. The role of gamma and alpha oscillations for blocking out distraction. Communicative & Integrative Biology 6:1, e22702; January/February 2013

Eriksson, J., Vogel, EK., Lansner, A., Bergström, F. & Nyberg L. Neurocognitive Architecture of Working Memory. Neuron. 2015 Oct 7;88(1):33-46.

Gajewski, P. & Falkenstein, M. Physical activity and neurocognitive functioning in aging - a condensed updated review. European Review of Aging and Physical Activity 2016 13:1

Gross, J. Analytical methods and experimental approaches for electrophysiological studies of brain oscillations. Journal of Neuroscience Methods 228 (2014) 57-66.

Hansen, P., Kringelbach, M. & Salmelin, R. 2010. MEG. An Introduction to Methods. Oxford University Press.

Heinilä, E., Monto, S., Leppäkangas, J., Pesonen, J., Rautio, A., Aliranta, K., Parkkonen, L., Ristaniemi, T. and Parviainen, T. (2018). Meggie. Jyväskylä: CIBR

Janowich, J., Mishra, J. & Gazzaley, A. A Cognitive Paradigm to Investigate Interference in Working Memory by Distractions and Interruptions. Journal of Visual Experiments (101), e52226. (2015)

Jokisch, D. & Jensen, O. Modulation of Gamma and Alpha Activity during a Working Memory Task Engaging the Dorsal or Ventral Stream. The Journal of Neuroscience, March 21, 2007. 27(12):3244–3251

Kane, M.J., & Engle, R.W. (2002). The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: An individual-differences perspective. Psychonomic Bulletin and Review, 9, 637-671.

Klimesch,W., Schack, B & Sauseng, P. (2005). The functional significance of theta and upper alpha oscillations. Experimental Psychology 52(2):99-108.

Lustig, C. & Lin,Z. (2016) Memory: Behavior and Neural Basis. In K. Warner Schaie & Sherry L. Willis (editors) The Handbook of The Psychology of Aging. Elsevier, 147-163.

Melloni, M., Urbistondo, C., Sedeno, L., Gelormini, C., Kichic, R. & Ibanez, A. The extended fronto-striatal model of obsessive compulsive disorder: convergence from event-related potentials: neuropsychology and neuroimaging. Frontiers in Human Neuroscience. September 2012

Murphy, JW., Foxe, JJ., Peters, JB. & Molholm, S. Susceptibility to distraction in autism spectrum disorder: probing the integrity of oscillatory alpha-band suppression mechanisms. Autism Res. 2014 Aug;7(4):442-458

Palva, S., Kulashekhar, S., Hämäläinen, M. & Palva, M. Localization of cortical phase and amplitude dynamics during visual working memory encoding and retention. Journal of Neuroscience. 2011 Mar 30; 31(13): 5013–5025.

Piispala, J., Starck, T., Jansson-Verkasalo, E. & Kallio, M. Decreased occipital alpha oscillation in children who stutter during visual Go/Nogo task. Clinical Neurophysiology. 2018 Sep;129(9):1971-1980.

Proskovec, A., Heinrichs-Graham, E & Wilson, T. Aging Modulates the Oscillatory Dynamics Underlying Successful Working Memory Encoding and Maintenance. Human Brain Mapping 37:2348-2361 (2016)

Rouhinen S, Panula J, Palva JM & Palva S. Load dependence of β and γ oscillations predicts individual capacity of visual attention. Journal of Neuroscience. 2013 Nov 27;33(48):19023-33. doi: 10.1523/JNEUROSCI.1666-13.2013.

Schweizer TA., Kan K., Hung Y., Tam F., Naglie G. & Graham SJ. Brain activity during driving with distraction: an immersive fMRI study. Frontiers in Human Neuroscience. 2013 Feb 28;7:53. doi: 10.3389/fnhum.2013.00053. eCollection 2013.

Solesio-Jofre, E., Lorenzo-López, L., Gutiérrez, R., López-Frutos, JM., Ruiz-Vargas, JM & Maestú, F. Age effects on retroactive interference during working memory maintenance. Biological Psychology. 2011 Sep; 88 (1) : 72-82.

Wang, Y.-K., Jung, T.-P., & Lin, C.-T. (2018). Theta and Alpha Oscillations in Attentional Interaction during Distracted Driving. Frontiers in Behavioral Neuroscience, 12, 3. http://doi.org/10.3389/fnbeh.2018.00003

Weise, A., Hartmann, T., Schröger, E., Weisz, N. & Ruhnau, P. Cross-modal distractors modulate oscillatory alpha power; the neural basis of impaired task performance. Psychophysiology. 2016 Nov;53(11):1651-1659.

Xie, Y., Feng, Z., Xu, Y., Bian, C & Li, M. (2016). The different oscillation patterns of alpha band in the early and later stages of working memory maintenance. Neuroscience Letters. 2016 Oct 28;633:220-226. doi: 10.1016/j.neulet.2016.09.047. Epub 2016 Sep 28.

APPENDIX

TABLE: Occipital alpha power in different time windows and correct answers.

correct answers	Pearson Correlation	sig	N
difficult 1	,061	,756	28
easy 1	,132	,503	28
difficult 2	,087	,658	28
easy 2	,173	,381	28
difficult 3	,210	,283	28
easy 3	-,090	,648	28

SCATTERPLOT: occipital alpha amplitude and correct answers